



Spectrum

Winter 2021 | Issue 100

100

ISSUE
CELEBRATION

**A special look behind Spectrum magazine,
100 issues in the making!**

“ The common mentality behind the concept has not changed from the beginning... It is about the industry, for the industry, by the industry. ”

+ Much more inside...





Machine Vibration & Plant Condition Monitoring Solutions



VIBRATION SENSORS



VIBRATION TRANSMITTER & SWITCH



VIBRATION MONITORING & DIAGNOSTICS



DIAGNOSTIC SOFTWARE



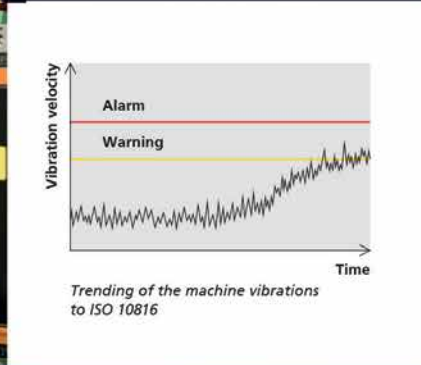
VIBRATION SENSOR WITH MEMORY CAPACITY



VIBRATION TRANSMITTER & SWITCH



VIBRATION MONITORING & DIAGNOSTICS



Trending of the machine vibrations to ISO 10816



GAS FLOW / TEMPERATURE / PRESSURE



TEMPERATURE SENSORS



FLOW / TEMPERATURE SENSORS

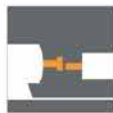


PRESSURE SENSORS

Looseness, unbalance



Misalignment



Rolling element bearing



Gearbox Meshing, tooth fault



Pump Eccentricity, cavitation

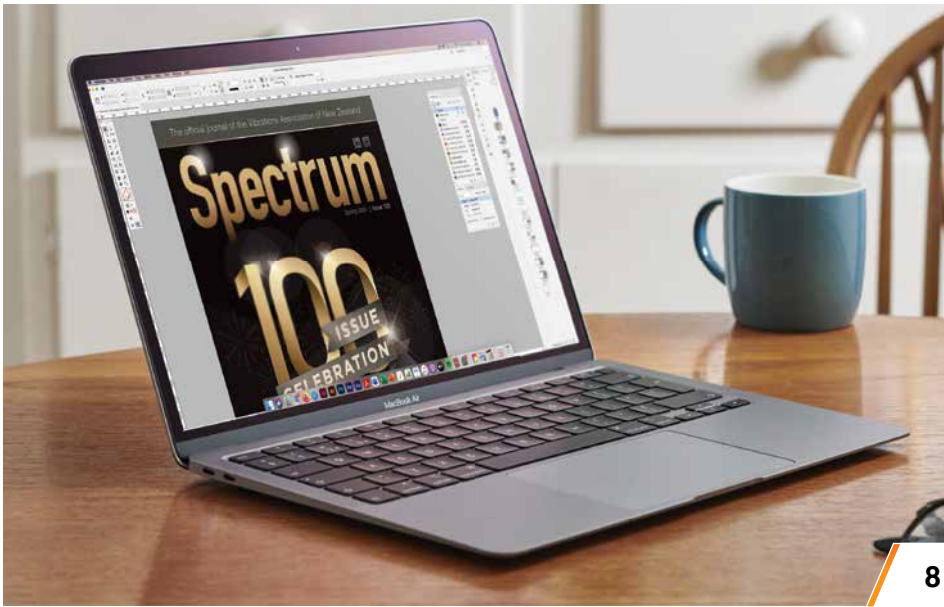


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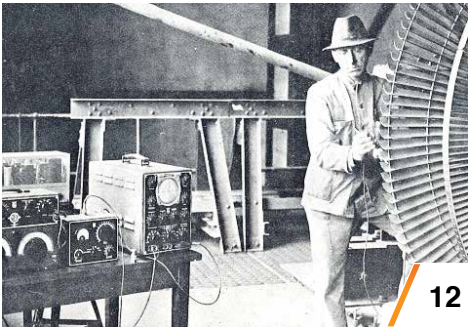


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Missed an issue of Spectrum magazine?

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*.

A QR code reading app will need to be installed on your device first.



Spectrum #100

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Statements made or opinions expressed in Spectrum are not necessarily the views of VANZ or its Officers and Committee.

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PRESIDENTS' REPORT

By Rodney Bell, VANZ President

Welcome everyone to the VANZ Spectrum 100th edition. What an amazing feat to accomplish 100 issues. As I mentioned in the previous digital issue, this is an exciting time for us, to mark the 100th edition with material from the very first issue of Spectrum, a brief history of VANZ and early AGM records.

We hope you will enjoy this very special edition as we mark our progression on a journey of Vibration Monitoring to Condition Monitoring and Asset Reliability throughout New Zealand being recorded in our Spectrum magazine along this journey over the past 32 years.

The 2021 annual VANZ Conference, being held this year at the Wairakei Resort and Conference centre, is well established and moving forward in leaps and bounds. It seems we all have been cooped up for far too long and we need to revert

to the closest thing we can consider normal pre-Covid. The numbers of Exhibitors and Delegates that have already registered is proof of this, but we can still make room for more if you wish to take advantage of the VANZ Exhibition and Maintenance and Reliability Conference. The online registration is available at www.vanz.org.nz under the '2021 Conference' tab.



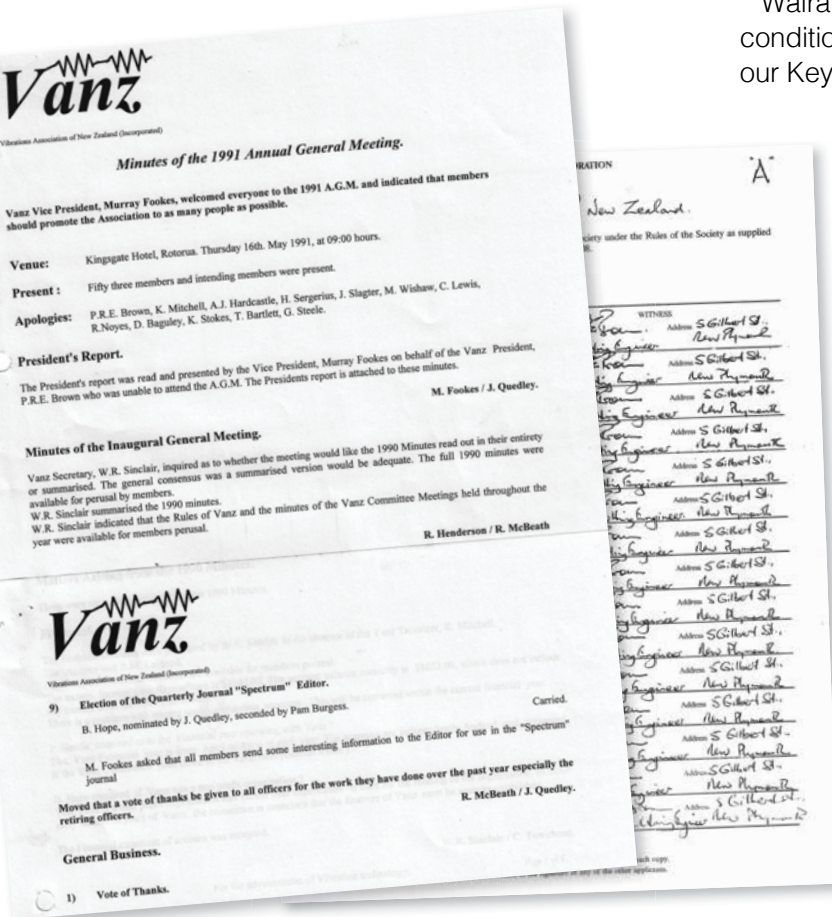
“ We hope you will enjoy this very special edition as we mark our progression on a journey of Vibration Monitoring to Condition Monitoring and Asset Reliability throughout New Zealand. ”

For delegates attending, remember there are 1, 2 and 3-day registration options available, with a lot registering for the all-inclusive and best value for money 3-day package, including 2 nights' accommodation pegged at a very attractive \$1,480 per person. The Apprentices and Trainees option for the first day - Awareness Day is free and the 2nd and 3rd day of the main conference for them is half price at \$400 per person. In this very special issue we have included the full 3-day programme for the 2021 Wairakei Conference with a range of reliability and condition monitoring topics. Also featuring are bios from our Keynote and Guest Speakers.

A new initiative to this year's Conference is 'live streaming' with some overseas Keynote & Guest speakers located outside New Zealand but not able to attend due to Covid, but from what I have already witnessed you almost get the same feeling as if these people were presenting right in front of you live on stage. I am personally looking forward to experiencing this with you all at the conference.

For now, I wish you all well as we continue through the Winter months, trying to keep warm and avoid any signs of a sniffle with the ongoing uncertainty of Covid19. I look forward to welcoming as many of you as possible to our Annual VANZ Conference at the Wairakei Resort on August 17th, 18th & 19th 2021. ■

Left: The 1991 AGM minutes where the Spectrum editor was elected, hence the start of Spectrum. The newsletter was circulated 1989/1990.





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FORUM

Photos from the recent VANZ Technical Forum, held at HERA House in Manukau City. VANZ is very grateful to our guest speakers and attendees for making for a very informative enjoyable day.



EDITORS' CORNER

Conference time is rolling around again and VANZ is a hive of activity planning this year's symposium so all who attend can benefit and take away new information and techniques not to mention the latest toys to roll out in to the field.

Our platinum sponsor for this conference is CSE New Zealand together with BkVibro, they will be providing the keynote speaker that will be addressing the attendees at the Wairakei Resort hotel during the 17-19th August.

As the Covid-19 vaccine continues to roll out, VANZ is committed to public health and safety, we have been putting measures in place to help guide our attendees thru a possible outbreak lockdown, or cancellation in case of an emergency. Please be assured that we are handling this with care and are taking all precautions to control the controllable.

