The official journal of the Vibrations Association of New Zealand

Spectrum

Issue 110

Conference '24

Full registration details / offers inside...

THE CHAOS THEORY OF maintenance management

Do you know your bearing numbers and codes?

+

Vibration mitigation of a Francis turbine and generator bearing gap adjustment

VANZ
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Spectrum

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Spectrum is published by the Vibrations Association of New Zealand (VANZ). The magazine is produced in a quarterly cycle annually in both digital and printed mediums.

The magazine is designed to cover all aspects of the Vibration, Condition Monitoring, Reliability and the wider Predictive Asset Management field and distributed to all VANZ members, including corporate members.

Missed an issue?

Simply scan the QR code here to link your device directly to the VANZ website. There you will find Spectrum issues available to view or download*. You can also access previous issues by visiting our website online at: **www.vanz.org.nz**

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SCAN ME!

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TUE 21st MAY 2024

Package	PRICE PER PERSON
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Condition Monitoring Hands On – Attendance to verified apprentices / trades trainees / university FREE!	FREE
Asset Management	$350

2-Day Registration

WED 22nd - THU 23rd MAY 2024

Package	PRICE PER PERSON
2-Day Conference – Includes option to register for the full-day Electrical Masterclass stream. (Wednesday)	$900
2-Day Conference – Attendance to verified apprentices / trades trainees / university 50% OFF!	$450

3-Day Registration

TUES 21st - THU 23rd MAY 2024

Package	PRICE PER PERSON
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Booking is quick, easy and hassle free! Visit our website www.vanz.org.nz
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Naming rights of conference			
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Official role at the opening of the conference and five minute speaking opportunity			
Trade stand that offers sponsors the opportunity to showcase products, services and ideas	Premium	Standard	Table
Signage opportunities at conference & dinner			
Pre conference Spectrum advertising opportunities (early registrations only)	✓		
Acknowledgement as sponsor & vendor	✓	✓	
Company literature in delegates goodie bags	✓	✓	
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Sponsorship on key online & offline promotional material before and during conference**	✓	✓	✓
Logo on VANZ conference publications & website***	✓	✓	✓
Post conference Spectrum advertising opportunities	✓	✓	
Conference entry for staff	x2	x1	x1

Booth size (Platinum and Gold)	1.8 x 3.0 metres
Booth size (Silver)	1.2 x 2.4 metres
Table top size (Bronze)	1.8 x 0.6 metres

*Website** *Animated landscape panels @ 460px wide x 200px high*
*Website*** *Animated landscape panels @ 460px wide x 200px high - x1*
*Logo file**** *To be supplied as either a vector eps or hi res tif/png/jpeg*

Files to be supplied to specifications.

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Informal Welcome Event (Tues night)	$2,000	Lanyard sponsor	$500 + lanyards
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Need to book accommodation? We've secured rooms at **Plymouth International** and **Auto Lodge Motor Inn** *(located just around the corner)* for a great rate – but only for a strictly limited time! Use the code **VANZ** when booking to secure this special rate.

1. Phone **Plymouth International** direct on 0800 800 597, or visit www.plymouth.co.nz
2. Phone **Auto Lodge Motor Inn** direct on 0800 800 896, or visit www.autolodge.co.nz

Alternatively, you can simply scan the associated QR code to link directly to their booking site.

1.

2.

VANZ Membership

Full year membership for 2024/25 is still only $100/pp

It's easy to renew too! Visit www.vanz.org.nz

If you purchase a Main Conference (2 or 3-day) attendee pass, your membership for the next 12 months is automatically included and updated in that price.

For further info or to register, please contact our conference team: email us at secretary@vanz.org.nz

A Call for Papers

We are looking for papers on Vibration related topics, Reliability related topics and Asset Management related topics. It would also be great to hear about any new technology, technology advancements or research topics in these areas too.

Do you have a case study you could share?

You don't need to be a professional speaker, in fact we would like to encourage new people to present. The papers ideally need to be 15min in length or longer – its up to you. You could do a solo presentation, or you could even team up and do it as a small group!

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Hosted by internationally renowed speaker Mike Davis

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REGISTRANTS RECEIVE

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- Course notes (180 pages)
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- Online Assessment (optional for completion of online component)
- Textbook. "Mike's Motor Minutes – 101 Electrical Machine Stories".

CERTIFICATION

- Certificate of attendance for masterclass
- Certificate of completion for successful completion of online components.

DURATION:	7.5 hours
DATE:	Wednesday 22nd May (Day-2 of VANZ Conference 2024)
PRICE:	Included as part of the 2-Day and 3-Day registration fee.

Conference'24
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With over 40 years experience in rotating equipment, essentially centred on the repair, redesign and maintenance of electrical rotating plant. Mike has developed an intense academic interest in machine failure mechanisms and root cause analysis of electrical machinery failure and has presented papers throughout Australia, New Zealand, United States of America, South East Asia and South Africa. Visit www.emkecoach.com to find out more.

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PRESIDENTS' REPORT

By Tim Murdoch | VANZ President

Happy New Year Everyone. I hope you have managed to get out and spend some quality time in this beautiful sunshine and hot weather with family and friends over the Christmas and New Year period. What have been your highlights so far this summer?

On a VANZ news front, Nicky Lord has stepped down from the role of Vice President and we welcome Alex Lawrence into the role as the new Vice President, congratulations Alex. Thank you Nicky for all of your hard work as VP, it was a pleasure working with you these past few years and we wish you all the best in all your endeavours.

> Our keynote speaker Allan Rienstra will be flying in from Canada to join us for the 2024 conference.

It's February already and the VANZ conference will be here before we know it! You'll be able to catch up with friends, old colleagues, make new friends, network, see new technology, meet exhibitors and learn a few new things. Block off May 21 – 23 in your calendars because you will be attending the VANZ conference. It is to be held at the Plymouth International Hotel in New Plymouth. We are also looking at a potential site tour on the Friday 24 May, watch out for further information about this.

We have such a dedicated, hardworking, highly skilled committee. They have been hard at work since the last conference organising and preparing everything that makes a successful conference. We do ask that you book your position in the conference as soon as possible at **www.vanz.org.nz**, also if you have an interesting problem that you need help with or an interesting problem that you have solved we would love to hear about them. We still have positions available, come along and share a paper.

We would love to hear from you. If you need assistance our team is here to assist. Email **papers@vanz.org.nz**

Our keynote speaker Allan Rienstra will be flying in from Canada to join us for the conference. We look forward to learning from you Allan. Have you checked out our pages on LinkedIn and Facebook yet? Allan's bio can be found on there, as well as here on page 11.

We are blessed to have some world class speakers join us and support us at our VANZ conferences. Mike Davis will be back this year to run his motors masterclass, this was a hit last year. If you want to learn more about motors come along to Mike's course, it is designed for everyone so you don't have to have an electrical background.

I look forward to seeing you all in May and I hope the year ahead will be a great one for you.

Below: One of the conference rooms at the Plymouth International Hotel in New Plymouth.

Conference24

Keynote Speakers

Like previous conferences, 2024 is shaping up as a wealth of knowledge through outstanding keynote speakers, from both around the globe and here in NZ. Make sure you're registered to join their seminars to find out more about these professionals have to share. Two of our keynote speakers are detailed below.

Mr. Allan Rienstra

Rienstra is the director of international business development for SDT Ultrasound Solutions, a 45-year-old company with operations in 5 continents. In his 32 years, Rienstra has helped thousands of organisations establish better practices for condition monitoring and asset health management based on the principles of inspect / detect / measure / trend / analyse / act / report - which follows his 10-step strategy to implement an effective and enduring ultrasound program. He is the author of Hear More, A Guide to Utilising Ultrasound for Predictive Maintenance and Leak Detection (2010) and serves on the Standards Council of Canada as a direct advisor to the International Standards Organisation with specific focus on the ISO 18436-8 working group for ultrasound in condition monitoring.

Mr. Mike Davis

With over 50 years experience in rotating equipment, essentially centred on the repair, redesign and maintenance of electrical rotating plant. Mike has developed an intense academic interest in machine failure mechanisms and root cause analysis of electrical machinery failure and has presented papers throughout Australia, New Zealand, United States of America, South East Asia and South Africa. For more than 20 years Mike developed tailored machines training courses which were presented to end-users in USA, NZ, Australia, South Africa, Indonesia, Singapore and Malaysia. Mike now shares his lifetime of engineering experience and knowledge through coaching and mentoring. Mike has won the Australian Small Business of the Year award and Australian Quality Award in 2000.

Accommodation

Of course, you could stay anywhere during your visit to the beautiful city of New Plymouth for our annual VANZ conference, but given the following accommodation options, why would you want to stay anywhere else? VANZ has a number of rooms secured at both the Plymouth International and the Auto Lodge New Plymouth, and can be pre-booked using the code **VANZ**. This will enable attendees to book the accommodation for a special discounted rate for the duration of their stay.

Above: The Auto Lodge in New Plymouth.

