Chapter 4
Water injection surface facilities and equipment

4.1 Water injection surface facilities

Water injection process platform processes seawater to make it suitable for injecting into the reservoir. The cleaned and treated seawater is pumped at high pressure for injecting into the reservoir through a number of injector wells. The water injection platforms (four in Mumbai High[15] and one each in Neelam[16] and Heera[17]) were commissioned during 1984 to 1994. Mumbai North Water Injection (MNW) platform of Mumbai High field was commissioned during 2006. The installed capacities of water injection platforms in Mumbai High were sufficient to meet the injection requirements of the re-development schemes. However, the delay in replacement/ overhauling of the equipment affected their reliability/ efficiency as discussed in the succeeding paragraphs.

4.2 Function of water injection equipment

The functions of water injection equipment are given in table 4.1.

Table 4.1: Functions of water injection equipment

Equipment	Function
Chlorinator	Marine organisms are abundant in seawater and they can form algae, barnacles or colonies of micro-organisms in the piping and equipment. Chlorinator unit, installed at inlet of Sea Water Lift Pump, generates hypochlorite by electrolysis of seawater. Chlorine, produced by the chlorinators, is injected as sodium hypochlorite in the water to kill the micro-organisms.
Sea Water Lift Pump	Seawater is lifted from approximately 25 to 30 meters below the sea level by Sea Water Lift Pump and pumped to the coarse/ fine filters.
Fine Filter	Fine filter is designed to remove all suspended solids of size greater than or equal to 2 microns from the seawater.
De-Oxygenation Tower system	Presence of oxygen in the seawater is the main reason for corrosion of pipelines, equipment etc. The De-Oxygenation Tower system is designed to treat, on a continuous basis, filtered sea water to reduce oxygen content of seawater, not exceeding 0.02 mg/ litre of dissolved oxygen.
Vacuum Pump	Vacuum Pump is designed to reduce dissolved oxygen level in the feed water from 7 ppm to 0.02 ppm.
Booster Pump	Booster Pump is designed to provide net pressure required for main injection pump at the pump's suction to the discharge pressure of 14.6 kg/ cm^2.
Main Injection Pump	Main injection pump is high-speed centrifugal pump, which provides required pressure for injection of the treated water to various injection wells.

[15] *South High Water Injection (1994), Water Injection South (1987), Infill Complex Water Injection (1988), Water Injection North (1984).*

[16] *Water Injection Neelam (1994).*

[17] *Water Injection Heera (1989).*

Equipment	Function
Dosing Pump	The chemical injection pump with manual stroke adjustment for capacity control is designed to inject chemicals (for various purposes) at required dosage in the injection water.
Source: Management response and IOGPT Report on 'Study on requirement of coarse filter in water injection complexes of Mumbai High'.	

The details of major equipment installed (running and standby) at water injection platforms at Mumbai High and Neelam and Heera fields is mentioned in **Annexure V**.

4.3 Critical and essential equipment

The company classified equipment installed at offshore facilities broadly into two categories, *viz*., critical equipment (which directly contribute to oil and gas production and meant for un-interrupted operation) and essential equipment (which do not directly contribute to oil and gas production but essential to support operations). Accordingly, the company categorised seawater lifting pumps, booster pumps and main injection pumps as 'critical' and chlorinators, fine filters, de-oxygenation tower and vacuum pumps as 'essential' equipment.

Audit observed that chemical dosing pumps were not considered as essential equipment. If the desired quality of water is not maintained at the platform, then it may corrode the water injection equipment, clog the wellbore and indirectly impact the crude oil production. Going by the definition of essential equipment adopted by the company, Audit is of the view that all chemical injection pumps should also be considered as essential.

Management/ Ministry stated (February/ June 2021) that as suggested by Audit, chemical dosing pumps would be considered for inclusion under essential equipment.

4.4 Equipment replacement/ revamping policy

As a sequel to C&AG Report No. 8 of 2006[18], the company formulated (2007) equipment replacement policy for all major equipment of offshore facilities. Design service life of water injection equipment formulated by the company as per the replacement policy is given at **Annexure VI**.