Terry Siggins is one of the keynote speakers this year and you can read more about him and his experience in this issue. You can also find out more about what this year's conference will contain, read over our President Rodney Bell's report or puzzle your grey matter with this issue's installment of Carl's Quiz. Our articles feature one of the conference speakers, Frank May from Auckland University Space Institute, our other article comes from Mark Gurney – Gerant 3Phi Reliability and notable pig farming truffle hunter, who takes us through motor terminations.

Keep sending those registrations in and get yourselves ready to absorb all the knowledge you can! Our thanks go out to all the companies who continue to support us thru advertising and sponsorship.

Happy reading! ■

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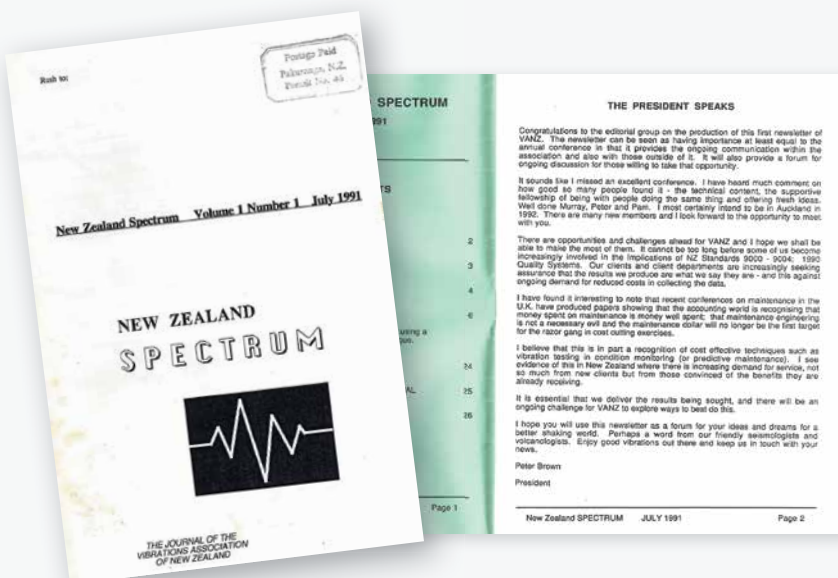
‘Breaking The Mould’

– A special look behind Spectrum magazine, 100 issues in the making!

It was an unusually quiet sunny afternoon at the Flashpoint office when the silence was suddenly broken with the sound of a phone call. “Hey mate, how’s it going? It’s Glen Pepper here, you know... President (at the time) of VANZ”. Eddie (the owner of Flashpoint Design and Marketing) knew Glen - well. He had been a loyal Flashpoint client since way back. They had a really good working relationship. “Mate,” he continued, “I need to you to pop into the office at the soonest convenience. I’d like you to chat with myself and Angie – our editor, about our quarterly magazine Spectrum, and what we can do to freshen it up...”

His voice was that of a man on a mission. That was all Eddie needed to hear. He jumped online - after the conversation ended of course, and did a search for previous issues of Spectrum to find out what he was dealing with. “Oh yeah...” he thought to himself, “It will indeed need a freshen up...”

Over the next few days before the meeting, Flashpoint spent hours working on concepts and formulating ideas, before mocking up a sample cover and a few pages to submit to



July 1991. The first edition of Spectrum. Present of VANZ at the time was Peter Brown.

SPECTRUM
Spectrum
 Spectrum
Spectrum

Above: Early ideas drawn for the Spectrum logo when the new look magazine was being designed. The bottom two (above left and right) were both final contenders before the final choice was made.

Spectrum
 magazine
SPECTRUM
Spectrum

Right: How the new look Spectrum may have looked had the second choice logo option been chosen.

Glen and the team at VANZ, as well as costings and ideas for the magazine content going forth. Glen knew Flashpoint was the company to see about this and he was spot on with his thinking. Eddie had had many years' experience designing and high-end publication material that not only looks good, but has a proven track record of selling and attracting interest.

The magazine started out in the early 90's with just a photocopier and a couple of guys stapling sheets together. The only splash of colour being that of the paper stock itself. A single colour sheet used as inside cover. It then progressed to looking more like a magazine, it went through several designers, printers and publishers until it landed in front of Flashpoint.

The idea presented was quite simple, and Glen and the team loved it. Inside, Flashpoint didn't want to change the 'VANZ feel' of the magazine, but wanted to give it a standalone appeal and a unique identity – essentially keeping the brand consistent. This was done by creating consistency with the text, the size of the font throughout the whole magazine was really important and for the headings of the articles. They also needed to be easy to read and the text flow easy to follow, which was sadly lacking in previous editions. It needed to create visual association with different sections of the magazine such as Editor's Corner and Presidents Report for example. Big bold photographs and more colour to

“
The magazine started out in the early 90's with just a photocopier and a couple of guys stapling sheets together.
 ”



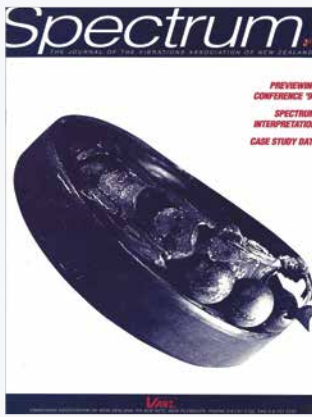
breath life into Spectrum was a huge part of the Flashpoint plan. Giving the title of the magazine its own identity was also paramount.

At the end of the day, the magazine needed an over-dose of street appeal. If it was sitting on a coffee table or welcome desk in the reception area of a large (or small) business alongside other reading material, it needed to stand out and shout 'READ ME!'

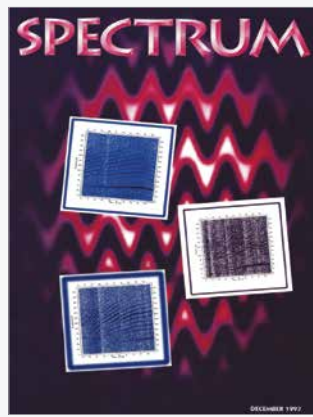
Another area Flashpoint wanted to explore with Spectrum was to create more interest and evoke longevity in terms of time spent reading the magazine, not only by making the articles more eye catching, but by incorporating an interactive element.

Continued over page >

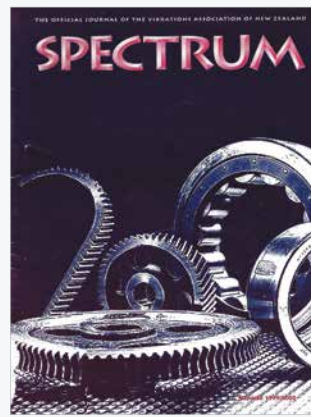
A snapshot of the changing face of Spectrum over the years...



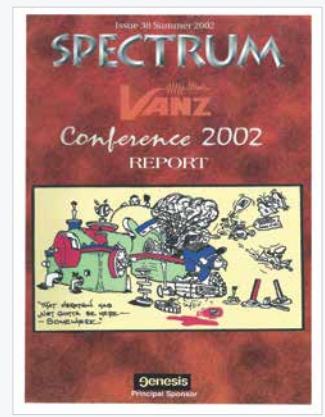
Spring 1995. Issue 17.
President: Pam Burgess.



Summer 1997. Issue 26.
President: Graeme Finch.



Summer 2000. Issue 32.
President: Colin Gacie.



Summer 2002. Issue 38.
President: Colin Gacie.

This turned out to be the puzzle corner. Everyone loves a word or number challenge in their spare time after all!

Perhaps the most important part of the design lay with how the magazine presented itself. What was the first thing people see when they pick it up? The banner? The name? The brand? Ideas were looked at, then binned, changed, then worked upon. Flashpoint had several options for the name 'Spectrum' and how it sat on the cover.

Options ranging from plain text, to graphic orientated wording – an option which would later be ruled out due to complexities. Simple looked best. Clean lines, easy to read and identify with was what was needed. At the end the best option was obvious. The first magazine Flashpoint was assigned to was issue 90. Headline for that issue was the VANZ Conference in Queenstown. A great place to start. The conference was also the 30th for the association. This too needed to be celebrated and showcased. A beautiful image with a young woman on the tussock blanketed foothills overlooking Queenstown with the sun low in the sky was perfect and set the tone for this issue and those to come. Bold, bright and inviting. The image was eventually used in all of the marketing for the conference to tie everything in together.

The magazine is printed using a thicker cover stock with a gloss laminate to not only give the colours punch, but to protect and give longevity to the magazine. The inner pages are printed on a lighter

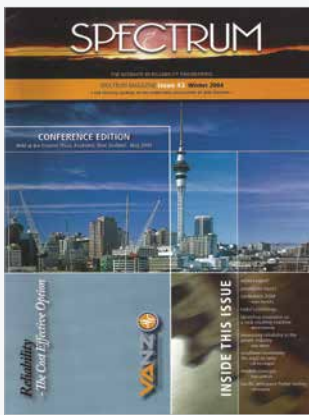
stock, but thick enough to make even the most colour saturated pages still look top notch without the paper warping or colour bleeding. The printers for Spectrum also manage the dispatch and distribution of all the magazines, not only here in New Zealand, but Australia as well, making the organisation process easy and hassle free for VANZ.

“ A beautiful image with a young woman on the tussock blanketed foothills overlooking Queenstown with the sun low in the sky was perfect. ”

Issue 90 was also the first issue VANZ had printed with Flashpoint and was about to go to press. The time had arrived. Incorporating all the suggested changes and ideas, sign off was given. Flashpoint wanted it to look great, and it did! It was an instant success – not only with VANZ members, but with industry competitors looking sheepishly over their shoulders! Glen and the team at the time received much deserved adulation about the new look Spectrum, and continue to do so to this day under the new management of Rodney Bell and his hardworking team.

The phone rang in the office a few days after issue 90 was dispatched. “Well done team”, the voice on the other end of the phone pronounced. It was Glen. “You’ve broken the mould!”