Plymouth International Hotel

The Plymouth International is host for the VANZ conference 2024. It is New Plymouth's largest independently owned hotel, conference facility and events centre and one of only a few 4-Star Qualmark hotels in town. Their very own The Orangery (restaurant) has been rated New Plymouth's best restaurant on Tripadvisor for the past year and won a Silver Sustainable Tourism Business award. The Plymouth is set between New Plymouth's two major one-way systems – so driving across town in either direction is super-easy. The town's beloved Coastal Walkway is a short stroll from our front desk and great swimming at East End Beach is less than five minutes from there. The CBD is 750m away and you can jump in the car and be at Fitzroy Beach's world-class surf break in five minutes.

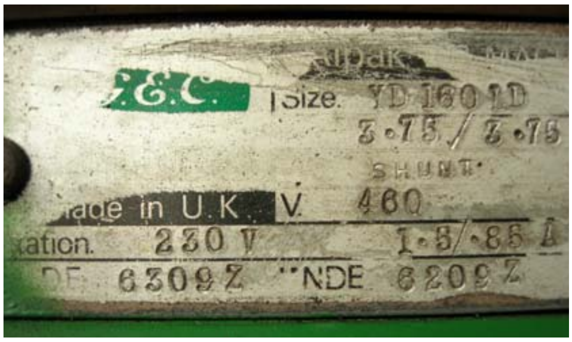
Address: 220 Courtenay Street, New Plymouth
Contact: 0800 800 597 / www.plymouth.co.nz

Auto Lodge New Plymouth

Located between the chic CBD and trendy suburbs of Strandon & Fitzroy, Auto Lodge is New Plymouth's most surprising accommodation. The Auto Lodge offers class-leading modern and refurbished studio rooms, executive & superior suites, private picturesque houses and a penthouse apartment. They even offer private garden areas with some of their rooms! With their own unique artistic style throughout the hotel you, will find hidden gems of architectural brilliance and flashes of our growing art collection. They pride themselves on personalised service and long term guest relationships and are proud to be a Qualmark 4-star rated accommodation provider. Auto Lodge is just literally around the corner from Plymouth International Hotel and is a brisk walk away from town.

Address: 393 Devon Street East, New Plymouth
Contact: 0800 800 896 / www.autolodge.co.nz

Bearing Numbers and Codes



Have you ever had to open a box to see what type of bearing it contains? Have you ever wondered about the bearing numbers on an electric motor nameplate?

These numbers and codes have some logic to them and the basics are easy to learn. For example, a four digit number starting with a 6 is a deep groove ball bearing (e.g. 6312). A five digit number starting with a 2 is a spherical roller bearing (e.g. 22216) and so on. These numbers and codes are shown in an abbreviated form on the next page. Note that the numbers and codes all mean something different (fig.1), so you must replace a bearing with another one that has EXACTLY the same numbers and codes.

Continued over page >

Article prepared by Rod Bennett.

EDITORS' CORNER

By Angie Delfino | Spectrum Editor

A very Happy New Year to all our readers/VANZ members/advertisers! Here's hoping the festive season was a chance for a good break with fun, sun and family. We are now gearing up for this years conference with committee members buzzing around like busy bees trying to organise venues, accommodation, presenters and the like.

From the 21st – 23rd May we are taking over New Plymouth! We have an educational, informational, and entertaining (-al?...) conference planned for you. Whether you are a practitioner working to detect and solve rotating machinery problems, an engineer hoping to improve reliability, or a manager trying to implement a successful program, our conference has the presentations that can provide you with the knowledge and contacts to help you in your role.

We are fortunate to have attracted top international and local experts willing to share their knowledge, and we have forward-thinking businesses from New Zealand and Australia who will have products and services on display. This is the premium place to learn and share so that you can gain the essential knowledge necessary in your specialised field. VANZ is an important event for people who work in an important field; we hope you will support our conference. For early-bird registration forms head over to our website **www.vanz.org.nz** where you can sign up online for individuals/teams or trade stand attendance.

Check out the first instalment of the year from Carl's Quiz, also the President's Report from Tim and the latest Skills & Practices. We have articles from Craig Carlyle - The Chaos Theory of Maintenance Management and Roengchai Chumai - Vibration mitigation of 265 MW Francis turbine and generator by turbine guide bearing gap adjustment.

Much appreciation goes to all the companies who continue to advertise with us, we really appreciate the ongoing support.

Happy Reading and have a prosperous 2024!

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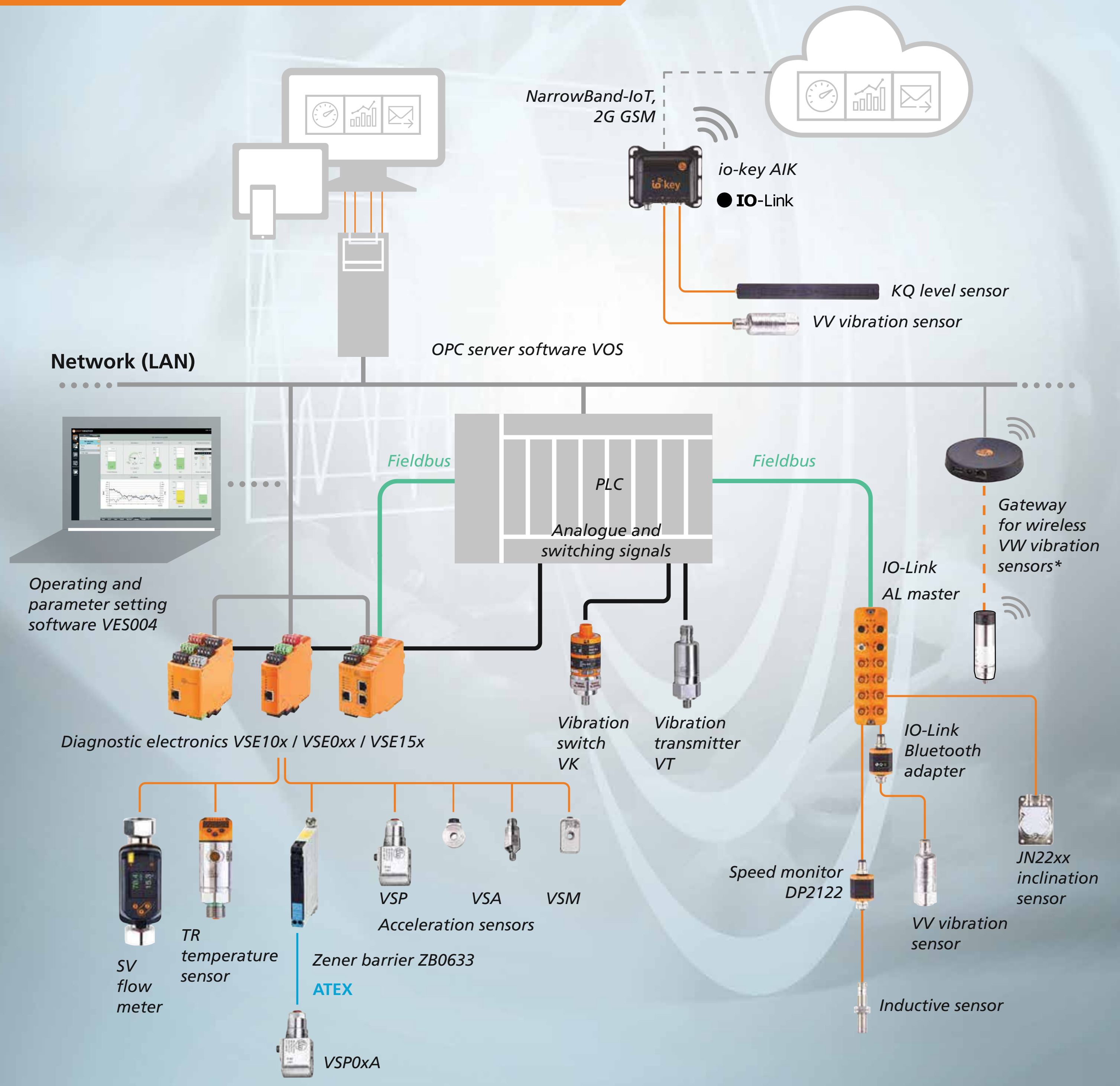

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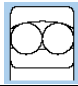
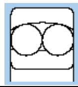
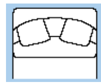
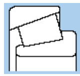
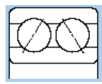
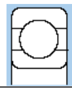
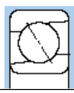
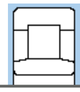
	1	X	X	X	Self Aligning Ball Bearing		K tapered bore D1 Lubrication groove / hole S pressed steel cage L1 brass cage G1 brass cage no rivets B inner race centre rib C inner race guide ring
	2	X	X	X	Self Aligning Ball Bearing		
	2 X	X	X	X	Self Aligning Roller Bearing		
(4T)	3 X	X	X	X	Tapered Roller Bearing		(Note that a 3 in the bearing series designates a metric bearing.)
	5	X	X	X	Double Row Angular Contact Ball Bearing		(A) 30 deg contact angle B 40 deg contact angle C 15 deg contact angle
	6	X	X	X	Single Row Deep Groove Ball Bearing		LL rubber seals ZZ steel shields 2A Shell Alvania 2 grease
	7	X	X	X	Single Row Angular Contact Ball Bearing		As for 5 series G ground faces
	N (x X)	X	X	X	Cylindrical Roller Bearing		L1 brass cage G1 brass cage no rivets

For example, a spherical roller bearing 22213B is NOT the same as a 22213E. Nor can a cylindrical roller bearing type NJ be replaced by a type NU. Cylindrical roller bearings can have a number of different internal configurations that govern if, and how, the bearing is fixed or floating.

