Successful initial filling of 15 km long 10.50 m dia. head race tunnel of Rampur hydroelectric project (412 mw) constructed in Himalayan Geology risks and challenges

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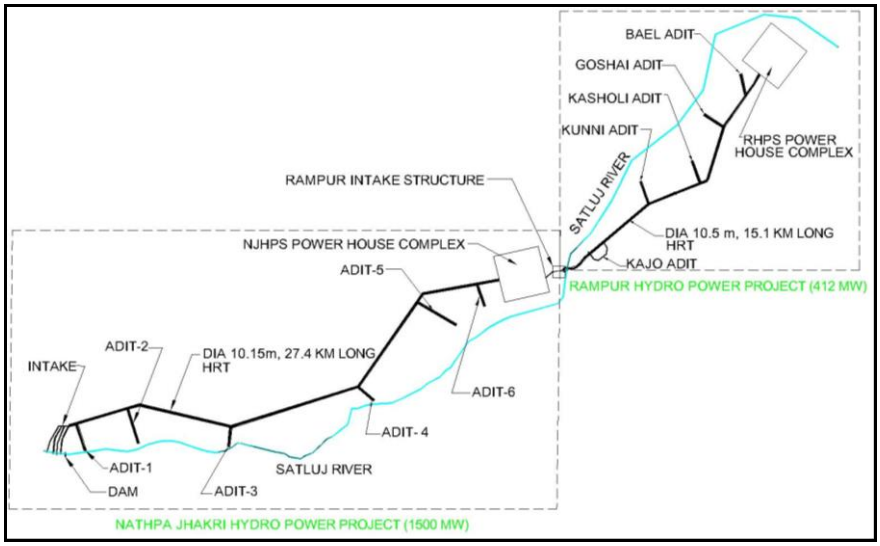
Abstract

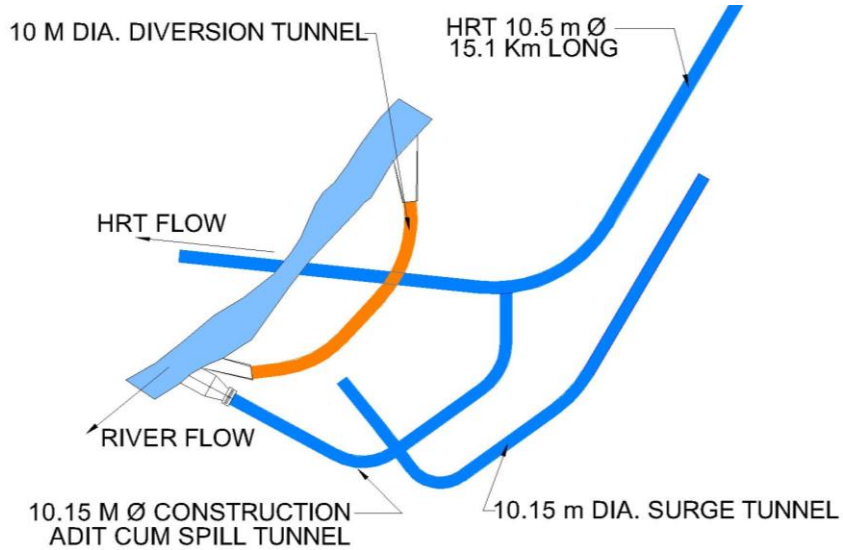
SJVN Limited successfully commissioned its Rampur HEP (412 MW) in 2014. The project has been planned to operate in tandem by directly utilizing the Tail Water of SJVN's prestigious Nathpa Jhakri Hydro Power Station 1500 MW located upstream. The initial filling of voluminous water conductor system of RHEP with 10.50 m diameter, 15 Kilometer long Head Race Tunnel, involved more than 1.5 million m3 of water. The filling operation of such a large diameter tunnel constructed in young folded Himalayas which always offer less ideal sites for tunnelling and their subsequent operations under pressurized conditions is worth sharing with tunnelling fraternity. The meticulous planning, execution, precautions taken, and performance monitoring during filling process keeping in view the fragile geology, low rock cover zones, shear zones in close vicinity of thickly inhabited areas, squeezing zones, hot water zones encountered during excavation shall be discussed in the paper.

1. Rampur Hydro power station in brief:

Rampur Hydroelectric Project (412 MW), is located in Himachal Pradesh (India). This project is a downstream development of Nathpa Jhakri Hydro Power Station (1500 MW) constructed on river Satluj and commissioned during 2003. Both the projects today are now successfully working in tandem. The upstream NJHPS has been constructed on the left bank of the river while the downstream Rampur HPS is located on right bank of the river (Picture-1).