Ten issues later under the new banner, and Spectrum continues to breathe a breath of fresh air, constantly evolving with each issue and looking great along the way! It is a true credit to all the hard working individuals involved behind the scenes and a very worthy companion to those in the industry. The common mentality behind the concept has not changed from the beginning and is something to be proud of given the length of time the magazine has



Winter 2004. Issue 43.
President: Colin Gacie.



Spring 2013. Issue 70.
President: Cam Blackburn.



Spring 2017. Issue 86.
President: Glen Pepper.



Autumn 2020. Issue 96.
President: Rodney Bell.

been around. It is about the industry, for the industry, by the industry.

Spectrum has always welcomed written contributions for the magazine from those in the industry and is a valuable on-hand resource for its VANZ members. The content has always been strong and relivent.

In recent time, with the advances in web technology, content from Spectrum has been paired with the VANZ website, allowing members to not only keep up to date online, but to also register for events and make payments online too, directly from the magazine by way of QR codes and hyperlinks! Graphics from the magazine have been recycled on the website pages to form the correlation. The magazine is now also available as an e-publication, allowing members and the general public to read it online with page flip-thru technology.

Now in August of 2021, we find ourselves at a new milestone for Spectrum and one VANZ can be very proud of, the 100th issue! Flashpoint would like to congratulate VANZ on this outstanding

achievement. Flashpoint is proud to have such a close association with the management team of this now well-established organisation, and hope it extends through many more milestones to come. ■

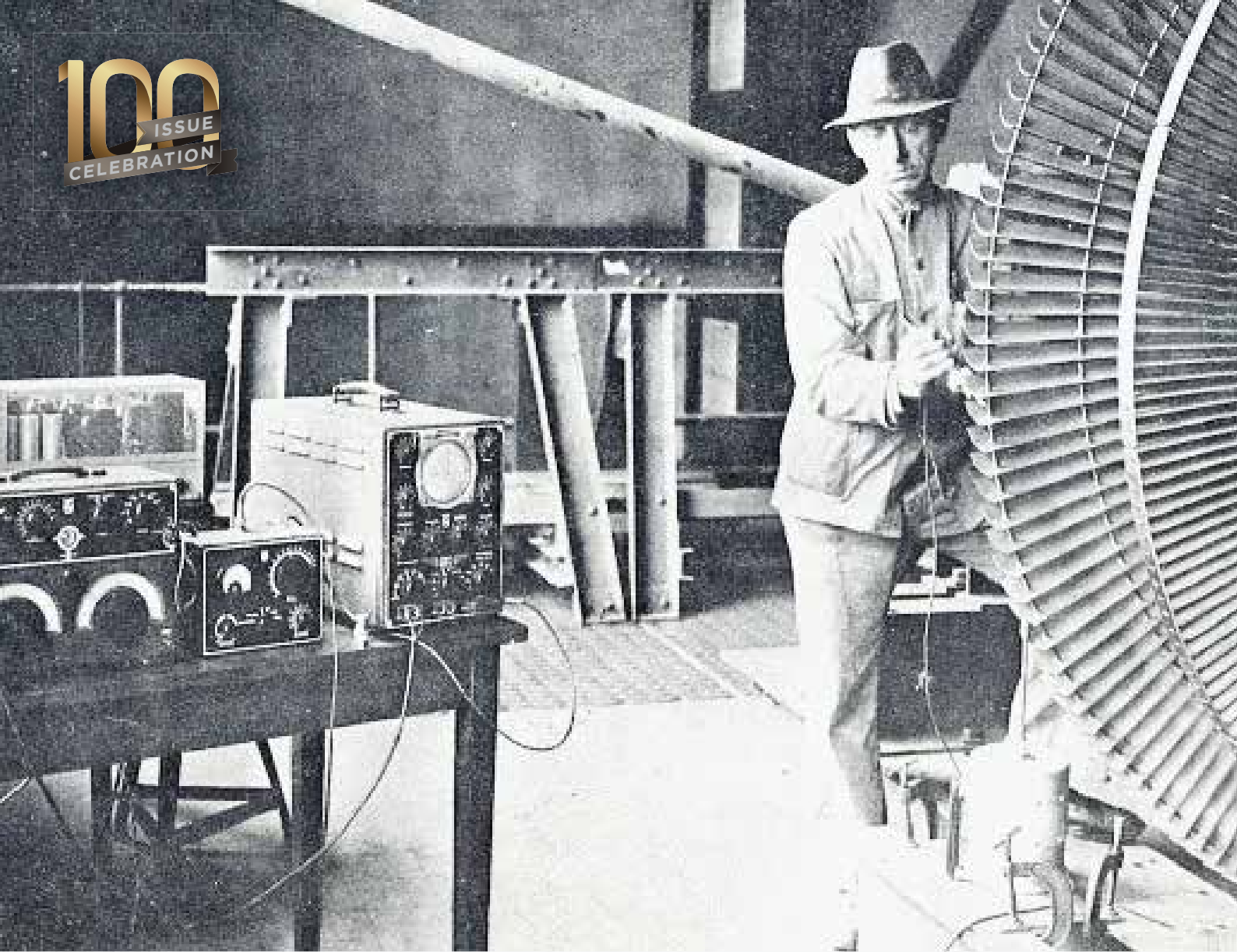
“ The mentality behind the concept has not changed and is something to be proud of. It is about the industry, for the industry, by the industry. ”



Above right: An early advert for the annual VANZ Conference. This was the 11th conference held in 2000 in sunny Nelson.

Right: Issue 90 of Spectrum. Summer 2018.
President at the time was Glen Pepper.

■ Article written by Eddie van den Broek, Flashpoint Design and Marketing.
Phone. 021 166 3556 or email: info@flashpoint.design.



VANZ history

– Then and now...

The Vibrations Association of New Zealand (VANZ) is a non-profit organisation focused in the area of condition-based maintenance, both predictive and preventative, and covers all aspects of reliability engineering.

The VANZ conference is a premium networking opportunity in New Zealand and Australia to get staff motivated and up-to-date with the latest trends, technology and methods in Predictive and Reliability Engineering.

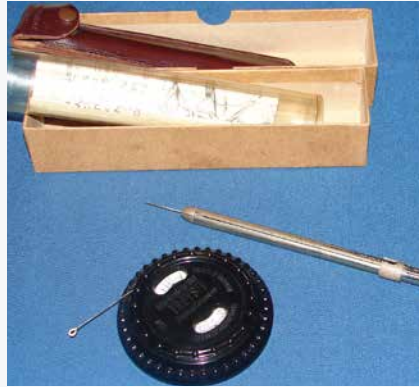
The conference features a wide range of case studies direct from a variety of industries such as Infrastructure, Power Generation, Pulp & Paper, Petrochemical, Dairy, Food & Beverage, Oil & Gas and Refining among others.

The very first VANZ conference was held in 1989 with about 20 members; this event now attracts a number of delegates from all over New Zealand, Australia and the world.

Technology, materials and manufacturing processes are continually developing, so too has the engineers knowledge and skills.



Today the engineering role has evolved to where the analyst, by diligent use of multiple Condition Monitoring



Above: Tools of the trade looking back...

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 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 was 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.

The core function of VANZ is the annual conference, 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 the conference, and importantly New Zealand presenters add a local context.

“ VANZ has continually developed to provide a platform for people to discuss their challenges and learn from their peers and industry experts. ”

VANZ is quite a unique society – it has withstood the test-of-time – and has run an Awareness Day training opportunity every year for 29 years for apprentices and those new to the industry.

It is a reasonable track-record which VANZ has consistently promoted for the New Zealand and Australian industry. From Sir John Ingram to the latest apprentice just starting out in the field to the next generation of engineers who are still in school and looking at their possible career opportunities, mechanical engineering will continue to run with the times, adapting and changing as new best practices are discovered and technology advances.

So whether you have something to learn or something to share, we hope to see you at the next conference! ■

Competition Page?

Missed an issue of Spectrum?

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Head on-line to www.vanz.org.nz to find back issues of the magazine which you can read online.

Or, simply scan the QR code here to link your device directly to the VANZ website. There you will find back issues of Spectrum available to view*.

* A QR code reading app will need to be installed on your device first.



would like to pass on a 'huge'



to all our advertisers who have supported the Association and Spectrum magazine over the past 100 issues...

We really appreciate it!

Conference Taupo 2021

Wairakei Resort: 17th – 19th August 2021

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Briuel & Kjaer Vibro

Conference Taupo Timetable 2021

Wairakei Resort: 17th – 19th August



Tuesday 17th August - Day 1 - Reliability Condition Monitoring Awareness stream plus Reliability Improvement stream

Start	Duration	End			
7:45 AM	0:45	8:30 AM	Registration and Exhibition / Trade Stand area is open for viewing, with Tea and Coffee available		
8:30 AM	0:10	8:40 AM	Welcome to Conference 2021: VANZ President		
8:40 AM	0:10	8:50 AM	Overview of Conference Timetable for the Day and the next 2 days: Vice President		
8:50 AM	0:40	9:30 AM	Key Note Address: The 'Big picture' an Introduction into Condition Monitoring and Reliability		
9:30 AM	0:30	10:00 AM	Morning Tea in the Exhibition room / Trade Stand area (With Exhibitor introductions)		
2 Streams; in Conf Rooms 1&2			The Tradesmans Tools' that enables the evolution of Reliability Condition Monitoring to Predictive Asset Management	2 Hour - Asset Management and Reliability Program Implementation	
10:00 AM	0:40	10:40 AM	Tribology Oil & Grease usage and practice. Wear & particle sampling and analysis. Commissioning new installs		
10:40 AM	0:40	11:20 AM	Install alignment -motor-coupling-gearbox-coupling-pump alignment Post commissioning hot alignment		
11:20 AM	0:40	12:00 PM	Basic vibration theory & practice Commissioning baseline data		
			Understanding criticality to guide your Reliability program and break out of the reactive maintenance cycle of doom... - A very brief overview of the benefits of Reliability and Condition Monitoring - How does CM and reliability help an organisation achieve its goals * Why does the organisation exist * What are the constraints * What are the risks * What are the opportunities. - How we can perform criticality analysis, and Pareto analysis to rank the equipment and thus prioritise all further activities.		
12:00 PM	1:00	1:00 PM	Lunch in the Exhibition room / Trade Stand area		
2 Streams; in Exhibition & Rm 2			Managed Interactive Forum	2 Hour - Asset Management and Reliability Program Implementation	
1:00 PM	2:00	3:00 PM	Tribology; Oil & Grease	Tribology; Methods and Usage	How the information can be greatly enhanced with accurate equipment health information. - How to use the information to break out of the "reactive maintenance cycle of doom"? - Examples will be provided from the Power and Dairy / Manufacturing industries, but it will be relevant to all service organisations and continuous/discreet manufacturing.
			Rotating Machine Alignment	Vibration Analysis	
			Infrared Usage & Practice	Ultrasound Usage & Practice	
3:00 PM	0:30	3:30 PM	Afternoon Tea in the Exhibition room / Trade Stand area		
3:30 PM	1:00	4:30 PM	Managed Forum Discussion	Round Table Discussions - Your chance to ask your questions from todays presenters, panel experts and colleagues on a specific subject at an assigned table	
4:30 PM	1:30	6:00 PM	'Meet & Greet' Networking Refreshments and Canapés available in the Exhibition Area that we encourage all to attend		
TBA Special Dinner					

