The official journal of the Vibrations Association of New Zealand

Spectrum

Autumn 2021 | Issue 98

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Taupo: 17th - 19th August

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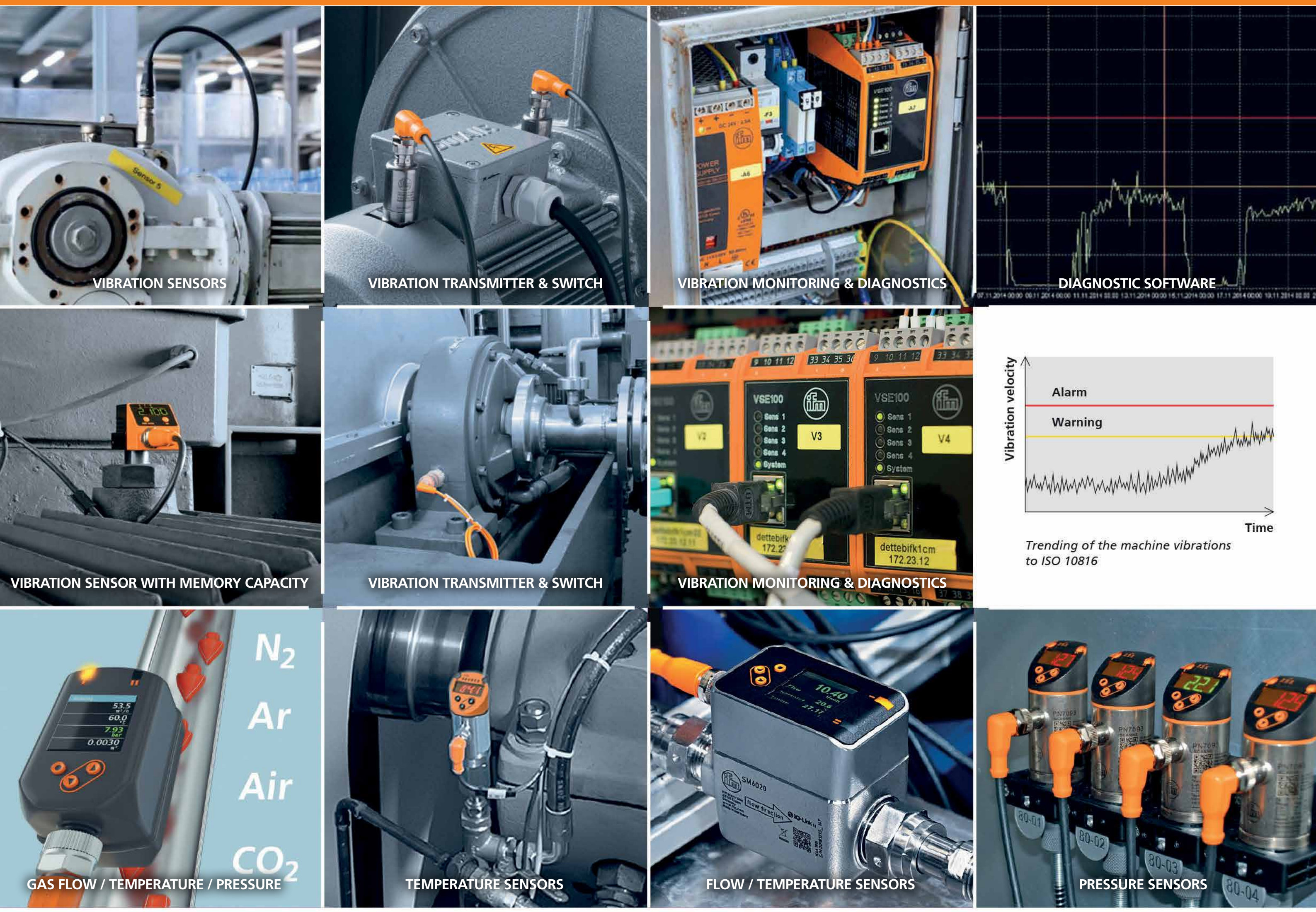

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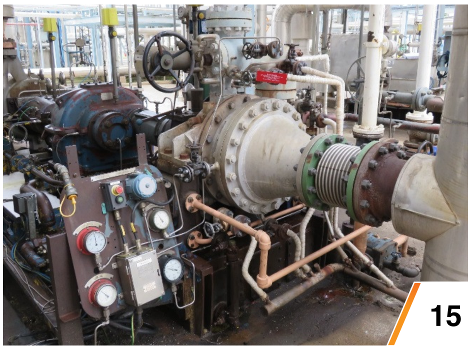

15

23

CONTENTS Autumn 2021

Features

Regulars

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VANZ
VIBRATIONS ASSOCIATION of NEW ZEALAND

PRESIDENTS' REPORT

By Rodney Bell, VANZ President

Welcome all to 2021 and I'm sure you will join me in hoping this will turn out to be a much better year than what we struggled through in 2020.

Late last year the committee proposed to carry out regional one day events instead of our normal 3-day conference, but after much discussion we have now decided to forgo these, except for the already planned Auckland session, that is still to be held at Hera House Manukau on the 28th of May 2021. The enrolment form will be available on our website soon.

As many of you are aware, the VANZ committee chose to act early and cancel the May 2020 Conference before the government COVID-19 lockdown announcement, this proved to be the correct call and the good news is we can now confirm we have locked in a date for the 2021 Conference. This is to be held at the **Wairakei Resort in Taupo**, at a later than normal date on the **17th to 19th August**, so please lock this date into your calendars.

.

VANZ is a platform for the NZ and Australian engineering industry engaged in Predictive Asset Management, and the VANZ Committee now feels confident we can hold this event while putting concerns around COVID-19 to rest to ensure companies and their employees that they will be kept safe as they move outside their region to attend the 2021 Reliability Conference. It's for this very reason, we have chosen the Wairakei Resort, which is in an isolated location away from major cities etc. We will also be putting in place several additional safety measures to further decrease any COVID-19 concerns. The feedback we received from potential attendees and their Management was very encouraging to hold this 3-day event at Wairakei.

"We have locked in a date for the 2021 Conference. This is to be held at the Wairakei Resort in Taupo, at a later than normal date of the 17th to 19th August, so please lock this date into your calendars."

Choosing August instead of May is to ensure we have enough time to complete the planning and by then hopefully we will have a NZ/Aussie bubble in place without the need for isolation at the border. Currently we are working on Keynote Speakers along with Guest Speakers, some of which may be delivered via live streaming.

We are also working on costing which if possible, will be consistent with other years and will still include free attendance to the Awareness days for all apprentices and trainees. Keep an eye out for our advertising campaign which will include all the above, plus very competitive hotel room rates etc.

For now, in NZ we have the freedom of exploring our fine country and with an extended forecast for sunshine until the end of March, I wish you all happiness and good will. I will be announcing further updates in the next edition of Spectrum scheduled for May 2021. ■

Read on for details on how to register! >

GET READY!

VANZ Conference 2021

Wairakei Resort, Taupo: 17th - 19th August

VANZ is a platform for New Zealand and Australian engineering industry engaged in Predictive Asset Management.

Our industry is hurting through Covid-19 pandemic. VANZ is willing and prepared to support our industry, our members, our sponsors, and our vendors. To this end VANZ is running a Reginal Technical Forum and importantly VANZ Conference 2021. VANZ Conference 2021 would signal to New Zealand, and Australian industry, indeed world industry, that we can, and must manage the Covid-19 pandemic. It is our way to support and aid industries bounce back.

For 2021 and beyond, registration for events have been made much simpler than ever before for members, with all forms avaliable online.

CONTINUES...

EDITORS' CORNER

With the start of a new year we hope that things around the world continue to get better. A certain aspect of uncertainty still over-shadows us all as our normal way of life can become fragile and disrupted with the threat of another threat of outbreak. However, our optimism and support of each other during this time.

The committee are making plans to organize a technical forum and later in the year a conference at Wairakei, you can read more about this in forth coming issues.

In this issue you can get an update from our President Rodney Bell, puzzle your grey matter again with Carl's Quiz, read up on Laying Foundations for A Healthy Machine Alignment Culture by Chris O'Leary from Alignment Engineering Group and an article from Rhiannon Swift about Diagnosing and Eliminating Oil Whirl Instability In Steam Turbine Journal Bearings. VANZ greatly appreciates all those companies that are able to continue supporting us through advertising, thank you.

If you are in area that continues to be affected by Covid-19 then please, continue to take all the measures to practice public health and safety along with common sense hygiene guidelines, we cannot become complacent as it's up to everyone to help protect the vulnerable before they are lost to us, take care of yourselves and each other.

Many thanks and happy reading!