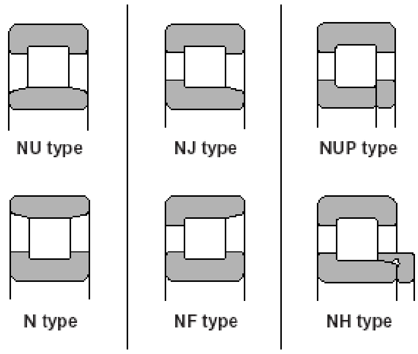
Another important thing you need to know is that the last two numbers can be multiplied by 5 to get the bearing's inner diameter. For example, a 6312 ball bearing has an inner diameter of 12 * 5 = 60 mm, and a 22216 spherical roller bearing has an I.D. of 16*5 = 80 mm. The common clearances are: C2 (less than normal clearance), CN (normal clearance), C3 (more than normal clearance), C4 (more than C3 clearance), and CM (electric motor clearance).

Can you decipher the numbers and codes on the box in the picture? It is a 22220BKD1C3.

NOTES: This table (above) is an abbreviation showing typical NTN bearings used at BlueScope Steel Western Port. Refer to the manufacturers catalogue for full information.

Upper case X represents any number. Lower case x represents a letter. Characters in brackets are not always present.

Below: Fig.1.



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FEATURE

The chaos theory of maintenance management

The fact that you have read past the title suggests that a nerve is already twitching when maintenance and chaos is used in the same sentence. Let's just leave it out there that perhaps the non-performance (in actual, management or political terms) of your maintenance department has irked you at some time.

So why is it that so many maintenance departments in industry become embroiled in stress, finger pointing and sweaty KPI's? What makes plant reliability so difficult to manage?

Simple, humans.

Even more than that, maintenance engineering humans. We will come back to that thought later.

I have spent many years guiding sites and companies towards maintenance excellence and have been fortunate to be involved in success stories measured in reliability, profits and satisfaction. But I have also seen efforts doomed to failure from the outset or railroaded by changes in management. So what makes the difference?

Systems and processes

I have seen attempts, (some of them lauded internationally) that start out with the highest academic processes and the sexiest 3 letter acronyms. High Priests and converts spout dramatic factors from on high whilst gathering their medals.

The acid test is when you scratch the surface of the site 1-2 years later; are the maintenance plans really being actioned? Is life continuously learning and improving? Far too often the answer is a resounding NO.

Continued over page >

It is one thing to create fabulous maintenance plans and even better if you install a flash computerised maintenance management system to run them, but it is the systems and processes of running your maintenance management that true success will live and die by.

Back to the humans. After meticulous study of mislaid perfect plans, I have made an earth shattering psychological discovery. I will call it "The Carlyle Effect" (all modesty intended). Here it is:

"Leave him to graze naturally and he will devolve to firefighting and squeaky door priorities as quick as look at you."

Maintenance Engineers do not like being systemised.

It's true. If you work in a manufacturing process you get it; the need to have systems and processes to prevent chaos. Even tradesmen working in engineering manufacturing get it; there is a plan – I need to work to it.

But your average run of the mill Maintenance Department tradesman is hard coded to lean towards chaos. Leave him to graze naturally and he will devolve to firefighting and squeaky door priorities as quick as look at you. Give him a maintenance schedule and he will quickly shovel the hard jobs to the backlog and wonder off to do the favoured jobs. And when something does break, watch him squeal onto the job, sirens and lights blazing, to save the day with his mission critical skills.

Smaller sites will display the "irreplaceable engineer" syndrome; Mr. Fixit who may appear to have the site running perfectly, but has all the info locked in his head. What value does he REALLY offer you?

By the same genetic path that drew him to like fixing broken things, he is averse to being told what to do and when to do it. He wants to make his own choices.

Sound familiar?

Let me elucidate further by couching maintenance management in manufacturing (widget) terms:

- You manage a team of blue (maintenance) widget makers:
- Your customers don't really understand blue widgets but they do like red (non maintenance) so they flood you with red widget orders.
- No one seems to care that you make more red widgets than blue.
- You have a backlog of widgets that you will never achieve.
- Your customers don't have a lot of faith in your widget making ability and would go elsewhere if they could.
- There is no formal widget making schedule. It pretty much works on who's yelling at you the loudest.
- You spend most of your time explaining to customers

why the promised widgets were not made or why they broke straight away.
- Your widget makers spend most of their time waiting for widget parts or access to the widget making machines.
- You need a massive store of widget parts because you never know which widget you might need to work on next.
- If you did give your widget makers a list of widgets to make they would pick out the nice-to-do widgets and leave the rest for the "back log".
- Some widget makers ignore the widget schedule and just make what they think is best.
- Some widget makers have learnt lots about making widgets over the years but they keep it all in their heads as their own little insurance scheme.
- Your budget is grossly overspent and you are unable to make all the blue widgets you need.
- You seem to be forever repeating the same widget making mistakes.
- The Chief widget maker can never retire as the place won't run without him.

This is the Chaos Theory of Maintenance Management and unfortunately I bet you recognise it. You certainly wouldn't last long in business running processes like this. So why do we accept it in maintenance management?

If you are happy with chaos theory in your process, stop reading now, I am happy for you. Maybe not happy for your shareholders, but you go for it! While it lasts.

My apologies to our maintenance engineering humans. There is nothing wrong with them, not in the slightest. It's just that the very skill set that makes them good reactive maintenance engineers almost precludes them from accepting proactive systems and processes.

There is however absolutely no reason in the modern environment that the maintenance function cannot be run with the same accuracy, predictability and transparency as a manufacturing process. The good news is that it also does not require expensive resources and is simple to achieve.

The reason why even the holiest systems will devolve to this level is the lack of formalised systems and processes. All it takes is negative culture and weak management to quickly undo years of positive work.

"If you are happy with chaos theory in your process, stop reading now, I am happy for you."

In order to improve maintenance management performance for the long term, the site must develop the maintenance scheduling systems and processes as a primary step before attempting to introduce maintenance planning disciplines. Put another way, why have a plan if you are not going to action it?

Put in the simplest terms, a truly successful maintenance management system will aim to put the right man on the right job at the right time with the right resources. This is the essential difference between Maintenance Planning and Maintenance Scheduling.
Let me describe a healthy maintenance management system:
- It has well developed maintenance plans utilising just-in-time resourcing instead of high inventory stores.
- Maintenance plans are fully optimised and bankable, based on evolved condition prediction and trades-confirmed resource requirements.
- Maintenance is the priority because our maintenance plans have evolved away from feel good periodic checks to optimised invasion points.
- The maintenance scheduling function adds approved non maintenance and corrective maintenance tasks to the existing planned maintenance schedule.

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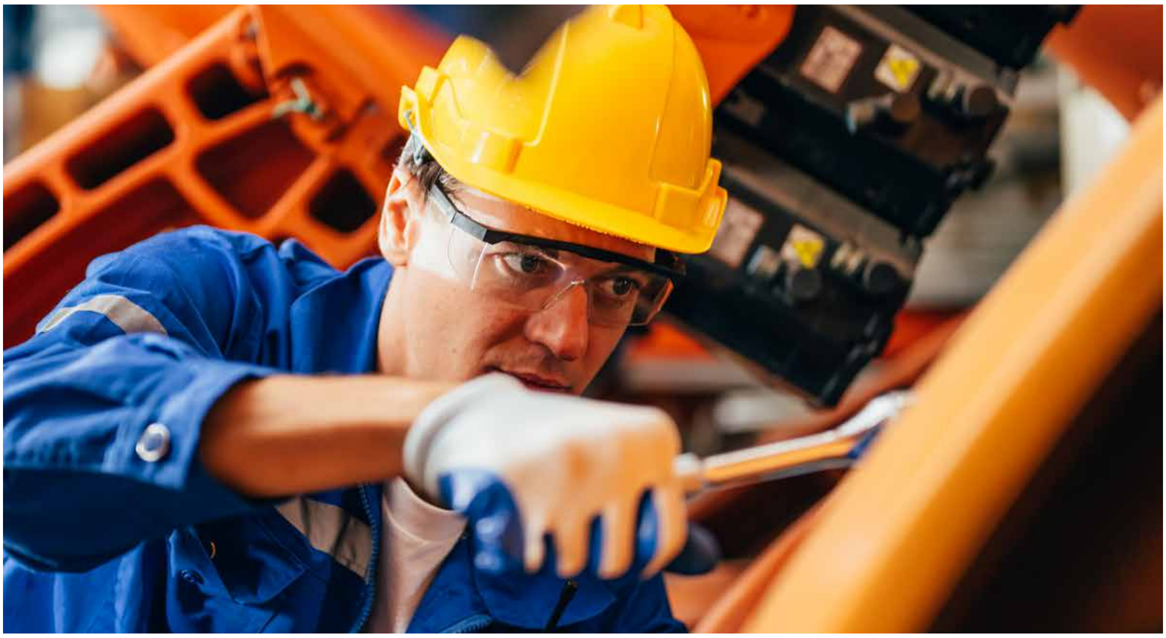

- The schedule is a reality driven rolling document that reflects the real site capability (Reality Schedule), (normally on a week by week basis). The reality schedule does not have nice-to-do tasks but only tasks expected to be actioned.
- The tradesmen understand and work to a 100% schedule achievement. Non achievement is the exception, not the rule.
- There is NO backlog. How can you do a job last week? Unachieved tasks are put back into the forward schedule.
- The operation understands the professionalism of the maintenance plans and processes and considers the schedule as bankable. They strive to make the plant available as the consequences of deferral are understood.