Wednesday 18th August - Day 2 - Main Conference

Start	Duration	End	
8:00 AM	0:30	8:30 AM	Registration and Exhibition / Trade Stand area is open for viewing, with Tea and Coffee available
8:30 AM	0:10	8:40 AM	Welcome to Conference 2019 VANZ President
8:40 AM	0:10	8:50 AM	Official Conference Opening by the Conference sponsor -CSE W Arthur Fisher / Bruel & Kjaer Vibro
8:50 AM	0:45	9:35 AM	Terry Siggins: BK Vibro Key Note Address
9:35 AM	0:45	10:20 AM	Morning Tea in the Exhibitor room / Trade Stand area (With trade stand introductions)
10:20 AM	0:40	11:00 AM	Clyde Volpe: TBA
11:00 AM	0:40	11:40 AM	Dr Iain Epps: Defect Severity Measurement in Rolling Element Bearings
11:40 AM	0:40	12:20 PM	Frank May: Vibration troubleshooting of vertical pumps (instabilities, application of tuned absorbers)
12:20 PM	0:50	1:10 PM	Lunch in Exhibitor room / Trade Stand area
Two Streams of Presentations			Stream 1: Room One CM based case histories
			Stream 2: Room Two Reliability based case histories
1:10 PM	0:40	1:50 PM	Mike Yardley: Motion Amplification case history. TBA
1:50 PM	0:40	2:30 PM	Matthew Fallow: The data was good. Case history
2:30 PM	0:40	3:10 PM	John Lawrence / GVS: Case History TBA
3:10 PM	0:30	3:40 PM	Afternoon Tea in the Exhibitor room / Trade Stand area
3:40 PM	0:40	4:20 PM	James Neale: TBA
4:20 PM	0:40	5:00 PM	Mike Davis: TBA
5:00 PM	1:30	6:30 PM	Complementary 'Meet & Greet' Networking Refreshments and Canapés available in the Exhibition Area that we encourage all to attend
7:00 PM	2:30	9:30 PM	Conference dinner

Thursday 19th August - Day 3 - Main Conference

****VANZ AGM will be held at 10:00 – PLEASE ATTEND!****

Start	Duration	End	
7:30 AM	0:30	8:00 AM	Exhibition room / Trade Stand area is open for viewing, with Tea and Coffee available
8:00 AM	0:40	8:40 AM	John Van Zwiene: BK Vibro Key note Address, MS Teams
8:40 AM	0:50	9:30 AM	Dr Iain Epps: Influence of the Load Zone in Defect Severity Measurement
9:30 AM	0:40	10:10 AM	Morning Tea in Exhibitor area – VANZ AGM WILL BE HELD IN STREAM-1 ROOM –
10:10 AM	0:40	10:50 AM	Colin Gracie: Case history TBA
10:50 AM	0:40	11:30 AM	Jason Trantor: Going beyond condition monitoring to improve asset reliability
11:30 AM	0:40	12:10 PM	Craig Caryle: How to stay out of jail (What people are being prosecuted for)
12:10 PM	0:50	1:00 PM	Lunch in the Exhibitor room / Trade Stand area
1:00 PM	0:35	1:35 PM	Matthew Fallow: TBA
1:35 PM	0:35	2:10 PM	Barry Robinson: Failure of Bolts - Good & Bad
2:10 PM	0:35	2:45 PM	Simon Hurricks: Remote monitoring and cyber security
2:45 PM	0:30	3:15 PM	Q&A session: Panel Q&A Discussions Your chance to ask any questions from all presenters, panel of experts and colleagues
3:15 PM	0:15	3:30 PM	Awards Presentations, Vendor Prize Draws You need to be there to claim the prizes & Conference closing address

Conference officially closed, we look forward to seeing you all again next year in 2022, at our 33rd anniversary, please ensure you travel safely home.

Conference Taupo

> Key Speaker Profiles



Here is a little background on some of the key presenters you'll hear at the upcoming VANZ Conference in Taupo later this year.



Terry Siggins

> Global Marketing & EMEA Sales Director with Brüel & Kjær Vibro



John van Zwielen

> Regional Sales Manager with Brüel & Kjær Vibro



Jason Tranter

> Managing Director of Mobius Australia



Dr. James Neale

> Research Center Director, University of Waikato



Frank May

> Environmental Test Facilities Manager
Auckland University Space Institute



Dr Iain Epps

> Managing Director Mobolo Technology Limited, New Zealand



Matthew Fallow

> Owner of Asset Quality Australia



Clyde Volpe

> International Trainer Vibration Institute of Australia



Simon Hurricks

> Predictive Maintenance Engineer
Genesis Energy Ltd



Mike Yardley

> Owner of Yardley Consulting Limited



Colin Gracie

> Owner of Inspyer Limited



Craig Carlyle

> Senior Consultant at HasTrak Health & Safety New Zealand



John Lawrence

> Engineer with GVS Reliability Product



Bruce Shepherd

> Condition Monitoring Engineer
ABB Limited





Notice of AGM

DATE:

Thursday 19th August 2021

TIME:

9:30am

LOCATION:

Wairakei Resort Hotel Conference Room

**Please attend if you can,
this association is run by you for you.**

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VANZ

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Conference Taupo 2021

Wairakei Resort: 17th – 19th August 2021

Australasia's Premier Annual 3-Day Predictive Asset Management and Reliability Condition Monitoring Event.

‘THE FUTURE OF CONDITION MONITORING?’

CONFERENCE INFORMATION



Get in quick for our off-season price grab on our accommodation deal at Wairakei Resort. See below for details.

TIMETABLE

* All prices exclude GST.

Tuesday, August 17th

Wednesday, August 18th

Thursday, August 19th

3
DAY

Technology Exhibition

Visit 20+ world-leading condition monitoring and reliability providers showcasing their latest technologies all under one roof over all-three days of the conference.

3
DAY

Three-Day VANZ Conference Pass (Early Bird Pass*)

Get the full conference experience incl. meals and accommodation. See page 2 for full package pricing and details.

1
DAY
OPT. 1

Practical Hands-on Awareness

See page 2 for full package pricing and details.

2
DAY

Two-Day VANZ Conference Pass

See page 2 for full package pricing and details.

+ Networking and Main Conference Dinner

+ Networking and Social Event

1
DAY
OPT. 2

Reliability/Asset Management

See page 2 for full package pricing and details.

+ Networking and Informal Welcome Evening

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pp = per person. * Early bird pass available until July 31st, 2021.

ACCOMMODATION

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For the conference, we've secured rooms at Wairakei Resort, Taupo for a great rate if you need to book accommodation separately, but it's only for a limited time and availability will reduce closer to the conference date. To reserve your room(s), phone Wairakei Resort on 07-374 8021, visit their website, www.wairakei.co.nz or scan the QR code to link directly to the booking site.

There is limited rooms available, so first in will be first served.

Note. Only those booked in for the 3-day conference event have their accommodation fully booked and arranged with the package. Other package options will require attendees to arrange rooms.



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We will be hosting two evening events

Tuesday, 17th August

Informal Welcome Evening

Book online: www.vanz.org.nz for additional tickets.
Please advise attendance numbers for catering.

Additional tickets: \$25/pp

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1 DAY

Tue 17th August 2021

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Full day entry to the **Practical Hands-on Awareness Day**. See below for additional benefits (1). Student ID Required.

1 DAY

Tue 17th August 2021

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Wed 18th - Thur 19th August 2021

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Figure 1: Energiezentrale Forsthaus in Berne, Switzerland.

Vibration analysis and condition monitoring of a gearbox

Summary

Gearboxes are essential and critical parts of many drive trains. There are many possible root causes associated with the gearbox, which could prevent reliable and uninterrupted operation of the drive train. Many of these root causes have consequences on the gearbox vibrations and acoustics and enable a possibility to investigate the problem during operation. In this case study, an urgent analysis of a gearbox is described with its findings, which also give an outlook to an improved method for continuous monitoring and predictive maintenance.

Problem description

After the revision of a steam turboset the noise generated was significantly different to the previous

state. Also, before the revision, the noise was already considered peculiar by the operators in comparison to other steam turbosets and other power plants. That peculiar sound was noticed one year before the revision and correlated with load. After the revision, the peculiar noise was much stronger than before. It was assumed that its source was the gearbox, although there was no indication for problems in the shaft vibration signals and the bearing temperature signals. The drive train was investigated mechanically before without any conclusions on the root cause. PROSE AG was requested to investigate the problem under strong time pressure. The steam turboset had urgently to go back into operation.

Continued over page >

■ By: Dr. Frank May, PROSE AG, Testing Department, Machinery Dynamics & Acoustics, Zuercherstr. 41, CH – 8400 Winterthur
The author is currently employed as a Senior Research Fellow and Manager National Satellite Test Facility to build up the environmental test facilities of the institute.



