REPAIRS TO A LIVE SEWAGE PUMP STATION

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ABSTRACT

Upgrading an operational public utility treatment plant presents numerous challenges to the team concerned. This case study examines a component of such an upgrade to show the pitfalls that can be encountered when work is undertaken in a sewage pump station which was required to remain operational during the plant upgrade.

This information is presented as an example of lessons learned when an apparently easily rectified vibration problem proved to be a symptom of much larger, and previously unrecognised, problems with this installation.

As a basis for the discussion the causes and effects of this vibration in a 2-duty, 1-standby pump configuration where the use of an existing layout designed for smaller pumps played a part, along with some work methodologies which exacerbated the problems are examined, and how these problems may be avoided in the future is discussed. The issues arising from this pump station being critical to the operation of the Waste Water Treatment Plant during the execution of the remedial works and how these issues were resolved is also commented on.

KEYWORDS

Sewage Treatment, Upgrade, Pump Station, Vibration, Work Methods

1 INTRODUCTION

Around 2002, the first steps were taken by the South Taranaki District Council (STDC) toward removing sewage discharges from the Eltham Waste Water Treatment Plant into an unnamed tributary of the Waingongoro Stream and Apex Consultants (now part of CPG NZ) were appointed to manage the process of selecting and implementing a solution. As options were examined, it became evident that one of the preferred options was to pipe the effluent from Eltham to Hawera and thence to discharge through an existing ocean outfall operated by Fonterra from the Whareroa Road dairy factory. This option was the one finally selected.

After a prolonged concept design and resource consenting period, the physical works began in 2009 with work packages split between four consultants (including Instrumentation and Electrical (I&E)) and three different physical works contracts. One of those packages and one contract involved the upgrading of an existing pump station and rising main at the Hawera Waste Water Treatment Plant (WWTP) to cater for the increased flow once the Eltham effluent was on stream.

This pump station was previously set up with three 150mm (6 inch) pumps in a 2 duty, 1 standby configuration capable of delivering a combined flow of approximately 560m^3/hr. In order to accommodate the increased flow expected from Eltham, and to provide capacity for growth, a flow rate of 700m3/hr was selected as the target flow parameter.

To this end, it was calculated that three 200mm (8 inch) pumps installed in the existing pipework and pumping via a new wet well from adjacent maturation cells, would provide the necessary flow. However, during the course of the plant construction work, in service failures were experienced with the specified maturation cell curtain wall design at another site. This meant that there was a lack of space available in the original location and it became necessary to shift the maturation cells to another position which had the volume available to accommodate an alternative cell wall construction. In order to connect the pump station, several hundred metres of large diameter pipeline then became necessary, with the overall result that the available level in the pump station wet well was approximately 2.2 metres lower than that assumed for the original design.

This became a factor, not so much as a cause of the problems later experienced in the pump station, but in making some of the problems experienced more critical.

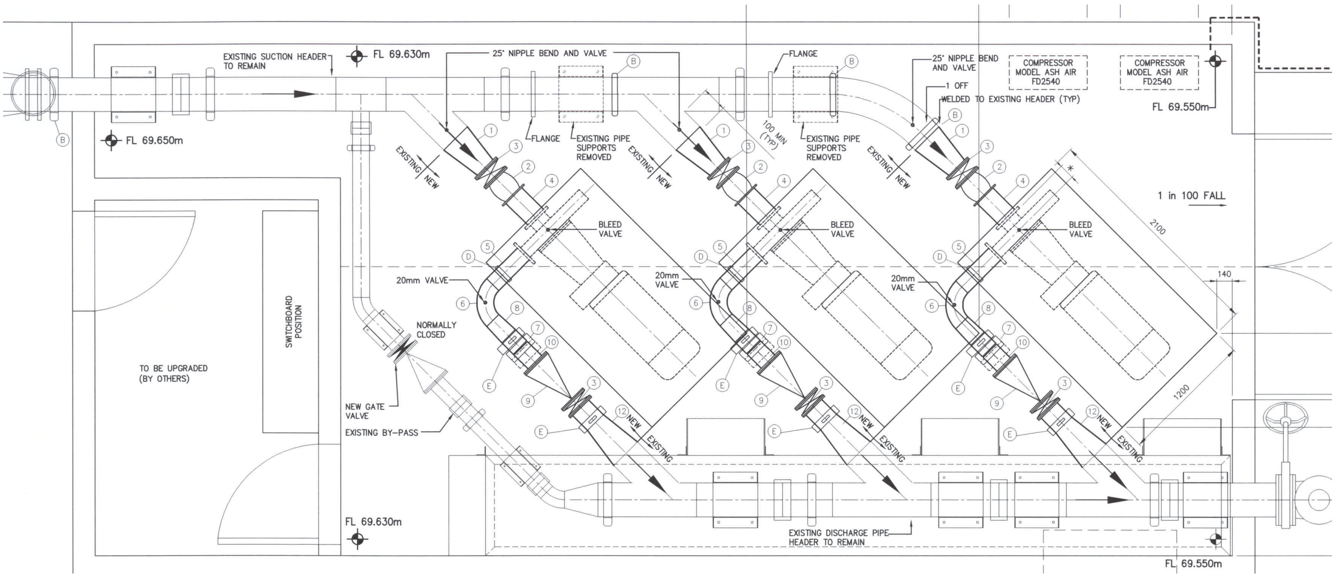
As this pump station was required to operate during the construction period with only limited windows in which to work in order to cater for the inflow into the WWTP, the pumps were changed over and restarted with no proper commissioning period available. During this period the only sign of the problems to come was a noticeable vibration in pump 1 which the Contractor assumed to be misalignment of the pump and motor and steps were taken to rectify this.

Once the problems outlined below became evident however, one of the most inhibiting factors in the remedial process was the need to continue pumping from the treatment plant in order to avoid an overflow. This meant that a staged, step-by-step diagnostic process which was envisioned by all parties became virtually impossible to follow, as the need to keep operating the pumps led to further failures which may have been avoided otherwise.

1.1 SYMPTOMS OVERVIEW

A view of the pump station layout is shown below to assist in visualisation of what happened, with pumps 1 to 3 from left to right.

Figure 1: Pump station configuration



The pumps were supplied by the pump supply sub-contractor complete and aligned mounted on a galvanised steel chassis and were installed on a concrete plinth following which they were packed to level using steel packers under the hold down bolts and then supported using “Sika 212” non-shrink dry pack mortar prior to placing flowable grout on the inside of the chassis.

Once the vibration issues became evident this became the source of some friction between the main contractor and the sub-contractor (see item 2.1 below).

The new pumps were installed one at a time starting in mid 2009 and some vibration became evident immediately. By around September 2009, once all three pumps were installed, the vibration levels had progressively became high enough that the vibration could be felt outside the building. As a vibration analysis was called for under the contract, an initial test was carried out in November 2009 on behalf of the Contractor. This test was subsequently followed by a further three tests in June 2010, December 2010 and January 2011.

The first two of these tests were mainly diagnostic in purpose and both test reports variously noted horizontal and/or angular misalignment in all 3 pumps, commented regarding insufficient holding down of the motor/pump chassis and noted that pump 2 was hard to turn. The graph below is shown as an example of the types of results that were obtained during these tests.

The final two tests were carried out to check that remedial work done was having the effect desired.