> **"Moving site cultures away from comfort points is always going to be like standing on someones toes."**

Sound wacky? Think about it in terms of running a manufacturing process. Strangely, the hardest thing to achieve above is the man management, which is where your systems and processes meet culture and management. It looks hard so it must be. Damn right.

Moving site cultures away from comfort points is always going to be like standing on someones toes. This may sound like total fantasy on your site but the challenge to you is to stand up and make it happen. If making the journey to maintenance excellence appeals to you, here are my top five foundation steps to success:

1. Publicly state that you are going to create a professional and proactive maintenance function.
2. Define the difference between maintenance and non-maintenance tasks. (What are you here to do?)
3. Engage support for your processes from the highest level of your operation.
4. Make sure you are rewarding your staff for success, not failure.
5. Engage the entire operation in your systems and processes. Formalise it, Live it, breathe it, back it.

The journey from "ok" to "excellence" is not that difficult and does not take a lot of expense, training, resources or tools. It takes the cheapest, most effective resource out there, ATTITUDE. There are some distinct steps along the way and embedded cultures that you might have to stomp on, but the rewards are enormous, in dollar and self esteem terms.

If I haven't touched a nerve, then good on you. You either have your act together and are already a white knight of engineering, or are blissfully unaware of a world outside of the trench.

Article by Craig Carlyle, Senior Consultant at HasTrak Health & Safety NZ, Auckland, New Zealand

Vibration mitigation of 265 MW Francis turbine and generator by turbine guide bearing gap adjustment

This paper discusses the vibration mitigation of a 265 MW Francis turbine and generator based on vibration analysis results. The vibration measurements revealed the unit's maximum shaft vibration amplitude was 870 µmpp, close to the trip setpoint at 900 µmpp, and occurred at the turbine guide bearing (TGB) during partial load operation at 150 MW. The dominant frequency was 0.94 Hz (0.3X RPM) with forward precession, whose amplitude significantly decreased as the MW was increased. The cause of this frequency is the vortex robe in the draft tube due to the operation in the rough load zone (RLZ), which is commonly occurred in the Francis turbines and mostly unavoidable. However, the shaft orbit and shaft centerline plot of TGB indicated excessive TGB bearing clearance in the up-downstream direction which was later confirmed during the following inspection. The gap of several TGB pads was adjusted by the OEM and then the unit was restarted. The measurement result shows that the unit's maximum vibration amplitude still occurred during partial load operation at 150 MW but it was reduced to less than 600 µmpp and the centerline movement during startup and normal operation was noticeably reduced.

Introduction

The machine train is a vertical Francis turbine rigidly coupled with a 32-pole generator with a nameplate output of 265 MW and an operating speed of 187.5 rpm. The turbine and generator rotors are radially supported by a 16-tilting-pad upper guide bearing (UGB), a 16-tilting-pad lower combined bearing (LCB), and an 8-tilting-pad turbine guide bearing (TGB) from top to bottom, respectively. The rotor is supported axially by a 16-tilting-pad thrust bearing at LCB. The ascommissioned diametral clearance of TGB was 0.6 mm.

The unit is fitted with X-Y proximity probes at UGB, LCB, and TGB for relative shaft vibration (suffix XD/YD) measurement as depicted in Figure 1. In addition, velocity sensors are attached to each bearing housing to measure casing vibration (suffix XV) and axial vibration (suffix ZV) at LCB. The inductive proximity switch keyphaser is fitted to the shaft just above the X probe at TGB. All vibration and keyphaser signals are fed to the vibration rack that has BNC buffered outputs for vibration analyzer connection.

Typically, Francis turbines experienced vortex robe in the draft tube during off-design operation due to the mismatching of inflow angle and fixed runner angle [1] as presented in Figure 2. At high load, see Figure 2a, the fluid in the runner tends to flow towards the machine axis causing a swirl against the runner rotation when entering the draft tube. The static pressure in the swirl center is very low, and at vapor pressure, cavitation is generated in the vortex core. This condition is usually stable and causes small pressure fluctuations in the draft tube. In the range around the best efficiency point (BEP), see Figure 2b, the inflow to the runner blades is aligned to the blade angle, and the streamlines follow the geometric design of the runner contours to a large extent. The draft tube flow is widely smooth and stable with a low swirl intensity. At part load, see Figure 2c, the fluid in the runner tends to flow toward the outer region of the machine, and the flow leaves the runner with a swirl rotating in the direction of the runner. This outflow condition leads to a vortex rope of helical shape. Since the pressure inside of the vortex is quite low, the vortex forms a cavitation bubble in the draft tube. Due to its movement, this vortex rope creates periodic pressure fluctuations in the turbine at a low frequency, which is typically 0.25-0.35 times the rotational speed of the runner, which also exerts the processional force on the runner [2].

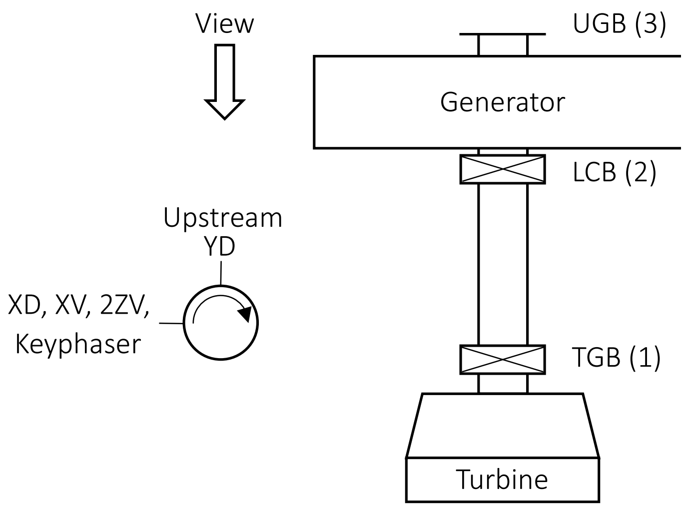

Figure 1: Machine train diagram and transducers layout.

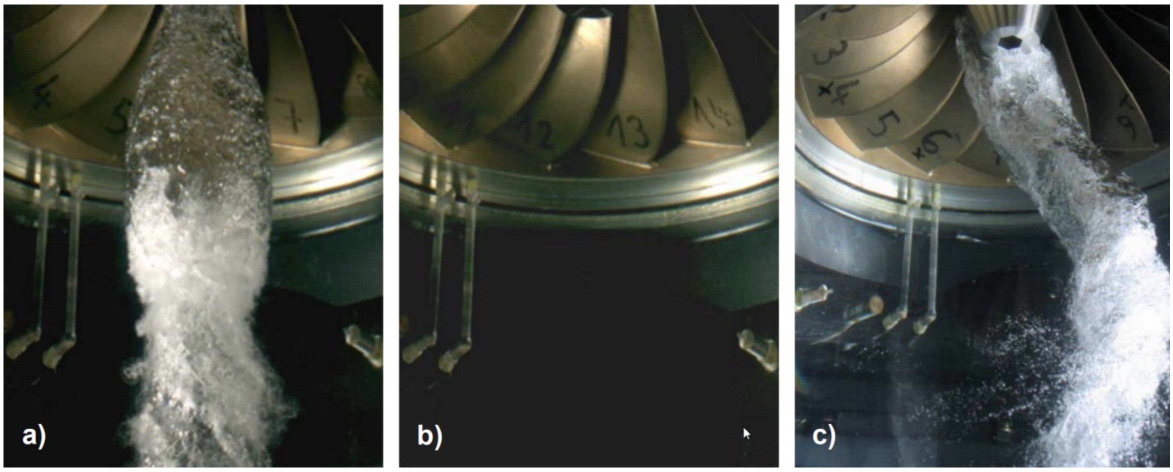

Figure 2: Typical flow patterns of a Francis turbine observed in model test: a) high load, b) around BEP, c) part load (Source: [1]).

Compared to fixed profile journal bearings, the tilting pad journal bearings are superior in terms of stability and misalignment resistance. Each pad in the bearing is free to rotate about a pivot and cannot support a moment. Hence, the destabilizing forces are greatly reduced or eliminated, and the bearings are no longer a potential source of rotodynamic instability [3]. The pad and bearing assembly clearances affect the dynamic characteristics of the bearing. Increasing bearing assembly clearance while keeping the pad clearance results in a decrease in bearing direct stiffness and damping [4], resulting in larger amplitude shaft vibration under identical excitation.