Figure 2: Steam turboset Renata.



Figure 3: Laser tachometer at the drive end generator bearing.

Description of the plant including drive train and gearbox

The steam turboset is part of the “Energiezentrale Forsthaus”, which is a combination of a waste incineration plant, a combined cycle power plant and a wood-fired power station in Berne, Switzerland (see Figure 1). The plant produces electrical power, steam and district heat with steam and gas turbines using natural gas, wood and waste. Two steam turbosets are used, which are named Lotti and Renata. The two steam turbosets are similar but not identical. The steam turboset under investigation was Renata.

The steam turboset Renata (see Figure 2) consists of a Siemens steam turbine of type SST-400 with a rated power of 27 MW at a speed of 5791.7 rpm, a ABB generator of type AMS 1250 SE with a rated power of 28.6 MW and an industrial (in contrary to an engineered) gearbox from Renk AG of type TBE-800. This gearbox has a straight spur gearing. The pinion has 36 teeth and the gear has 139 teeth, so that the generator speed is 1500 rpm. A rigid coupling is connecting generator and gearbox, while turbine and gearbox are connected by a multiple-disc clutch with allows for axial clearance. The steam turbine has a high-pressure, a middle-pressure and a low-pressure steam extraction. The steam turboset Renata had acquired 20000 hours of operation at the time of the request.

Measurement setup and execution

The field measurement on site was performed only a few days after the request. It was intended as a fore observation to develop a hypothesis on the root cause to prepare comprehensive field measurements and to develop preliminary countermeasures if possible.

For this reason and also due to a high workload on other projects, only a simple measurement setup was selected, consisting of a speed sensor, a microphone and two accelerometers. The sensors were in particular:

Laser tachometer:	1 LaserTach
Microphone:	1 Microtech Gefell MM210
Accelerometers:	2 Brüel & Kjaer Type 4370 together with charge amplifiers MMF IEPE100

All signals were recorded by an analogue-digital converter from National Instruments of type NI USB-4431 with a sample rate of 25.6 kHz to have a bandwidth of 10 kHz.

“ A rigid coupling is connecting generator and gearbox, while turbine and gearbox are connected by a multiple-disc clutch with allows for axial clearance. ”

The speed was measured at the generator shaft with one pulse per revolution from a strip of retroreflective tape (see Figure 3).

The microphone was placed near the gearbox on the left side (looking from the generator towards the turbine). The exact distance was not important because the objective of the measurement was not the correct determination of sound power or sound pressure. (See Figure 4.)

The accelerometers were placed for most measurements on the drive end pinion bearing (see Figure 5) and non-drive end gear bearing (see Figure 6), both in vertical directions. For some analyses the accelerometers were placed at other positions to investigate if local resonances were contributing to the problem.

All measurements were done during one day. During the instrumentation the drive train was slowly rotating to enable a fast run-up. The drive train was



Figure 4: Microphone on the left gear box side looking from the generator towards the turbine.



Figure 5: Accelerometer 1 on the drive end pinion bearing in vertical direction.



Figure 6: Accelerometer 2 on the non-drive end gear bearing in vertical direction

run-up without load after the instrumentation and synchronized. Once the drive train was synchronized, a minimal load of 3 MW was applied. As soon as a load was applied, the described peculiar sound instantly occurred. Several influences were investigated, in particular the influence of the generator load and the steam extraction from the steam turbine. It was observed that some foundation screws of the gearbox were not tightened. An additional measurement was recorded while the screws were tightened.

Analysis and results

All analyses were done in Matlab. A preferred method of signal analysis and signal representation is the spectrogram. A spectrogram is a representation in the time-frequency domain and very useful to gain a fast overview. The abscissa of the spectrogram is the time and the ordinate the frequency. The amplitudes are displayed following a colour coding. A peak-hold spectrum is displayed on the right side of the spectrogram, showing the highest occurred amplitudes for every frequency, while the diagram below the spectrogram shows the sum level of the signal over time. An example of a spectrogram is shown in Figure 7. Generally spoken forced vibrations by drive train excitation orders are recognisable by thin lines in the spectrogram which follow the speed of the drive train. Natural frequencies can often be recognised by broad horizontal lines. The width of the lines is dependent on the damping of the respective natural frequency.

If an excitation order meets a horizontal line of a natural frequency often a resonance occurs with much higher amplitudes.

In order to decide on the next steps for the plant operation, the analyses had to provide results and conclusions very quickly. For that reason, the focus of the analyses was based on the microphone signal. To support and to confirm certain conclusions also the accelerometer signals were analysed. As mentioned above, two steam turbosets are in operation in the plant and their signals have to be differentiated. The first measurement still during slow stand-by rotation of the steam turboset Renata enables this, as the spectrogram mainly shows attributes of the other steam turboset Lotti (see Figure 7). No significant energy was contained in the steam turboset Renata during this measurement, therefore all peaks noticeable in the peak-hold spectrum were caused by steam turboset Lotti. For all further analyses, these frequency peaks for example at 3525 Hz and at 7288 Hz were ignored.

The first run-up of the steam turboset Renata showed that all relevant frequency peaks are below 5 kHz and for further analyses the signals were decimated by a factor of 2. The spectrogram of the run-up without load is dominated by the gear meshing frequency (see Figure 8). Every time the excitation of the gear meshing frequency passes a natural frequency, the amplitudes become amplified and sidebands become visible (see Figure 9). That is an indication of nonuniform gear meshing. The frequency difference of the sideband to the gear meshing corresponds to the pinion rotating frequency, which is a hint to an error at the pinion. But it seems that there is not only one abnormality around the pinion perimeter, but also an error with an ovality of order 12. This is indicated by subharmonic excitation orders with sidebands at a third of the gear meshing frequency, which correlates the 12X of the pinion speed (see Figure 10). Also, attributes of the

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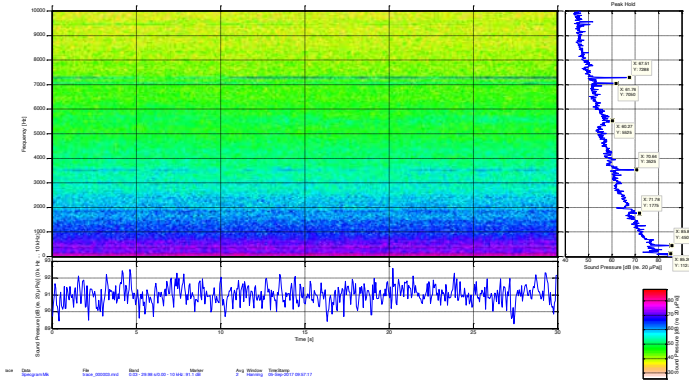


Figure 7: Spectrogram of the microphone signal during slow stand-by rotation of steam turboset Renata.

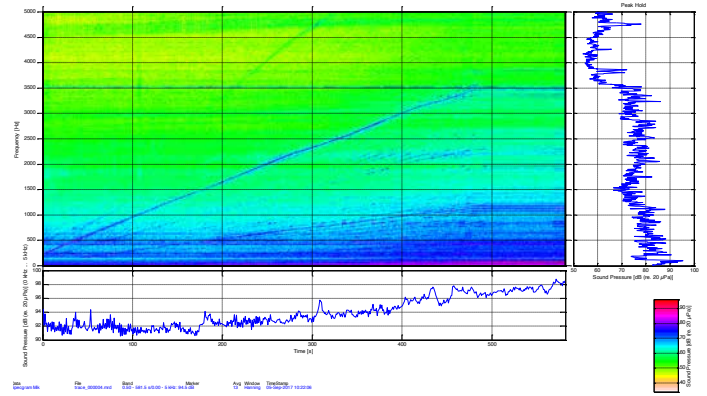


Figure 8: Spectrogram of the microphone signal during run-up without load.

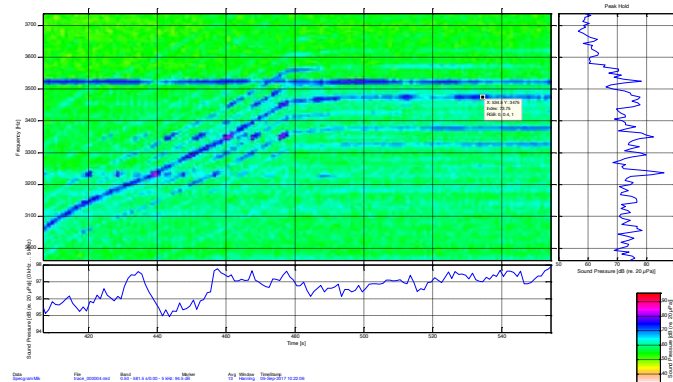


Figure 9: Detail of the spectrogram of Figure 8 showing the sidebands of the gear meshing frequency.

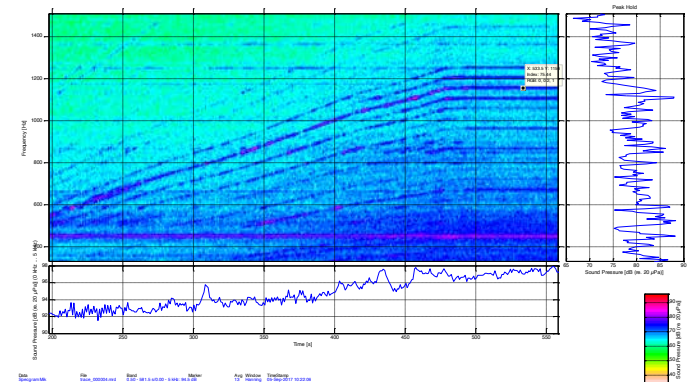


Figure 10: Detail of the spectrogram of Figure 8 showing excitation order of a third of the gear meshing frequency and sidebands.

generator and of the steam turbine are visible in the spectrogram, for example the first blade passing frequency at 4293 Hz. The auto power spectrum derived from a high-resolution FFT of the microphone signal for the synchronized generator without load shows nothing suspicious (see Figure 11). As expected, the gear meshing frequency at 3476 Hz with sideband corresponding to the pinion speed and the gear speed are visible. The generator causes a peak at 100 Hz and probably as well at 450 Hz and 850 Hz. This auto power spectrum could be a baseline for an advanced condition monitoring system as described later.