Picture 1 Combined Layout of NJHPS (1500 MW)



Picture 2 Rampur HRT Layout in initial reach

The major length of HRT of Rampur project lies on right bank of river before it crosses under the river in its initial reach (Picture 2). The main features of the project are as below:

- 10.50 m diameter 15 km long HRT ending in a 155.75 m deep, 38.00 m diameter surge shaft.
- 3 steel lined pressure shafts, 5.4 m dia, 211-220m long.
- Surface valve house 69 m long x 10.50 m wide x 23 m high housing 3 No. butterfly valves
- 3 No. surface penstocks 5.4m dia 368-382m long, bifurcating into six penstocks, each of 3.80 m dia. to feed six generating units of surface power house 158 m long x 24.50 m wide x 48 m high, with Francis turbines each of 68.67 MW capacity.

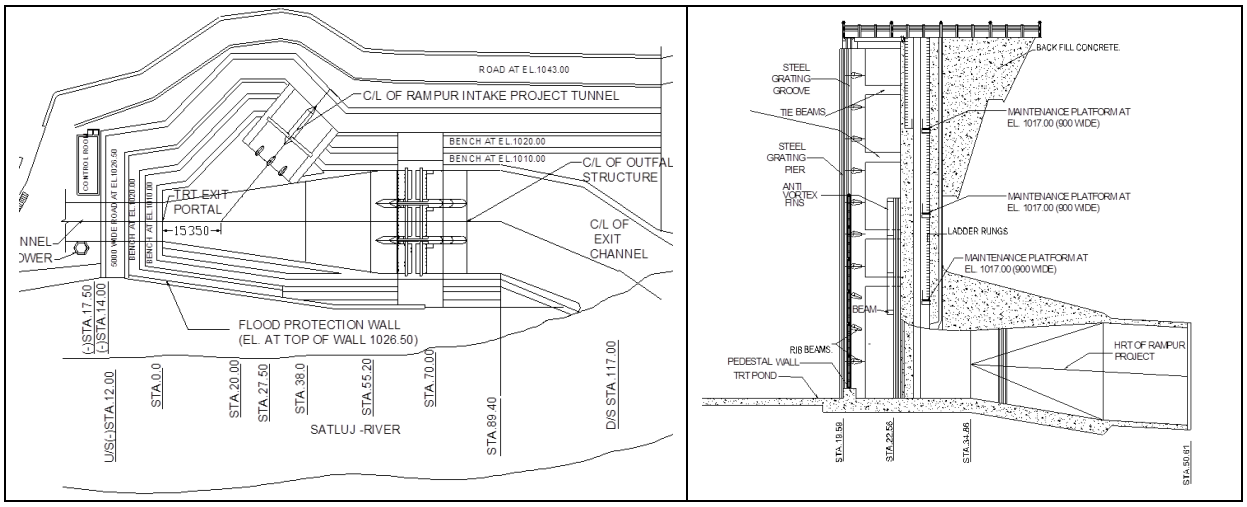
The discharge from the turbines is fed to a collection gallery and leads back to river Satluj through 10.15m horse shoe shaped 67.15m long tail race tunnel. The HRT construction has been completed using 5 no. construction adits at right bank and 1 no. construction adit cum spill tunnel at left bank of the river. The spill tunnel has been provided to release the excess discharge in case of tripping of machine in RHPS. Since the Rampur Hydroelectric Project is directly utilizing the already desilted tailrace water of NJHPS, thereby major diversion and desilting components have not been provided. A gated intake structure for diverting 383.88 cumecs of flow emerging from Tail Race of NJHPS and HRT length of 50.61 m were already constructed in the tail pool of NJHPS before its commissioning.

The water after generating 1500 MW of power from Nathpa Jhakri Power Station comes out through a 982 m long tail race tunnel of 10.15 m diameter into the out fall structure 89 m long and 26.5 wide and is further lead to river Satluj through gated openings provided in the outfall structure (Picture-3) when Rampur HPS is not operating. Automatic regulating gates are provided at out fall to divert the water towards Rampur intake to meet the discharge requirements at Rampur HPS in downstream

Picture 3 (TRT Out-Fall, Nathpa-Jhakri HEP)

Picture 4 (Intake Structure, Rampur HEP)

A gate control for drawl of water for head race tunnel of Rampur HEP has been provided in the pond of TRT out fall structure (Picture-4). This Intake Structure comprises two intakes spaced at 8 m c/c. The center line of HRT of Rampur HEP has been aligned at an angle of 50° with the center line of TRT Outfall of NJHPS. The sill level of the gate has been kept at El. 989 m and the top of opening is at El. 996.54 m. The two rectangular gate openings of 6.0 m X 7.54 m, after a transition starting from Sta. 34.86m to Sta. 55.61 m, finally merge into a circular concrete lined HRT section of 10.5 m finished diameter (Picture 5).



