TE MIHI GEOTHERMAL POWER STATION – HOTWELL PUMPS – A TALE OF UNINTENDED CONSEQUENCES

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ABSTRACT

The Te Mihi geothermal power station hotwell pumps (HWP) are a special duty "closed can" design of pump used to extract condensate under vacuum from a direct contact condenser and return it to the cooling tower (CT).

During procurement the Engineer Procure Construct (EPC) contractor pursued a variation with the pump Original Equipment Manufacturer (OEM) for the closed can material selection. With the change in material, the can shape was modified from a typical Hydraulic Institute type of design and this affected the hydraulic performance of the can.

This case study reviews a number of lessons learned for design impacts from an apparently small change.

1. THE CASE STUDY ENVIRONMENT

The Te Mihi power station uses a direct contact condenser whereby the steam exhausting the steam turbine is in direct contact with cooling water to condenser the steam. The condensate is removed from the condenser and pumped by the HWP's back to the CT for heat rejection to atmosphere. The advantage of this cooling water (CW) design is that the vacuum in the condenser is used to draw CW from the CT cold well basin into the condenser without requiring a pump. Thus the CW circuit requires only the HWP and has a lower auxiliary electrical load compared to an indirect contact condenser configuration.

There are two 50% rated HWP per Unit. Each HWP has a rated operation of 2.9m^3/s and a 900kW fixed speed electric motor. The pump has no separate thrust bearing and is hard coupled to the motor for support from the HWP motor thrust bearing. There is no soft start or variable speed control of the HWP.

As the condenser is operating under a vacuum, a closed can pump is used to provide enough depth below the operating level within the condenser to provide an adequate net positive suction head (NPSH) at the pump inlet. Should there not be enough NPSH available at the pump inlet this would result in cavitation.

The HWP's are located in an annex to the turbine generator building that has a removable roof for mobile crane maintenance access for HWP removal.

1.1 Chronology

The following are the major contract dates over the duration of the Te Mihi power station development:

- Dec 2010 - EPC contract awarded
- May 2011 – EPC contractor issued variation to HWP supplier to change pump can material
- July 2012 – Factory acceptance tests
- Oct / Nov 2013 – HWP commissioning and remedial works to CT cold well and basin
- Dec 2013 – HWP 2B vane failure
- Jan – Apr 2014 – Investigation and remedial works to HWP
- Apr 2014 – HWP's returned to service
- May 2014 – Unit completion

2. CONTRACTOR EQUIPMENT PROCUREMENT

2.1 Prototype Equipment

The hotwell pump can material / design change implemented by the EPC contractor was a material change from stainless steel to Fibre Reinforced Plastic (FRP).

This material selection change resulted in a number of unintended consequences in the design, construction and commissioning of the power station and Contact Energy (CE) has inherited a design that incurs higher ongoing costs for every maintenance overhaul event than should have otherwise been necessary.

The original OEM pump drawing (Figure 1) provided to CE prior to the EPC contractor procurement change to FRP, shows a conventional closed can pump configuration similar to the requirement of a typical ANSI/HI 9.8 design. While ANSI/HI 9.8 was not expressly specified, it is the most relevant standard for this type of pump and application. It is noted that the original can, while being of apparent conventional design, had omitted guide vanes in the bottom of the can. ANSI HI 9.8.2.6.5 provides the following general guidance "A set of vanes in the form of a cross should be provided under the pump bell. In some applications, the pump manufacturer may wish to use other methods to prevent swirling." In appendix D ANSI HI 9.8 provides an illustration on the use of flow cones and an alternative method of reducing swirling.

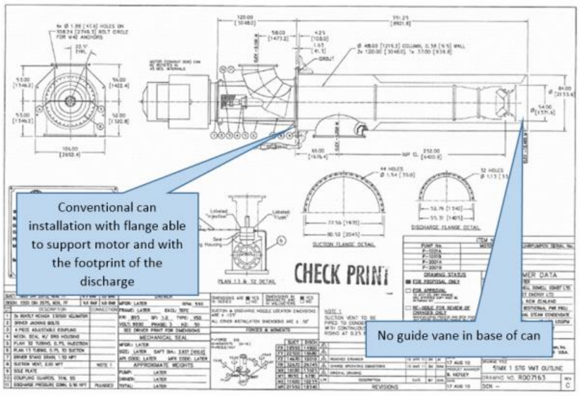

Figure 1: Original OEM HWP can design.