In the next step during the measurements, a minimal load of 3 MW was applied to the generator. Instantly, the reported peculiar noise set on. Actually, the sound was quite surprising and uncommon, reminding more of an alarm buzzer than of a normal gearbox noise. The spectrogram of the microphone signal (see Figure 12) corresponds to the subjective hearing impression. When the load was applied, many additional peaks appeared in the spectrum in the whole frequency bandwidth investigated and the sound pressure level was increased strongly. An alarm buzzer has a similar

characteristic. An obvious suspicion was that the generator load influenced the alignment of the steam turboset because not only the gear meshing became worse, but also multiples of generator frequency peaks occurred. The largest consequence is on the gearbox, most frequency peaks are harmonics of the pinion speed (see Figure 13).

When the load was increased, the frequency spectrum became dominated by the gear meshing frequency and sidebands as well as by the subharmonic of one-third of the gear meshing frequency and sidebands. The influence of the different steam extractions was visible but not significant. During the measurements, the observation was made that some foundation bolts of the gearbox were loose. At approximately 254 s of the respective measurement file the bolts were tightened, which became visible in the spectrogram as well. That supported the suspicion that misalignment also contributed to nonuniform gear meshing, but the primary cause was in the shape of the pinion. (See Figure 14.)

In order to ensure that the noise was not caused by local resonances of the gear box casing, several

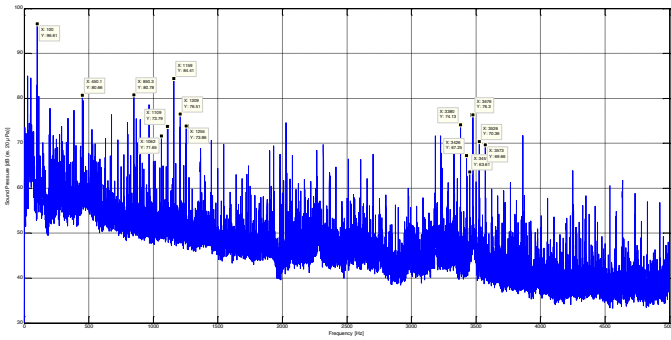


Figure 11: Auto power spectrum of the microphone signal for the state when the generator is synchronized but without load

Figure 11: Auto power spectrum of the microphone signal for the state when the generator is synchronized but without load.

measurements were done with different accelerometer locations. The results showed that the accelerations at the gear box casing were quite uniform, which confirmed that the noise was caused by forced vibration. Furthermore, the accelerations were very different at different locations along the drive train, which confirmed that the noise source was in the gearbox.

Conclusions and recommendations

The root cause for the reported peculiar noise of the steam turboset Renata was a nonuniform gear meshing caused by shape deviations of the pinion. It was recommended to disassemble the pinion and to refurbish it to its original and designed condition. Furthermore, it was recommended to control the alignment of the drive train. The plant operator did not observe any anomalies in the shaft vibrations and in the bearing temperatures, although the change

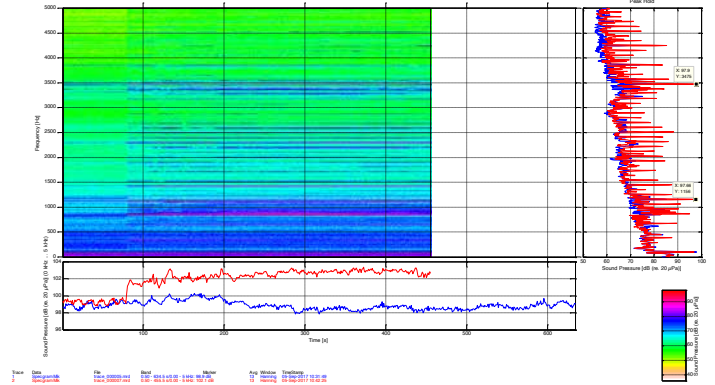


Figure 12: Spectrogram of the microphone signal when the minimal load of 3 MW is applied to the generator. The red curves belong to the measurement, when the load was applied, the blue curves originate from the state without load for comparison.

in the noise was pronounced. The reason lied in the frequency range. The shaft vibrations were analysed only up to 1 kHz while the gear meshing frequency is 3475 Hz. The noise indicated the problem very early, while a rise in temperature in the bearings will occur much later, when the damage would have progressed much further.

Realised countermeasures

Following our recommendations, the pinion was disassembled and overhauled. The alignment of the drive train was checked after reassembly of the gearbox and all bolts were tightened accordingly. The peculiar noise was gone and the measurements during commissioning showed expected auto power spectra, which are dominated by the gear meshing frequency without the presence of a

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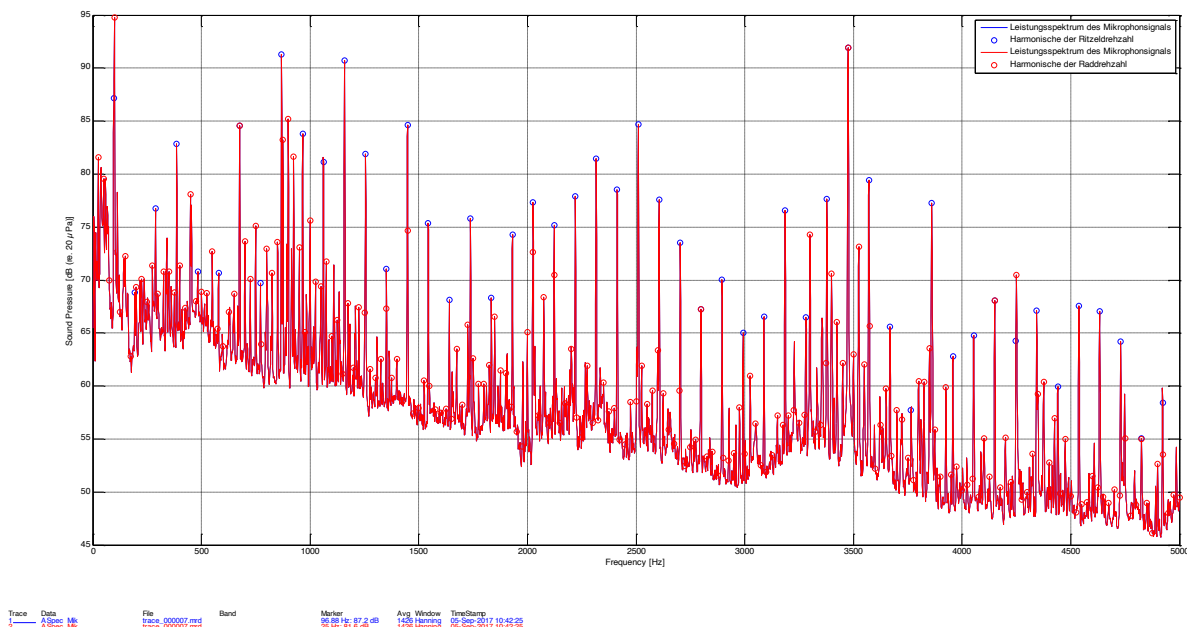


Figure 13: Auto power spectrum of the microphone signal for a generator load of 3 MW. Small red circles indicate harmonics of the gear speed. Small blue circles indicate harmonics of the pinion speed.

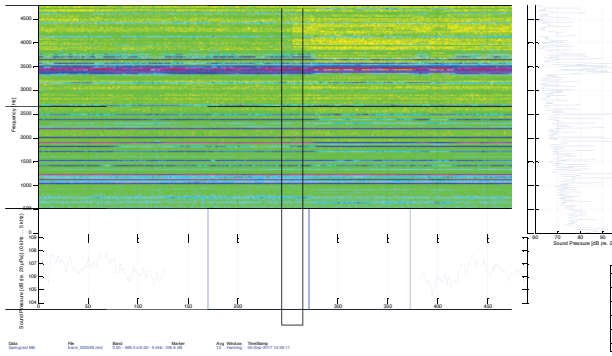


Figure 14: Spectrogram of the microphone signal with a load of 19 MW. Different steam extractions were performed during the recording. Around 254 s, the foundation bolts of the gearbox were tightened.

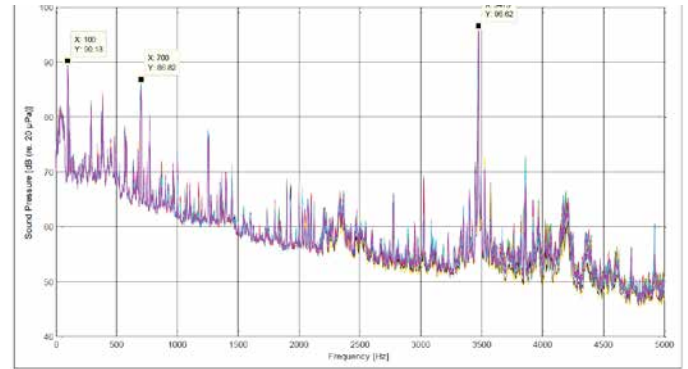


Figure 15: Auto power spectra of the microphone signal with different generator loads after pinion revision.

Figure 15: Auto power spectra of the microphone signal with different generator loads after pinion revision

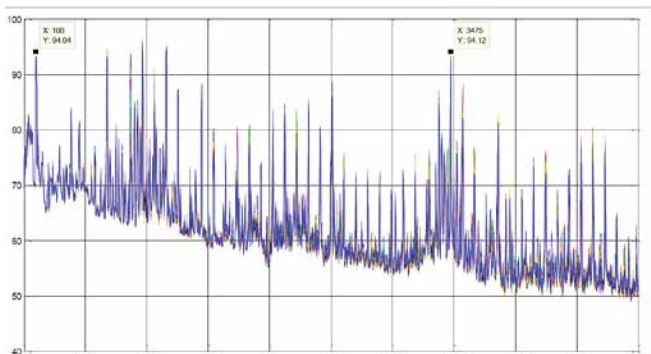


Figure 16: Auto power spectra of the microphone signal with different generator loads before pinion revision.