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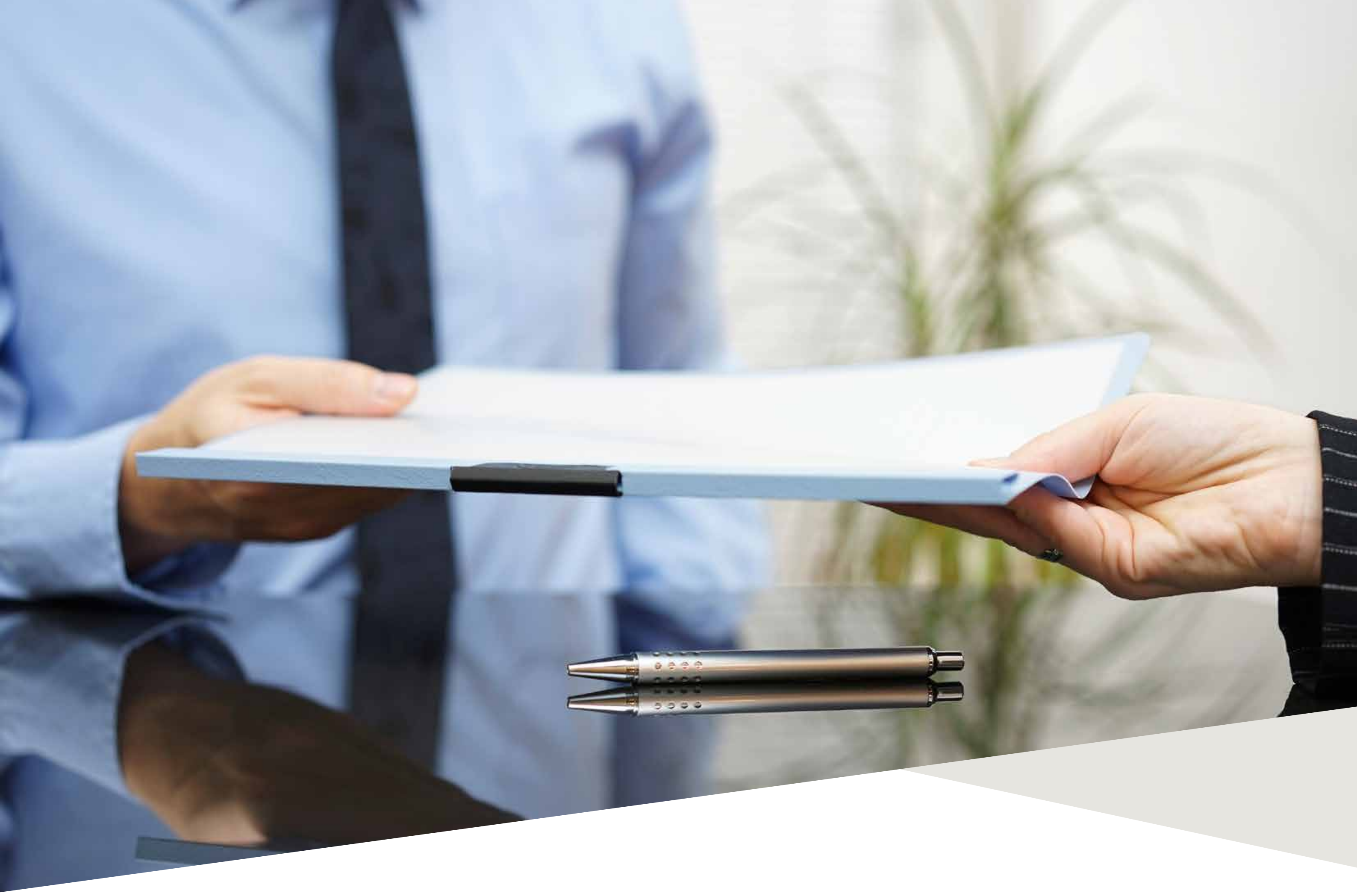
2020 has been a very challenging year for most of us, we are very fortunate to be among a very few countries in the world being able to enjoy the normality after the lockdown. CSE New Zealand together with BkVibro are proud to be the Platinum Sponsor for the 2021 VANZ Conference scheduled for 17- 19 August at Wairakei Resort. With the help and support from VANZ Committees and many participants, we are following Health & Safety guidelines issued by MoH to organise a safe Conference Environment for those who can attend. We are looking forward to meeting with you in August to share the latest in Asset Management and Condition Monitoring world.

- Alan Wang, CSE New Zealand

Regional Technical Forum Timetable

TIME	PRESENTATION	PRESENTER
08.50 to 09.00	Welcome to Hera House	Michael Karpenko
09.00 to 09:05	VANZ RTF Programme Introduction	Larry Wiechern
09:10 to 09:40	Vibration Analysis fundamentals and usage	Bruce Shepherd
09:45 to 10:30	Ultrasonics fundamentals and usage	Dr James Neal
10:35 to 11:10	Infrared fundamentals and usage	Tom Aldridge
11:10 to 11:30	Networking break, with tea, coffee	
11:30 to 12:00	Lubrication [Oil and wear particle analysis]	Mike Wharry
12:05 to 12:35	Lubrication methods of application	Chris Unsworth
12:40 to 13:10	Rotating equipment alignment	Chris O'Leary
13:15 to 13:45	Networking break, with tea, coffee	
13:45 to 14:30	Question and answers discussion with presenters	
14:20 to 15:30	Forum Discussion: Problems experienced in industry related to the topics covered by the presenters.	Bruce Shepherd Simon Hurricks Bill Sinclair
	'Forum Discussion' and networking is designed to assist those with issues that a little knowledge and assistance from our expert panel might be able to provide a solution and answer questions related to problems they may be experiencing.	
A PDF file of the presenter session will be available for attendees.		



CALL FOR PAPERS

The VANZ conference is a place for learning and sharing

- Have you ever had an experience that you think others would benefit from?
- Something that went right or wrong?

We can all learn from our own experience, but we can avoid a lot of problems if we learn from other people too! That is what VANZ is all about. If you could talk for just 15 minutes (or longer if you like), please write to
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Fig.1a

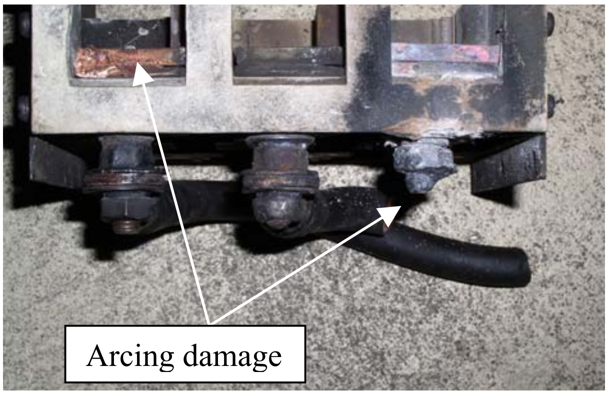


Fig.1b

Case History – Failure of Cable Lug Connection on Combined Fuse Switch unit (CFS)

The CFS shown *(in fig. 1)* **had a DEFECT that eventually caused a fire and a line stop.**

The line stop lasted 10.5 hours and a conservative estimate of the cost to the business is $50,000. This could all have been avoided if best practice had been applied.
The damage to the CFS is the result of arcing that eventually occurred between the Red and Blue phases. This resulted in one of the cable studs burning through.

The root cause of this failure was the poor lug connection practices at the rear of the CFS.
On this style of CFS, the cables are normally bolted to the copper bus on the inside of the CFS as shown *(in fig. 2)*. This is good practice as the conductors are side by side and the steel components are not in the current path. However, in this case the CFS was positioned at the top of the switchboard. This did not allow room for the cables to enter from the top. The cables had to come from below, so an alternative connection was contrived.

The picture above *(in fig. 3)* shows the arrangement of the connections. It consists of a stud (sweated to a copper plate) that passes through a hole in the copper bus and the hexagonal hole in the fibreglass, and exits to the rear of the CFS. Note: The deformed brass washer *(in fig. 4)* that was only just bigger than the hole.

This arrangement is bad practice for 2 reasons.
1. There are steel components in the current path. This creates a high resistance joint.

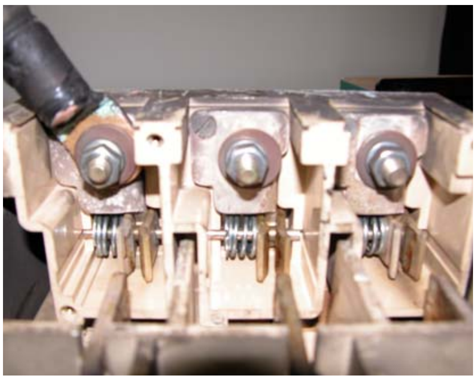


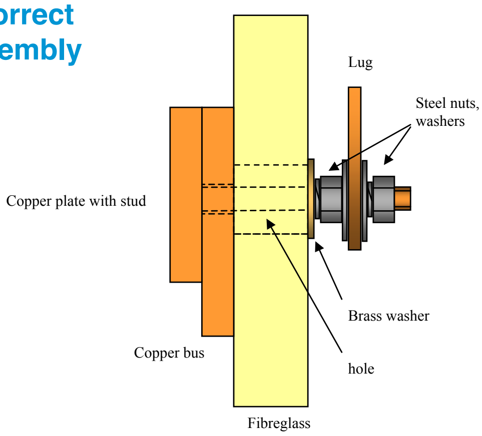
Fig.2

Fig.3

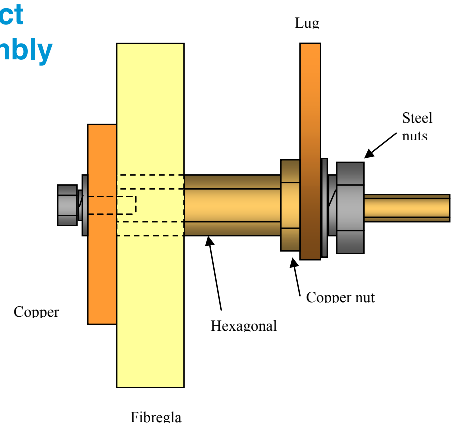
Fig.4

Prepared by Bluescope Steel.

Incorrect assembly



Correct assembly



2. The insulating material (fibreglass) is under compression. This is a breach of the wiring rules. Any compression of the insulating material over time will allow the connection to become loose, again resulting in a high resistance joint.

In this instance, there was also deformation of the brass washer to the point where the spring washers were no longer applying any tension to the connection.

The correct arrangement for connecting to the back of these CFS units involves the use of hexagonal pillars made from copper. These are inserted into the hexagonal hole in the fibreglass. The copper bus has a hole in it that allows the pillars to be bolted directly to the bus using a steel bolt, steel washer and steel spring washer.
The use of steel components here is okay because the conductors are side by side and the steel components are not in the current path. These pillars are available in our Stores system *(Mat no. 10159012)*. They are supplied by Alstom. The lug is assembled to the copper pillar in the following order: copper nut, lug, flat washer, spring washer, steel nut. Once again, the conductors are side by side and the steel components are not in the current path.

The pillar comes with 2 copper nuts, a bolt and flat washers. You will need to source an 8mm spring washer, a 10 mm spring washer, and a 10 mm steel nut. Discard one of the copper nuts.

To avoid another defect, these fasteners must be correctly torqued. The 8mm bolt should be torqued to 9 Nm, and the 10 mm nut should be torqued to 20 Nm. ■

Diagnosing & Eliminating

Oil Whirl Instability in Steam Turbine Journal Bearings

This case study deals with the investigation and resolution of long-standing but intermittent shaft instability on process feed pump turbines at Kapuni Gas Treatment Plant. The steam turbines are horizontal direct drive,running on journal bearings, with a rated speed of 9200RPM. The units are required to run below their rated speed and at low loads. In April 2016, a detailed root cause analysis was held and a subsequent bearing design trial executed, using proximity probes to generate an orbit plot and track the shaft dynamics at different operating conditions. This trial successfully proved that oil whirl was the root cause of the shaft instability, and resolved the issue via bearing redesign.