Before Corrective Action Data Discussion

The direct shaft and casing vibration amplitude trends at test water levels of the upper surface (U/S) 274.8 m and discharge surface (D/S) 144.0 m are presented in Figure 3 and Figure 4, respectively. The maximum shaft vibration amplitude was observed at 150 MW at TGB (1YD) and was close to the trip setpoint. The maximum casing vibration amplitude was observed during full speed no load in the axial direction of LCB (2ZV) but the amplitude was less than 2 mm/srms. Note that the casing vibration amplitude of TGB (1XV) was low even the shaft vibration amplitudes were large due to the massive TGB housing and its supporting structure.

The full waterfall plot of TGB in Figure 5 shows the dominant frequency of 0.94 Hz (0.3X of turbine speed) with forward precession which is caused by vortex robe in the draft tube due to off-design operation. The amplitude of this frequency decreased significantly when the MW was increased to 170 MW and almost completely disappeared at above 210 MW. The waterfall plot of axial casing vibration (2ZV) in Figure 6 reveals the broadband frequencies during no-load operation due to flow turbulence.

These frequencies diminished during on-load operation.

The direct and synchronous (1X) shaft orbits of TGB at various MWs are presented in Figure 7. The shape of 1X orbits is elliptical with the major axis in the up-downstream direction. This finding indicates anisotropic dynamic stiffness at TGB, which is considered abnormal for a vertical machine with an even pad number.

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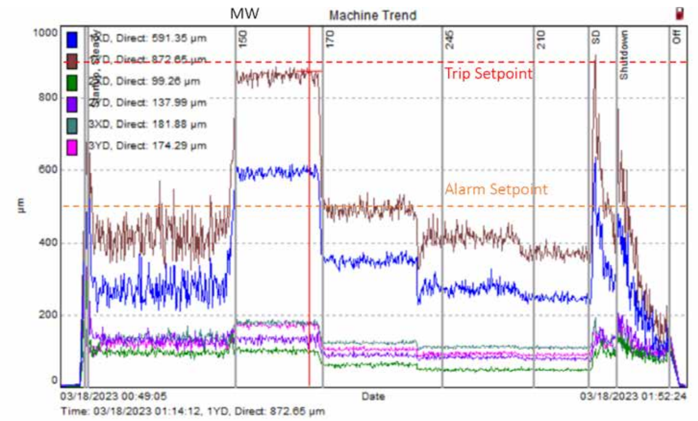

Figure 3: Trend plots of Direct (overall) shaft vibration amplitudes with corresponding MW before TGB gap adjustment.

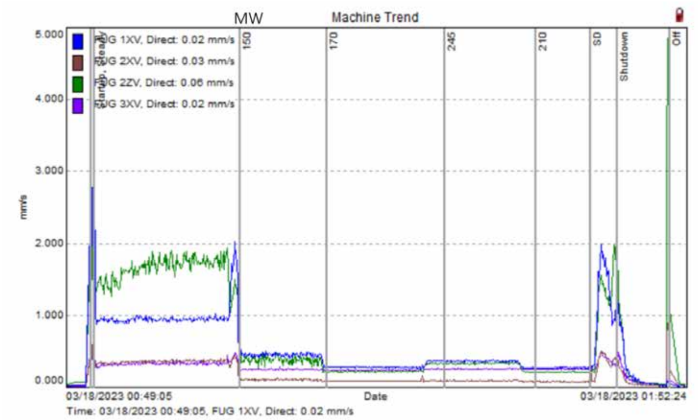

Figure 4: Trend plots of Direct (overall) casing vibration amplitudes with corresponding MW before TGB gap adjustment.

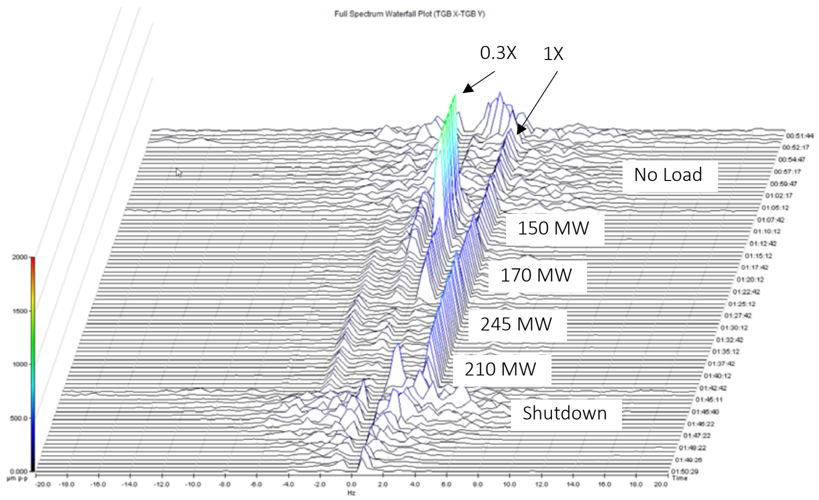

Figure 5: Full waterfall spectrum of TGB before TGB gap adjustment.

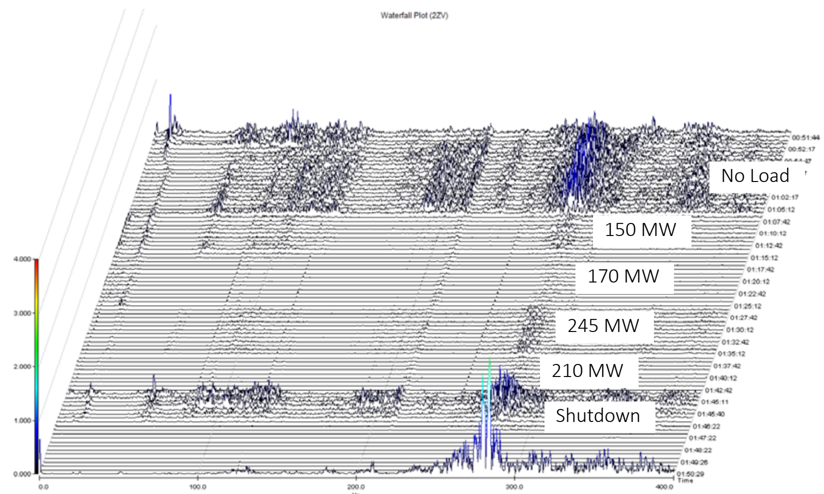

Figure 6: Waterfall spectrum of axial casing vibration (2ZV) before TGB gap adjustment.

The shaft centerline plot of TGB during startup, normal operation, and shutdown in Figure 8 indicates almost 0.6 mm movement in the up-downstream direction during startup. Hence, from the 1X orbit shape and the shaft centerline movement TGB, it was suspected that the TGB gap in the up-downstream direction was excessive.

Corrective Action

The TGB was inspected by the OEM and the clearances of pads in the up-downstream direction, shown in Figure 9, were excessive. The visual inspection showed the journal and the pads were in good condition and the clearances of the pads in the up-downstream direction were adjusted. The as-found and as-left clearances record was not disclosed by the OEM due to warranty-related reasons.

After Corrective Action Data Discussion

The direct shaft and casing vibration amplitude trends after the TGB gap adjustment are presented in Figure 10 and Figure 11, respectively. The maximum shaft vibration amplitude was observed at 150 MW at TGB (1YD) and was about 300 μmpp lower than the before adjustment shown

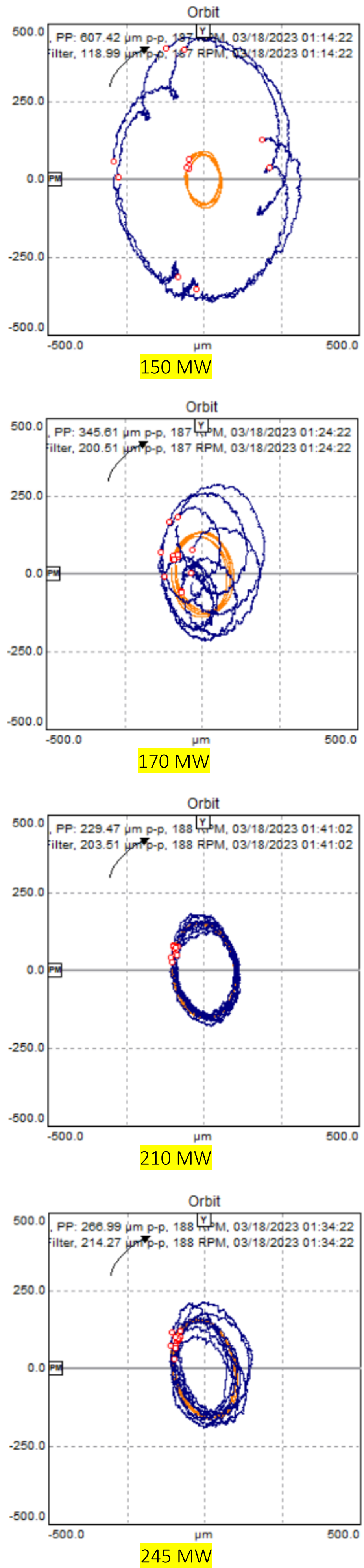

Figure 7 (Right): Direct (blue) and synchronous (1X, orange) shaft orbits of TGB at different load conditions before TGB gap adjustment.