Changing the pump can material to FRP resulted in a geometry change for the manufacture of the can (Figure 2).

The use of a domed end to the can intrinsically changed the hydraulic design of the pump can with subsequent inlet vapour core vortices resulting in cavitation and ultimately failure of the pump impeller.

Procurement was the first opportunity to have identified the potential for the subsequent cavitation failure had the prototype HWP equipment procurement included a physical model study.

Following guidance within the ANSI/HI Standard 9.8-2012 for Rotodynamic Pumps for Pump Intake Design would have identified the impeller inlet vapour core vortices and avoided the subsequent cavitation failure. However this would not have changed the subsequent design impacts for ongoing maintenance costs resulting from the FRP material selection.

At the time of procurement the following areas were not identified and subsequently addressed :

- The OEM had no previous experience with installation of a vertical pump of this size into a closed can of this geometry i.e. no type test existed
- A physical model study was omitted by the EPC contractor / OEM in the equipment procurement
- ANSI / HI 9.8.2.6.5 requires closed bottom can intakes for pump flows exceeding 630l/s to have a physical model study. The HWP is rated for 2900l/s
- For large capacity pumps ANSI HI Figure 9.8.2.6.5 expressly specifies that guide vanes are required if flow > 189l/s.

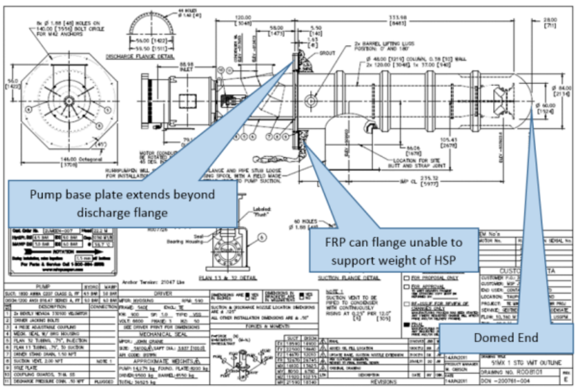

Figure 2: HWP with FRP domed end closed can design.

2.2 OEM Experience

The OEM is a recognised large scale provider of pumps to industry. The experience identified in this case study highlights that an industry recognised OEM by itself is not an adequate determiner of equipment suitability. Very large pumps are a bespoke equipment supply and there may not be identical pump capacity and designs in the OEM equipment range. The OEM needs to be able to demonstrate capability with similar sized previous equipment where there is no express operating performance of an identical design pump / closed can. Following the express guidance within the applicable pump standard ANSI HI 9.8-2012 for physical model study would have mitigated the design risk for impeller intake cavitation.

Post failure investigation established that the OEM specific 51MX design experience list identified nine pumps in total. CE is not aware that the OEM had previously manufactured similar comparable sized vertical pumps in closed cans of this geometry. The first four 51MX pumps were for Te Mihi. A subsequent order for five pumps were to the Czech Republic. CE is not aware if the Czech pumps were provided as a vertical pump or as a closed can pump.

The OEM manufactured the pumps in their Monterrey (Mexico) facility. CE is not aware that this facility / foundary had previously manufactured pumps of this size. The impellers exhibited foundry slips and casting voids resulting in vane dimensional thickness variation and multiple factory casting repairs evident in all pumps.

The remediation works in NZ following Unit 2B HWP failure required impeller / housing match machining and rebalancing to bring the pumps to an acceptable balance state. Similarly spare impellers and casings procured by CE also required rework when received in NZ.

2.3 Factory Acceptance Test

The Factory Acceptance Test (FAT) was the second opportunity to have identified the impeller inlet cavitation prior to the HWP installation on site.

CE elected not to witness the FAT because the deviations to the contract by the OEM for FAT, without the pump can and with one pump section removed and at atmospheric pressure, did not simulate a test based on site conditions.

The EPC contractor / OEM proposed three deviations to the contract:

- Deviation No 1; Removal of one pump section – The test did not simulate the "as installed" pump configuration for operation and vibration performance and required a calculated correction for head loss
- Deviation No 2; Pump column directly immersed in the RP test loop tank –The test loop tank would not simulate the hydraulic performance of the HWP closed can for suction head loss nor flow distribution into the pump impeller
- Deviation No 3; NPSH testing carried out on only one of the four impellers – A single impeller would not be a representative "type" test for all four pump impellers as the impellers were not dimensionally identical due to the slips in the castings.