In this regard, Audit observed that this policy, however, has not been adhered to. As recorded in the internal documents, failure of equipment is attributed to poor maintenance practices, delay in overhauling, replacement/ revamping etc.

Management/ Ministry stated (February/ June 2021) that equipment package replacement/ revamping depends on the operating condition and age of the equipment. All decision pertaining to replacement/ retention of the equipment are being taken as per the extant replacement/ retention policy.

Audit is of the view that rather than having a timely approach, Management adopted a reactive approach for revamping of platform/ replacement of equipment after expiry of its

[18] ***Availability and Utilisation of Critical Equipment of Offshore Installation in ONGC.***

design operational life and system became unreliable. This affected the quantity and quality of water injection.

4.5 System and equipment availability

The term 'equipment availability' has been defined internally by the company as 'the availability of particular equipment for operating purposes'. Equipment availability was taken care of by the standby equipment during the period of maintenance and repairs of equipment in operation. Similarly, 'system availability' of any critical equipment has been denoted as 'availability of equipment (both operating and standby) for un-interrupted flow of production'. While setting the operational targets, the 'system availability' of 100 *per cent* was assured to the extent that the equipment down time was less than equipment standby time. Considering this philosophy, ONGC has set the target of 100 *per cent* for system availability and 95 *per cent* for equipment availability. The system availability of water injection equipment installed in various water injection platforms at Mumbai High and Neelam and Heera fields during the 2014-15 to 2018-19 is given in **Annexure-VII**.

In Mumbai High and Neelam and Heera fields, 'system availability' of critical equipment at platforms *viz*., Infill Complex Water injection, South High Water injection, Water Injection South and Neelam Water injection was below the target of 100 *per cent*. Similarly, at Infill Complex Water injection, Water Injection South, Neelam Water injection and Water Injection Heera platforms, 'system availability' of essential equipment was below the target of 100 *per cent.* Audit observed that though system availability of some of the equipment was denoted as 100 *per cent*, performance of the equipment was below par due to ageing, coupled with delay in replacement/ revamping.

Management/ Ministry stated (February/ June 2021) that it has taken many initiatives from time to time to improve the water injection quality and quantity. It is a regular ongoing process considering the matured field environment and the ageing of installed equipment/ systems/ sub-systems including the peripheral and control.

Audit is of the view that the company adopted a reactive approach rather than timely revamping of platform/ replacement of equipment, after expiry of its design operational life and after the system became unreliable. This impacted the quality and quantity of water injection.

4.6 Reliability of equipment availability/ system data

From the review of Monthly Progress Report (MPR) and Daily Progress Report (DPR) of equipment in Mumbai High, Audit observed that in a large number of cases, the equipment run/ standby/ maintenance hours were not matching with each other and to that extent equipment availability data was not reliable. Audit highlighted instances in Neelam MPRs, where equipment was continued to be shown as available with running hours, even when it was sent for repairs and where average dispatch of water injection was denoted even when running hours was nil for all injection pumps (**Annexure-VIII**).

Management stated (June 2020) that most of the reports are manually handled by different sections and departments; accepted that some error in manual data entry had taken place and that the teams at offshore have been advised to feed all data in SAP system for removing any discrepancies.

Recommendation No. 3

The company should ensure maintenance of the equipment availability data through SAP system and ensure generation of reports directly from SAP.

4.7 Methodology for working out 'system availability' of equipment

System availability of equipment is one of the key indicators to measure the performance of the Asset. Audit however, observed instances where despite the system being 'available', it could not meet the performance criteria as discussed below:

- In Water Injection South platform, as against the planned injection of 247,115 bwpd during 2018-19, actual water injection was only 177,549 bwpd (shortfall of 28 *per cent*). However, system availability of main injection pumps was reported as 100 *per cent*, even though only one injection pump with capacity of 1.20 lakh bwpd was in operation during December 2017 to July 2018.

- The 'system availability' of fine filters in South High Water Injection platform during 2016-17 and 2017-18 was recorded as 100 *per cent*. However, the particle counts exceeded the operational limit of <2000 per ml due to inefficiency in operation of fine filters.