Picture -5

The two Intake gates of vertical lift wheel type have been provided. Each gate has been provided with upstream skin plate and upstream sealing. The gates have been designed to close under balance head conditions and are not intended for regulation purposes. The gates are designed to crack open under normal upstream water level and continue opening till balanced head condition is achieved.

2. First filling operation of RHEP

The first filling of RHPS was meticulously planned after a lot of desk study in such a way so as not to stop/interrupt the commercial generation of NJHPS even for a minute. The entire filling process was finalized keeping into consideration past experience, the safety of RHPS components, like HRT and surge shaft which passes through very adverse geological conditions and other control structures. Also the steep slopes with in HRT, High head at the Rampur Intake gates and the velocity restrictions for filling were kept in mind. As such the filling was taken up as a combination of filling through gates using Tail race Water of NJHPS & with pumps using the running river water at spill tunnel outfall. Adequate pauses were planned for slow filling along with regular checks at weak points like the adit plugs, low cover zones, surge shaft area , inhabited areas etc.
The total volume of water to be filled in the entire water conductor system was of the tune of 1.50 million m3. The breakup of the volume of water in various components has been tabulated below:-

Table 1
Volume of water in the Water Conductor System

Sr. No.	**Component**	**Volume of Water (m3)**
1.	Head Race Tunnel	1446046
2.	Pressure Shafts & Penstocks	25969
3.	Tail Race System	19023
Total		**1491038**

Due to several constraints in long Water Conductor System and for safety of structures against unbalanced head conditions likely to develop due to water filling and likely formation of hydraulic jumps at the points of changes in gradients, it was desirable to fill the system at a gradual, steady and slow rate with intermediate waiting period (saturation pause) during first filling operations. Keeping in view the type of rocks encountered in Head Race Tunnel, the filling was planned to be carried out with rate of increase of water head not exceeding 1m per hour. As such the maximum allowable velocity of flow at tunnel invert was limited to 6m/s. The velocity of flow was worked out for different invert slopes assuming open channel flow and maximum velocity was observed in the reach of HRT with steepest invert slope i.e. 1:15. This 95 m reach was located near the intake at RD 373.6 m and was prone to abrasion damage at higher velocity, since almost whole of the water volume was to pass through this reach. As such the maximum

permissible discharge 3.85m3/s was worked out. However, in order to adhere to the rate of increase of water head of 1m per hour in the reaches having steep slopes, discharge much less than 3.85m3/s was required.

Bureau of Indian standard Guidelines for first filling of Pressure Tunnels were referred for safe initial filling of HRT. A comprehensive filling manual was prepared considering the following key points:

- A number of probable seepage observation points were identified.
- Filling rate was kept slow, so that the internal pressure increases gradually and surrounding conditions get sufficient time for stabilization and there is no scope for the air to get entrapped, compressed and then released.
- To avoid excessive tension in the lining the filling was carried out in pre-determined steps of water head based upon the known properties of the surrounding rock mass.
- HRT was planned to be filled initially up to the Surge shaft gates. The part of water conductor system between Surge shaft gates and Butterfly valves and MIV's was planned to be filled subsequently by operating Filling/Needle valves provided in Surge shaft gates/Butterfly valve.
- Filling of TRT up to minimum Tail water level was planned by pumping water from River Satluj.

Following were the major challenges and constraints in first filling operation:

- The construction of RHEP Intake and HRT up to station 50.61 m was completed with the commissioning of NJHPS in 2002-03. Since then the Intake Gates remained in dogged position. During the 10 years of operation of NJHPS, this reach of HRT (up to Sta. 50.61 m) remained filled with silted water resulting in heavy silt deposition at gate sill which hindered with lowering of gates. The final connection of HRT of RHEP with NJHPS Tail pond was only possible after lowering of Intake gates.
- Drawl of water for filling through Intake gates, from Tail pond of under operation NJHPS under High head (14-16 m) without depleting the Tail pond was a major constraint.
- Intake gates without Filling valves / stop logs, were designed to crack open 150 mm, which would have delivered very high discharge than permissible discharge of 3.85m3/s.
- Due to the variable invert slopes (1:15 to 1: 2555) in HRT, the required discharge for steady filling varied for every 1m head increment. Operation of Intake gates with different openings (10-150 mm) for regulation of the discharge was a big constraint.
- Damage to the invert concrete due to high velocity of water (about 12 m/s) near the crack opened Intake gates was anticipated.
- Water availability from NJHPS machines was not constant during the day because of lean season as the plant was producing peak power during part of a day as per grid requirements.