A FAT with the HWP in its closed can simulating site conditions would have identified the inlet cavitation prior to dispatch of the HWP from the OEM manufacturing facility.

3. MINIMUM ACCEPTABLE EQUIPMENT OPERATION

3.1 Startup Issues

On commissioning all HWPs demonstrated high levels of vibration, surging and cavitation noise. Initial field testing showed that noise and vibration was sensitive to flowrate. Throttling of the discharge valves moved the apparent source of noise. The acoustic measurements (at 1m) of the pump noise due to cavitation were 93.8 dBA / 100.3 dBC for Unit 1 and 92.5dBA / 100.8 dBC for Unit 2. Following remediation works, noise levels were reduced between 5.1 and 8.3 dB.

During commissioning the HWP were not operating within the ISO10816-7 zone A boundary for newly commissioned pumps and the HWP vibration levels where within a damage accumulation regime.

There was considerable discussion with the EPC contractor on the applicable vibration codes for the pump. Irrespective of whether this be ISO 10816, API 610, ANSI/HI 9.6.4 the codes are relatively similar for new plant acceptance.

Proximity probes were installed on the pump body but were not commissioned until after remediation works.

The other indication of upset operation of the HWP during the commissioning and reliability run operation was the additional energy absorbed with the cavitation with the HWP motors continuously running at 950kW (rated for 900kW) with a motor amp load of 99 – 100 amp which was operating just below the thermal overload trip of 102 amp. Post flow cone modification this reduced to 780 – 800 kW.

CE installation of new impellers, coatings and bowls in 2016 (performed on one HWP per unit) has increased load on the modified HWP to 900kW with a commensurate increase in flow rate to 3.4m^3/s. The second unmodified HWP has load dropped to 750kW and 2.7m^3/s.

3.2 Maintenance Impact

The FRP material selection resulted in a can flange that could not support the weight of the pump and motor. This required a change to the base plate design to straddle the FRP can flange. The pump base plate size increased from 2.69m square for the original pump/can design to a 3.7m diameter octagonal base plate with the base plate extending beyond the pump discharge flange.

CE expectations were "...withdrawal areas...without unnecessary dismantling of adjacent Equipment or structure to gain access". The HWP equipment provided did not meet these requirements:

- HWP pump base plate configuration did not provide a clear lifting area for the hotwell pump maintenance withdrawal to minimise unnecessary dismantling of Equipment
- additional work is required for removal / reinstallation whenever a HWP is required to be removed for maintenance. Should the HWP works be on the outage critical path this will result in additional outage time
- additional unnecessary piping connection between seal water equipment, supply and return piping and hotwell sump seals traversing the lifting withdrawal area.

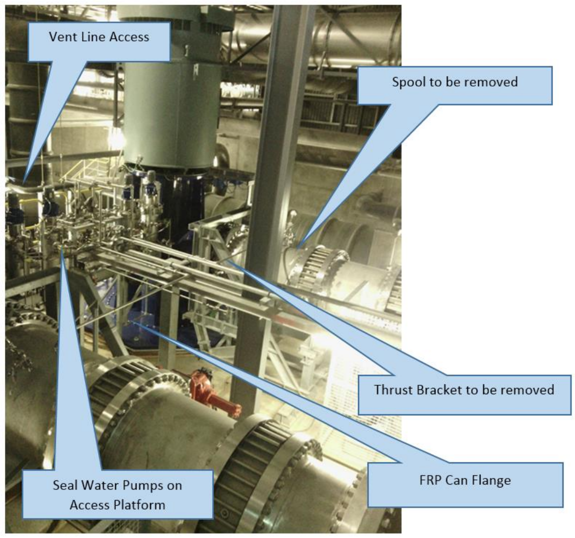

Figure 3: HWP withdrawal through removable roof.

The extended base plate beyond the pump discharge flange compromised the HWP withdrawal access and hence requires additional maintenance works to remove the discharge spool, can vent lines and seal water filter equipment for a pump lift.

CE routine maintenance works for pump withdrawal / installation has increased the HWP outage time required to remove / reinstate the pipework restraint structure, discharge spool, instrumentation mounted on the discharge spool and the CW control valve. Whereas a base plate within the discharge flange would only have required the coupling bellows to be removed to enable HWP withdrawal.