The first and subsequent reports commented that more holding down of the pump chassis was required so that the pumps were held down evenly and a number of further recommendations were included with a view to rectifying problems identified. In summary these were:

- Make motor hold down bolts accessible on all pump sets
- Add side adjusters to motors on all pump sets
- Make hold down bolts all the same size
- Add at least 4 more M12 hold down bolts to chassis
- Laser align all pump sets
- Replace all coupling elements
- Check stable power supply from VSD
- Stroboscopic check on new coupler

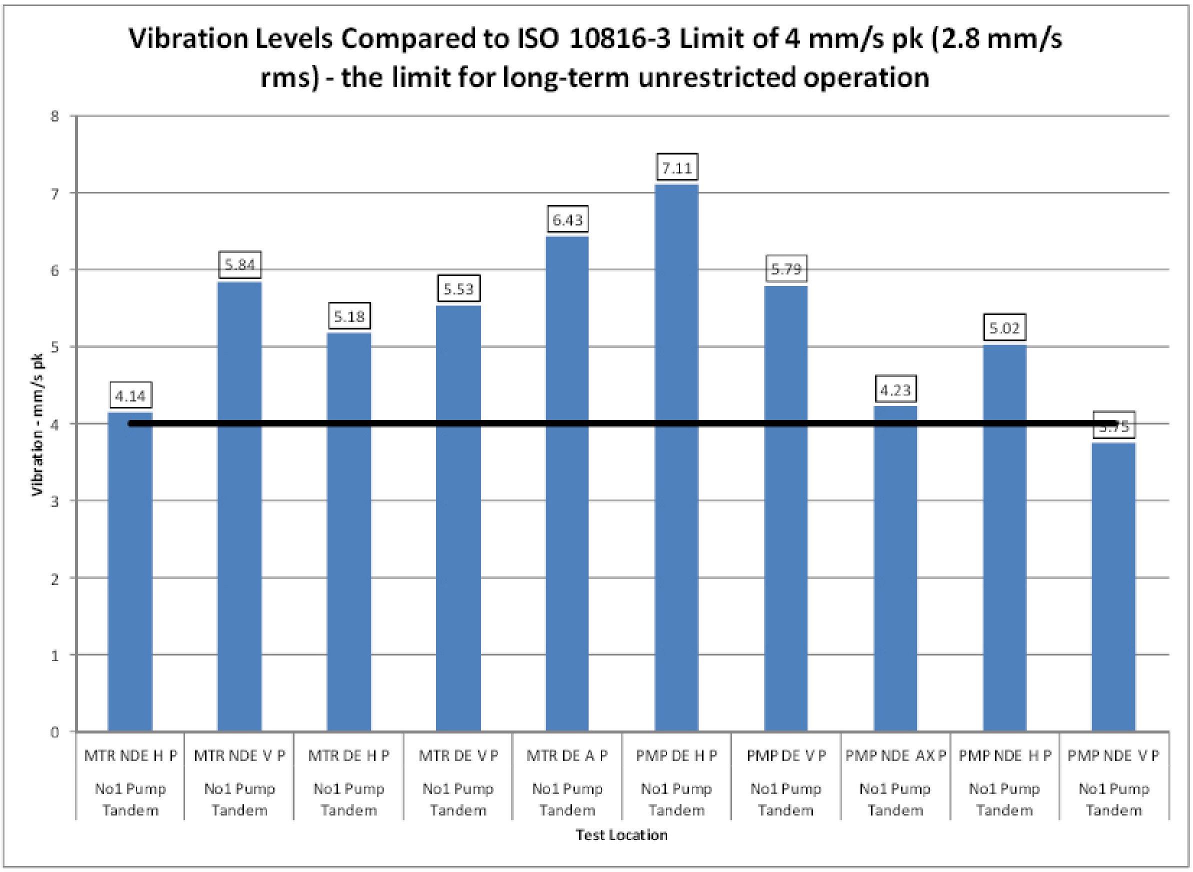
There were also distinct increases in noise from upstream to downstream of the pipework couplers, especially in the header pipework which indicated increased turbulence in the pipe due to disturbance at the coupler.

Due to a lack of acceptance of liability on the part of several of the parties, many of these recommendations were not accepted or acted on initially, but all of these items were eventually required to be fixed in some degree, with the exception of the power supply which was stable and found not to be a factor in this case.

A sample of the type of graph supplied in the vibration reports is shown below showing the positions and levels of vibration experienced, the highest levels in this case being the pump drive end bearing (7.11 mm/s pk) and motor drive end bearing (6.43 mm/s pk).

Figure 2: Sample vibration level graph Pump 1

No1 Pump – Pump 2 Running



In addition, the mortar under the pump chassis became cracked and started to vibrate loose (photograph 1). It was later found that air voids created behind this dry pack were a partial cause as the web of the chassis channels was largely unsupported.

Photograph 1: Loose and cracked dry-pack at Pumps 1 and 2 motor ends

1.2 BREAKDOWNS AND FAILURES

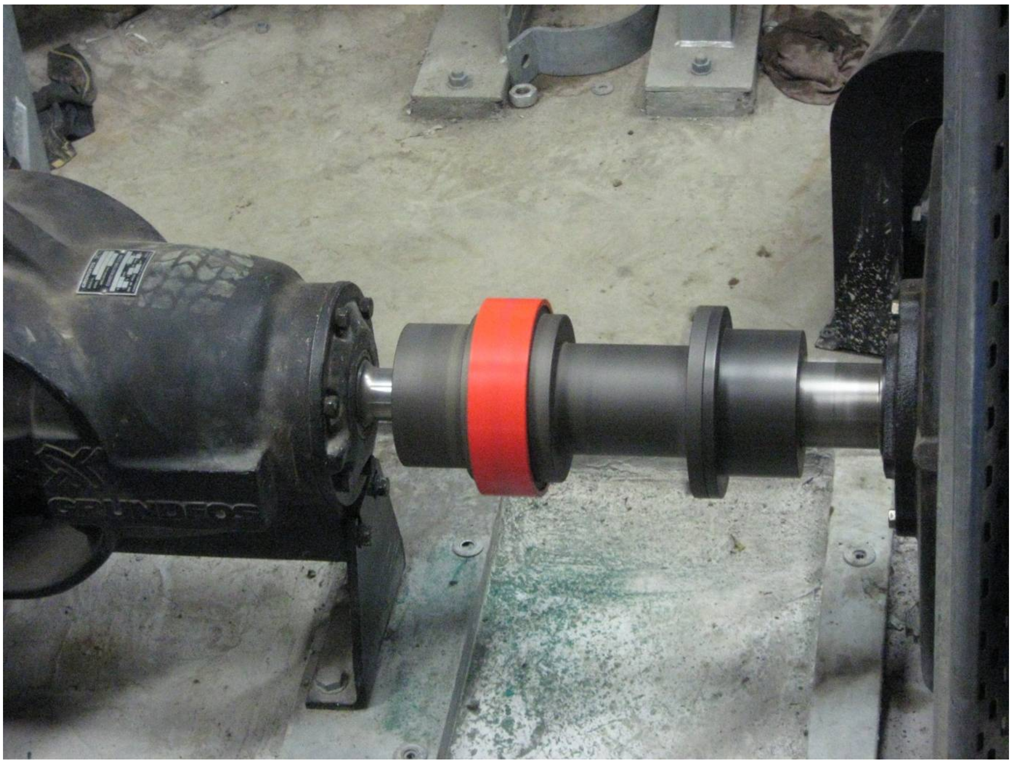
A number of failures occurred in components of the pump station, and many of these are discussed in more depth later. Some of these proved to be side issues but all are listed below for completeness. The rest are discussed more fully in item 3 below.

1.2.1 COUPLER FAILURES

The pump sets when supplied were fitted with coupler elements which proved too soft and these suffered excessive wear which was attributed to misalignment and vibration (photograph 2).