Introduction

CARBONATE FEED PUMPS

The Carbonate Feed Pumps G-101-1, G-101-2, G-101-3 and G-101-4 are the heart of the Kapuni Gas Treatment Plant, used to strip CO2 from natural gas in the Kapuni Gas Field. They are used to supply regenerated Potassium Carbonate solution to the CO2 absorber vessel to facilitate CO2 removal via the Benfield process.

These pumps are Weir TFR 150 single stage centrifugal pumps with an axial flow inducer and centrifugal impeller. They are typically running at 1.3 bar(g) suction and 43 bar(g) discharge, at a flow of 10910 LPM (831.4TPH) of Potassium Carbonate Solution at 108OC. They are driven via a Weir 1-18-2 Horizontal Direct Drive steam turbine, stepped down via a David Brown Type TH double herringbone gearbox with a 2.75:1 reduction. Plain bore cylindrical journal bearings are installed along the whole drive train. To the authors' knowledge, these are the only four units of their kind.

An axial probe and one radial proximity probe was fitted to the turbine shaft & pump shaft in 2005. This allowed both spectral data and gap voltages to be collected as well as monitored on the DCS. Prior to this, all VA data was collected using seismic acceleration.

During an equipment survey undertaken on G-101-2, in December 2015, the coupling end turbine bearing was inspected and found to have material loss due to rubbing on the bottom shell near the joint. The decision was made to replace the coupling end bearing only.

Figure 1. Carbonate Feed Pump G-101-2, Turbine End.

Immediately following the bearing change, there was a significant change in the turbine radial vibration readings, causing intermittent high vibration alarms above 60 microns, and as high as 90 microns in operation. A vibration spectral peak at 0.41x shaft speed pointed to a subsynchronous issue such as auxiliary gear drive or oil whirl. Initially, efforts to control lube oil temperature within a certain range, boosting oil pressure and increasing load on the pump were somewhat successful. However, the problem persisted.

Background

Oil whirl is described as "probably the most common cause of subsynchronous instability in hydrodynamic journal bearings" (Berry, J. E. 2005). When a shaft is rotating within a journal bearing, it sits on an oil wedge.

Continues on page 16 >

Authors: Rhiannon Swift, Mechanical Asset Engineer and Ross Gilbert, Lead Mechanical Technician

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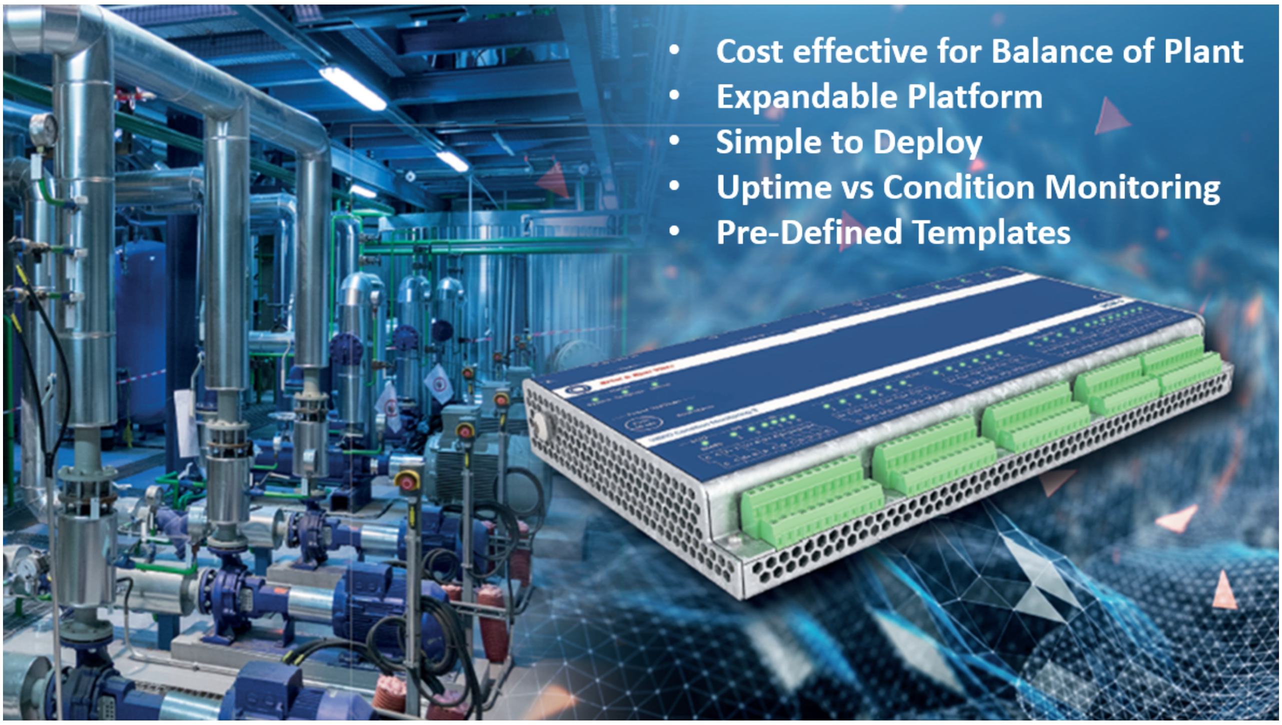

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Oil whirl describes the mechanism when the wedge becomes unstable, and moves around the perimeter of the bearing. The shaft follows the motion of this oil wedge. Oil whirl can be difficult to detect and correct. There are few cases in industry for guidance. The orbit plot trials in this paper visualise oil whirl on the KGTP Carbonate pumps for the first time. Prior to this the presence of oil whirl has not been proved.

Shaft instability has been a recurring issue on the Carbonate Pump units for many years. Prior to the installation of proximity probes at the journal bearings, this went unseen. However, when the pumps were brought down for annual service or reactive maintenance, several issues were found, including coupling wear (membrane breakage) and worn or overheated bearings. This was mitigated by replacement of the components. No changes were made to correct the cause.

KGTP engaged the site lubrication supplier to check the suitability of the oil, and determined that it was right in the range that would cause instability, but no recommendations or changes were made.

Resolving shaft instability on carbonate pumps is a key step to optimisation of Benfield operation. Shaft instability prevents operation at minimum flow on the pumps, which in turn leads to steam inefficiencies through the turbine. There are approximately $126-142k per annum to be saved by correcting this.

A methodical RCA approach was used to work through the problem. As a result of the findings of the RCA, the turbine journal bearing design was examined in detail. Previous approaches either addressed the symptoms of the issue, adjusting parameters such as lube oil temperature, rotor balance, shaft alignment and journal bearing clearances, or corrected the root cause but the solution was not fully understood. For instance, “good” and “bad” bearings were identified but not in a repeatable manner. The bearings themselves were not consistent in quality or dimensions, with some varying as much as 0.004” in outer diameter.

Approach

The key focus of this investigation was a multi-disciplinary, detailed and methodical Root Cause Analysis. An RCA team was established, representing Operations, Mechanical and Electrical & Instrumentation Maintenance, and Process and Reliability Engineering. Information sources were gathered from the collective experience of the team, maintenance and production data, OEM advice and manuals, and external resources including ASME Tribology, Mobius Institute and Texas A&M University. Although intermittent high vibration alarms had been a problem across all four pump sets, the scope of the investigation was limited to G-101-2 for simplicity. G-101-2 was a good candidate for analysis, as the instability on this unit was the most complex and unpredictable out of the four pump sets.
A suite of solutions was prepared, and the preferred solution implemented and trialled to confirm the effectiveness of the chosen solution.

Figure 2. Damaged Coupling End Turbine Bearing.

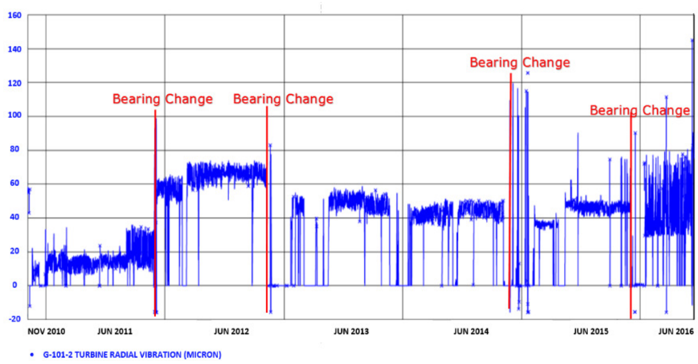


Figure 3. Turbine Bearing Vibration Readings. Nov 2010 - Jun 2016.

Investigation

ROOT CAUSE ANALYSIS

The decision was made to hold an RCA in April 2016. The problem statement was as follows:
“On Carbonate Turbine 2, we are currently seeing sporadic vibration alarms, possible oil whirl, and an apparent relationship between lube oil temp and bearing vibration.”
The following deliverables were proposed as an outcome of the RCA:

- An RCA report, including all findings as a result of the work;
- A suite of solutions for consideration by

Management;
- Work orders as required to complete investigation/modification tasks;
- Procedural changes as required, including check sheets, operating procedures, etc.
- Management of Change documentation to cover necessary modifications;
- Conceptual designs for approved changes.

A number of causal factors were determined during the RCA. It was apparent that further investigative work was necessary to prove or disprove each causal factor in turn. Once this was complete, a finalised list of solutions was developed.

Identified Solutions

Identified solutions were presented to KGTP Management for their consideration.

Short-Term Solutions (3-6 months to achieve):

- Accept current status quo, accepting routine equipment checks/maintenance;
- Modification of current bearing displacement measurement;
  - The VA analyser and proximity probe record total overall vibration levels over wide bandwidths – 0-2kHz and 5Hz-3kHz respectively, returning a reading higher than shaft speed.
- Place aux oil pump in service in parallel with main oil pump;
  - Trial higher lube system oil flows, based on OEM advice that instability is expected at current turbine operating speeds, with lower main oil pump speeds a contributing factor.
- Installation of tighter clearance bearings.
  - OEM Manual specifies clearances between 0.0085-0.016" diametral bearing clearance. Bearings are currently mid-range (~0.012") and OEM advice is to operate with tighter bearing clearances at current speeds.