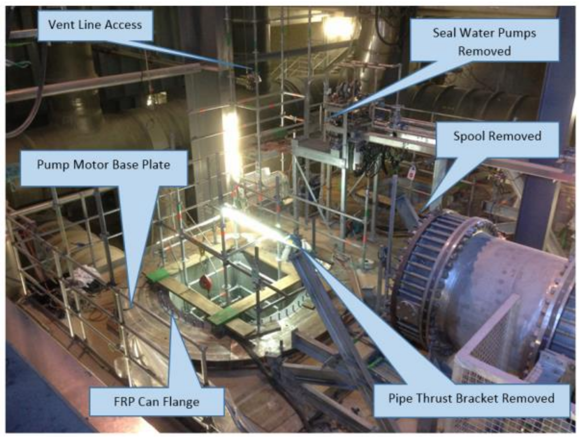

Figure 4: HWP withdrawal through removable roof.

The FRP can is not removable. The FRP can was embedded in concrete as it is not able to support the weight of the pump and motor. Typically a stainless steel can would embedded in an oil/sand grout and hence would potentially be removable.

While FRP is an acceptable material for service in contact with geothermal condensate, the gel coat is susceptible to impact damage. The withdrawal and installation of the 14.3t pump and 9.5t motor using mobile cranes, as well as dropped object risk whilst the can is open to the environment, provides opportunity for inadvertent contact with the gel coat. Damage to gel coat, particularly on installation could potentially result in an additional 5 day extension to the HWP schedule for repair and subsequent cure of the gel coat. Should the HWP works be on the critical path of a Unit outage this would unnecessarily extend the Unit return to service. This risk is mitigated with the conventional stainless steel can material selection.

The FRP flange to base plate had sealing issues with air ingress under load and water egress when the unit was out of service with water in the condenser. Gasket replacement is a high consequence event should a seal not be achieved on reinstatement.

The oversized pump flange requires an oversized lifting withdrawal void that creates an interference with the discharge pipe, fire water sprinkler pipework, seal water filter Equipment and HWP can vent lines.

Figure 5: HWP withdrawal through removable roof.

The fire water distribution pipework is supported from the CW sump pit roof. The CW sump roof is a removable roof panel that provides mobile crane maintenance access to the CW sump for the hot well pump, the CW discharge valves and any other equipment requiring crane access for removal.

Vertical and horizontal legs of cable tray are installed in the lifting withdrawal area. Only the horizontal cable tray run should be fitted across the lifting area to the terminal box to allow for minimal work to pull cable and tray out of the lift withdrawal area.

The various piping connections such as seal water and NCG vent lines traversing the lifting withdrawal area would ideally have been provided with removable spools that were suitably located with terminal connections not requiring additional scaffolding and lifting to access.

The seal water self-cleaning system is mounted on a removable platform in the lift withdrawal area. CE is reviewing the relocation of the seal water system so that this is located in a permanent location requiring only removable spools

The CW discharge pipework restraint bracing requires disassembly to clear the lifting withdrawal area. The EPC contractor modified the bracing frame to provide additional flange plates to enable the grouted base to be left in place.

The elevated NCG vent line isolation valve is located outside of the hand rail and above head height and requires scaffolding access to unbolt and lift the removable spool. CE has modified pipe supports and valve location to improve access and minimize handling requirements for vent line spool removal.

The additional works associated with the removal / reinstatement of the HWP extends the time that each pump removal sequence would otherwise have occurred by 1 ½ days. This also incurs additional man power and crane hire costs. Should the HWP works be on the Unit outage critical path this would extend the outage period and incur lost generation.

3.4 Other Maintenance Considerations

The HWP design does not have a separate pump thrust bearing. The pump is supported from the motor non drive end thrust bearing. The weight of the pump and motor set is such that the boom reach required with locally available 80t mobile cranes requires the motor to be separately removed and installed.

Maintenance of pump and any reassembly of the pump is performed with pump in the horizontal position which makes alignment more complex.

With the motor thrust bearing support configuration, the pump can only be rotated and impeller clearance set insitu in the fully installed state.

CE is considering the provision of a large scale vertical platform with a temporary thrust bearing to enable pump overhaul and alignment to occur in the vertical orientation to provide higher confidence in overhaul and minimise the insitu works required following reinstallation of the HWP.