Measures taken to counter the Major Constraints and Challenges

- In order to connect the Rampur HRT with NJHPS Tail pool, Rampur intake gates were lowered in a planned manner, after removing the heavy silt deposits near the sill beam area. This 2.5 months long operation involved mapping of silt using RoV from gate groove and pond side and removal of silt by using agitator pumps for safe seating of intake gates. After lowering of intake gates, the Rock plug of HRT was removed and concrete lining was completed in this reach.
- Keeping in view the discharges required in HRT for 1m/hour rise in steep slopes, the operation of gates for very small openings was found risky as well as very tedious. Therefore, it was decided to fill the HRT by using pumps in very steep slopes where otherwise the required gate opening would have been 10 mm to 35 mm. A fleet of 10 pumps (150 lps capacity each), with total discharging capacity of 1.5 Cumecs was installed at the Spill Tunnel Portal lifting water from River Satluj
- For HRT reaches with medium and mild slopes, filling was planned to be carried out by operating Intake gates with Gate opening varying from 50 mm to 65 mm.
- In order to avoid the loss of generation at NJHPS, it was decided to go for filling at the same head (14-16 m) but with following precautions:-

  i. Providing High strength concrete (M:50) in invert near Intake gates to counter the effect of high velocities (12 m /sec) generating from orifice flow beneath intake gates.
  ii. Providing High strength concrete (M: 50) just downstream of Intake gates side walls to counter abrasion of concrete due to and Hydraulic Jump formation.
  iii. Prior checking of Intake gates for lesser opening i.e. 50-60 mm using manual operation.

- The filling operation by virtue of the project completion fell in the lean season. In order to fulfill the water requirements during spinning /dry out tests for units of RHPS it was planned to operate one machine of NJHPS even at no load for shorter periods if required.

Following were the major risks foreseen in first filling operation:

- Majority of the HRT (62%) was having Q-value less than 0.1. In this reach the majority of rocks were phyllites/ carbonaceous phyllites. Filling in these geologically poor reaches was vulnerable to leakages, high stresses in lining leading to cracking.
- A number of cavities were encountered in HRT during construction stage. These patches were prone to non-uniform stressing of concrete lining and surrounding rock mass.
- Poor geology encountered at some of the HRT-Adit junctions was prone to leakages.
- HRT passing through thickly inhabited areas at various locations and zones having low rock cover.

Measures taken for Risk mitigation:

- Keeping in view the very poor geology encountered in the HRT, consolidation grouting was done to strengthen the poor rock mass and to reduce the permeability to about 5 Lugeon. Apart from contact grouting in entire tunnel length, consolidation grouting in about 70% of length of HRT was carried out. The efficacy of grouting was ensured by following a set pattern of permeability tests. The reaches where required permeability values were not achieved were re-grouted and retested.
- The reaches where cavities were encountered during excavation, were thoroughly pre and post grouted and kept under observation both before and after lining. These reaches were provided with RCC lining irrespective of the rock class encountered during excavation.
- The vulnerable areas of Junction of HRT with construction adits were thoroughly grouted both from HRT and Adit side. Additional two rows of Curtain grouting 12 m long were provided near the junction.
- Since the HRT was passing in close vicinity of highly populated areas, it was ensured that the grouting of surrounding rock mass was thoroughly done. Prior to the start of the filling operation, reconnaissance survey was done a number of times to check and identify the vulnerable surface outcrops in these areas. These identified areas were constantly monitored during the filling operation. The natural water sources in these areas were identified, photographed and video graphed beforehand.
- Although as per the codal provisions, the rock covers (Horizontal-Vertical) along the entire HRT were sufficient, still keeping in view the geology encountered comparatively lower cover areas were grouted and no drainage holes were provided in these areas.

Keeping in view, the length of the water conductor system, probable seepage observations and filling requirements, the total time of about 20.5 days was estimated to complete the initial filling. This period included an observation period of 3 days after completion of filling. The process comprised of 23 Pressure steps to fill the system completely up to MIV level (EL. 856.4 m). However, the HRT filling was planned to be carried out in 13 pressure steps and rest were provided to fill the conductor downstream of the Surge shaft gates as a parallel activity taken up during saturation pause periods of HRT filling. Table-2 below shows the planned filling schedule for filling of Upstream Water Conductor System (HRT/Surge Shaft) only.