It was acknowledged by the pump supplier that an error had been made and these elements were replaced and no further failure of this type has been evident.

Photograph 2: Motor coupler showing green powder from deteriorating element below unit



1.2.2 BEARING FAILURES

Two types of bearing failure were experienced. The first of these was attributed to false brinelling due to transmitted vibration to the static pump; the second was a catastrophic failure in pump 2 both of which are discussed later in this paper.

1.2.3 MISALIGNMENT

The pumps and motors were continually found to be in misalignment. While there were undoubtedly a number of factors which contributed to this, it is probable that pressure from poorly supported pipework allied with vibration and a lack of positive side adjustment on the pump sets caused / allowed this to occur and these are also discussed later.

1.2.4 VALVE SEAL FAILURE

The knife gate valve seals failed in all three pump trains. This was found to be a manufacturing fault and these were repaired under warranty by the valve supplier without argument. Because the failed seals ended up in a pump impeller on at least one occasion, some items were also were affected by this.

2 THE ISSUES

2.1 CONTRACTUAL ISSUES

The specification for the pump installation stated "The Contractor shall not purchase the pump and motor separately and make their own baseplate" and further required the Contractor to "ensure that the overall responsibility for correct alignment of the pump, motor, coupling and baseplate/skid shall rest with the pump supplier". The main Contractor sub-contracted a pump supplier who nominated a local agent to provide installation services and support for this work.

While this type of clause may have been intended to ensure that the responsibility for the installation rested with the party with the most technical knowledge of the pumps and drive set-up, the main Contractor was still responsible for the pipework alignment and mounting of the pump set (particularly the holding down and grouting). This led to problems of demarcation between the main Contractor and his Sub-contractor, with the pump supplier adamant that pipework deficiencies were causing the vibration, and the main Contractor being equally certain that misalignment in the pump set was causing the issues. As a result, the first work done was an attempt to smooth flow into the pumps by removing sources of turbulence.

Also, no vibration limits for the pump sets were set in the specification, even though a vibration analysis was required to be carried out by the Contractor before acceptance by the Principal. Thus an “industry standard” 4 mm/s pk was adopted as a pass/fail benchmark for the purposes of determining acceptable limits on vibration in these units.

2.2 SYSTEM ISSUES

2.2.1 LACK OF SCREENS IN SUCTION MANHOLE

Screens were originally included in the design of this manhole for the primary purpose of removing swirl from the incoming flows in order to reduce the likelihood of vortices forming at the suction bell-mouth.

During commissioning, no swirl was observed, thus the screens were not installed. Unfortunately this allowed plastic bags (mainly wind-blown) which had not been caught by the primary screens at the plant inlet, and feathers from the swans inhabiting the ponds which had negotiated the pond outlet baffles, to enter the pumps, causing issues with jamming of the impellers (photograph 3). Screens were fitted to this MH to alleviate this problem. Subsequently however, problems have occurred with these screens blocking and bending with feathers as the manhole is in the order of 4 metres deep and feathers are difficult to rake from the screens.

Photograph 3: Debris including part of a valve seal removed from the impeller of Pump 1

2.2.2 GENERAL CONFIGURATION

The use of existing header pipework in this pump station meant that the configuration used was not ideal. It should be noted however, that many pump stations are operating successfully around the country with even less ideal configurations.

Photograph 4: Before and after header pipework configuration

Principally, the configuration has less than optimum distance between the pump inlet and the tee from the main header pipe, the design originally had no isolation mechanism between the pipework and the pump, and the configuration of the delivery side pipework meant that the pumps were mounted with a side delivery, rather than a vertical delivery.

As can be seen from photograph 4, there was also minimal isolation between the pipework and the pumps with the only movement available being that permitted by the Straub couplers.

2.2.3 LOSS OF PRIME

One of the features of this pump station is that Fonterra can shut down the pumps remotely to enable wash procedures at their plant to be carried out without surcharging the ocean outfall. These events often occur at night and during one of these shut downs, a loss of prime occurred which led to severe overheating of the running pumps. During the early morning of 5 November 2010 Fonterra stopped the pumps to allow higher flows from the Fonterra site and upon restarting the pumps ran with a zero flow. In spite of several attempts to replicate this event under controlled conditions, it has not been possible to force this loss of prime to reoccur, so the reasons for this event have not been fully explained to date.

It is possible that there was slight air leakage in the system, or that as the pumps are set up to only run when electricity prices are low or there was methane build up in the pipework etc. which may have contributed to this.

However the pump control logic has now been modified to ensure that current drawn by the pump motors is compared with flow, thus enabling the pumps to be stopped and an alarm raised should loss of prime occur in the future.

Some bearings were replaced as a result of this incident, which complicated the diagnostic process required to define the problems to be resolved.

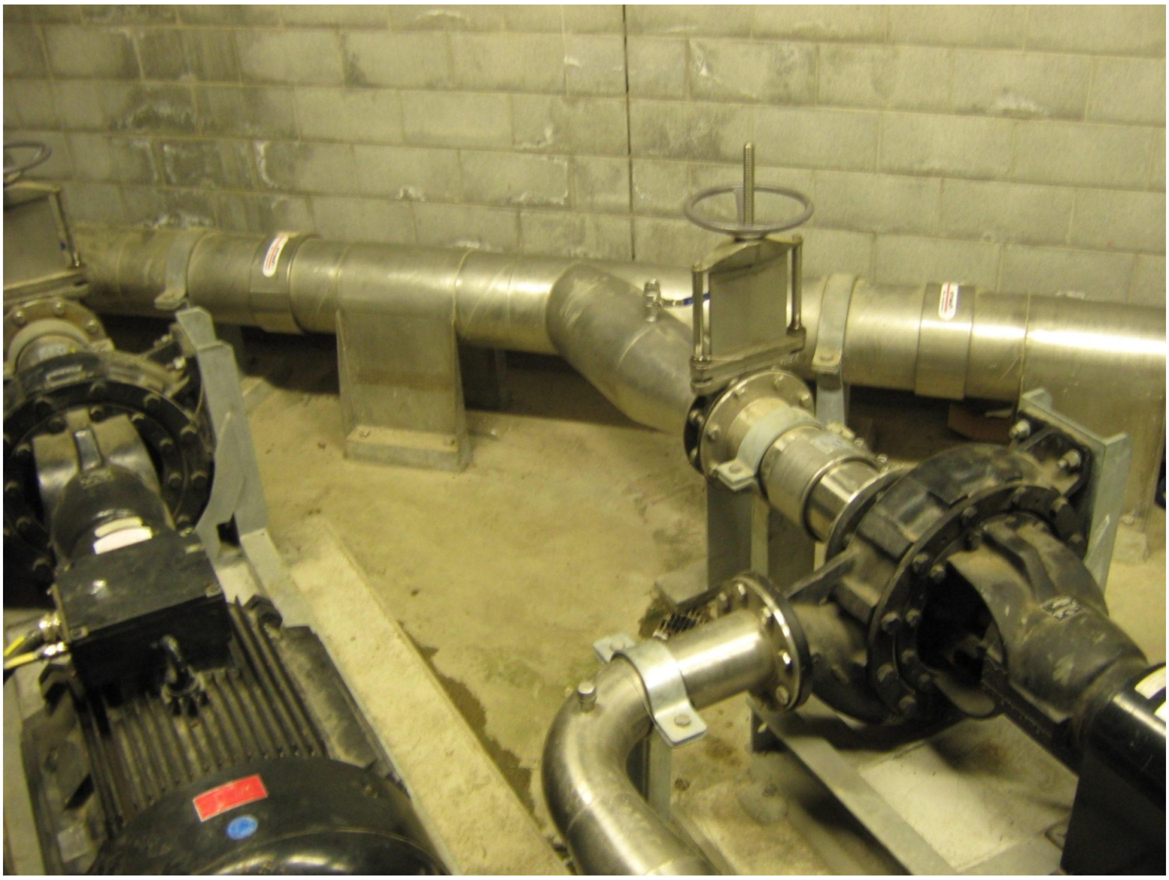
2.3 PIPEWORK ISSUES

2.3.1 LACK OF RIGIDITY IN HEADER PIPEWORK

The existing pipework used in this installation is light walled stainless steel, spiral welded tubing secured to the floor with a combination of bolted galvanized steel brackets and light stainless steel supports folded and welded to the pipe, joined using semi-rigid straub couplers (photograph 5).