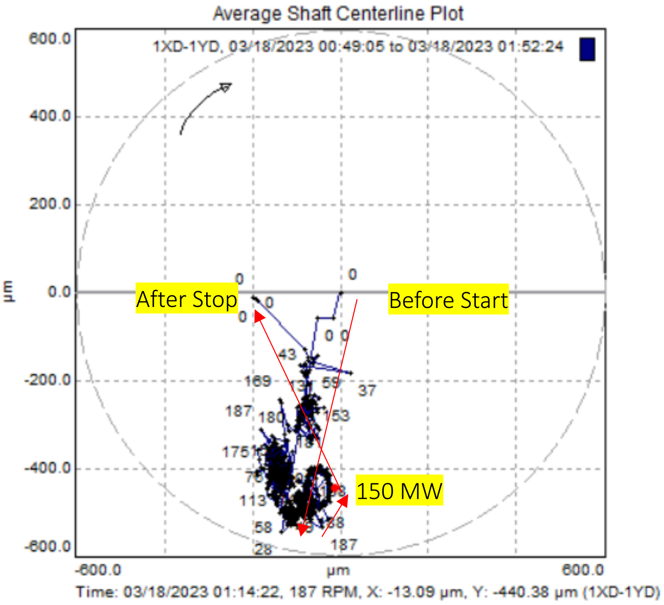

Figure 8: Shaft centerline plot of TGB during startup, normal operation, and shutdown before TGB gap adjustment.

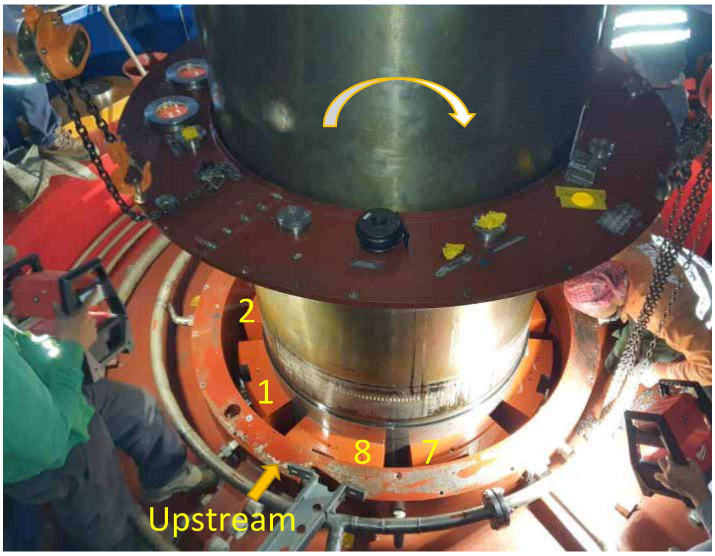

Figure 9: TGB pads inspection and numbering

in Figure 4. Hence, the risk of unit trip was alleviated. The maximum casing vibration amplitude trends were considered unchanged compared with the before values in Figure 4. Hence, shaft vibration measurement is considered the effective tool for machine condition monitoring as it is sensitive to changes in bearing gap/clearance, hence, dynamic stiffness.

The direct and synchronous (1X) shaft orbits of TGB at various MWs after the adjustment shown in Figure 12 indicated smaller direct and 1X orbits with more circular 1X orbits compared to the orbits at the same MW presented in Figure 7. Hence, reducing TGB gaps in the up-downstream direction can effectively increase the dynamic stiffness in the corresponding direction.

The shaft centerline plot in Figure 13 also reveals that the maximum downstream movement during startup and downstream position at 150 MW were reduced from the movement before adjustment, shown in Figure 8, by 0.25 mm.

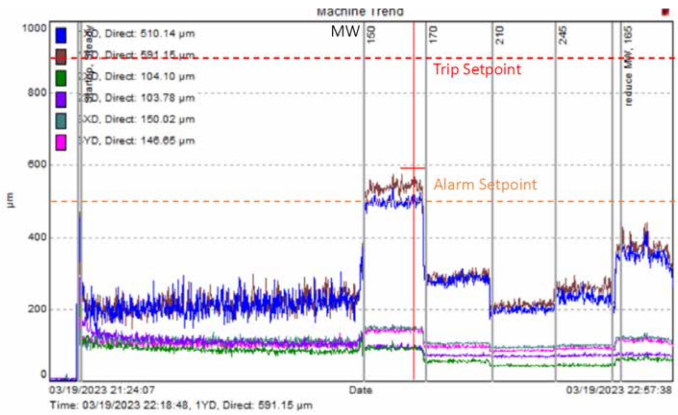

Figure 10: Trend plots of Direct (overall) shaft vibration amplitudes with corresponding MW after TGB gap adjustment.

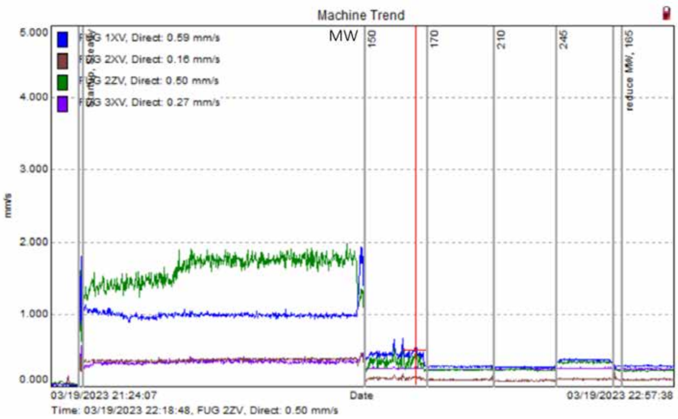

Figure 11: Trend plots of Direct (overall) casing vibration amplitudes with corresponding MW after TGB gap adjustment.

Conclusions

Excessive shaft vibration amplitude at TGB during 150 MW was caused by the combination of vortex robe in the draft tube due to operation in the off-design condition that produces large amplitude forward precession vibration at 0.94 Hz (0.3X RPM) and excessive TGB clearance in the up-downstream direction.

The shaft orbits and centerline plots are useful tools for identifying the excessive TGB clearance issue which was subsequently confirmed by the inspection result.

After TGB gap adjustment, shaft vibration amplitudes and shaft centerline movement from the resting position at TGB were significantly reduced.

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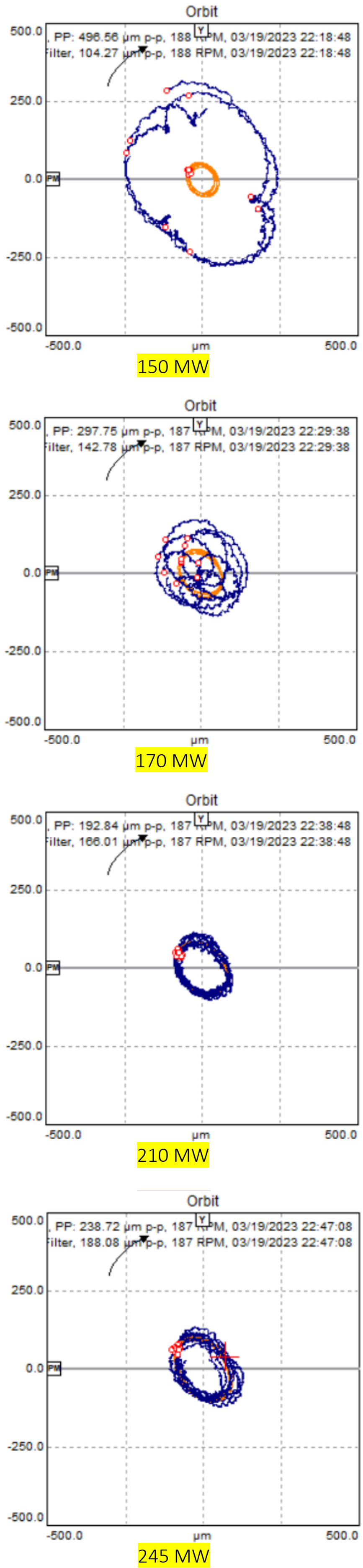
Figure 12 (Right): Direct (blue) and synchronous (1X, orange) shaft orbits of TGB after TGB gap adjustment.