3.5 Pump Coupling Material

The HWP is hard coupled to the motor and thrust is taken on the motor non drive end bearing. The original pump couplings are fabricated from 316S/S. CE has observed distortion of the coupling and subsequently replaced the couplings.

The distortion of the coupling is exacerbated as motor has a direct on line start. There is no soft start and hence start up torque is in the order of up to 6 time the running load. The yield strength of the 316 coupling is similar to the applied loads from the starting torque hence distortion has occurred.

CE fabricated locally new couplings out of 2205 Duplex stainless steel. This has a higher yield strength than the original 316 stainless steel coupling and will be less susceptible to distortion.

Provision of a variable speed drive /soft starter for the HWP motor would have been a better long term solution for reducing any damage mechanisms that may continue to result from the high starting torque.

3.6 Hydraulic Dynamic Loading on CW Pipework

The CW supply pipework to the condenser is approx. 2m diameter and is supported on elevated concrete pedestal supports with saddle straps.

During both start up and shutdown dynamic loading events occurred. On start up the condenser inlet valves remain closed until vacuum is pulled. The condenser inlet valves then open to 25%. A 2.6m height differential slug of air sits between the water in the risers, which is nominally at CT basin level, and the butterfly valve centerline so that when the valve opens the momentum of water initially impacting the inlet butterfly valve wafer loaded the pipework.

On shut down the condenser inlet valve rapidly close (to prevent high level in condenser). This provides a water hammer loading to the pipework from the change in momentum from 5.9 m^3/s to zero. The shut down event results in a pressure wave back to the CT basin. During initial commissioning whereby the CT basin level was raised to no effective free board this resulted in a wave within the CT basin with consequential overflow of the basin and discharge of geothermal condensate into the stormwater system. The EPC contractor mitigation for this overflow event was to install a wooden wall on top of the CT concrete basin wall.

The dynamic loading on the CW pipework eventually resulted in the anchor bolts on the saddle straps shearing, anchor bolt failure in tension, concrete spalling of the anchor bolt embedment and anchor bolts being pulled out of the pedestal supports. CE made changes to the control logic to slow down the closing time of the condenser inlet valves. On start up a bleed is used to raise the water level in the risers up to the condenser inlet valves to eliminate any air gap prior to the condenser inlet valves opening.

The hold down arrangement on the saddle straps was also changed to have the bolting in the side wall of the concrete pedestal so that bolt loading is in shear load.

4. COLD WELL INLET ISSUES

4.1 Hydraulic Step

Initial commissioning identified a significant hydraulic step as soon as the second HWP was put into operation (Figure 6). With two pumps (5.8m^3/s) in operation there was approximately a 1m hydraulic step into the cold well and the turbulent flow resulted in a high level of air entrainment into CW system which also affected the performance of the non-condensable gas extraction system.

Figure 6: Initial hydraulic step at cold well inlet.

The air entrainment was such that the ultrasonic CW flow measurement failed whenever a second HWP was in service.

The original intake design was provided with a central pillar to support duplicate sets of intake screens to meet contract requirements. The CT basin was designed with an intended 150mm freeboard. The submergence depth of the cold well intake was such that it should have been possible to lower the CT basin level so as to enable CE to use the Ohaaki power station CT “super sucker” equipment to clean the basin floor. A lowered basin level would have provided clearance beneath structural members for the floating discharge hose on the “super sucker”.

The contract did not have any specific requirements for a flow model to be provided to demonstrate adequacy of any hydraulic design to CE. Although the cold well is not a pump sump in this direct contact condenser application, there is guidance is provided within ANSI/HI 9.8:2012 for open channel flow that would have greatly assisted in preventing this from occurring. The flow velocity of the cold well intake design would have triggered the requirements in ANSI/HI 9.8.4.1 for physical model studies.

4.2 Modifications to Cold Well Inlet

The EPC contractor implemented the following mitigations at the cold well to reduce the velocity and head loss through the inlet channel:

- CT basin water level elevated to within 20mm of the top of CT basin thus eliminating any freeboard (increased cross section to reduce velocity)
- CT basin over flow outlet level raised
- Centre pillar removed (increased cross section to reduce velocity)
- Redundant intake screens at the intake step removed and replaced with a single intake screen set back into the full depth of the cold well
- Bell mouth intake in CT basin to improve flow distribution into the cold well intake channel
- Intake channel modified with an Ogee plate spillway transition installed to convert potential energy to kinetic energy. This replaced the concrete stepped intake floor to in an endeavor to produce a smooth flow down the ogee ramp to assist with reducing the standing waves from the hydraulic step.