- The 'system availability' of the vacuum pumps was reported as 99 *per cent* in Neelam during 2014-15 to 2018-19. Out of 60 months, in 22 months the average dissolved oxygen level was higher than the prescribed level of 20 parts per billion (ppb). Of these, in 19 months higher dissolved oxygen levels matched with non-availability of vacuum pump. Similarly, in case of Heera, out of 25 months where dissolved oxygen levels were higher than the prescribed level of 20 ppb, 23 months matched with non-availability of vacuum pumps. The system availability of vacuum pumps was, however, denoted as 100 *per cent* in all the months.

Management stated (February 2021) that with 100 *per cent* system availability of main injection pumps, it is apparent that available injection pumps were adequate to meet the actual field requirement and injection pump was stopped due to other field conditions.

The reply is not borne out of facts as the second pump was partially available during the period December 2017 to July 2018 and after its restoration, the injection was restored to the planned levels as before. Audit is of the view that achievement of 'system availability' target without meeting the operational requirement is of diminished utility.

Recommendation No. 4

The company needs to consider efficiency/ performance of the equipment for meeting the operational requirement while working out the 'system availability' of equipment and the Management should ensure reliability and availability of equipment for uninterrupted operation.

4.8 Monitoring mechanism – Plant Maintenance module in SAP system

The company implemented SAP ERP system including the Plant Maintenance module in 2003. Plant Maintenance module is designed to meet the requirement of planned and unplanned maintenance of equipment, mapping of critical parts of equipment and their overhaul/ repair history. Processing of maintenance data can aid performance analysis, improve operational effectiveness, and provide useful insights to enable management decisions.

In this regard, Audit observed that Plant Maintenance module was not extensively used to obtain the intended benefits. It was used only for rotary equipment (pumps, motors) under maintenance. Static equipment[19] were not mapped and the maintenance activities and their details are not fed in the module. Equipment logs/ history of repairs/ make-wise performance of equipment could not be obtained from the Plant Maintenance module in the absence of data not being fed or lack of mapping.

Audit further observed that in large number of cases, day-wise equipment availability data does not match with the monthly equipment availability data. The equipment history, tripping details and monthly performance reports were also maintained outside the SAP system. The monitoring and control mechanism is not strengthened as envisaged, by selectively utilising the Plant Maintenance module and by relying on manual reports. The effectiveness of the Plant Maintenance module and the monitoring mechanism is thus undermined.

Management/ Ministry (February 2021/ June 2021) assured that all functionalities of Plant Maintenance module would be extensively used to get the intended benefit.

Recommendation No. 5

Management may extensively use functionalities under Plant Maintenance module in SAP system so as to get its intended benefit of aiding performance analysis, improving operational effectiveness and providing useful insights to Management decisions.

4.9 Delay in replacement/ revamping of equipment

4.9.1 Non-functional Chlorinators for more than eight years

Chlorination of seawater is the first step to get the desired quality of injection water. Raw seawater is chlorinated at the intake of seawater lift pump to control growth of both micro-organism and bacteria. The bacteria present in the seawater, which choke filters, can also

[19] ***Equipment having no moving parts-like fine filters, DO tower in water injection system.***

plug the formation. Bacteria, especially sulphate reducing bacteria which caused microbial induced corrosion, is extremely aggressive and in its worst form will lead to piping failures within a short period. Once established, microbial induced corrosion is difficult to be eliminated and may elevate into chronic maintenance and operating problem for years to come. In the absence of chlorine, even 90 *per cent* removal efficiency of particles >2 microns is difficult to achieve.

Design life of chlorinators is 15 years. Audit observed that the chlorinators installed with the platforms outlived their design life as early as 2002 to 2008 (except Mumbai North Water Injection platform which was commissioned in 2006). Chlorinators were replaced in Water Injection North Platform in 2012. The chlorinators stopped working in Water Injection South Platform (2009, 2012), Infill Complex Water injection platform (2010, 2017), South High Water Injection Platform (2010), Neelam Water Injection (2010) and Heera Water Injection (2010) Platforms. Presence of general aerobic bacteria and sulphate reducing bacteria in various stages of water injection system was observed in the absence of functioning chlorinators.