Table -2
Filling schedule for filling of Upstream Water Conductor System (HRT/Surge Shaft)

	Water Level		Volume per step	Cumulative volume	Filling Mode
	From	To			
	(m)	(m)	(Cum)	(Cum)	
HRT/Surge Shaft Pressure Step – 1	927.5	933.5	4768	4768	(Through Pumps)
HRT/Surge Shaft Pressure Step – 2	933.5	939.5	13250	18018	
HRT/Surge Shaft Pressure Step – 3	939.5	945.5	16120	34138	
HRT/Surge Shaft Pressure Step – 4	945.5	948.5	21733	55871	

HRT/Surge Shaft Pressure Step – 4	948.5	951.5	55608	111479	(Through INTAKE GATE)
HRT/Surge Shaft Pressure Step – 5	951.5	957.5	207692	319171	
HRT/Surge Shaft Pressure Step – 6	957.5	963.5	231895	551066	
HRT/Surge Shaft Pressure Step – 7	963.5	969.5	231706	782772	
HRT/Surge Shaft Pressure Step – 8	969.5	975.5	243718	1026490	
HRT/Surge Shaft Pressure Step – 9	975.5	981.5	248758	1275248	
HRT/Surge Shaft Pressure Step – 10	981.5	983.5	46200	1321448	
HRT/Surge Shaft Pressure Step – 10	983.5	987.5	28550	1349998	(Through Pumps)
HRT/Surge Shaft Pressure Step – 11	987.5	993.5	28437	1378435	
HRT/Surge Shaft Pressure Step – 12	993.5	999.5	30151	1408586	
HRT/Surge Shaft Pressure Step – 13	999.5	1005	37460	1446046	

3. Activities carried out before start of filling operation

The following were ensured before start of actual filling process:

Pre-fill checks:

As the components after filling shall not be accessible, it was imperative that thorough inspection of all the components is carried out well before releasing water into the system. Their satisfactory completion and cleaning was ensured. Structural defects if any, noticed during various inspections were rectified under proper supervision. Entire length of all the tunnels and shafts of water conductor system of RHEP i.e. Head race tunnel, surge tunnel, spill tunnel, Surge shaft, Pressure shafts, Penstocks, Draft tube tunnels and Tail race tunnel etc. were thoroughly inspected and cleaned of all extraneous material.
Construction Defects i.e. cold joints, cracks and honey comb's etc. where ever present were spotted, properly treated and repaired. Contact and consolidation grouting in the prescribed reaches was completely ensured by the means of water permeability tests. Holes provided for grouting, were suitably plugged, ground flushed. Drifts and bore holes provided during Investigation stage were located and properly plugged. Drainage holes, where specified, were ensured as per the Construction Drawings.

All the gates i.e. Surge shaft gates, Draft tube gates and TRT gates were cleaned and ensured ready for water flow. The air vents at all the gates were checked and found clear of any obstruction. The access gate 2.5 m x 2.5 m provided in Goshai adit plug for future inspection of HRT was bolted/ locked properly and ensured for perfect sealing.

The pre-commissioning tests and inspections in the dry stage were completed in all respects and certified by the Manufacturer, Suppliers and Erector prior to filling operation. Proper functioning of all the air release valves, anti-vacuum valves and drainage valves was ensured. The drainage and dewatering pumps including spare pumps were checked and made in operational condition. The communication and control systems were checked and tested for proper operation.

Inspection of Intake Gates:

It was ensured that all maintenance platforms provided in the RHEP Intake structure i.e. at El.999 m, El.1010 m and El.1017 m are clean and properly painted with anticorrosive paint. Weak members which had rusted with passage of time and after long submergence in the water were removed, replaced and repainted. Exposed parts of embedment except rust-resistant steel surfaces in the intake structure were painted as per relevant specifications. Wire ropes, electric installations, limit switches were thoroughly checked.

Location of observation points along the Water Conductor System:

Before filling the Water Conductor System, the observation points were located at many places along the system such as near Spill Tunnel, near the tunnel plugs of all construction adits, in vicinity of Surge Shaft, near Valve chamber, along slopes of penstocks and near Main Inlet Valves in Power House.

In addition to above, observation points were located at existing nallahs, springs in low cover reaches. Minor leakage through the plug concrete was anticipated. Grouting equipment and material were kept handy for urgent requirements. A unique Unified Control Command Unit (U3C) was set up to avoid any grapevine communication.