The open channel flow in the cold well intake approach channel still exceeds the maximum 0.9 – 1.2m/s velocity recommendations in ANSI/HI 9.8. However the modifications installed reduce most of the hydraulic step, turbulence and entrained air.

With no freeboard in the basin, the EPC contractor installed a wooden wall extension. This was to address the consequence of a CT basin overflow from a pressure wave following Unit trip and condenser inlet valve closure. This had resulted in a discharge of geothermal condensate from the CT basin. Any freeboard margin for differential settlement over time now has to be compensated by the wooden wall extension.

5. HOTWELL PUMP FAILURE

The reliability run commenced with the HWP operating with elevated levels of vibration. Analysis of the vibration spectrum indicated relatively high cavitation “curtain’. A sudden step change in vibration levels occurred indicating the in service failure of the 2B hotwell pump vane 1 after approximately 1150 hours of operation. The 2B HWP was removed for inspection and the failed section of impeller was found in the bottom of the pump can (Figure 7). The pump impeller was found to have multiple fatigue cracks at the base of the vanes. Large areas of cavitation damage were found on leading and trailing edges and on both the suction and pressure faces of the impeller vanes. Up to 6 mm deep material loss was observed. The cavitation damage showed the presence of both impeller inlet cavitation from vortices into the impeller and recirculation cavitation at the discharge of the impeller. The pump bowl also exhibited areas of cavitation damage.

Figure 7: Unit 2B HWP impeller failure.

The EPC contractor engaged Alden Research Laboratory (Alden) to perform physical modelling of the HWP. In parallel CE engaged Hydro Australia for CFD modelling from the condenser hotwell to the HWP.

A replacement impeller was manufactured by the OEM. The other pumps were stripped down and rebuilt at AIE Ltd workshops. This involved weld rebuild, match machining impeller and bowl, and rebalancing the impellers.

The physical modelling performed by Alden comprised a scale physical model (Figure 8). The physical model identified the formation of vapour core vortices from the pump can into the impeller inlet. The model showed the proposed mitigation for a false floor and hydro-cone beneath pump suction prevented formation of vortices and reduced velocity fluctuations at pump throat. Alden established that the “as installed” available NPSH (NPSHa) safety margin was 25%, whereas Alden considered that the recommended factor of safety should be 35%. Alden recommended that the operating water level in condenser be increased to the extent possible to maximise factor of safety on the required NPSH (NPSHr). The physical model also identified eddies shedding from the trailing edge of the pump can guide vanes that produced elevated velocity fluctuation and hence the original guide vanes were removed with pump can modifications.

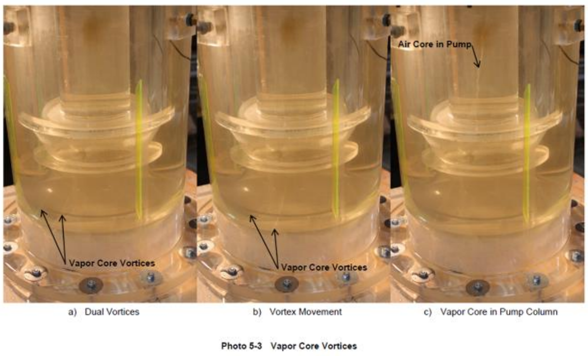

Figure 8: Alden Lab physical flow modelling.

The remediation works identified and implemented were the installation of a false floor and inlet flow cone to the HWP can and the removal of can guide vanes.

In addition a Belzona epoxy coating was also applied to the impellers. This coating lasted less than a year before it delaminated. The coating was subsequently replaced with a two part Belzona anti-cavitation coating. This coating also incurred delamination within 1 year operation.

Following the rebuild of the HWP and installation of false floor and inlet flow cone, the pumps were recommissioned. The inlet cavitation has been substantially reduced but not totally eliminated, vibration levels reduced to ISO10816-7 Zone A and pump motor load also reduced.

The HWP pumps were returned to service following about a four month period for failure investigation and remediation works.