Institute of Engineering and Ocean Technology (IEOT), research and development institute of the company which conducted study (October 2012) on failure analysis of water injection pipelines in Neelam and Heera, mentioned that the chlorinator units were not in use since last few years in Neelam water injection platform and recommended the practice of use of primary biocide i.e., chlorine generated through electrolysis of seawater. The in-house committee which studied pre-mature failure of pipelines for Mumbai High and Neelam and Heera fields also observed (August 2014) that the presence of general aerobic bacteria and sulphate reducing bacteria at the main injection pump discharge was due to non-functioning of chlorinators, more or less at all the platforms. The committee recommended that proper functioning of chlorinator and regular injection of chlorine at seawater lifting pump inlet must be ensured or alternative chlorination system be considered.

Audit observed inordinate delay in finalisation of tender/ re-tender for chlorinators. In the absence of chlorinators, in large number of cases, general aerobic bacteria and sulphate reducing bacteria was observed at the fine filter itself. This resulted in continuous deterioration of fine filters and affected the quality of injection water. The poor quality of injection water also led to deterioration in water injection pipelines and contributed to their pre-mature failure.

Management stated (February 2021) that chlorinators are being replaced in phases; new units were commissioned at Neelam (March 2019) and at Heera (May 2019), being replaced at South High-Water Injection and Infill Complex Water Injection and new chlorinators along with other facilities will be installed at Water Injection South by September 2021.

The reply may be viewed in light of the fact that chlorinators in water injection platforms were not functional for more than 8-10 years, which have affected quality of water

injection. The company has fixed operational life of 15 years for replacement of chlorinator and should have taken timely action for its replacement.

4.9.2 Delay in revamping of other equipment

The company had internally assessed 15-20 years as the estimated useful life of critical/ major equipment as per the equipment replacement policy of 2007.

In this regard, Audit observed that the policy was not adhered to and the equipment on the platforms were not functioning to the desired level due to prolonged use in the marine environment and ageing. Considering the lead period required for installation of any facility in an offshore platform, the proposals should be initiated much earlier. Delayed initiation of revamping process was observed indicating improper planning and lack of importance attributed to water injection. There were delays in replacement/ overhauling and in some cases, non-adherence to the recommended maintenance practices of OEM was observed. Meantime, condition of major systems and main equipment deteriorated and it was unsafe to continue its full-scaled operation. With reduced scale of operation at existing platforms along with safety constraints, the desired injection quantity/ quality envisaged for reservoir health maintenance to meet long term plans could not be achieved as depicted in table 4.2.

Table 4.2: Delay in revamping of equipment in water injection platforms and its impact

Platform	Installed in and completed 20 years	Proposal initiated (year) and approval (year)	Scheduled/ revised completion	Water injection equipment failures in platforms	Consequent effect on quantity/ quality
South High Water Injection	1994 and 2014	2009 and 2016	2019/2020	Frequent break down of vacuum pumps and non-availability of vacuum pumps	Water quality parameters exceeded the permissible limits, which affected water quality. Quantity pumped reduced from 2.37 lakh bwpd (2014-15) to 1.66 lakh bwpd (2018-19).
Water Injection South	1987 and 2007	2012 and 2019 (De-oxygenation tower revamped)	2021	4 Fine filters were not functional. Out of 4 vacuum pumps, 3 were under downtime during entire audit period. Out of 2 de-oxygenation towers only 1 was used while other (whose internals were damaged) was continuously kept under standby. System availability of booster pump was less than 50 *per cent* during 2018-19. One booster pump was under downtime since May 2015 (2 booster pumps slated to be installed only by May 2021). Against 5 main injection	Water quality parameters exceeded permissible limits, which affected water quality. Drop in injection quantity from 1.91 lakh bwpd (2014-15) to 1.77 lakh bwpd (2018-19). Capacity utilisation of only 36.06 *per cent.* Excessive De-oxygenation in injection water upto 3565 ppb.