Extra rigidity was added to this pipework by replacing the couplers with flanges and the folded supports with galvanised steel brackets (photograph 4).

Photograph 5: Pumps 1 & 2 showing original supports and couplers



2.3.2 HEADER PIPEWORK OUT-OF-ROUND AT STRAUB COUPLERS

When the Straub couplers were removed the pipework sprang sideways and the end of the downstream pipe was noticeably out of round. This was difficult to photograph, but some of the misalignment shown in photograph 7 was due to this.

This distortion was probably due to the Straub couplers being used to force the pipework into alignment at the joints against slightly out of position pipe supports, but any uneven pressure from any source on such thin walled tube would be sufficient to cause this distortion.

This pressure possibly also contributed to misalignment problems between pump and motor in some cases.

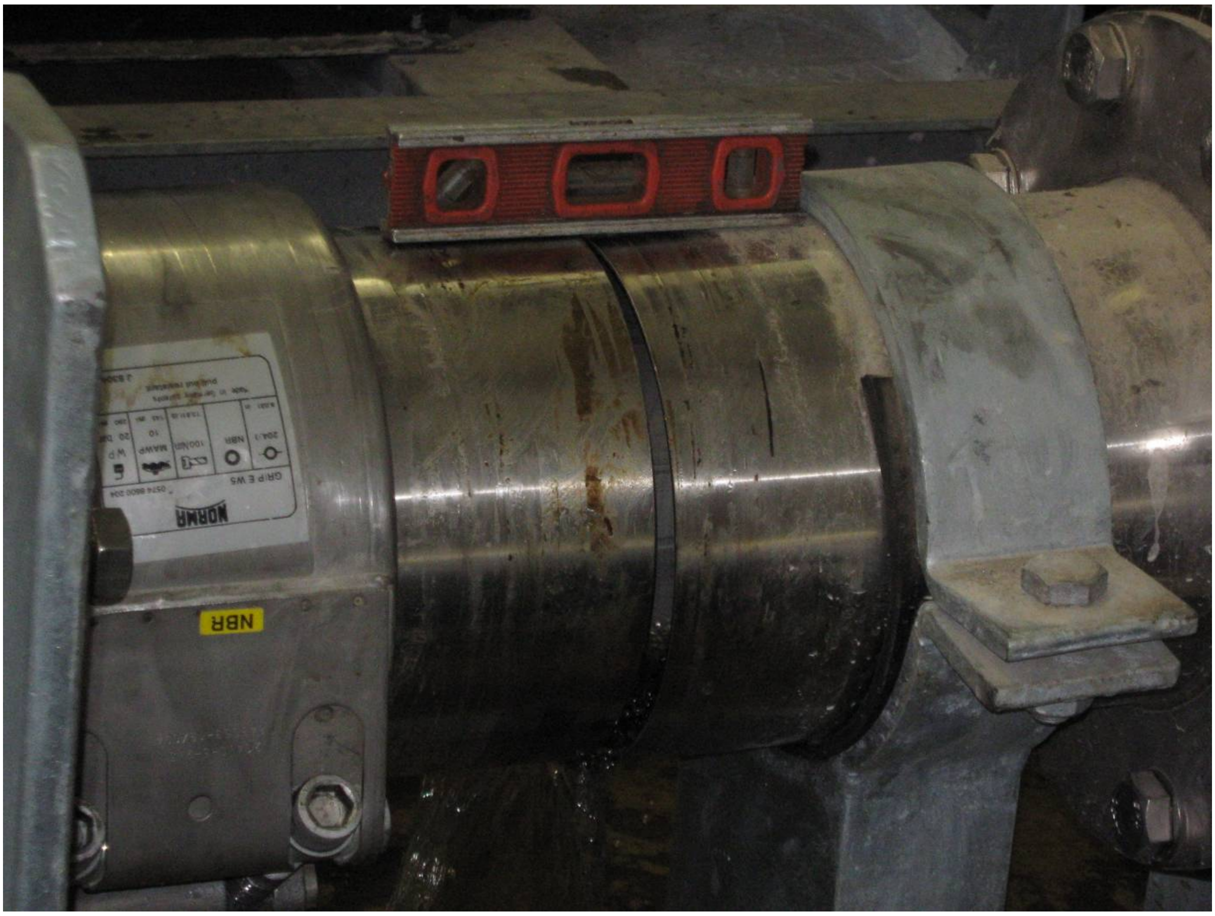
2.3.3 MISALIGNMENT IN SUCTION PIPEWORK

There was marked angular and lateral (both vertical and horizontal) misalignment in the existing header pipework at the Straub couplers. This was particularly noticeable at the joint between pumps 1 & 2 (photograph 7) where the displacement was between 6mm and 10mm depending where it was measured.

This misalignment was corrected by removing the Straub couplers and pipe supports and fitting flanges at the joint before reinstalling the supports. The folded stainless steel supports were also replaced with galvanized units of greater rigidity.

Once the new flanges were fitted and the pipe supports were to be reinstalled, the hold down bolts for the existing brackets were displaced in relation to the final pipe alignment, suggesting that some of the misalignment and out of round could have been due to inaccurate placing of the original support brackets.

Photograph 6: Misalignment in the 200 mm pipework at Pump 2



It was noticeable that once the misalignment in the header had been corrected and the pipe supports repositioned, that much of the misalignment in the smaller pipes at the pump was corrected also. The rest of this misalignment was dealt with by use of isolation bellows which provided some flexibility at the knife gate valve position.

Photograph 7: Lateral and angular misalignment at Straub coupler in 300dia header pipe

2.3.4 KNIFE-GATE VALVE SEALS

Issues have arisen with the knife-gate valves on the pump suction pipes. In spite of manufacturers data indicating that these valves are suitable for the location used, and for the velocities encountered, these seals in all three valves have failed and in one instance have been sucked into the pump (photograph 3).

In other instances the valve seal has become dislodged and protruded into the flow with the likelihood of also migrating to the impeller (photograph 8).