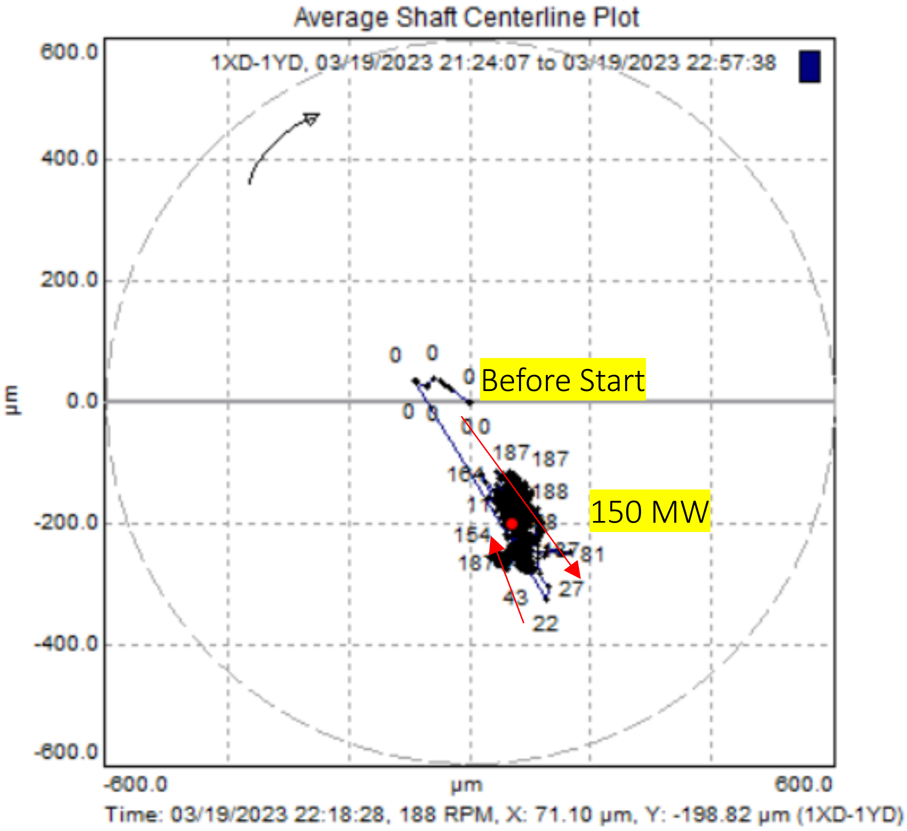


Figure 13: Shaft centerline plot of TGB during startup, normal operation, and shutdown after TGB gap adjustment.

Shaft vibration measurement is considered the effective and sensitive tool for machine condition monitoring and diagnostics of the large vertical hydro turbine and generator which has massive bearing housings and supporting structures in contrast to casing vibration measurement. ■

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[2] P. Dörfler, M. Sick and A. Coutu, Flow-Induced Pulsation and Vibration in Hydroelectric Machinery, London: Springer-Verlag, 2012.

[3] T. Dimond, A. Younan and P. Allaire, “A Review of Tilting Pad Bearing Theory,” International Journal of Rotating Machinery, 2011.

[4] G. J. Jones and F. A. Martin, “Geometry Effects in Tilting-Pad Journal Bearings,” ASLE Transactions, vol. 22, no. 3, pp. 227-244, 1979.

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TEST YOUR KNOWLEDGE - PART 74 OF A SERIES

1 Vibration readings are collected on a centrifugal fan when it was operating at its full speed of 1500 rpm. The "1x" vibration level is 20 mm/s pk. The fan is turned off and it was noticed that the vibration worsened at one point as the fan ran down through the speed range. Which of the following statements is most-likely to be true?

a The impeller is unbalanced and resonance was encountered during the run-down
b The impeller is well balanced and resonance was encountered during the run-down
c There is clear evidence of mechanical looseness
d The fan impeller has a strong couple unbalance

2 The rolling element bearings in a large gearbox were found to have a dull appearance and micro-pitting. What might be the cause of this?

a Poor Lubricant condition
b Operating temperature too high
c Water penetration
d Any or all of the above

3 Misalignment can negatively affect asset reliability. Which if the following statements is true?

a Vibration levels will always be high when a machine is misaligned
b Misalignment is not problematic as coupling types can be chosen that absorb misalignment
c Misalignment is only detrimental on rotating machines with a power rating in excess of 50 kW
d It can be possible for some machines to run in a misaligned condition without generating excessive vibration

4 A dynamic absorber consists of a steel mass mounted on a threaded steel rod. The mass, drilled through its centre, is located on the threaded rod via lock nuts either side. The position of the mass on the steel rod can be adjusted. One end of the threaded rod is screwed into the structure that is vibrating, the other is free. If the position of the mass is changed so that it is moved closer to the free end of the rod, what effect will that change have?

a The tuned frequency of the dynamic absorber will be increased
b The tuned frequency of the dynamic absorber will be reduced
c The dynamic absorber will be more directional in its response
d None of the above

5 Two machines vibrate at the same frequency in a purely sinusoidal fashion. Machine "A" vibrates at 10 mm/s pk, and machine "B" vibrates at 13 mm/s rms. Which machine has the highest vibration?

a Machine "A"
b Machine "B"
c The frequency of the vibration needs to be known to answer this question
d Both have equal levels of vibration

6 You are conducting vibration analysis on a DC motor in New Zealand. Which of the following frequencies might be evident in the spectra?

a 150 Hz
b 300 Hz
c 600 Hz
d Any or all of the above could be evident

7 Which of the following is most-likely to be associated with the term "coincidence frequency"?

a An electric motor
b A sheet of glass
c A steel column
d The surface of a pond

8 Which of the following is most-likely to produce half-order vibration and harmonics?

a A cavitating pump
b A bearing loose on a shaft
c A 2-stroke engine
d A two-bladed wind turbine

9 A simply-supported beam is vibrating in its 2nd mode. At what locations on the beam will the displacement be minimal?

a Both ends and centre of beam
b Both ends only
c Centre of the beam only
d At one end only

10 If you are using a mains-powered vibration analyser in New Zealand, what might you need to be mindful of?

a Erroneous signals resulting in ski-slope effects
b Ground loops resulting in erroneous signals at 50 Hz
c Ground loops resulting in erroneous signals at 100 Hz
d All of the above

Check your answers on page 35 >

Above: Maintenance on a centrifugal fan.

TEST YOUR KNOWLEDGE

Further enquiries can be directed to: Carl Townsend at Carlton Technology Ltd.
Phone: 64-6-759 1134 | Email: ctownsend@xtra.co.nz | Address: P.O. Box 18046 Merrilands, New Plymouth 4360, NZ

acoem
CREATING ENVIRONMENTS OF POSSIBILITY

Shaft alignment precision at every turn with the Acoem AT series

Acoem – a global leader in Industry 4.0 augmented mechanics for enhanced industrial reliability – continually invests in research and development to improve the customer experience and make the process of aligning and balancing your critical machinery easier and more dynamic. As technology advances becomes available, Acoem adapts and integrates them into their shaft alignment solutions to provide an even greater range of capabilities and functionality.

With four different versions of its innovative AT series now available, Acoem gives you the choice of alignment tools with varying degrees of sophistication and monitoring parameters, depending on your individual needs.

In 2023, Acoem introduced the latest addition to its AT series – the next generation, revolutionary AT-400. As it did with the previous AT models (the AT-100, AT-200 and AT-300), Acoem considered its customers' feedback and evolving industry needs when developing its newest solution.

The fully integrated Acoem AT-400 system comes complete with a robust storage/transportation case, new M9/ S9 dual-axis sensors, the powerful AT-400 app, an enhanced display unit, accessories and long-life power supply.

You asked and we listened, incorporating everything you wanted in a shaft alignment tool

The AT-400 delivers:

- Repeatable and reliable measurement accuracy
- Highly responsive and intuitive file manager interface with extended battery life
- Single screen displays all data, reports and apps in one place
- Faster reporting functionality and job history retrieval
- Wireless communication protocol between the sensors and your interface
- High IP rating (IP65)
- Robust frame that protects against water, dust and accidents
- Direct access to online help with manuals and quick guides
- Features for indicating/measuring thermal growth, soft-foot, feet lock, vertical alignment and machine train between individual machinery relative to your operational network.

Dual-axis technology combined with the Acoem integrated ecosystem equals a superior solution

This is the first time that Acoem has integrated dual-axis technology into its class-leading ecosystem of alignment solutions that features seamless connectivity, app-based intuitive data management and reporting, cutting-edge sensors, WebPortal, and the service and support Acoem that comes with being an Acoem customer.

With dual axis technology, precise shaft alignment is in your hands.

- Secure accurate measurements of large-scale machinery with significant distances (over 15 metres) between sensors

Continued over page >

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CREATING ENVIRONMENTS OF POSSIBILITY

AT-400

DUAL PRECISION AT EVERY TURN

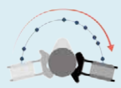
Acoem, a trusted name in condition monitoring and predictive maintenance, has been a pioneer in laser shaft alignment technology for decades. That tradition continues with our latest innovation - Acoem AT-400 dual-axis shaft alignment solution. With this cutting-edge system, precise laser alignment is easier than ever before.

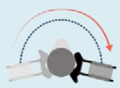
What makes the AT-400 remarkable is its ability to effortlessly blend precision with simplicity. This advanced alignment solution ensures your machinery operates with unmatched accuracy and efficiency.

Maximising alignment performance

AT-400 integrates dual-axis technology seamlessly, offering unrivaled precision for large machinery. With extended sensor distances, it outperforms traditional line lasers.