Platform	Installed in and completed 20 years	Proposal initiated (year) and approval (year)	Scheduled/ revised completion	Water injection equipment failures in platforms	Consequent effect on quantity/ quality
				pumps installed, 3 main injection pumps were not working for extended period (more than 2 years).	
Infill Complex Water Injection	1988 and 2008	2010 (De-oxygenation tower) and 2011 (De-oxygenation tower and fine filters revamped)	2015	Even after revamping, the system availability of de-oxygenation tower and Fine Filters was below the requirement. Out of 2+1 operation philosophy, one booster pump was not available for operation during 2014 to 2017. However, it was maintained as standby during October 2016 to September 2017. Total 3 main injection pumps are required to cater to the demand of water injection, but only 2 main injection pumps are in operative condition.	Water quality parameters exceeded permissible limits. Average capacity utilisation of water injection capacity was only 42.96 *per cent*, which affect water injection quantity.
Water Injection Heera	1989 and 2009	2016 (Booster Pump) and 2018 (Booster Pump)	Main Injection Pumps yet to be replaced. De-oxygenation tower, Fine filters revamped in Sept 2019. All booster pumps are under replacement.	Even after revamp of De-oxygenation tower towers, Main Injection Pumps lack capacity to handle additional capacity. Frequent failures/ tripping in booster pump and main injection pump.	Shortfall in achieving water injection targets of Heera by 30 to 57 *per cent.* Quality of water, especially dissolved oxygen (upto 800 ppb levels) particle count, residual sulphite levels could not be maintained. Chemical dosing was not adequate resulting in failure to maintain the quality norms of injected water. Only one main injection pump in operation in Neelam from February 2018. Achievement against redevelopment plan targets by Neelam was 48 *per cent* (2018-19).
Water Injection Neelam	1994 and 2014		3 booster pumps replaced in Nov 2018. 2 main injection pumps to be replaced in 2021. 3 seawater lift pumps under replacement. Chemical dosing pump planned for replacement	Main Injection Pumps were not delivering as per their design capacity. Frequent failures/ tripping in booster pump and main injection pump. Against design philosophy of 2+1, only one booster pump was operated. Even reporting of system availability is not reliable. Lack of monitoring of chemical dosing pumps as 'data not captured'.	

Source: Data furnished by company in response to Audit requisitions and observations, Monthly Reports

Management attributed (February 2021) operational reasons and capital intensive nature of the projects for delay in revamping and stated that revamping is a regular ongoing process and the company has replaced/ revamped/ modified many equipment under various projects. It further stated that replacement/ revamping of aged equipment had resulted in improvement in quantity and quality of injected water. Management further added that the tripping is expected to be significantly reduced in view of revamping/ replacement of equipment.

Management response needs to be seen in light of the fact that the age of facilities exceeded the accepted age norms by many years resulting in failures/ inefficiencies of aged equipment and ineffective operation. Timely action would have avoided deficiencies in water injection operations.

Recommendation No. 6

The company should timely initiate proposals for overhauling and replacement/ revamping to ensure system availability. Also, Original Equipment Manufacturer recommendations for maintenance practices should be adhered to.

4.10 Overhauling of critical water injection equipment

A reference is invited to CAG Report[20] No. 8 of 2006, wherein *inter alia,* Audit commented on delay in carrying out overhaul of critical equipment and recommended that the company should follow OEM norms for overhauling. The Management accepted the Audit observation and cited procedural delays. During the current Audit, it was observed that the company has been following its overhaul norms for main injection pumps, booster pumps and seawater lift pumps which is less stringent than the norms prescribed by the OEM.

Audit observed that overhauling continued to be delayed in large number of critical/ major equipment even after considering own norms. As of February 2020, 52 *per cent* of critical/ major water injection rotary equipment in Mumbai High were overdue for overhaul. This indicated that despite the assurance provided in the Action Taken Note to the earlier Audit Report, non-adherence to the timely overhauls continued in large number of cases.