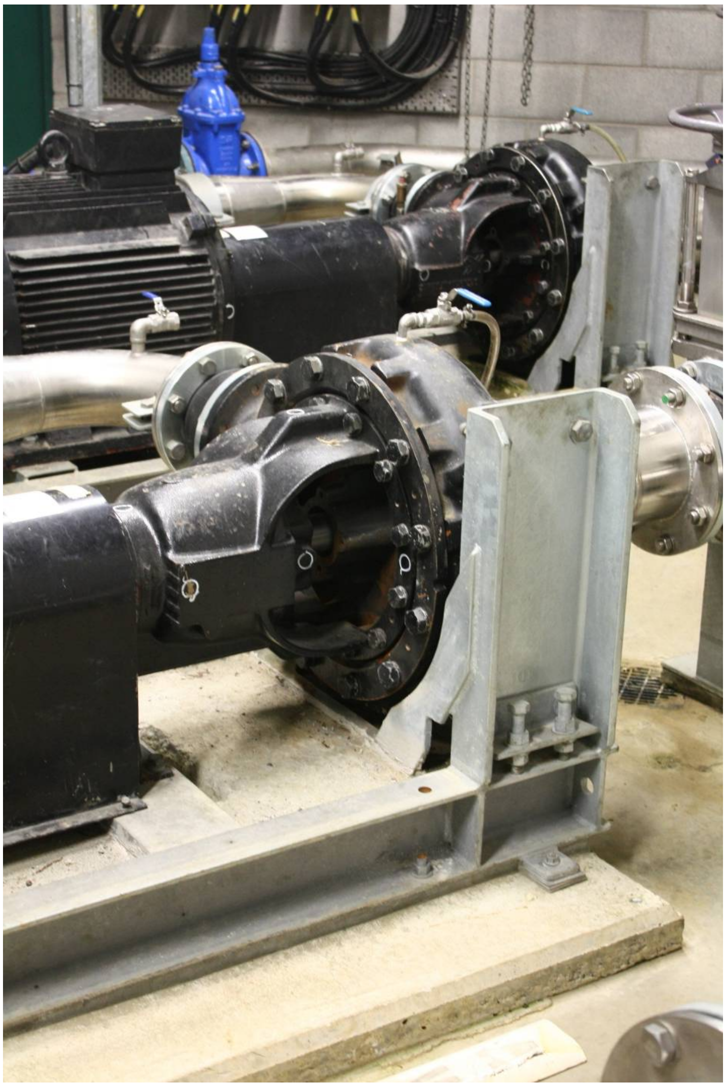
Photograph 8: Loose and broken valve seal Pump 3

2.4 PUMP ISSUES

2.4.1 HOLDING DOWN ISSUES

Holding down of these pumps was a contentious issue from the time of the first vibration report, with the pump supplier unwilling to accept that the holding down detail was inadequate. The reason being that similar pump sets elsewhere used a similar detail with no apparent vibration issues. However the mounting of the pump on a vertical strut (photograph 9) does introduce a marked increase in rotational moment at the holding down bolt position compared to a vertical delivery installation with the pump bolted directly to the base frame.

Photograph 9:   Pump mounting detail



It was also noted that the four bolts used in the original installation of each pump set were of different sizes (photograph 10). Possibly a support on the delivery side pump flange may have assisted these bolts to resist the forces imposed, and this was given serious consideration, but due to the other problems encountered and resolved this was found to be not required.

Photograph 10: Different size HD bolts Pump 3

This lack of holding down capacity was made worse by workmanship issues discussed in section 3.4 below.

The final solution adopted was to install three bolts on each side of the chassis, drilled directly through the flanges into the floor.

2.4.2 COUPLER ISSUES

The initial coupler elements used between the motors and pumps were apparently of the wrong grade and initially suffered excessive wear (photograph 2). These were replaced with harder elements after the first vibration test and realignment was done and there have been no further issues apparent with these elements.

In at least one case, excessive clearance between coupler elements was observed with the gap between the ends of the shafts being outside of tolerance. In this case the coupler was also out of balance and once an extra weight (grub screw) had been added the out-of-balance vibration was substantially reduced.

2.4.3 MISALIGNMENT ISSUES

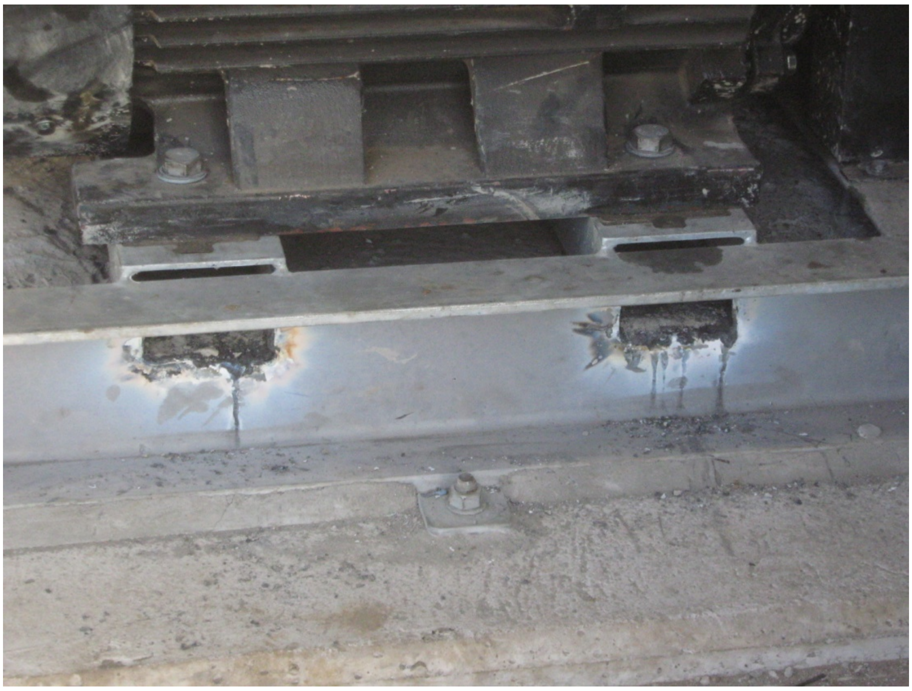
As commented previously, the pumps were delivered mounted on a chassis having been aligned at the factory. Once on site however, the assembled units could not be lifted into position due to headroom and weight limitations, and rather than increasing the lifting capacity of the overhead rail and chain block available and undertaking temporary decommissioning and recommissioning of the existing pumps, the Contractor disassembled the units to lift them into place in pieces. Laser alignment of the pumps and motors was not carried out on reassembly when the pump units were first installed. Once the initial vibration analysis was undertaken an independent company was employed by the main Contractor to check the alignment of each set and a number of issues were found.

In order to achieve accurate alignment, the mounting bolts for the motor first had to be made accessible and the holes slotted to allow movement for horizontal alignment (photograph 11) and the shims under the motor itself had to be changed to achieve accurate vertical alignment.

In cases where the pump was removed from the housing, reassembly of the impeller mounting ring without applying even torque to the bolts also created issues with alignment and in at least one instance caused the impeller to bind on the convolute making it almost impossible to turn.

Vertical adjustment of the pump was possible using adjusting bolts (photograph 9); however horizontal adjustment relied on slotted holes and friction which made it easier for units to vibrate out of line.