6. POST HANDOVER MODIFICATIONS

CE has installed a number of modifications to the HWP that would ideally be included into the scope of supply for any future HWP procurement specification:

- HWP motor lube oil reservoir remote level measurement and alarm
- HWP motor reservoir topping up pump and fill line accessible from grade level at the pumps
- Pump flange body nozzles to enable draining of pump can for borescope inspection
- Additional accelerometer mounted on pump impeller casing
- Impeller coating replaced with a Metalline elastomeric anti-cavitation coating.

7. LESSONS LEARNED

The following items address concerns that are specific to how the Te Mihi HWP issues progressed. Understanding the context can assist with ensuring that these are not repeated. The EPC contract technical specification was primarily a functional specification. Where good engineering practice was not followed the contract did not necessarily provide the express specification to enforce compliance. The following includes items that are considered appropriate additional prescriptive requirements to include into any future HWP specification to prevent this occurring again :

7.1 Operability and maintainability

- Removable roof panels should not have any suspended services. Services such as fire sprinkler manifolds should be independently supported and outside of the HWP withdrawal void
- Supplementary equipment e.g. seal water to be located outside of withdrawal area to avoid unnecessary dismantling for pump withdrawal
- There should only be removable spools traversing withdrawal area with flange joints readily accessible without requiring scaffold access

- Electrical and control cable ways should be readily removable and with quick connections wherever practical

- Pump body to be provided with independent thrust bearing and not suspended from the motor thrust bearing

- Manway access hatches be provided either side of isolation / discharge valves to provide safe access for inspection.

7.2 HWP specification

- The EPC contract should expressly call out ANSI/HI 9.8 as the applicable standard

- In the light of the issues encountered in modifying the HWP footplate and FRP closed can mounting arrangement with the resultant access and maintainability impacts, the HWP can material be specified as 316 stainless steel only

- The available NPSHa shall have a factor of safety of not less than 35% above the required NPSHr.

7.3 HWP procurement review

- The prototype closed can design and lack of OEM type test verification should have initiated a need for a physical model study / hydraulic investigation during procurement

- Owner witness of factory recommended for assurance on quality of manufacture

7.4 Hydraulic modelling of HWP and CW system

- Should a type tested pump not be provided, a physical flow model should be provided to demonstrate the hydraulic design of the HWP and closed can, and that hydraulic phenomena, vortices, pre-swirl, non-uniform distribution of velocity to the impeller eye, entrained gas bubbles are not present

- Hydraulic design to be modelled to demonstrate that the CW system from CT basin to condenser and from the condenser hotwell discharge to CT that flow is stable; resonance, vortices and cavitation, harmonics have been prevented and hydraulic steps are not present

- Open channel flow in the basin and intake chamber shall be stable subcritical flow without submerged hydraulic jump, swirl, turbulence, large eddies, air entrainment or vortex formation. The flow velocity in the approach channel to the cold well should not exceed 0.8m/s. The CW intake from the cold well shall have adequate submergence depth, bell mouth and anti-vortex device to prevent air entrainment at minimum operating basin level. The Contractor should provide a hydraulic flow model to demonstrate the basin and cold well intake geometry meets design requirements

7.5 Vibration acceptance and progression through contract gate ways

- The prerequisite for issue of the functional test certificate on successful completion of all functional tests and handling trials shall be all rotating plant vibration measurement operating in ISO10816-7 Zone A

- All rotating plant from acceptance of functional testing, handling trials, through to commercial operation to be operating in ISO10816-7 Zone A (unless mutually agreed otherwise)

- Vibration monitoring equipment shall be provided on both motor and pump bearing housings and shall provide displacement and velocity (RMS) measurement. Axial vibration measurement shall also be provided on the thrust bearing. Shaft displacement measurement using proximity probes shall be provided on pumps with hydrodynamic bearings

7.6 Performance Test

- The HWP FAT shall be with the closed can and shall simulate the site conditions

- Performance tests on the pump assembly shall be in accordance with API 610 and with the guidelines of the Hydraulic Institute. Performance testing will be required of all pumps fully assembled in a job receiver closed can with job accessories. Testing will be done in a manner that duplicates actual pump support configuration and in-service conditions. The Contractor shall develop a job specific test procedure for the pumps that shall be submitted to the Owner for approval in the ITP documentation. Performance test shall simulate the site conditions, according to ANSI HI / ISO Standards (or equivalent)

ACKNOWLEDGEMENTS

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