- DualXL PSD detectors
- 7 measurement methods
- GuideU™ 3D shaft alignment interface
- 20 metres measuring distance


Dual Sweep


Multi Point

Lifetime Warranty


Seamless Cloud Connectivity

MV-x
AI-powered system with real-time edge computing that pinpoints the source, direction and intensity of vibration

EAGLE
The first wireless monitoring solution with automatic AI diagnostics


Sparrow
Advanced IIoT wireless diagnostics for balance-of-plant assets


FALCON
The fastest and smartest tool for vibration measurement and analysis


RT-300
Customisable app-based augmented mechanics ecosystem that combines vibration, laser lineage and thermography

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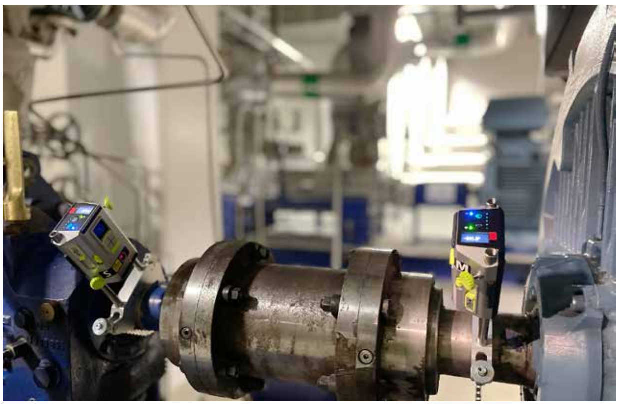

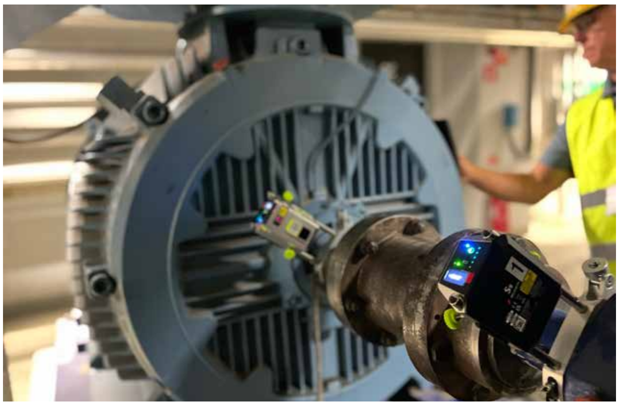

- Capture critical sweep and flatness measurements easily and more precisely
- Gain accurate multipoint alignment data – vertically and horizontally –in any rotational position simultaneously over greater distances
- Monitor complex machines that can't be easily accessed or manually rotated.

According to Mathew Smart, Acoem Australasia Reliability Solutions Manager, the Acoem AT-400 solution unlocks the potential for faster and more precise alignment decisions – ultimately saving your business time and resources.

"With less maintenance downtime and advanced functionality that simplifies data capture and diagnosis of a wide range of complex machines, you'll increase operational productivity and be able to focus on your key output functions instead of reliability challenges," he said.

Maximise alignment performance over a diverse range of applications

The multipoint measurement system of the AT-400 makes shaft alignment of power plant turbines simpler and more accurate, especially for uncoupled shafts, coupled shafts with sleeve bearings, shafts with jerky rotation, white metal bearings, journal bearings or difficult-to-rotate/ non-rotatable shafts.

High-speed compressors and turbines require exact measurements, and the multipoint capability of the dual axis sensors lets you rotate shafts at any position with an infinite number of turns.

For spacer shaft alignment in cooling towers the new extended laser distance gives you accurate measurement over distances of 20 metres or more, even in bright sunlight and under extreme heat conditions. You no longer need to position the shaft at the 3 o'clock position, saving you time and resources.

Short haul and yard diesel locomotives traditionally required special alignment procedures like the complex dials method, but the AT-400 makes things easier with the alignment tool automatically measuring and adjusting the angular misalignment between the engine and alternator shafts.

With non-rotatable shafts, additional readings spread around the shaft improve reliability, even in difficult situations and for machine train alignment, the AT-400 provides a solution with the smallest possible move for the bolt-bound machine.

Precision alignment diagnoses for all types of machinery

- Compressors
- Cooling towers
- Energy generation turbines
- Mainline, short-haul and yard diesel locomotives
- Machine trains
- Maritime
- Non-rotatable shafts.

To learn how the AT-400 can help solve your machinery alignment challenges, or to view our entire AT series, visit acoem.com/australasia/ranges/proactive-maintenance/shaft-alignment-tools or contact info.au@acoem.com to arrange a demonstration.

PUZZLE CORNER

Solutions on page 35

WORD BUILDER

How many words of **three or more** letters can you make using the five letters below? You can only use each letter once. Plurals are allowed, but no foreign words or words beginning with a capital.

Word scores expected...

15 - Good | 25 - Very Good | 35+ - Excellent

A	R	L	I	S

There is six 5 letter words in this puzzle.

WORD LADDER

A Word Ladder has two words in the ladder, one at the top and one at the bottom. You must form a sequence of words going down. On every step of the ladder (1-6), you must unscramble and create a new word that only differs by one letter from the word above it until you reach the destination word on line 6.

Head to Tail...

1 HEAD
2
3
4
5
6 TAIL

SUDOKU

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. **We've started it off for you...**

Puzzle difficulty: **Hard**

68.2% of puzzlers can solve this. Can you?

	3	1		5				4
	9	5	7					1
			2					5
	2	4			6			9
	8						5	
5				2		7	8	
9							2	
6			4		7			

Are you a VANZ member?

You could be. Anyone with an interest in the area of mechanical and electrical machine condition monitoring, to facilitate predictive asset management is eligible to join VANZ. Asset managers, reliability engineers, technicians, consulting engineers, suppliers and distributors of specialised equipment, engineering students and apprentices can all contribute and gain immensely from membership and our annual conferences.

> **"Membership ranges from a business with a line of small water pumps to personnel from some of the largest plants running million dollar machines."**

Technology, materials and manufacturing processes are continually developing. And so too has the engineer skills and knowledge developed. Today the engineering role has evolved to where the analyst, by diligent use of multiple Condition Monitoring tools and principles, can empower Predictive Asset Management. But it is a challenging role! So much is at stake with the high cost of downtime, equipment replacement costs, and the potential safety risks. The future of the business can hinge on the Predictive Asset Management achieved by this special group of people. Yet detecting, diagnosing, and preventing these faults takes training, knowledge, skill and experience. That is why VANZ exists, and why VANZ constantly evolves!

VANZ recognises that the engineers who apply the technology are one half of the equation. Equally important are the industries and businesses served by it, with their varied experiences and evolving requirements. The size of the operation and the machinery it runs are not an issue either.

For Analysts and Predictive Asset Management specialists

VANZ is a volunteer-run, not-for-profit, membership group of like-minded people from New Zealand and Australia. VANZ as an organisation evolved from a Workshop Conference held in New Plymouth in 1989. From this Workshop Conference the Vibrations Association of New Zealand was registered as an Incorporated Society and the first annual technical conference held in Rotorua 1990.

From this beginning VANZ has continually developed to provide a platform for people to discuss their challenges with their fellow analysts and learn from their peers and industry experts.

Annual conference for networking and learning

The core function of VANZ is the annual conference held every year in May. Like a family reunion, over 100 people gather in a friendly environment to participate in technical presentations, round-table discussions, and at times debate. Keynote speakers from Australia, Europe, America, and Turkey have, and continue to present technical papers at conference. And importantly New Zealand presenters add a New Zealand context.

VANZ membership is FREE if you attend the conference.

VANZ is quite a unique society – it has withstood the 'test-of-time' – and has, for many years, run an awareness day training for apprentices and trainees alongside an asset management stream for technicians, supervisors and management. It is a well respected 'track-record' which VANZ has consistently promoted for the New Zealand and Australian industry.

GETTING IN TOUCH IS EASY...

For more information about membership, contact the VANZ secretary by emailing:

secretary@vanz.org.nz

Spectrum

The official journal of the Vibrations Association of New Zealand (VANZ)

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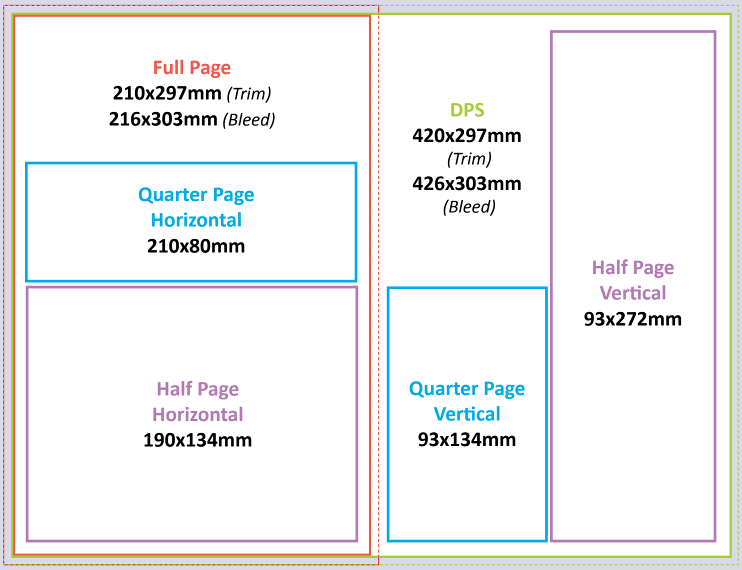
Please email **spectrumeditor@vanz.org.nz** with your submission or should you require further information.



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Carlton Technology Quiz 74: 1A, 2D, 3D, 4B, 5A, 6D, 7B, 8B, 9A, 10B
Word Builder: arils, lairs, laris, liras, rails, rials
Word Ladder: 1. head 2. heal 3. teal 4. tell 5. tall 6. tail

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