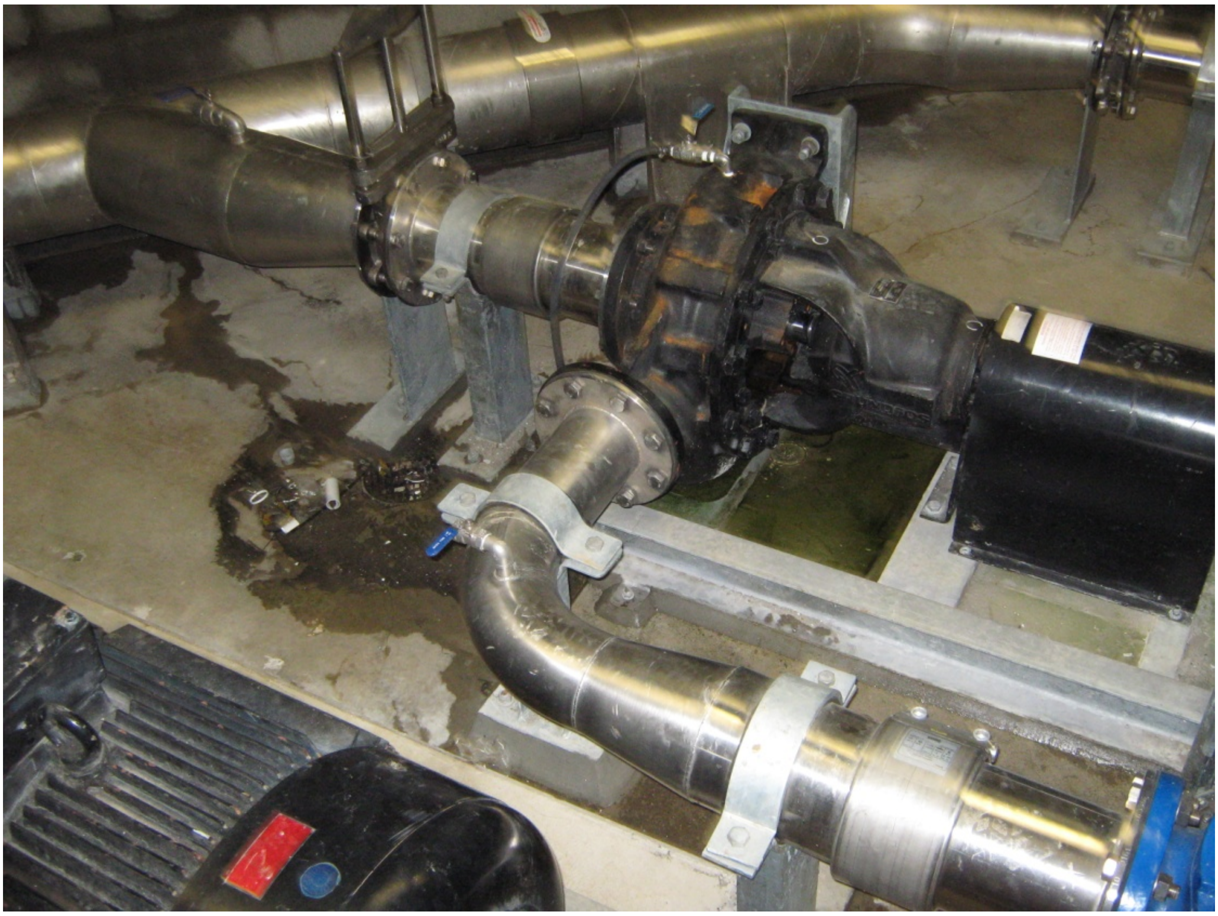
Photograph 11: Pump 3 chassis showing access slots cut to enable motor adjustment.



2.4.4 SEAL LEAK ISSUES

On at least two occasions pump seals were observed to be leaking after the pumps were reinstalled (photograph 12). These issues were largely resolved by applying correct torque to the mounting ring.

Photograph 12: Pump 2 seal leak after reinstallation



2.4.5 BEARING ISSUES

A number of bearing failures occurred in both pumps and motors. The motor bearing failures have been attributed to false brinelling. In pumps 1 and 3 the motor bearing types were changed from "roller" bearings to deep race ball bearings, as these are less susceptible to false brinelling under vibration when static. Pump 2 which had bearing issues earlier had the bearings replaced like-for-like, and it has been recommended that these also be changed to deep race ball type bearings also, as bearing damage is evident in the final vibration readings on the motor of pump 2.

The bearings in pump 2 also failed catastrophically in September 2010 (photograph 13). This pump had shown lower levels of vibration than pump 1 so was being used as a duty pump in preference to pump 1, notwithstanding that it had been noted as hard to turn. From the shaft and housing damage noted after the failure, it is likely that the bearings had been rotating on the impeller shaft, and also possibly in the bearing housing. This was probably the reason this pump was hard to turn. It is also possible the impeller had been touching the housing to cause this.

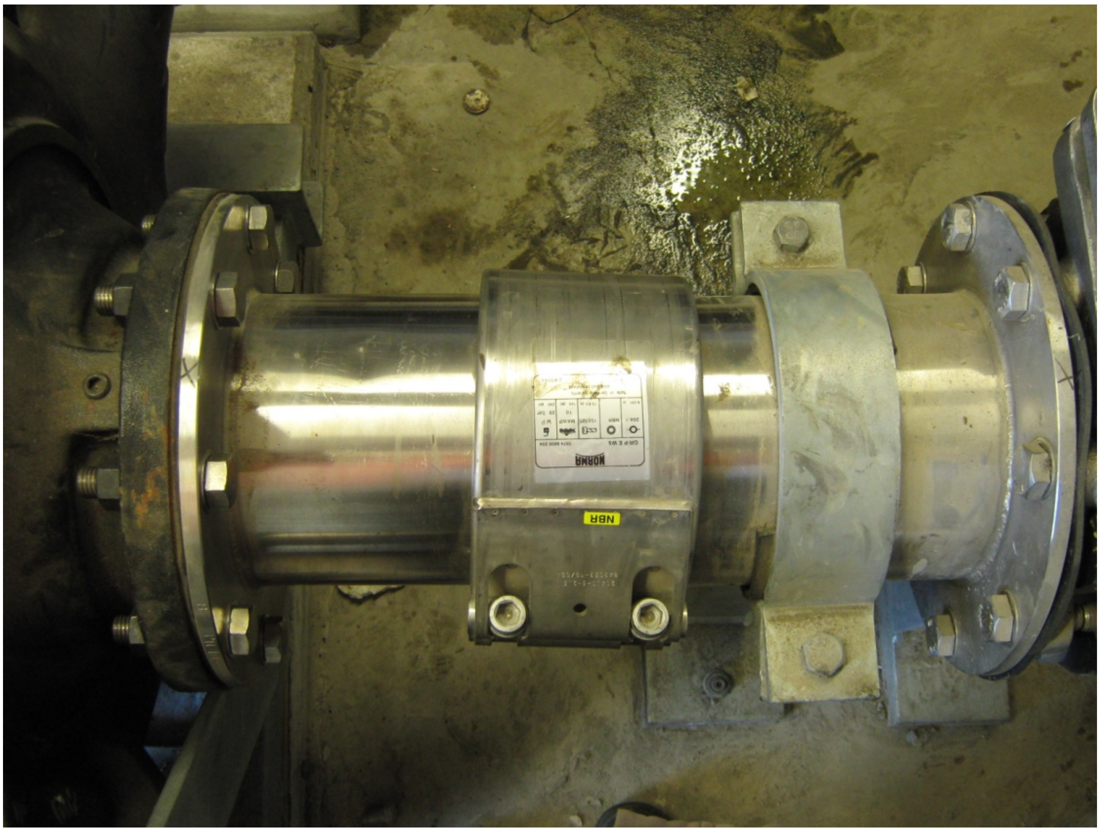
Photograph 13: Bearing from Pump2 showing typical damage.

2.5 WORKMANSHIP ISSUES

2.5.1 MISALIGNED PIPEWORK FROM KNIFE-GATE VALVE TO PUMP

A varying degree of misalignment was discovered in the modified pipework between the new knife-gate valves and each pump, both angular and lateral being present to varying degrees (photograph 6). This was worst at pump 3, where there was both angular and lateral misalignment as well as an excessive gap but lesser degrees of misalignment were present at all pumps with Straub couplers being obviously out of parallel with the pipe (photograph 14).