Long-Term Solutions (6-12 months to achieve):

- Bearing redesign – cylindrical profiled bearing;
  - o Certain bearing profiles, such as lemon bore or multi-lobe, are less susceptible to the effects of oil whirl.
- Bearing redesign – tilting pad bearing;
  - o Tilting pad bearings are not susceptible to the effects of oil whirl, due to the constantly hanging bearing profile. Significant modification of bearing housings required.
- Increase load on pumps;
  - We are at or below the minimum load for these pumpsets. At low loads, cross coupled forces are not efficiently dampened by the oil wedge in a bearing assembly. This is a known problem throughout industry and is supported by theory.
- Re-gear main oil pump drive for higher flows.
  - Based on OEM advice. Lower lube oil output could be a contributing factor to poor bearing stability. The main oil pump is direct driven off the auxiliary drive, therefore its speed and performance are directly proportional to the turbine operating speed.

The decision was made to pursue a bearing redesign to a cylindrical profiled bearing.

Design

Based on the knowledge that the currently installed turbine bearings were proving stable, the first step was to measure critical dimensions to establish the bearing clearances, concentricity and fit within the housing so as to replicate these dimensions with the new bearing design.

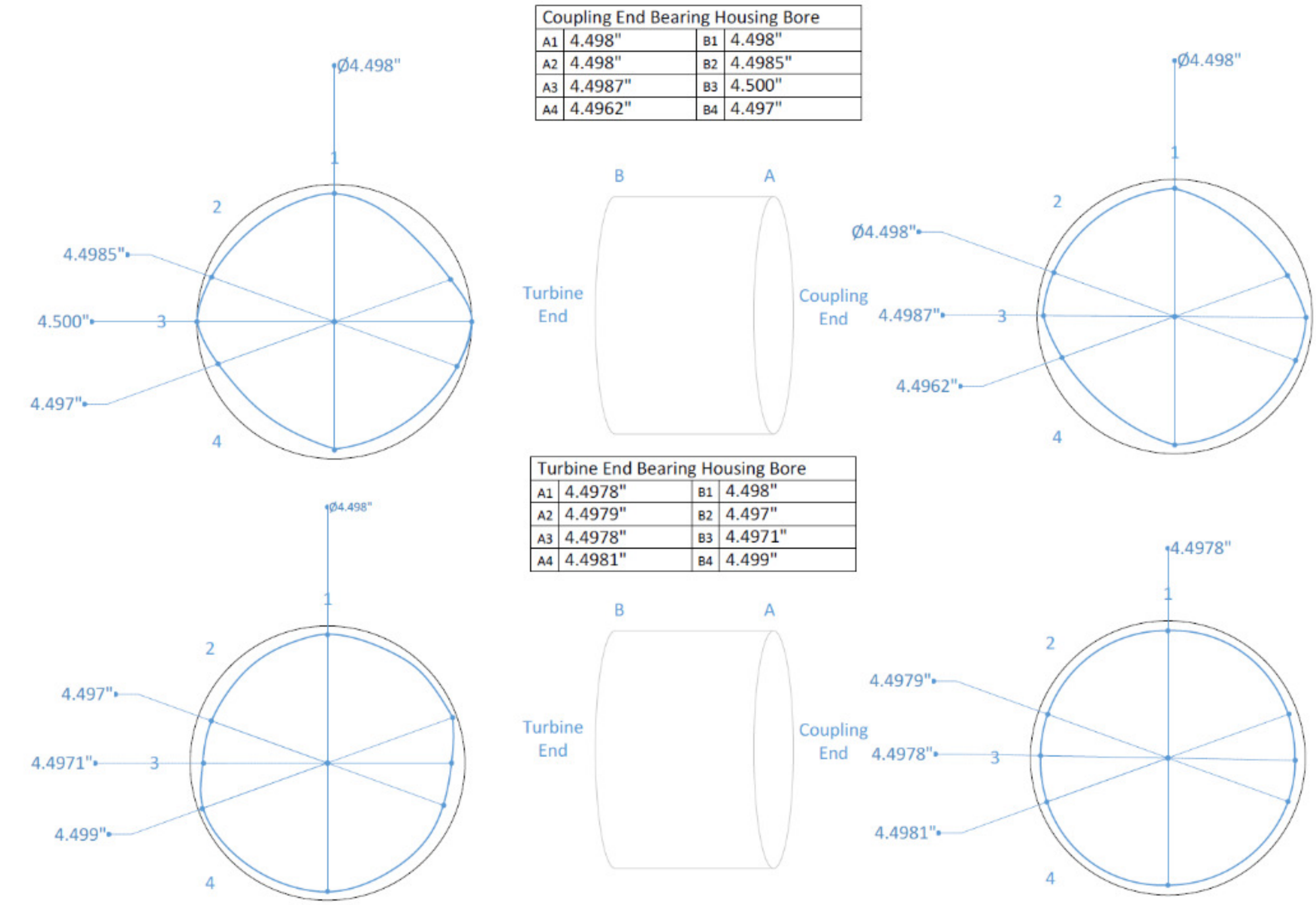
The measurements revealed that there was significant variation in the housing bore ID, resulting in eccentricity and therefore inconsistent bearing crush. Compounded with the variation in bearing shell ODs, this had led to differences in bearing clearances and profiles that contributed to the presence of oil whirl.

To avoid the need to perform a costly and difficult housing rebore, four bearings were identified from spares as having the best potential for use in the trials. These bearings had the best concentricity, and bearing shell measurements of 4.500", meaning that the bearing crush variance outside of the allowable 0.001-0.003" was minimised. Each bearing had 0.010" clearance before fitting. This ensured that no remetalling would be necessary.

To ready the bearings for trial, it was necessary to dowel the respective bearing halves together to prevent their becoming offset once installed in the bearing housing, and to machine the dammed overshot features into one of the nominated coupling end bearings.

The dammed overshot feature added by Alloy Bearings was machined based on prior applications. Their industry experience had led to the conclusion that the generic geometry rather than specific dimensional factors had the greatest effect on performance. The machined overshot dam was based on proportions appropriate for the bearing size, and machining details were recorded as-built.

Continues on page 18 >



Coupling End Bearing Housing Bore			
A1	4.498"	B1	4.498"
A2	4.498"	B2	4.4985"
A3	4.4987"	B3	4.500"
A4	4.4962"	B4	4.497"

Turbine End Bearing Housing Bore			
A1	4.4978"	B1	4.498"
A2	4.4979"	B2	4.497"
A3	4.4978"	B3	4.4971"
A4	4.4981"	B4	4.499"

Figure 4. As-found Turbine Bearing Housing Bore Diameters.

Performance Experiments/ Trials

PARAMETERS

A bearing trial was conducted on Thursday 3rd November 2016, initially with the turbine uncoupled. The trial was constrained to the coupling end bearing for ease, and because historical changes of the coupling end bearing had a large influence on shaft stability.

Measurements were constrained to the turbine end bearing only, due to the position of the radial proximity probes. An additional radial proximity probe was mounted at 90O to the existing so that orbit plots could be taken. A trigger reading was obtained via a phototach indication adjacent to the turbine coupling hub. The proximity probe and phototach reading were taken and processed using Commtest data collector and software supplied by Micah Technologies. Orbit plots were subsequently produced using these readings. The results displayed below are displaying 50 shaft revolutions, filtered for 0.25x – 1x shaft speed for a cleaner signal in the theorised oil whirl region.

The coupling bearings trialled are as below:

- Control bearing, already installed. Plain bore cylindrical bearing with reasonably stable performance.
- Known unstable bearing. Plain bore cylindrical

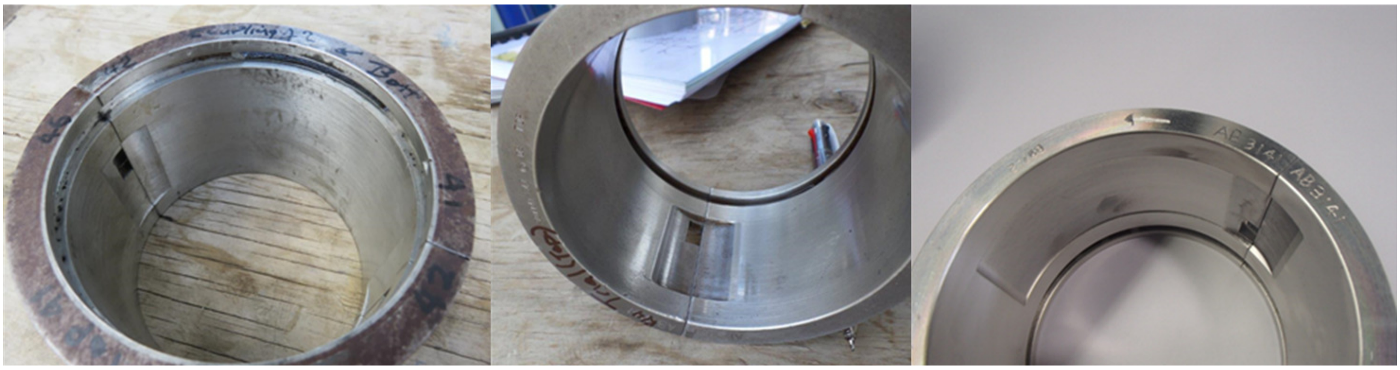


Figure 6. Control Bearing (Left), Known Unstable Bearing (Middle), New Profile Bearing (Right).

bearing with known susceptibility to oil whirl.

- New profile bearing. Overshot dam profile bearing, machined and supplied by Alloy Bearings.

Each bearing was trialled at several turbine running speeds. Results below are for the intended running speed of 8500RPM only, for simplicity. Confirmation of results was achieved via the following:

- Proximity probe readings transmitted to the DCS;
- Orbit plots obtained via vibration analysis;
- Machine vibrations during coupled run on Friday 4th November;
- Associated gearbox acceleration readings during coupled run.

Control Bearing

The first uncoupled test results were taken with the already-installed coupling end turbine bearing. This bearing had historically performed well since installed in June 2016. This bearing is a plain bore cylindrical bearing, with small oil reservoirs as seen and dimensions generally as per OEM original design.

Unstable Bearing

The second uncoupled test results were taken with a proven unstable bearing on the coupling end. This bearing had been known to cause oil whirl issues but was generally comparable in design with the control bearing.