Flushing of HRT:

The entire water conductor system was ready for water filling except the Pressure Shaft no 3 which was further feeding the Unit No 5 and 6. The remaining part of surface penstock was planned to be completed on later date as this pressure shaft was being used for draining the seepage water from HRT after plugging of all the construction adits. Since the butterfly valve was about 40 m upstream of the open portion of the line no 3 of the Pressure Shafts, the entire water was planned to be stopped behind this valve to achieve the scheduled commissioning of the project. For the other 2 no lines of the pressure shafts, the valves were to be operated as and when required to feed the other 4 no. units ready for testing/commissioning. After various rounds of manual cleaning of Water Conductor system and plugging of all the adits, the entire seepage of the HRT (abouts 80 Lps) was collected at the bottom of surge shaft. At the end of HRT near the Surge shaft Multi Junction, a temporary bund was created to prevent entry of any foreign material to multi junction area about 1.5 m lower in elevation than that of pressure shaft bell mouth entry. Further, a bulkhead at the open portion of the pressure shaft at EL 902 m was provided to divert the seepage water by gravity to the river through an opening of about 1 m dia. in the bulkhead and a temporary dewatering arrangement (Picture 6).

Picture 6

After completion of all activities in Multi Junction area, the entire HRT was flushed with water to ensure complete cleaning. During flushing of the HRT, Surge shaft gates/Butterfly valve no 1 & 2 were kept in closed position and 11 no. pumps installed at Spill Tunnel Portal were operated one by one. (Picture 7)

Pumps installed for HRT filling at Spill tunnel portal

Start of flushing operation

View from Spill tunnel

Picture 7

The pumped water reached the temporary bund after about 4.5 to 5 hours, where the slush and gravel was checked and clean water was allowed to enter the multi junction area. When water started entering the Pressure Shaft no-3 after reaching EL 929.1 m, only one pump was kept in operation. At this stage, the collected foreign material and the temporary bund was removed through the surge shaft.

Cleaning of pressure shaft

Orifice as seen from Surge shaft Bottom

Surge Shaft viewed from orifice slab

Pressure shaft bifurcations seen from pressure shaft 3

Surge shaft bottom and rock trap seen in upstream

Butterfly valve in closed position

Picture 8

Thereafter the water started flowing out through the open part of Pressure shaft no-3. The silt contained in this water started settling in the horizontal reach of Pressure shaft no-3 near the Butterfly valve. Cleaning of the silt in this area and the perfect closure of the butterfly valve without excessive leakage was a very difficult job accomplished after a lot of trials and repeated efforts of the team (Picture 8).

4. Execution of water filling operation:

4.1 Filling of TRT System:

Before commencing the HRT filling, the filling of the TRT system between the Draft tube gates and the TRT Outfall gate was done. This was essential to maintain a water cushion downstream of the machines for wet spinning and to discharge the water of HRT at High Head into the water body avoiding the damage to the surrounding concrete/steel structure in case of emergency dewatering of HRT. The volume of 19023 m3 was filled in the TRT system with a head difference of 12 m. The filling of the TRT system was done in two pressure steps of 6 m each with an intermediate saturation pause of 1 day by deploying two pumps of 150 Lps capacity at the river bank near the TRT outfall. The draft tubes of units were filled up through filling valves of the draft tube gates of respective units. During this process, the water was allowed to rise above MIV into the penstock.

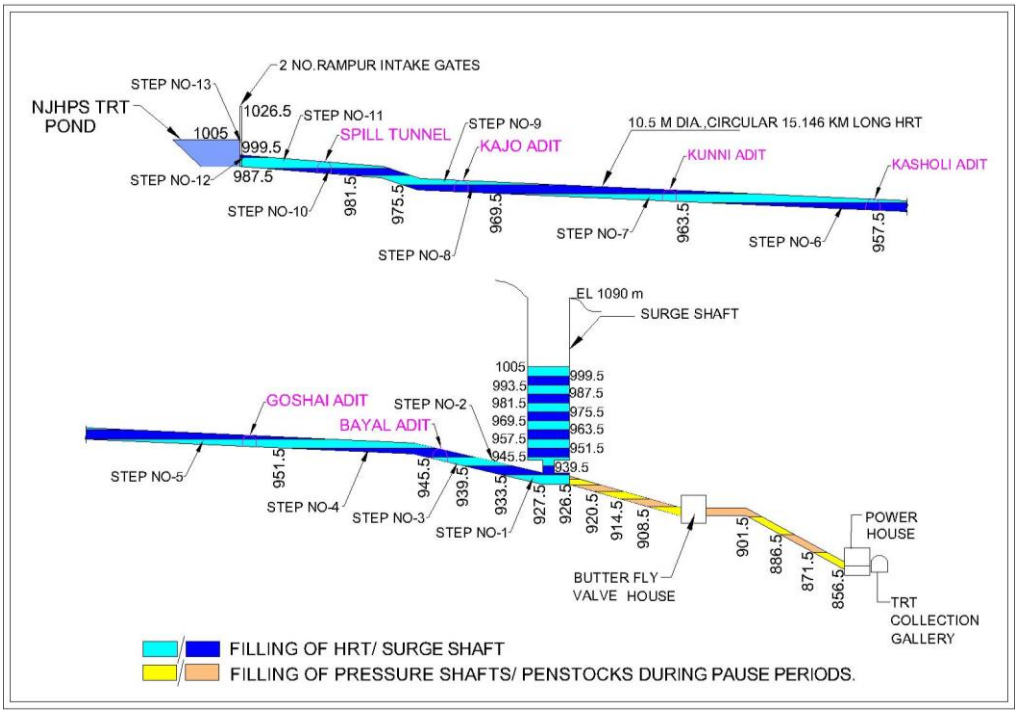
Table 3
Filling schedule for filling of Tail Race Tunnel