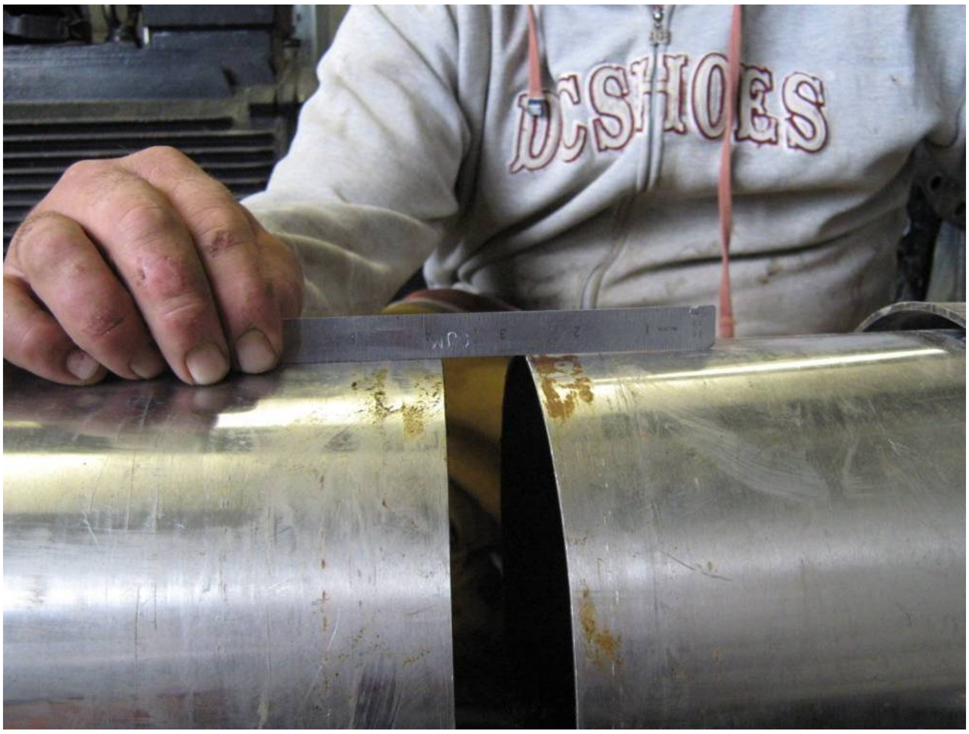
Photograph 14: Pump 2 Straub coupler not parallel



2.5.2 EXCESSIVE CLEARANCES AT STRAUB COUPLER (PUMP 3)

At Pump 3, it was discovered that the gap between the ends of the pipework in the coupler was excessive, with a gap of approx 25mm at one side of the coupler increasing to approx 35mm at the other. It is probable that the removal of this gap was a large contributor to the reduction in average vibration levels shown at this pump, the only point where the pipework changes did show a marked improvement in level experienced.

Photograph 15: Angular misalignment/ excessive gap at 200dia Straub coupler pump 3



2.5.3 DRY-PACK UNDER PUMP CHASSIS, GROUTING METHODOLOGY

The "Sika 212" non-shrink dry pack under the pump chassis showed uneven compaction, with air voids evident once inside the outer 15mm or so (photograph 16). The penetration of the dry pack was also uneven, in spite of staff stating that the material was rodded into place against a timber form placed at the back of the chassis member. It is clear that the method employed to place this material was not effective. When the pumps were initially installed, dry pack was placed under all 4 sides of each chassis, and then a free-flow concrete grout poured into the inside.

Examination of textures visible in samples of the dry pack removed (photograph 17) strongly suggest that this methodology resulted in pockets of air being trapped under the inner (web) side of the main chassis members. It is likely that the resulting lack of support for the web of this channel contributed to the issues arising from the lack of holding down discussed in item 3.3.1 above.

Photograph 16: Sample of original dry pack from under pump 3

Photograph 17: Sample of original dry pack from under pump 2 plan view and edge view

2.5.4 COVERING OF BOLTS WITH CONCRETE

The hold down bolts for the motors were made inaccessible by the level of concrete poured into the base frame (this can be seen in photograph 2). This meant that slots had to be cut in the main chassis members to enable access to the motor bolts (photograph 11).

It was also found to be impossible to remove the impellers from the pump as access to the bolts holding the support bracket was concreted over and concrete had to be chipped out to enable this work to proceed.

2.5.5 PUMP REINSTALLATION WITH UNEVEN TORQUE ON THE MOUNTING RING

On at least two occasions, once on pump 1 and once on pump 2, the impellers and shafts were reinstalled in the convolute housing with uneven torque being applied to the bolts. This resulted in the pumps being difficult to turn until these bolts were reinstalled and tightened in the correct sequence and with the correct torque.

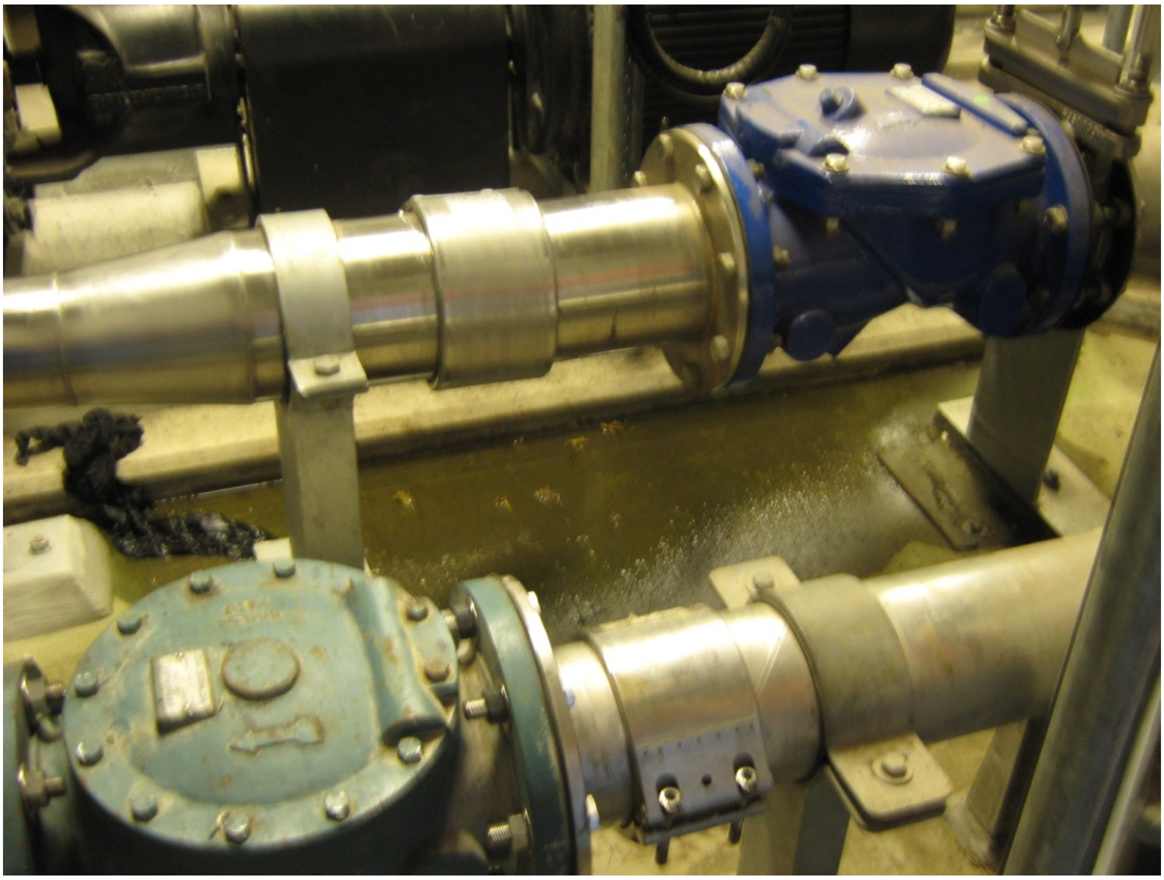
It was also noted that when this was done a large part of the misalignment between motor and pump was corrected.