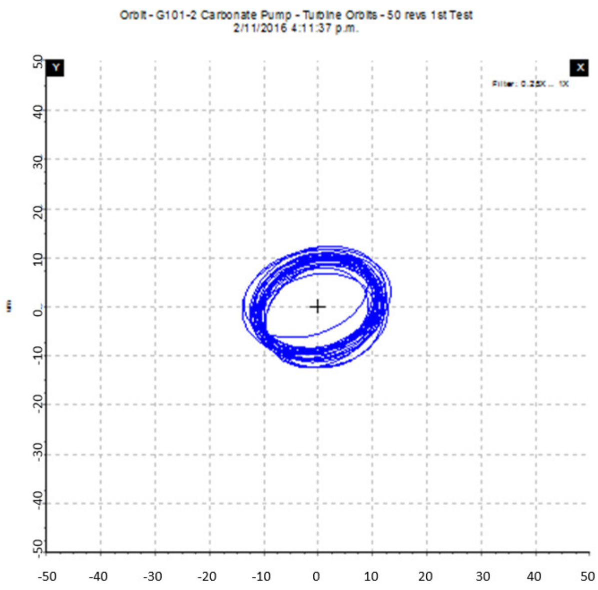


Figure 7. Orbit Plot, Control Bearing @ 8504RPM.

New Design – Overshot Dam Bearing

The third uncoupled trial saw the newly manufactured bearing with overshot dams installed.

Overshot Dam Bearing Continued

The change in performance was immediately clear. During the trial run at 6500RPM, all evidence of a frequency in the oil whirl region had disappeared. There was a clear shaft speed peak visible at 1x shaft speed. The orbit plot revealed a very tight and repeatable shaft orbit.

Continues on page 20 >

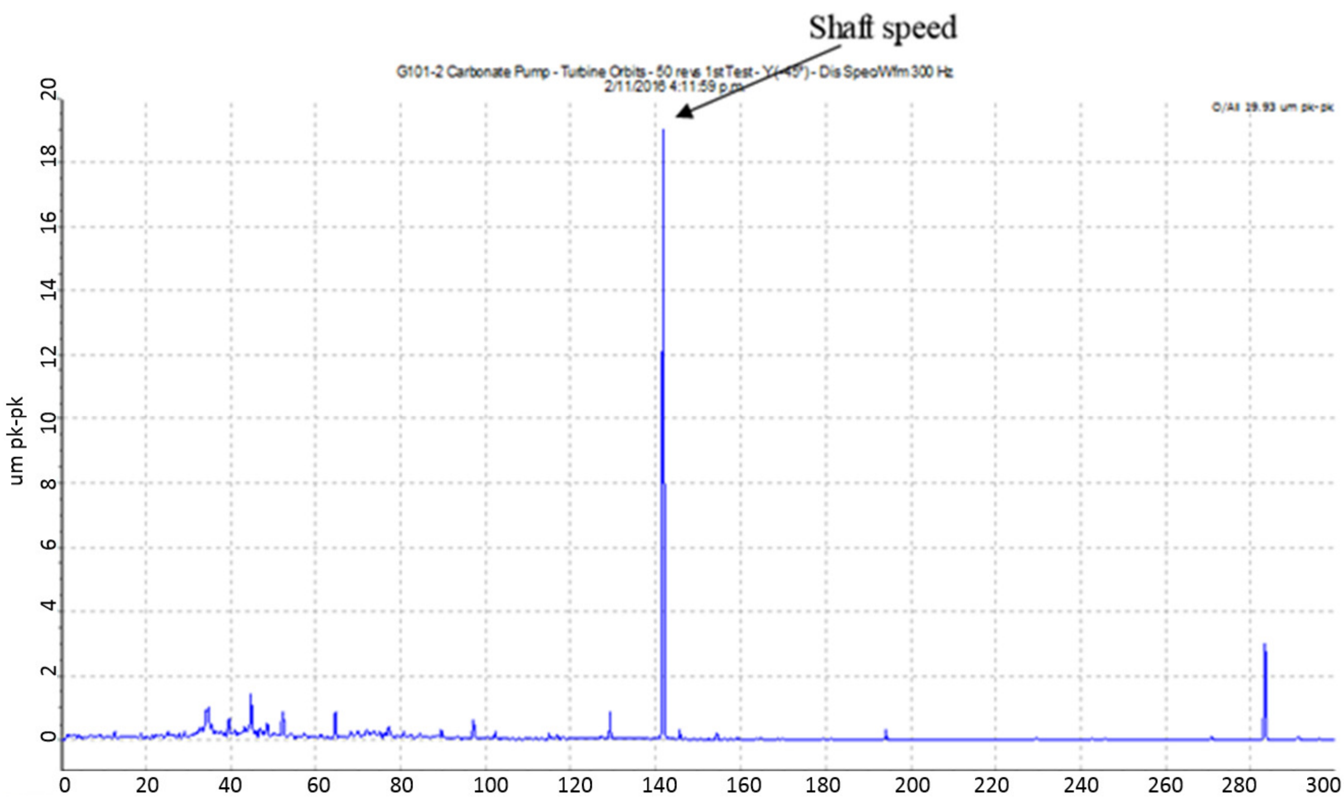


Figure 8. Spectrum 0-300Hz, Control Bearing @ 8504RPM.

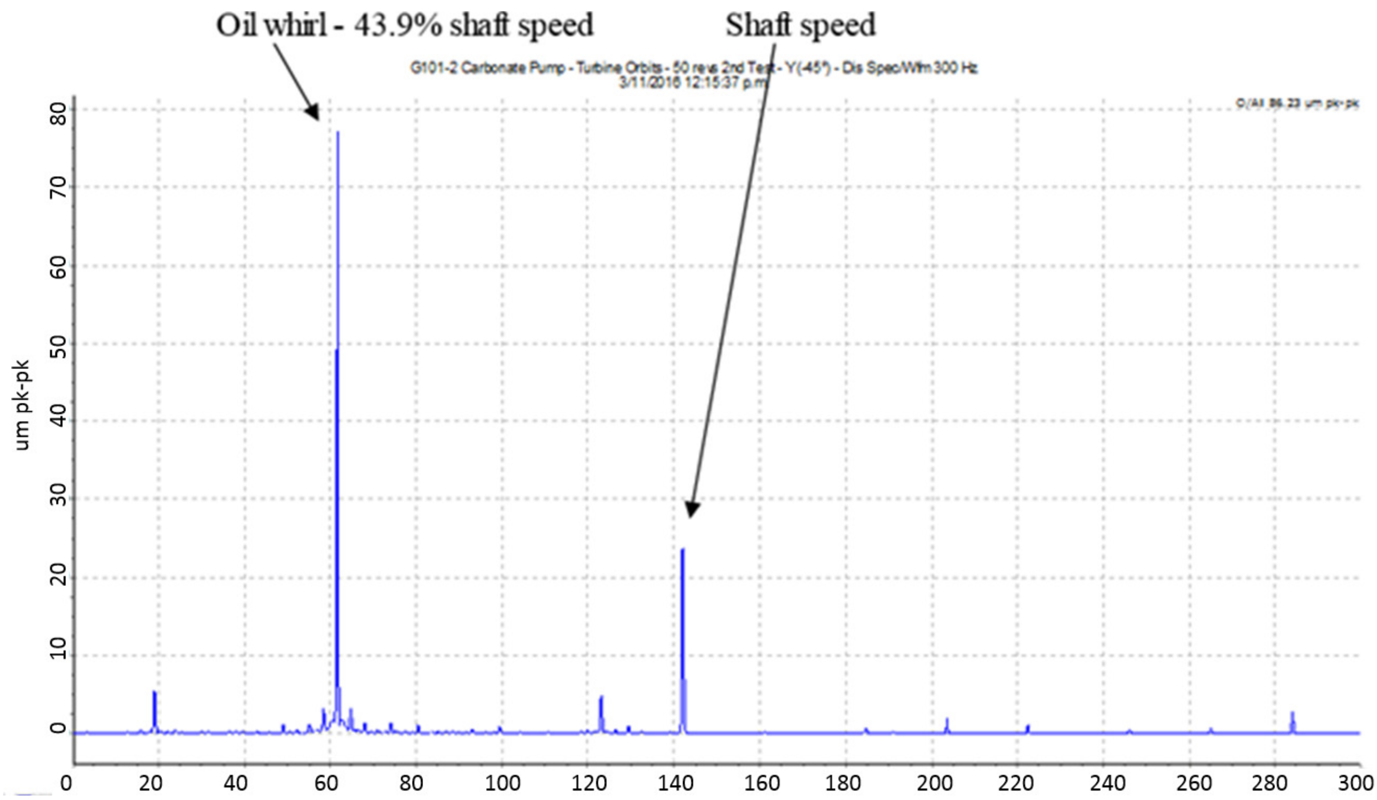


Figure 10. Spectrum 0-300Hz, Unstable Bearing @ 8521RPM.

The same stable performance was found to be repeatable at 8500RPM. The orbit appears to change shape slightly and become more symmetrical at the higher speed.

Results & Confirmation

The coupled run was completed on Friday 4th November, and used as a chance to trial lower flowrates through the pump at the same time. The performance of the overshot dam bearing was stable at all times during the test. Vibration displacement levels of the turbine shaft remained consistent at 23-25um. Flowrates were able to be reduced by an additional 50TPH from 500TPH to approximately 450TPH before reaching limitations on governor speed control and pump cavitation.

Lower gearbox acceleration readings during the coupled runs compared to performance prior to the bearing change serve to confirm an apparent reduction in turbine shaft movement.

G-101-2 turbine shaft stability has been consistent with the new overshot dam bearing since the 3rd November.

Conclusions

The changed bearing profile proved to have good stability across low speeds and loads on the pump sets. Data collection via two radial proximity probes offset at 90O and a keyphasor proved highly effective at visualising oil whirl for the first time at KGTP.