In a first step, sound pressure auto power spectra are acquired in defined intervals to compare the current state with an original state. The approach can be refined and automated later.

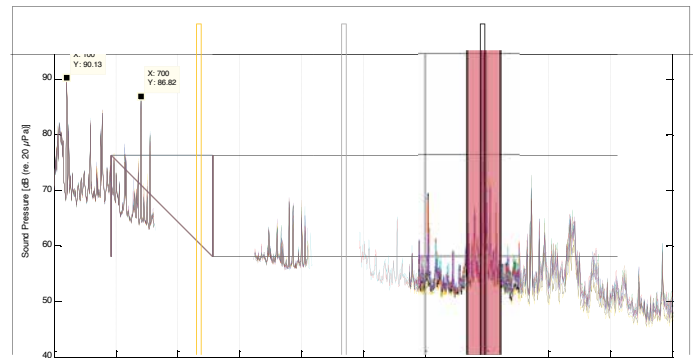


Figure 17: Illustration of the proposed method of condition monitoring of a gearbox.

multitude of sidebands with high amplitudes (see Figure 15) in comparison to the state before the pinion revision (see Figure 16). Based on the results of the countermeasures, our conclusions and recommendations were correct.

Proposal for an improved gear box condition monitoring

Condition monitoring of rotating equipment is common practice in industrial applications. But the described project shows that the sensors and signal analyses have to be adapted to the individual application to generate some benefit and early warnings. A rise in temperature is generally a very late indication for mechanical problems. Severe damage will have occurred already when a temperature sensor gives a warning or alarm. Vibration sensors are a much better means to derive early warnings, but the signal processing and analysis have to be adapted to the actual machinery. For a gearbox an analysis in the frequency range of the gear meshing is highly recommended. Even better than just monitoring the amplitude at the gear meshing frequency would be also to monitor subharmonics of the gear meshing frequency and to consider the sidebands, which are naturally caused by the rotation of pinion and gear.

If the ratio of the amplitudes of the sidebands to the amplitude of the gear meshing frequency changes, it is an indication that the gear meshing itself is changing. Figure 17 illustrates the proposed method of gearbox condition monitoring.

The microphone signal not only contains attributes of the gearbox but also of the steam turbine and the generator and allows therefore also condition monitoring of this equipment.

It remains the typical problem of condition monitoring and predictive maintenance to define, which amplitude level or which change compared to the state of a good condition, will trigger a warning, an alarm or even a machine trip. It is necessary to gain experience with the individual type of machinery to define these limits. In some cases, the OEM (original equipment manufacturer) might be able to provide advice.

The operator followed our recommendation also for an improved equipment condition monitoring. In a first step, sound pressure auto power spectra are acquired in defined intervals to compare the current state with an original state. The approach can be refined and automated later. ■

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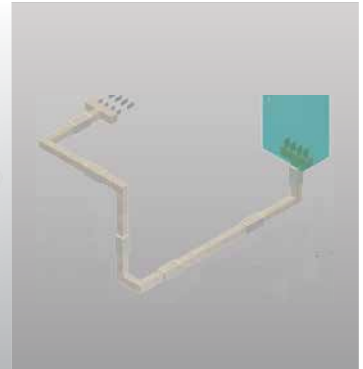
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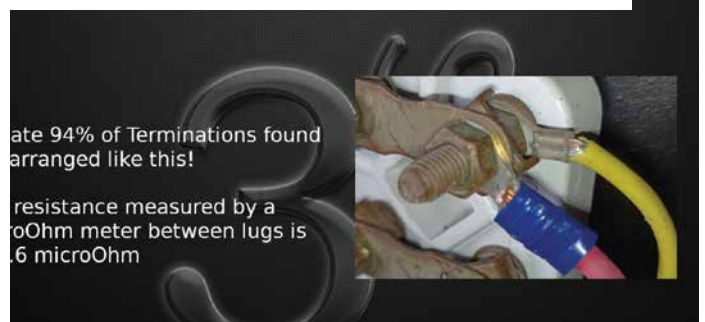
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- 1 **A bucket elevator is driven by a shaft-mount gearbox with a flange-fit motor. The motor runs at 1490 rpm, and the gearbox ratio is 15.64:1. The top drum (which is driven directly by this arrangement) has a diameter of 425 mm. The buckets are spaced on the belt at 210 mm centres. The bucket-passing frequency will be closest to which of the following? (N.B. Neglect belt thickness).**
 - a 2 Hz
 - b 5 Hz
 - c 10 Hz
 - d 12 Hz

- 2 **Where might you find “L10” quoted?**
 - a In ISO standards as an acceptable vibration limit for casing measurements
 - b In bearing life calculations
 - c In ISO standards as an acceptable vibration limit for balancing
 - d None of the above

- 3 **You are confident that the shaft speed has been accurately measured, yet what appears to be a bearing fault frequency for the fitted rolling element bearing is measured at 169 Hz, yet the calculated fault frequency for that bearing is 172 Hz. Is it possible that the 169 Hz can in fact be representative of that bearing fault? Choose the best answer.**
 - a No, the measured frequency must match the calculated frequency exactly
 - b Yes, that certainly means the bearing is slipping on the shaft
 - c Yes, it is possible and the difference is sometimes explained by axial load or wear in the bearing
 - d Yes, this is a certain indication that this bearing is a counterfeit bearing

- 4 **A centrifugal pump which is routinely vibration tested develops vibration at vane pass frequency when that is not part of its usual signature. What might be the cause of this?**
 - a The impeller might have moved after becoming loose on the shaft, or moved due to bearing wear
 - b Flow conditions (pressure, flow, temp) might have changed
 - c A single foreign body might have become lodged in the impeller between two of the vanes
 - d A and/or B are possible causes

- 5 **The words “Four run balancing” might often be followed by what other words?**
 - a “without phase”
 - b “without amplitude”
 - c “with phase”
 - d “with amplitude”

- 6 **When running well, a direct-coupled Feedmill grinder exhibits some 1x vibration that can be caused by beater wear. However if harmonics of running speed are evident, what might this indicate?**
 - a Looseness in stationary parts – such as hold-down bolts working loose
 - b Looseness in rotating parts – such as wear in the bearings, bearings loose on the shaft or in the housings
 - c Coupling wear
 - d All of the above are possible

- 7 **A gearbox operating at variable speeds (from test-to-test) shows increased vibration at gearmesh frequency during one of the routine tests. What is the best recommended action?**
 - a Check to see if there is previous history at this speed and if so compare amplitudes at gearmesh frequency
 - b Request an oil sample if one has not been done recently and conduct another vibration test
 - c Report that the gearbox is failing and recommend overhaul or replacement
 - d A and B might be the most sensible options for most situations

- 8 **The pilot of a jet-fighter throws his plane into a series of tight manoeuvres at speed. From bodily responses, what might he/she be most conscious of?**
 - a Acceleration levels
 - b Velocity levels
 - c Displacement levels
 - d All of the above equally

- 9 **A waveform for a measurement point is collected based on the spectral setup for that point of 5000 Hz Fmax and 3200 lines of resolution. If the shaft speed is 25 Hz, how many revolutions will be captured in the waveform?**
 - a 2
 - b 4
 - c 8
 - d 16

- 10 **The 2021 VANZ conference will be hosted in which of the following locations?**
 - a Wairakei
 - b Hamilton
 - c Rotorua
 - d Tauranga

Answers on page 39

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Eliminate the Downtime

Traditionally, condition monitoring involves at least one technician walking around a mine site to perform a health check on the various pieces of equipment. The time and legwork involved in capturing the machine data is significant and the technicians then still need to analyse the data, not to mention the travel costs and the inevitable risk exposures that come with a site visit, which may only happen once a quarter.

The age of COVID-19 now often means it is physically impossible for personnel to get to site, which means surveys are being missed. So what if the technicians and maintenance crew could constantly access real-time data at any time, from any location? The Australian Mining Review spoke to GVS Reliability Products managing director Nathan Osborn and Waites technology product manager John Lawrence to discuss how the use of Waites wireless sensors is revolutionising condition-monitoring to eliminate downtime.

John said the mining industry was increasingly harnessing cutting-edge technology to monitor and manage assets, with the use of sensors gaining traction over the last five years. He said GVS spent two years testing and researching various products before finally settling on the Waites Wireless Vibration and Temperature System.

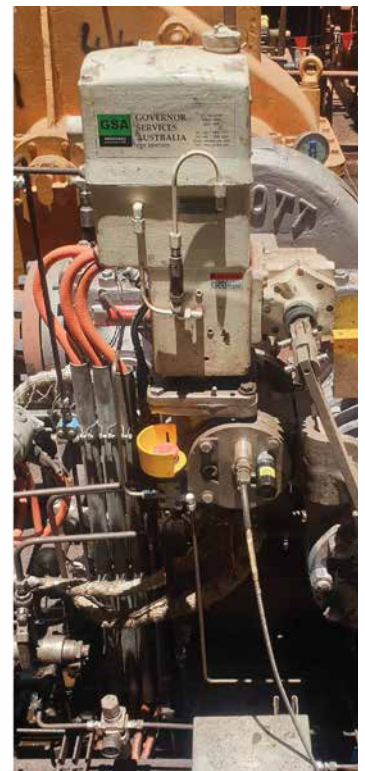
"It was a long journey for us in evaluating dozens of systems out there and Waites is really the clear market leader in this space in terms of capabilities," he said. "It is a topical technology and it's the way of the future for mining so it was important that we went with an established company. "The whole industry has been watching this space closely, especially in the last three years, and this system has all the bells and whistles and satisfies all the requirements." Waites Wireless Sensor Technologies are a North American OEM founded in 2006 which designs and manufactures world class condition monitoring systems with more than 150,000 sensors now installed globally, saving clients about \$100m a year annually."