2.5.6 PIPE SUPPORT INSTALLATION

A number of the galvanized support brackets were not installed correctly. In these cases the posts were not vertical and displaced from the true line of the pipework. This was evident on both the suction and delivery sides of the pumps.

The result of this was side pressure on the affected pipework with potential to pull the pumps out of alignment when this was coupled with even moderate levels of vibration. It is difficult to see this in photographs but an example is shown below (photograph 18).

Photograph 18: Support on delivery pipework out of plumb



2.5.7 OVERFLOW PREVENTION

During this entire remedial operation, the inflow to the plant continued. Some relief was available by using the detention facilities at Eltham to remove those flows temporarily from Hawera. However, as is often the case, these problems occurred when inflows were at their highest, and the weather was at the worst. It was therefore necessary to work on one pump set at a time and to leave the other pumps operational.

This became an issue when the knife gate valves would not seal and in the end the pipes between the pump and valve were removed and a temporary blanking plate was installed to prevent air being sucked into the other pumps (photograph 19).

Photograph 19: Work on pump 2 showing pump & pipework removed

3 LESSONS LEARNED

3.1 SUPERVISION

The ACENZ / IPENZ guidelines provide various options (CM1 to CM5) for the level of construction supervision required for a project. The level of supervision required for this contract was included in the agreement between the Principal and the relevant Consultant and was equivalent to a CM4 level with a K value of 11-12. This was appropriate for much of the work covered by this contract (pipeline upgrade) but for the pump installation itself, a CM 5 level would have been more appropriate. This example highlights the importance of making a good assessment of the level of construction supervision required at the very outset of a project.

For installations such as this it would be better to have direct on-site supervision by suitably qualified and authorised personnel for all critical parts of the work, so in the event of decisions being needed they can be taken in a timely manner. Inclusion in the specification of a requirement for the Contractor to notify the Engineer when defined critical work is to be undertaken should be considered.

Alternatively, a construction quality control plan / risk management plan that is strictly enforced is another mechanism available to achieve this. For retrofits / augmentation work of this nature, it is very important to have a good understanding of the existing operating characteristics of the plant.

3.2 HEALTH AND SAFETY

3.2.1 ACCESS

When designing / sizing pumps and pipes for a retrofit, sufficient access / space to carry out the construction work and then to maintain the installation safely requires consideration. If space is not available, identify what other work may be required to enable this and design and specify accordingly.

It is not usually reasonable to transfer this entire responsibility to the construction contractor.

3.2.2 CONTAMINATION

Due to the knife gate valve seat failures, it proved impossible to drain pipework at one pump without losing prime at the others, and thus contamination and spillage became inevitable.

Suitable PPE is always necessary, but as an additional precaution in this case no person with any open wound was permitted to work on the installation.

3.3 SPECIFICATION

3.3.1 DESIGN RISK

Placing the design risk for the pumps with the pump supplier created problems once the vibration issue came to the fore. The pump supplier and the local agent both felt able to maintain a position that factors outside of their control (the suction and delivery pipework), were the causal factors and that this absolved them from further responsibility.

The demarcation of design risk needs to be carefully thought through before including such clauses in specifications.

3.3.2 ACCEPTANCE CRITERIA

Placing a requirement on the Contractor to carry out a vibration analysis without specifying an acceptance value made for some interesting discussions between the parties.

Acceptance criteria require definition, if possible with an easily measured pass / fail mark.

3.4 PUMP INSTALLATION

3.4.1 PUMP MOUNTING

The pump mounting base design had been used by the pump supplier in similar installations previously. However, there were some differences and combined with improper installation techniques, these were sufficient to cause the failures discussed above.

“It worked last time” is not a valid argument when designing these mountings as each installation is unique, and the designer must ensure that the pump supplier / base designer are fully aware of all of the likely operating conditions.

The refusal of the pump supplier to sanction any change to the design of the holding-down system for the pump chassis (for which it was responsible under the contract) until all other possibilities were exhausted, despite recommendations from the vibration analysts.

3.4.2 IMPELLER INSTALLATION

Correct impeller installation is critical as the clearances are small and very slight variations in torque on a large diameter mounting ring can translate to millimeters of displacement at the shaft ends, as well as affecting internal clearances for the impeller itself.

3.4.3 WORKMANSHIP

Improper techniques when installing the pump sets contributed to many of these issues.

Specifications should be very specific regarding materials and techniques used, especially where air may become trapped underneath mounting plates. Many of the problems associated with this installation would have been less critical if air had been able to escape when the flowable grout around the base was poured.

3.5 EXISTING PIPEWORK

3.5.1 PIPEWORK VIBRATION

The existing pipework was hydraulically adequate, but due to installation issues, some dating to the original construction some 20 years previously, the turbulence from increased flow and velocity past substandard jointing created vibration in the pipework.

The light walled pipework did not have sufficient mass to damp this, and it was transmitted directly to the pumps. This was made worse by the way that the couplers had been used to pull the pipes into line against poorly placed supports, thus introducing a side force as well as vibration to the pumps.

When upgrading an existing installation, particularly when upsizing as in this case, the workmanship in the reused items needs to be checked, as well as capacities calculated.

3.5.2 VIBRATION TRANSMISSION

The couplers used instead of flexible bellows proved ineffective in preventing bearing damage occurring in the stationary pump set.

In this case, the desire to improve flow entry conditions at the pump due to a very short entry leg dictated the use of semi-rigid couplers rather than isolation bellows. However, this enabled vibration from the running pumps to be transmitted directly to the standby unit and damage to stationary bearings resulted.

Depending on circumstances, in-service life considerations need to be balanced against, in this case, pump efficiency when designing such upgrades.

4 CONCLUSIONS

In this installation, what should have been a relatively straightforward, albeit intricate, upgrade operation became problematic when a large number of factors, each on its own not necessarily critical, combined to cause failure. The failure of the Contractor to fully understand the critical nature of the installation was compounded by supervision which failed to note critical mistakes made during the work.

A timeline of in excess of a year to resolve these issues meant that what started as gradual failures escalated to catastrophic failure in some components. Thus, in cases such as this timeliness of decision making and execution should be given priority.

Vibration in any rotating machinery is usually symptomatic of underlying issues with the installation, and if possible, it is better to cease operation of the equipment, and move to a step-by-step analysis of the issues. In this case that was not possible, and continuing to operate the pump station in spite of the evident problems made it inevitable that some problems became worse during the rectification of others. It is evident that costs to all parties would have been reduced if adversarial positions were avoided, as time and cost was incurred while responsibility was attributed, and it is probable that at least one major bearing failure was directly attributable to this.

While supervision is often seen as an expensive adjunct to the contract, and many of us resist extra supervision costs, these costs pale into insignificance compared with the costs of the remedial work required in cases such as this.

There are lessons here for all parties involved, the client, the designer, the supervisor, the equipment supplier and the contractor and it is hoped that these lessons can be incorporated in later designs of this nature to prevent costly and unnecessary failure in the future.

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