Also approval for specific extension to overhaul schedule from the competent authority was not obtained. Even where overhaul was done, it was much after the equipment attaining recommended norm prescribed by the OEM. Few such deficiencies are detailed below:

[20] ***CAG Report on 'Availability and utilisation of critical equipment of offshore installations in ONGC'.***

a. Pumps were operated even after they were due for overhaul. There were instances where the pumps were sent for major repairs after frequent failures. In one case, the OEM had recorded that '*the unit has run substantially over the recommended overhaul period with damage that could have been prevented by following routine maintenance and monitoring of the unit'*. In view of extensive damage, equipment was declared (December 2019) beyond economical repair.

b. Certain pumps were shown as standby continuously and thereafter taken to repairs, thereby raising doubts on the reliability of equipment availability during the standby period in Neelam field.

c. There was considerable delay in initiating the proposals for overhauling (in some cases proposal for overhauling was initiated after the equipment ran more than the hours prescribed by original equipment manufacturer), approval and finalisation of tender for overhauling against the company norms. The average time lag between date of indent and actual completion of overhaul in Mumbai High was around 40 months[21]. Two main injection pumps at Neelam platform (out of four pumps) were at original equipment manufacturer workshop for four years.

d. Pumps which were overhauled/ major repaired, failed within few months of operation pointing out to the non-efficacy of such repairs.

e. At Neelam platform, only one main injection pump was operated against two required, when pumps were under overhaul for extended period or when more than one pump was sent for repair.

f. Equipment which outlived their design life were overhauled instead of getting them replaced based on assurance from OEM for additional running hours. However, failures/ tripping continued to adversely impact the deliverables and operational capacity even after overhauling.

Thus, there is lack of timely approach for maintenance/ overhauling of water injection equipment. CMD of the company had observed (April 2017) that overhaul of equipment is not being done after running stipulated hours, as contracts are not being awarded in time. CMD stressed that the overhaul be taken up without any delay to avoid loss of production due to process disruptions as a result of failure of such equipment.

Management/ Ministry stated (February 2021/ June 2021) that equipment can be operated, over and above the recommended period if all operating parameters are being maintained within limit. Actions are in place for overhauling of equipment/ replacement of pumps and are at different stages of implementation. The main injection pump which failed immediately after overhaul is under warranty repair.

Management reply needs to be seen in the context of tripping/ extended periods of non-availability and multiple failures of the aged equipment. This led to non-achievement of required injection volumes planned. Replacement of equipment is also much delayed

[21] ***Average time taken for overhauling of critical equipment from the date the process started.***

leading to deficiencies in the operation. Management reply is silent on excessive time taken (average 40 months) for overhauling of the equipment, particularly in approval and finalisation of tender.

Recommendation No. 7

The Replacement policy needs a relook to ensure that the efficiency of the aged pumps is also considered when repair versus replacement decisions are taken.

4.11 Tripping of water injection equipment

Frequent tripping was observed in main injection pumps due to deteriorated condition of critical equipment, lack of effective maintenance/ overhaul and timely replacement. In Mumbai High, number of main injection pumps tripping in Infill Complex Water injection South High Water Injection and Water Injection South platforms was on higher side compared to other two platforms *viz.*, Water Injection North and Mumbai North Water. This was due to delay in overhauling of main injection pumps which affected its system availability and resulted in loss of water injection. In Neelam and Heera, tripping of the main injection pumps was attributed to booster pump failures/ leakages and due to turbine generators tripping. There are multiple instances where only one main injection pump was available to maintain pressure. In case of Heera, most of the tripping was attributed to water injection line leakages.

Management/ Ministry stated (February 2021/ June 2021) that tripping is expected to significantly reduce going forward because of revamping/ replacement action taken for critical equipment and its peripherals.

Reply needs to be seen in the light of loss of water injection due to delayed revamping/ replacement action.

4.12 Summing up

The company could not ensure timely replacement/ overhaul of water injection equipment. Many of the equipment had outlived their design operational life, which impacted the operational availability and reliability of the equipment. Chlorinators, one of the crucial equipment ensuring quality of water, were not functioning for more than eight years in many water injection platforms. Timely revamping of critical equipment was also not ensured after their mandated running hours prescribed by the OEM and the company prescribed running hours. This resulted in frequent failures/ tripping of the equipment affecting both quality and quantity of water injected in the reservoir. Discrepancies were noticed in manual reporting which made the equipment performance data unreliable. In addition, Plant Maintenance module in SAP was not properly used to monitor maintenance/ equipment performance levels. Thus, the water injection facilities were insufficient to meet the water injection requirements.

De-oxygenation Towers