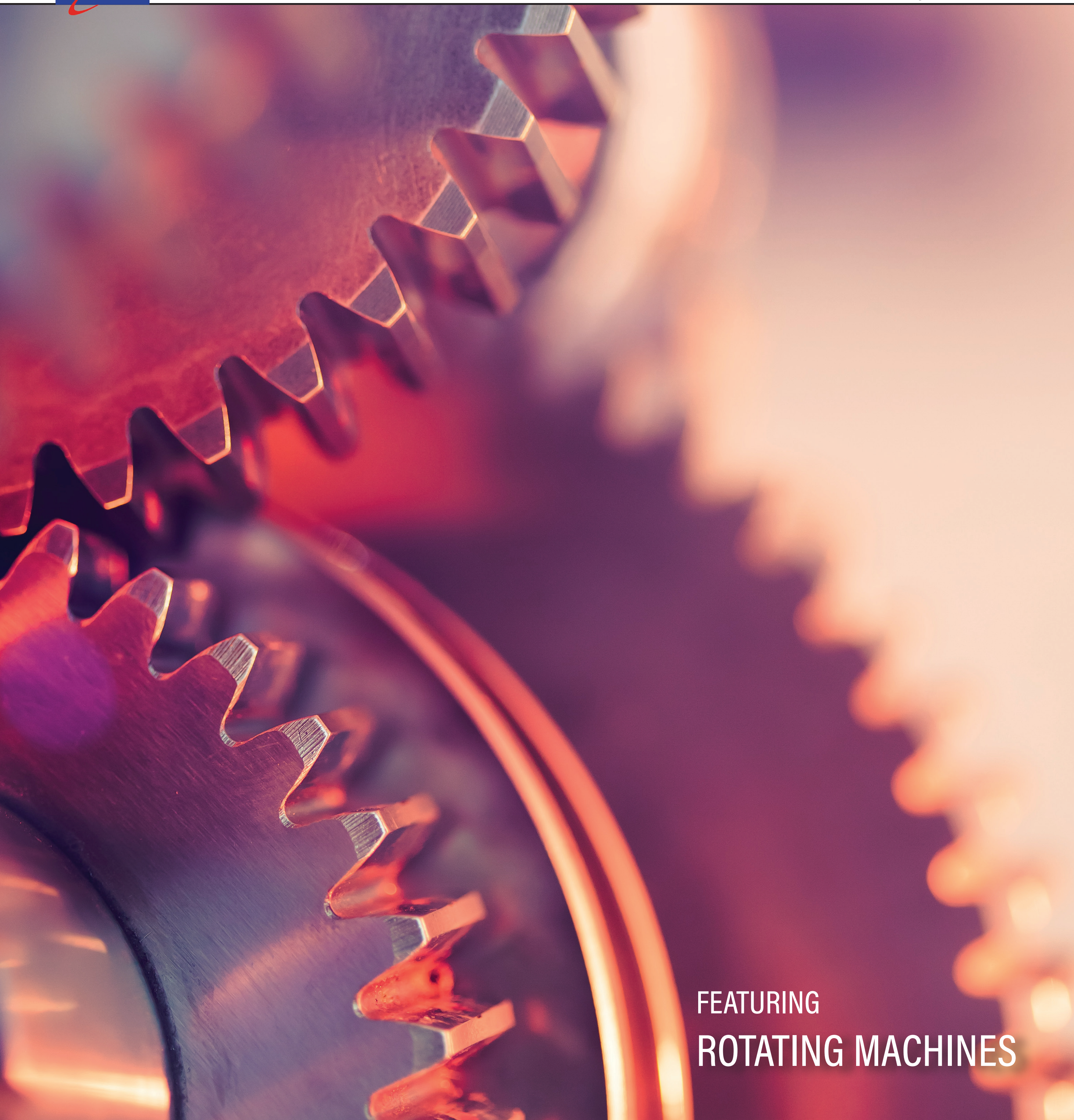
wattnow

SAIEE THE OFFICIAL PUBLICATION OF THE SOUTH AFRICAN INSTITUTE OF ELECTRICAL ENGINEERS | APRIL 2022



FEATURING

ROTATING MACHINES

SAIEE OFFICE BEARERS 2021/2022

PRINCE MOYO
2022 SAIEE President

PROF JAN DE KOCK
Deputy President

PASCAL MOTSOASELE
Senior Vice President

VEER RAMNARAIN
Junior Vice President

PROF SUNIL MAHARAJ
Immediate Past President

JACOB MACHINJIKE
Honorary Treasurer

JANE BUISSON-STREET
Honorary Vice President

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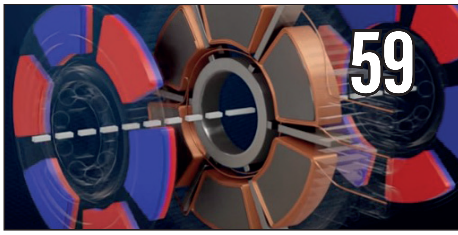

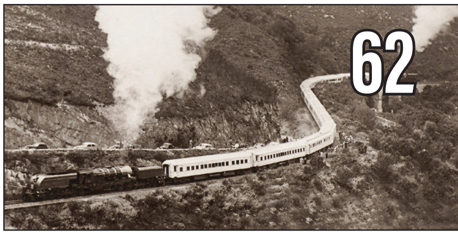

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ISSN: 1991-0452

Dear Valued wattnow reader

Firstly, let me apologise for the lateness of this issue. The SAIEE celebrated many events in the past month, all that needs to be shared with you in this issue.

The SAIEE Annual Awards took place on 11 March, and you will find all the winners on page 16.

We have inaugurated our 2022 SAIEE President, Prince Moyo, on 23 March at a hybrid AGM. We have also inaugurated our 2022 council members and Office Bearers. Find the information on page 6 onwards.

We have renamed the SAIEE Museum to honour one of our fallen stalwarts to the Max Clarke Museum. Read more on page 28.

So, this issue features Rotating Machines, and we have a few interesting articles. Rotating equipment is used across industries and is mission-critical in manufacturing. From compressors to pumps to motors, plant profitability revolves around equipment productivity. Read more on page 40.

On page 48, I share an article on 6 Common Equipment failures you can detect with wireless vibration sensors.

Mr Hendry du Preez, an avid member of the SAIEE Rotating Machine Section, wrote an article on Induction Motor Testing. Find it on page 52.

The wattnow May issue features Renewable Energy, and the deadline is 25 April.

Here's wishing you all a Happy Easter.

Herewith the April issue; enjoy the read!

PS: The SAIEE Training Academy will be hosting a virtual open day on 20 April 2022.
For more information, email cpd@saiee.org.za.

PRINCE MOYO
2022 SAIEE PRESIDENT