How It Works

Machine diagnosis through vibration analysis is common but the Waites tri-axial sensor also measures temperature. The system pre-emptively finds and resolves issues before they cause damage or catastrophic failures to prevent unexpected downtime, extends equipment life and revolutionises the way teams perform maintenance.

Sensors:

Waites sensors can be easily connected to any piece of equipment, even in the most hard- to-reach locations. The sensors continuously gather fullspectrum vibration, temperature and more than a dozen other metrics. This data is securely relayed to the cloud via a mobile data connection.



Note:

The mote is a compact, full spectrum tri-axial and temperature sensor utilising the latest wireless technology. It includes a frequency range of up to 11.2kHz, an excellent dynamic range of 50g and a battery life of up to five and a half years. Batteries are changed in situ using off-theshelf CR123A lithium Ion batteries. Wireless communications are either via the wireless router or directly with the Gateway with a range of up to 600m line-of-site between each component.

Gateway:

The gateway manages the entire system. It wirelessly gathers data from the node and sensors and the uses a mobile phone data connection to securely pass that information to the cloud.

Plug And Play

John said the use of a mobile dataconnection is a major advantage because it eliminates the potential of interference with the facility's IT system and company servers."I have done a lot of work in plants where the

Continued over page >



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system has to tie into the network and getting that approved is like pulling teeth,” he said. “Other than letting the IT guys know it is going in there, there is no involvement because it is a standalone system, that is the beauty of it.”

“The gateway has a sim card that operates directly through the mobile phone network to the cloud and it creates its own wireless network back through the sensors. “Routers can be used to extend the distance if required. Basically, the install is you mount a central gateway and that receives a signal and then you bang the sensors on and it starts recording within the hour. It is very quick and you are not running or securing cables. I know everyone promotes plug and play solutions but this one truly is.”

The data can be viewed via a web browser from any location, at any time, by multiple users with unlimited frequency. There is also a phone app, which provides a mirror of the cloud portal to give maintenance personnel access to data at their fingertips. There is an API interface option as well, which acts as a cloud server that can transfer data into a site to allow an operator to monitor data through the plant while also being able to view the temperature and vibration values from the sensors on the screen. The interface caters for everyone who may benefit from seeing the data from a consultant reliability engineer who is off-site to on-site employees who may need it for maintenance scheduling.

Software

The cloud analysis software platform is an intuitive, easy-to-learn program. Data is stored at AWS (Amazon Web Services), using industry standard methods of security including SSL/TLS, with encryption from the sensor to the database. It is feature-rich and includes all the expected analysis tools plus some features usually only found in high-end online vibration systems. Record on demand, statistical based alarm creation and a bearing database make this a powerful analysis tool. Alarm notification can be sent via email or SMS to any of the unlimited number of software users.

Diagnostic capability:

- Cursors – Normal, Harmonic, Side Band, Delta
- Plots – Trends, TWF, FFT, Waterfall, Pk-PK,
- Crest Factor Alarms – Statistical generation, Email notification
- HFD - High Frequency Demodulation
- Bearing and Individual fault frequency markers
- Auto Correlation
- Record on Demand

Enhanced Fault Detection

The frequency range of up to 11.2kHz and dynamic range of 50g drastically reduces the chance of unexpected downtime through enhanced early fault detection. John said plants were often going to the effort of adopting a sensor system for condition monitoring but the range was not big enough to pick up faults. “Where we have seen it fail is they will have a frequency of 1 or 2 kHz and a measurement range of 8 or 16g, they can easily miss faults,” John said. “With lubrication issues for example, which will be one of the early indicators leading into bearing wear, that is going to need a frequency range of 3 to 5 kHz. So they try and adopt technology but the vibration and sensor monitoring guys say: ‘What is the point?’”

The Waites system can be applied to multiple machines used in mining including conveyors, pulleys, gear boxes, motors, pumps and fans. A lot of the time pulleys and conveyors are mounted up in areas that are inaccessible, so a wireless solution is ideal.

Low Cost

The use of a mobile phone network means a plant could have hundreds of sensors running off a \$15-a-month data plan. As the installation is so quick and there is no interaction with the plant’s servers, there is no need for downtime, which also saves money. Traditionally vibration software is sold by the license or by the seat, forcing companies to pay handsomely for multiple users. The Waites system allows for unlimited users. GVS quoted against a competitor, which could only cover 40 sensors, and the Waites system, which caters for up to 480 sensors per gateway, came out less than half the price.

“The other beauty of the system is because it is a real time, cloud-based software, it is constantly under maintenance,” John said. “Other systems may only be upgraded once a year whereas the Waites system is upgraded at a rate of knots, there are constant improvements and updates.” John said the use of sensors was the way the industry was heading, as automation, asset digitisation, machine learning, robotics and other technological advances gained traction in the industry. “For years everyone has been waiting for wireless sensors, but they just haven’t been up to the job,” he said. “The offerings to date have left a lot of doubt in people’s minds but this one covers all the bases.”

GVS Reliability Products

GVS has earned a solid reputation for supplying world class reliability products to the mining industry for 13 years. The company started out specialising in fixed accelerometers with cables and since then has expanded its product range to offer a whole suite of condition monitoring products. The Waites wireless solution has slotted in perfectly with its historical focus on sensors and also within its new model of offering a full solution to customers—sales, installation and a maintenance service.

With offices in NSW, Queensland and Victoria, GVS is perfectly positioned to offer support across Australia, New Zealand and the Pacific regions. ■



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.

6 - Good | 10 - Very Good | 15+ - Excellent

T	E	C	N	S
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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. **115** words (four letters or more) that can be made from the combination of letters below. How many can you make?

Solution on page 31.

C	E	S
T	P	M
R	U	S

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.

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

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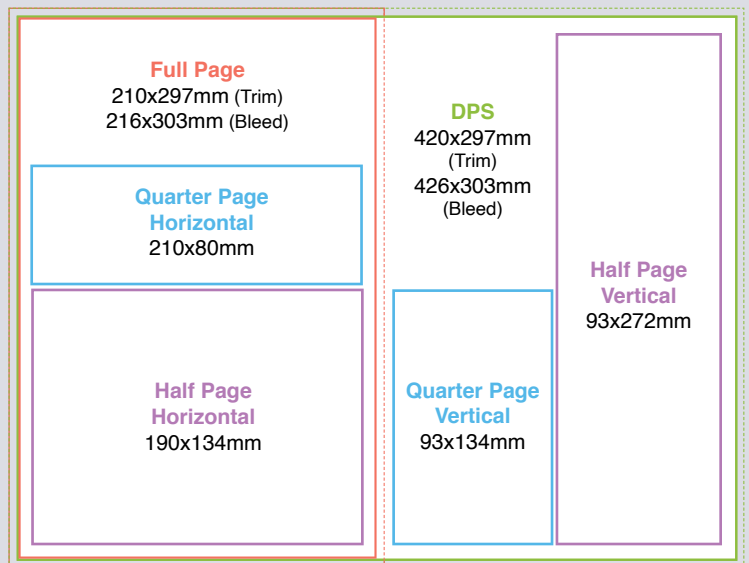
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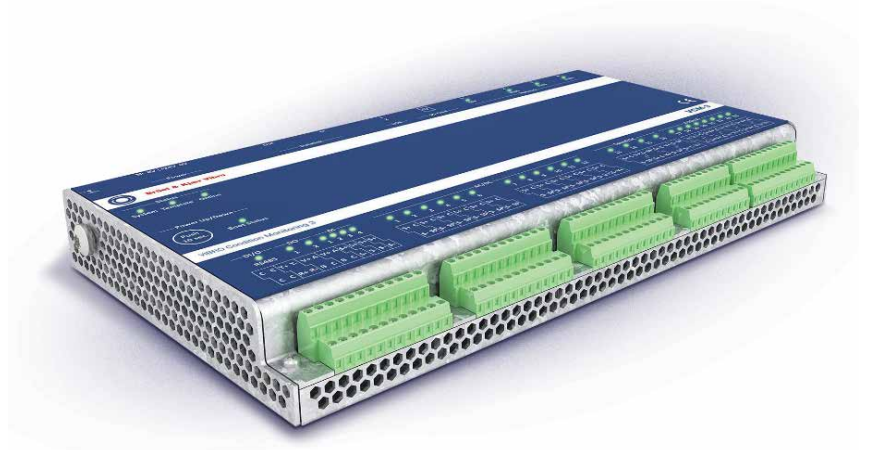
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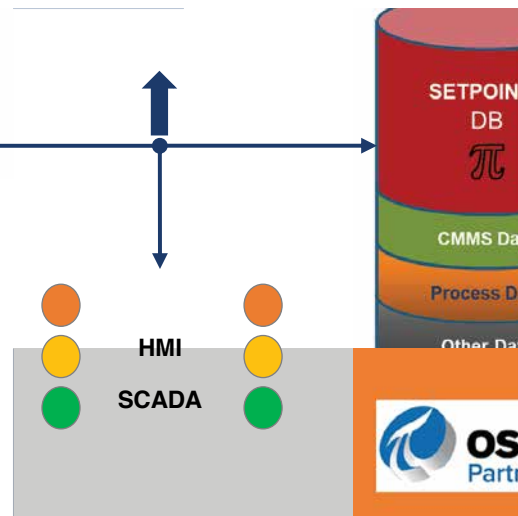
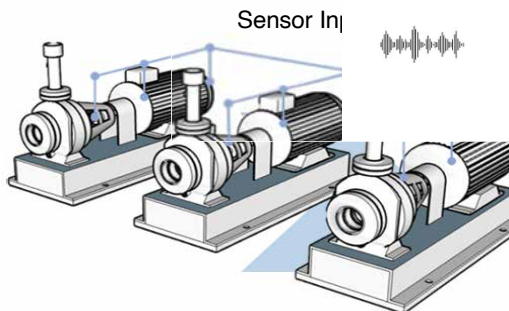
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