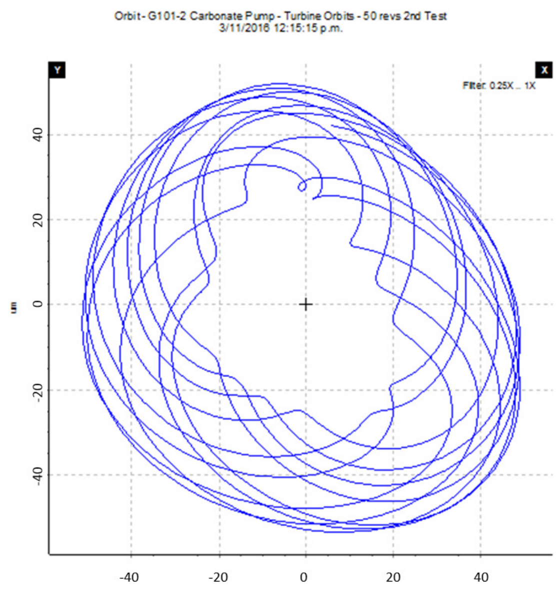


Figure 9. Orbit Plot, Unstable Bearing @ 8521RPM.

At the time of writing, the performance of the new bearing design has shown to be repeatable over five months of operation. The increased stability of the turbine has enabled pump flows to be lowered to 450TPH. There is potential to further reduce pump flow, pending limitations on governor control, cavitation and vessel wall wetting. Running the turbine at subsequently lower steam rates will allow steam savingsvbetween $126-142k per annum at the current operating conditions, which are forecast until 2020.

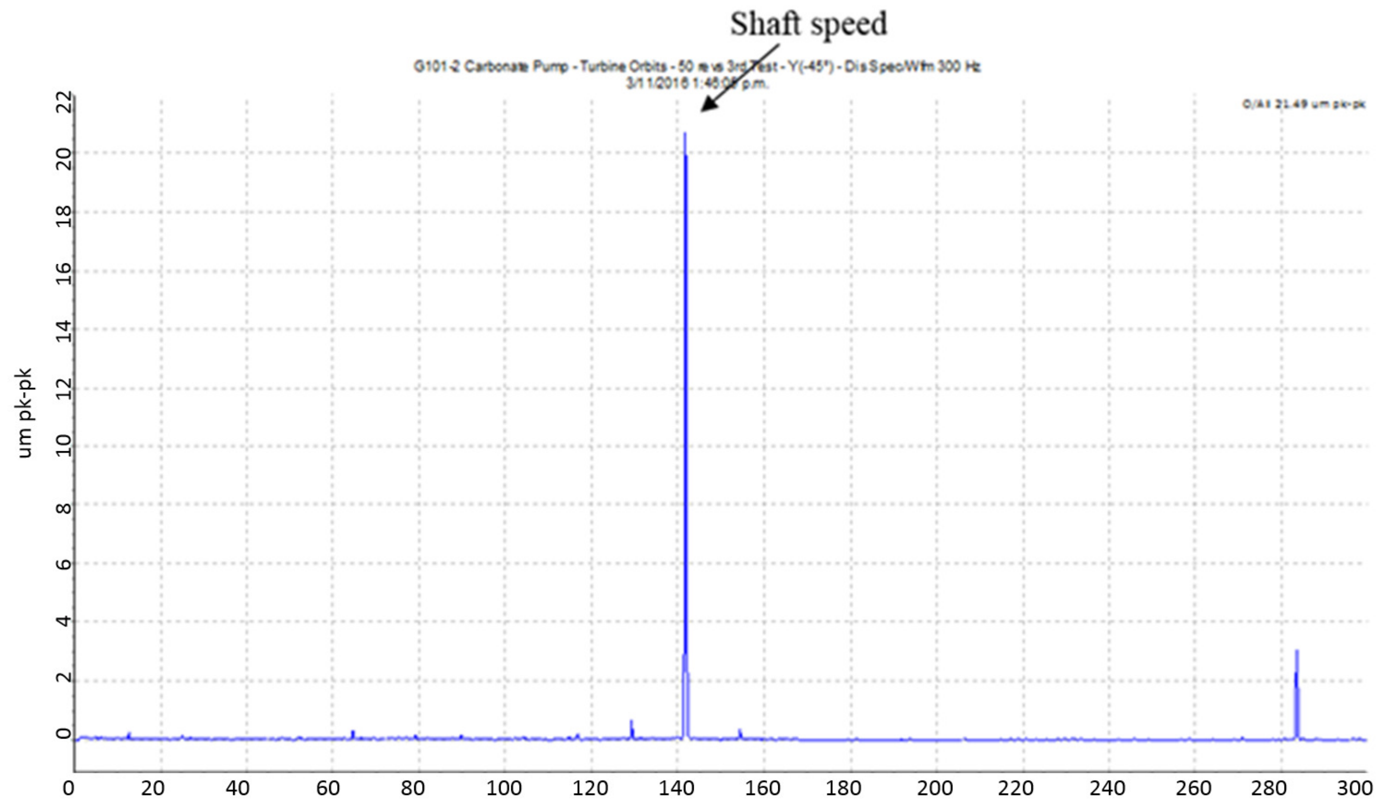


Figure 12. Spectrum 0-300Hz, Overshot Dam Bearing @ 8507RPM.

The positive results that have been achieved are a testament to the power of a robust RCA process, and good attention to detail. Multiple causal factors were identified during the RCA, however incorrect bearing profile was successfully determined as the root cause of the shaft instability experienced.

Future Work

A number of ongoing initiatives have been generated as a result of the findings of this investigation. These are listed below:

- Determine if bearing clearance and fit in the housing (including out-of-roundness) affects bearing performance;
- Continue to monitor condition of bearing dam profile, and bearing sensitivity to wear;
- Progressively change bearing design across the four pump sets and rationalise bearing supply;
- Perform quality control of currently held spares, addressing inconsistency in manufacturing details such as drains and oil dams;
- Continue investigation and resolution of limiting factors to lower pump flow. Governor control issues preventing lower flows appear to have been resolved recently, and operation has successfully been brought down to 450TPH without resulting in cavitation. Currently we are limited to 450TPH due to wall wetting constraints. Further vessel inspection is required to ensure that we can go lower without detrimental corrosion. ■

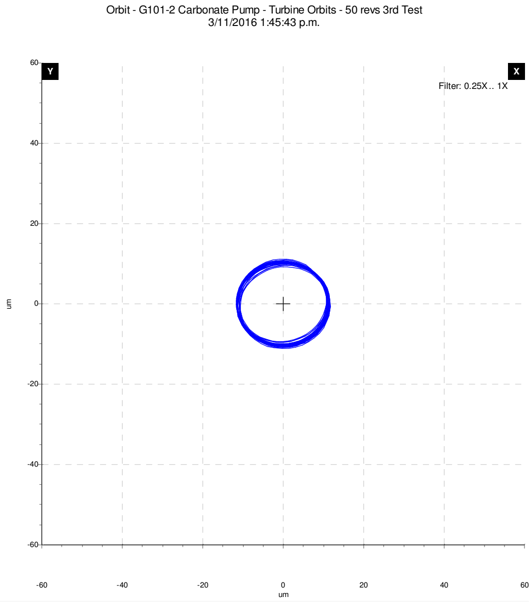


Figure 11. Orbit Plot, Overshot Dam Bearing @ 8507RPM.

Citations

- Alloy Bearings (April 2016). Multistage Pump Bearings – High Vacuum Column Bottom Pump.
- Berry, James E. (May 2005). "Oil Whirl and Whip Instabilities - Within Journal Bearings." - http://www.machinerylubrication.com/Read/754/oil-whirl-whip
- K. Tupp, personal correspondence, 19-31st October 2016.
- Orbit Plots and Centerline Diagrams – Webinar (Mobius Institute) - https://www.youtube.com/watch?v=wXtOYtl_qqw
- van der Sar, I. (November 2016). G-101-2 Carbonate Pump (Report No. VECGTP16-11-02S).
- Weir TFR150/1-18-2HDD Equipment Manual (1969).

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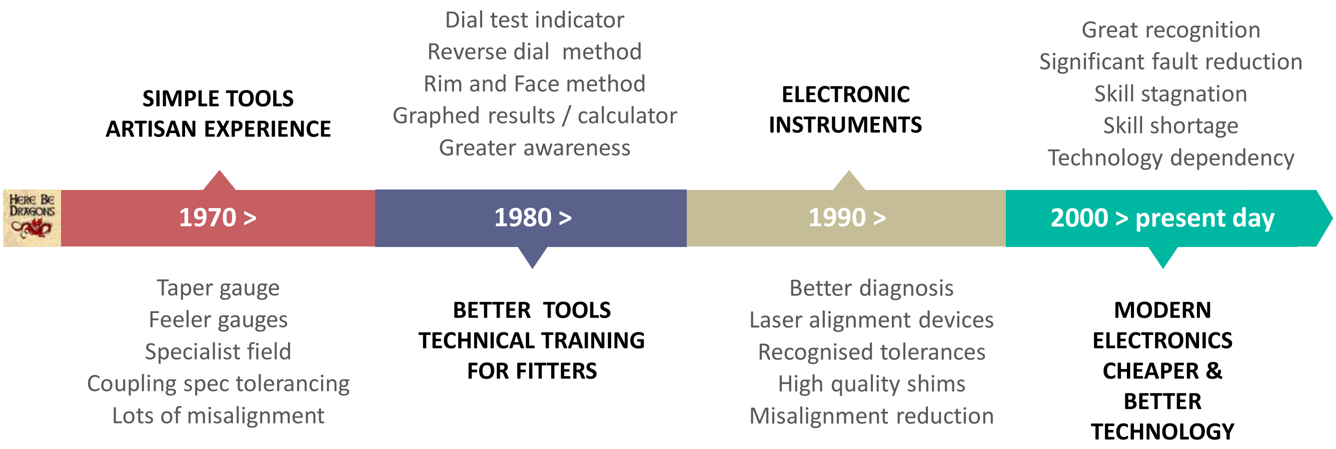
Timeline of Alignment Development



Laying Foundations for a Healthy Machine Alignment Culture

This article considers the family of faults associated with machine alignment and their influence on machinery. It considers related cultural features in the working environment that work towards the reduction of fault incidence, improving plant reliability and saving associated costs.

Machinery alignment has developed and improved dramatically over the last 50 years. It is helpful and motivating to remember and celebrate how far it has come. Rework and new plant installation under good guidelines has reduced the incidence of misalignment faults.

The application of modern technology in the hands of trained technicians is also a big contributor. Each decade has seen changes in greater machine reliability through performance of the machines themselves and also the people responsible for them.