Description	Water Level		Volume per step	Cumulative volume	Filling Mode
	From	To			
	(m)	(m)	(Cum)	(Cum)	
TRT Pressure Step - 1	849.19	855.19	11192	11192	(Through Pumps)
TRT Pressure Step - 2	855.19	862	7831	19023	

4.2 Filling of Head Race Tunnel / Surge Shaft:

During the 13 pressure steps of HRT filling shown in (Picture 9), an average rise of 6 m was taken followed by a suitable saturation pauses after each pressure step. The saturation pauses were given for gradual saturation of the surrounding rock mass. After

complete filling of tunnel, intake gates were opened and kept in dogged position and water level was maintained at 1005 m which was monitored for 3 days. During this watch period of three days, the observation points along the Water Conductor System were closely monitored for any leakages and Slope destabilization. The pressure steps planned for filling of water conductor system down stream of surge shaft gates/butterfly valves were executed as per the requirement of machines. This involved wet testing of all the valves and other equipment provided along the lines.



Picture 9 Schematic diagram showing pressure steps

Pressure Steps 1 to 3 -Filling from El 927.5 to 949.70 m:

Keeping the surge shaft gates and all the three butterfly valves in closed the first three pressure steps were completed in four days by giving suitable pauses in between. A total rise of 22 m was achieved involving a volume of 75000 m^3. However, because of lesser unbalanced head acting on surge shaft gates, the leakages through the bottom and side seals of gates partially filled the 3 no. pressure shafts up to Butterfly Valves. Further, Gate no 1 & 2 of Rampur Intake were got inspected by the divers on the upstream side for accumulation of any foreign material. It was observed that the area upstream of Gate no 2 was comparatively cleaner than Gate no 1. Hence, Gate no 2 was operated for the filling operation.

Pressure Steps 4- Filling from El 949.7 to 951.3 m:

On day 5 the filling operation was started after calibrating the gate opening w.r.t. no. of rotations required for lifting the gate. During this process the gate was lifted 10 mm and lowered down. This process was repeated with an incremental opening of 10mm till the

desired 50 mm opening was achieved. Finally the gate was opened 50 mm and the water level at spill tunnel junction was observed. HRT was inspected through the spill tunnel after filling of 7 hrs up to elevation 951.3 m and No damage to invert concrete or increase in seepage near the downstream of the intake gate was observed.

Discharge of 1.23 cumecs was observed for 33033 cum volume of water filled in 7 hours which indicated the actual gate opening of about 20 mm instead of 50 mm. Therefore, the gate was recalibrated to achieve discharge corresponding to 50 mm opening.

Pressure Step No-5 to 7- Filling from El 951.3 m to 964.5 m:

The pressure steps 5 to 7 were completed in 3 days with suitable intermediate pauses. Total Volume 425591 Cum. was filled resulting in a rise of 13.2 m up to elevation 964.5 m through gate no.2 with an opening of 50-60 mm. After this step of filling, the downstream side of intake gate was inspected and no signs of abrasion on the invert concrete were observed. After attaining the desired head on day 8, the initial wet spinning of unit no 1 was successfully taken up for 5 hrs .The filling process was continued during the spinning process so as to maintain the water level achieved so far.

Pressure Step No-8 Filling from El 964.5 to 967.6 m:

After providing a pause of 15.5 hours, the filling was continued through gate no 2. The total volume filled during this operation was 119635 cum, with a total rise of 3.2 m up to elevation 967.6 m. Subsequently, initial wet spinning of unit no 2 was taken up till satisfactory completion for about 6.5 hrs. The rated RPM of the machine was achieved in first 2.5 hrs. The filling process was continued during the spinning process so as to maintain the water level achieved so far.