"Each decade has seen changes in greater machine reliability through performance of the machines themselves and also the people responsible for them."

Happily, alignment terminology is now heard relatively often. Once the language of specialists, terms like laser aligned, smiley faces, jacking screws, fixed and movable machines, geometric alignment and soft foot can be overheard in workshops, tea rooms and meeting rooms. In recent times however, the skills needed to carry out quality realignment have become harder to find. Inadequate technical training is allowing bad habits to resurface.

There is a growing trend towards blind dependency on instrument technology when carrying out realignment work. Simple tools and techniques are overlooked at times. Vibration analysis is relied on to detect that the job was not done well. Unfortunately this is after the machine has been put into service, complete with unacceptable vibration.

Let's take a wide view of the subject of machine alignment, starting with perceptions in the

Continues on page 24 >

Prepared by: Chris O'Leary, Alignment Engineering Group.

workplace. The word alignment usually conjures thoughts of a technician measuring and realigning machinery. That person will remember carefully positioning machines to hundredths of a mm.
A wider view shows that sustainable mastery of machine alignment as a condition calls for a team performance. If every person with an influence on the outcome understands their role and contributes accordingly, misalignment faults will become a rarity.

At this point it is worthwhile briefly reviewing what we know about the effects of misalignment on machine performance. One driver of change is a much greater understanding of consequences if precision alignment is neglected or ignored. Physical consequences of misalignment can be detected dynamically in a variety of units such as displacement, velocity, temperature, power, etc. This is an important role of reliability technicians as they monitor plant looking for faults as they develop. Reduction of these faults usually coincide with a disproportionately large reduction in operating costs. Across the many machines in a manufacturing facility, return from effort is worthwhile.
Examples of negative consequences include;

- Excessive radial displacement of a shaft causing seal wear and allows ingress of contaminants and escape of lubricant.
- Excessive dynamic displacement of a turbine shaft in a plain metal bearing results in a bearing rub.
- Out-of-tolerance shaft coupling misalignment loads rolling bearing elements and shortens their life.
- Strain in a machine casing due to soft foot creates a resonance that excites excessive vibration under certain operating conditions.
- Soft foot induces non-uniform stator / rotor air gap in an electric motor, making operation inefficient and creating serious reliability shortcomings.

Alignment Condition and Consequences

Shaft Alignment

- Out of tolerance offset and gap
- Coupling wear
- Shorter bearing life
- Bearing rub
- Shorter seal life
- Compromised seal integrity

Soft Foot

- Most often related to support structure
- Casing strain
- Compromised electric motor air gap
- Reduced clearances
- Affected gear mesh > gear failure
- Resonance

Alignment
Verb - Tasks required to align machinery.
Noun – Alignment condition and impact on machine operation.

Precision can be something of a buzz word. Once upon a time, when something was described as 'agricultural' it used to mean rough and ready but also ruggedly built. Today agriculture management embraces modern concepts looking for greater returns through technology and innovation. One crop management concept is called precision agriculture. It wasn't long ago that machinery alignment was truly agricultural in the old sense of the word.

Engineering maintenance has joined the search for value from precision. Applied to alignment, precision suggests re-evaluation of current performance and a focus on moving to the 'next level'. The word precision when applied to machinery alignment also says something important about the performance of the group of people who influence the alignment and consequently the way their plant performs.

Culture directs our focus towards a team performance rather than the role of one or two good people. Experience has shown that a strong Reliability Culture is beneficial for machines and equally desirable for the people who care for them. The search for reliability is better resourced now than 20 years ago because it has proved its role in the profitability of industrial plants. Strong culture is the essence of great teamwork. Healthy workplace collaboration is a large element. Examples include mechanical disciplines understanding overlaps with electrical influences and vice versa. Management grows understanding of the impact on planning and the workshop and so on. Precision alignment significantly contributes to reliability outcomes... but can do better.

Lasting change usually takes time. Establishing consist results won't happen overnight. Thinking about alignment over the life of a machine, contributions come from a number of people with diverse roles. Firstly, Individuals as well as the team as a whole should be conscious of the need for repeatable, high-quality precision alignment. Each person would do well to understand the nature and impact of their influence during steps along the life of a machine train. Let's look at what can happen, versus what we want to happen during the alignment life of a typical open-coupled machine train.

The role responsibility of every person who influences a machine's alignment condition was recently highlighted in a comment from our service engineer. He had recently been involved in realignment and redesign recommendations for a hot-oil pump set. This machine had been troublesome and costly for many years. In fact it began when he himself managed the original installation as project supervising engineer. His comment illustrates well a lost opportunity for precision alignment and subsequent reliability. Without over simplifying the reasons for the chequered life of this machine, the example shows that good or bad influence on a machine performance begins early and can persist for decades.

The alignment life of a machine train begins very early. The first 9 months, like a baby's gestation development are the most critical for the future. Influential people and roles include;

- Principal (with budget)
- Designer
- Operator input
- Reliability input.

From a future performance point of view, the various roles have their own KPI's.

Continues on page 26>

What is *Precision* Alignment?

- Precision speaks to tackling deficiencies, continuous improvement
- Precision reduces consequences and costs to rarity
- Precision represents excellence
- Well-conceived precision environment desirable for everyone / everything

Why 'Alignment Culture'?

'the way of life, especially the general customs and beliefs, of a particular group of people at a particular time'

(Dictionary.cambridge.org, 2017)

'Transmitted through language, material objects, ritual, institutions and art, from one generation to the next'

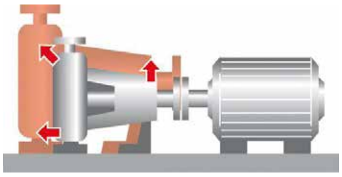
(Dictionary.com, 2017)

Team Alignment Culture

- Infers a deep and lasting change
- Brings focus on team of people with influence
  - Not just Reliability
  - Not even just Reliability and Maintenance
  - Nor Reliability, Maintenance, Engineering and Management
  - The team is even bigger than that...

Alignment Life of Pump Machine Train

STAGE 1: *9 months gestation*



- Foundations
- Base frame
- Machine elements: Pipes / Pump / Coupling / Motor / Shims
- Procedures: Assembly / Installation / Operation / Maintenance

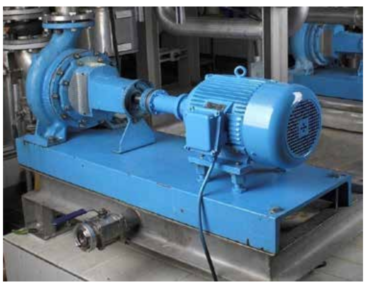
Arguably the most important indicators, the business indicators rely on the combined performance of every person and all machines.

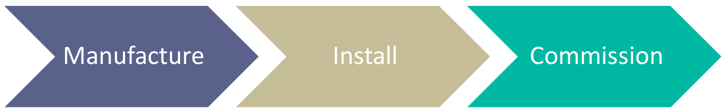
This is a critical period with every action having a potential for positive or negative affect on decades of performance. During the next 12 months, the machine train like an infant, is also subject to infant mortality factors. Machines that did not have the necessary attention paid in the development years suffer problems that can impact performance of the entire operation. The accumulated impact is not necessarily well documented and actual costs grow very large over time.

Influential people and roles include;

- Construction / fabrication company
- Project Supervisor
- Quality Controller
- Installation Technician.

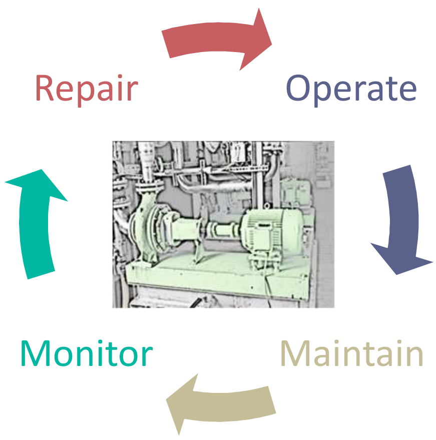
STAGE 2: *12 months through infancy*





- Fabrication and civil works
- Assembly in factory
- Transport / Install
- Assemble on site (incl. pipes)

STAGE 3: *30 years in service (maturity)*



Upgrade

STAGE 1 > STAGE 2 > STAGE 3

Old age performance issues

Then begins the long, hopefully profitable, period of service. During this, the longest period of life, a great deal rests on decisions made by reliability and engineering management influencers.
Influential people and roles include;

- Executive management (budget availability)
- Maintenance management (budget allocation)
- Reliability Group
- Maintenance & Repair Technicians.

At time of upgrades, various Stage 1 and 2 roles are required once again before the machine settles back into another long operating period. Such times present a new opportunity to deal with legacy problems. Reviewing this machine's life we can identify a few simple examples of influences at various stages.
Early on we can include;

- Selection of configuration that isn't price focussed at the expense of being fit for purpose.
- Incorporation of alignment jacking screws
- Base frame rigidity
- Allowance for enough shim
- Specifications for alignment, including factors such as target alignment values.

A few influences at this stage include;

- Construction and fabrication features acknowledging alignment. For example optimising hole clearances on assembly.
- Careful frame transportation and handling to preserve alignment integrity.
- Pipe strain minimised
- Confirmation of alignment condition (acceptance testing).

Two-way communication with executive management is perhaps even more important now than in the formative years of this machine's life. 'How important to continued profitability is the reliability of this machine?'... is a question that everyone needs to understand.