Pressure Step No-9 Filling from El 967.6 to 973.6 m:

During this step the dry out spinning of unit no 1 was taken up. Before the start of dry out spinning the Intake Gate No-2 was opened 50 mm in order to maintain a constant water level during the dry out. The dry out spinning was completed to the satisfaction of the machine manufacturers in 28 hrs. Large variations in filling levels due to no load to part load operation of NJHPS were observed. With special permissions NJHPS could manage one machine generating during most of the day. During dry out test the pumps were again made operational to achieve the scheduled levels as filling operation could not be done effectively because of continuous outflow from unit no-1 of RHEP. The discharge drawn from NJHPS TRT pond was more or less same as that of released from Rampur unit. Further after the dry out test, the filling operation was continued and the final stabilized level of 973.6 m was achieved. A total rise during this pressure step was 6 m. The total volume filled during this operation was 231714 cum.

Pressure Step No-10 Filling from El 973.6 to 979.6 m:

After providing a pause of 24.5 hrs the gate operation was again started and continued for about 11.5 hours. The total volume of 270800 cum was filled up to the level of 979.6 m and a total rise of 6.0 m was recorded during this step.

Pressure Step No-11 & 12 Filling from El 979.6 to 993.0 m:

After a pause of 26.5 Hrs. gate no. 1 was operated for the first time with 25-30 mm gate opening. A total volume of 164972 cum was filled in two steps of 10 hours and 6 hours with an intermediate saturation pause of 24 Hrs. The water level of 993.0 m with a total rise of 13.4 m was recorded.

Pressure Step No-13 Filling from El 993.0 to 1002.3 m:

After providing a pause of 18 hrs on day 16, the gate operation was again started from bay no 1. The gate operation was kept at 25-30 mm initially. At about 3 PM i.e. 5 hrs later the water level started to become constant at about 1000.6 m at spill tunnel. Now the increase in water level was very slow. As such at about 4:30 the lifting of gate no 1 (bay-1) was started initially with crack opening electrically and thereafter lifting the gate electrically. At about 6 PM on 13.03.14 the gate no 1 was dogged at El 1026 m. During this process the water level in the pond and spill tunnel had stabilized at 1002.3 m.

The Chronology of Commissioning of Units after first filling water conductor system of RHEP is shown in Table-4. As of today both power houses (Picture 10) are operating in tandem and providing valuable power to Northern grid of the country.

Table 4
Chronology of Commissioning of Units

Sr. NO.	Unit No.	Synchronization	Commissioning of Unit
1	Unit-1	March 19, 2014	May 13, 2014
2	Unit-2	March 21, 2014	May 13, 2014
3	Unit-5	March 29, 2014	May 13, 2014
4	Unit-4	June 12, 2014	June 18, 2014
5	Unit-3	July 31, 2014	Aug. 8, 2014
6	Unit-6	Dec. 4, 2014	Dec.16,2014

Underground Power House NJHPS 1500 MW

Surface Power House RHPS 412 MW

Picture 10

5. Conclusion:

Before the start of commercial generation from any hydroelectric scheme, the project passes through various stages and finally First Filling and testing. This phase i.e. first filling of the Water Conductor System is considered to be one of the most important of all the phases. During the process of initial filling, each and every underwater component and associated parts are tested for the first time under actual operational condition for which it has been designed. The response of the water conductor system and the surrounding rock mass under increasing water pressure during initial filling authenticates the design, construction & fabrication of every component on the way. In future more and more such underground passages would need to be built in Himalayan Mountains. In general, the Himalayas are young fold mountains offering very challenging sites. Apart from design and construction, the first filling of large diameter, long and voluminous water conductor systems will be a very challenging task keeping in view the geology, adjoining highways, infrastructure and habitations. Any abnormal seepage may lead to large scale erosions, danger to life and property in nearby areas. This may further lead to emptying and refilling of the system, causing risks, repair costs and huge loss of generation as well. After first filling of the water conductor system of Rampur HEP, the recorded seepages, only near plugs of underground construction adits are less than 5Lps. This is a minute fraction of design discharge being carried through the tunnel i.e. 383.88 cumecs. At present, Rampur HPS 412 MW is successfully running in tandem with NJHPS 1500 MW and providing valuable power to the northern grid of the country. The experience gained in dealing with above mentioned issues can be utilized in other projects with similar conditions.

References:

1. Guidelines for first filling and emptying of pressure tunnels IS 12633:1984
2. Guidelines for first filling and emptying of HRT of NJHEP year 2001