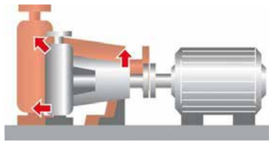
Let's look briefly at the precision tasks performed by the technician at the machine. Misalignment faults very often originate at the time the alignment

Continues on page 28 >

Lessons from the Pump /Motor example

1. Significant lifetime influencers even before machine is built

- Principal / owner (with budget)
- Designer
- Operator input
- Reliability input

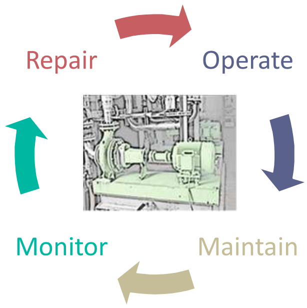


2. Significant lifetime influencers when machine built / installed

- Construction / fabrication company
- Project Supervisor
- Quality Controller
- Installation Technician

3. Significant lifetime influencers of machine in service

- Executive management (allocating budget)
- Maintenance management (spending budget)
- Reliability Group
- Maintenance & Repair Technicians



Classical Alignment Focus Points

Shaft Alignment	Support structure condition (incl. Geometry)	Deal with Soft Foot	Apply Quality Shimming
• Axial angle • Radial offset • Axial position • Excellent tolerances	• Base installation • Pads flatness • Pads planar • Adjusters • Hole clearance	• As a temporary fix • As a long term solution	• Suitable design • Suitable materials • Minimum quantity

Widen the Alignment Scope

Using a DTI	Allow for Operating Environment	Dealing with Strain	Other applications & checks
• Shaft play • Bent shaft • Hub runouts – Radial – Axial	• Thermal changes • Dynamic position • Gear coupling lube & Lightly loaded bearing (offsets)	• Not just pipes • Can affect more than shaft align • Coupling element strain	• Belt drive • Chain drive • Gear mesh • Shaft sag • Shaft deflection • Parallel

technician realigns the repaired machine. Other causes may be linked to changes in machine condition but a good number of potential faults can be readily addressed at this point in time. If the skills are not available in-house, expect them from your contractor. If the procedures are not available in-house, look for suitable characteristics from your contractor and request a procedure, something more than a report.

The range of tasks that may be carried out during machinery alignment is extensive. Alignment procedure for each machine train should identify and account for these for every application. Preparation of written procedures might seem a costly undertaking. A good place to start is code of practise and method statement with procedures / specifications developed over time.

A suitably qualified technician can identify the tabled faults through analysis of a vibration signature from the operating machine. Alternatively, a person with maintenance skills can pick them up with relatively simple check procedures. Such measurements are best dealt with at the time of realignment. It makes sense to include applicable tasks in alignment specifications and procedures, to be attended to while the machine is available before operating.

As previously noted, presently we are experiencing a shortage of technical skills in NZ industry. The need is growing and a lasting solution is not clear. Where in-house resources cannot cope, outsourced skills make up the numbers.

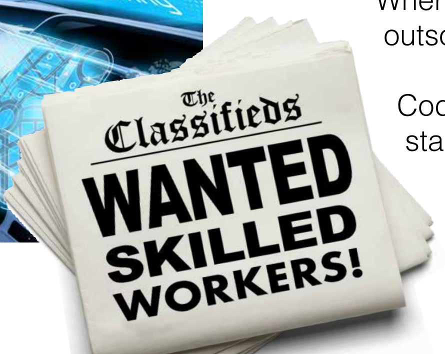
Codes, methods and procedures provide stability in the face of these challenges. Modern technology is wonderfully capable but does not yet make

Future proofing
- Code of practice
- Method statement
- Procedures
- Training in Best Practice
- Team members can be in-house and outsourced

Method Statement Inclusions

I. Planning and Schedule info
II. Safety
III. Equipment and skills
IV. Procedure outline
V. Report
VI. Conclusion

Conclusions
- Next step - Precision
- Precision Alignment strengthens Reliability Culture
- Enlarge the scope of tasks
- Learn legacy lessons
- Define Procedures

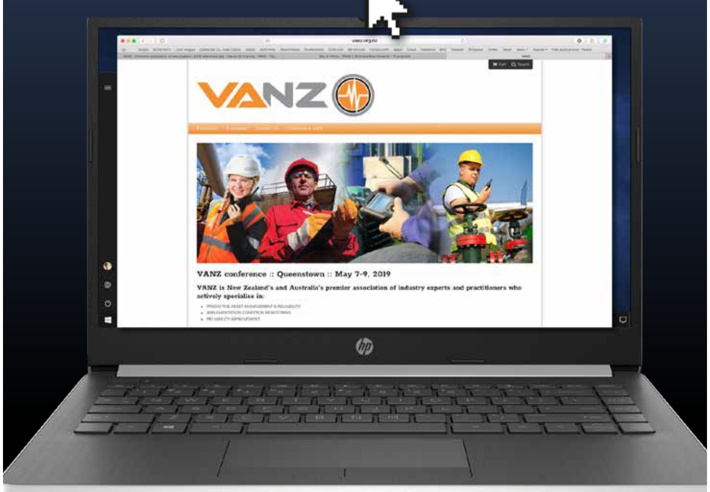


up for an informed team with understanding of alignment needs.

Whether supplied by your in-house team or included in an outsourced contract, the method statement adds to precision alignment.

The recipe for precision alignment success remains simple in principle but can seem complex in practise. A focussed and determined team with the right culture can instil what is necessary to get the desired results.

The future has arrived. Cars drive themselves and houses can be printed. We might wonder where this amazing and rapid change will end up. Will alignment tasks be carried out by robots? Will smart algorithms replace smart managers? Will people be needed after robotics and computers have learned what we know? One thing to remember is that in the past people imagined each human endeavor we marvel at today. People imagine the best and worst possibilities. Sometimes we get it wrong. Because you can't imagine it, doesn't mean it won't happen. As it stands and looking into the foreseeable future, there is no substitute for a smart, informed, imaginative team of people. ■



PUZZLE CORNER

WORD BUILDER

How many words of three or more letters can you make, using each letter only once? Plurals are allowed, but no foreign words or words beginning with a capital. There is at least one 5 letter word.

12 - Good | **16** - Very Good | **20+** - Excellent

A	G	D	E	B

There is three 5 letter words above. Can you find all three?

WORD MARCH

Draw a path from one square to another to find the secret nine letter word. You may move in any direction. Each square can only be used once.

There are approx. **30** words (three letters or more) that can be made from the combination of letters below. How many can you make?

Solution on page 31.

J	A	K
C	K	C
A	L	B

Nine letter word is... ____________

SODUKU

To solve, each number from 1 to 9 must appear once in:

- Each of the nine vertical columns
- Each of the nine horizontal rows
- Each of the nine 3 x 3 boxes

No number can be repeated twice in a box, row or column. Why not time yourself? See how well you go.

	7			1			2	
2		6	9		5			1
9		1						
						6	1	
4			1			2		7
7	1	3	6	2			5	
3		7		6		4	9	
		4		9				
1								

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TEST YOUR KNOWLEDGE - PART 62 OF A SERIES

1 Which of the following averaging methods would best capture the effects of random impacting?

a Summation (aka normal or linear)
b Peak-hold
c Negative
d Exponential

2 The skidding of rolling element bearings can be problematic and is something that is reasonably common in industry. What factors might influence the likelihood of skidding occurring?

a Rotational speed
b Bearing type (e.g. roller bearing, ball bearing etc)
c Bearing clearance (e.g. C2, C3 etc)
d All of the above could have an influence

3 A bias voltage test was conducted on an ICP accelerometer. Which of the following results is likely to indicate a healthy sensor?

a 0 volts
b 5.7 volts
c 10.7 volts
d 22 volts

4 Which of the following people might be most-likely to suffer from "white-finger"?

a Road-worker using a jack-hammer
b An industrial painter
c A white-collar worker (e.g. accountant, lawyer)
d Secretary

5 Accelerometers all have a mounted natural frequency. One long-established manufacturer recommends that the useful frequency range should be up to what proportion of the mounted natural frequency?

a 1/4
b 1/3
c 1/2
d 3/4

6 In what part of your measuring system might there be the potential to generate triboelectric noise?

a Analyser
b Measurement cable
c Accelerometer
d Shoulder strap

7 In the early years of VANZ conferences (e.g. 25 or more years ago), the term "CPB" was sometimes referenced during presentations. What do these letters represent?

a Common Proximitor Base
b Circuit Potential Bias
c Constant Percentage Bandwidth
d None of the above

8 Collecting a high-resolution spectrum (i.e. a high number of spectral lines) will ordinarily give the analyst a better definition of peaks in the spectrum. When might this not be the case?

a When there is amplitude modulation
b When the vibrations are of a high amplitude
c When the shaft speeds of the machine are varying during the measurement
d When the shaft speeds are highly stable

9 When conducting routine walk-around vibration analysis on bearing housings etc with a magnetically mounted accelerometer, what type of vibration are you measuring?

a Absolute vibration
b Relative vibration
c Torsional vibration
d All of the above at all times

10 Which of the following is true about a soft-bearing balancing machine?

a Soft-bearing machines are heavier and therefore less likely to be used as transportable machines than hard-bearing machines
b Soft-bearing machines are more sensitive to extraneous vibrations than hard-bearing machines
c Soft bearing machines operate above their resonant frequency
d Soft-bearing machines have been superseded by hard-bearing machines

Answers on page 31

Further enquiries can be directed to: Carl Townsend at Carlton Technology Ltd.
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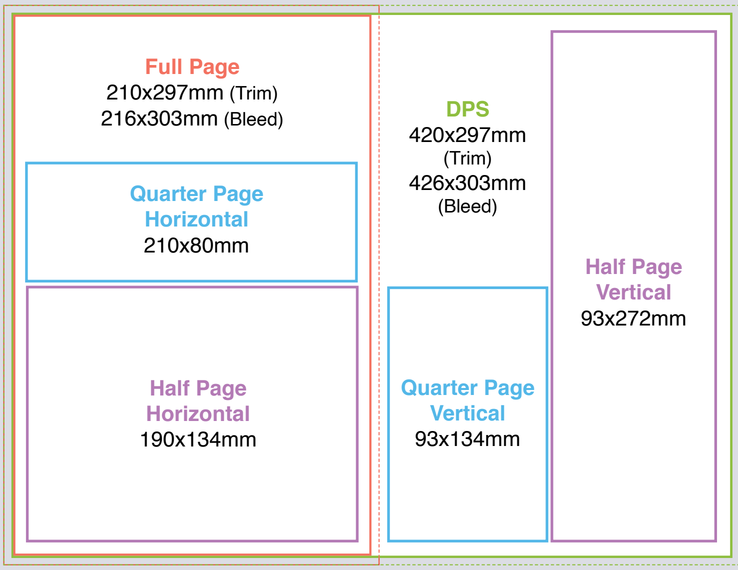

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Answers to Carlton Technology Quiz 62:
1B, 2D, 3C, 4A, 5B, 6B, 7C, 8C, 9A, 10C

Answer to Word March #98: Blackjack


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