The General Manager: Engineering in Eskom Transmissions, Mr Prince Moyo delivered his inaugural address as President of the South African Institute of Electrical Engineers (SAIEE) for 2022/23 via a hybrid event held on 24 March 2022. The topic of his address was "Analytics and Decision-Making in Business".

The world has been under the grip of COVID-19 since March 2020. Freedom of movement has been severely curtailed during this time. Indeed, at one point, access to non-essential premises was prohibited; it was illegal to walk outside the boundaries of your dwelling.

The world has witnessed 460 million recorded infections of COVID-19. Six thousand sixty-nine million people lost their lives to the various variants of the disease globally, and South Africa lost over 99 000 citizens.

As we speak, tens of millions of people are under lockdown in Eastern China, fighting a new resurgence of Omicron virus infections.

Of course, every cloud has a silver lining. Some positives are:

- COVID-19 has shown companies that they probably do not require as much real estate.
- We have perfected the art of working from home, leading to a better work-life balance.
- Fortunately, the daily spectre of grinding traffic jams, which are a nightmare during load shedding, is an option for some.
- A new industry has emerged for servicing this work-from-home reality – examples are technology applications for remote meetings, ergonomic furniture, psycho-social support programmes, etc.

ANALYTICS AND DECISION-MAKING IN BUSINESS

Let us keep in mind that business is a microcosm of the broader society.

In my talk, I will use information and analytics in business to make economically better and more sustainable decisions. I will also explore how technology can contribute to solving the various social challenges that our society faces.

The world has moved fastest in technological development in the last few decades than in any similar period. In his essay, A Brief History of General Purpose Technologies, Bruce Stephenson notes that some technologies, called general-purpose technologies (GPTs), give rise to other technologies that significantly influence the human condition. It was so with the wheel, fire, gun powder, the printing press, the transistor (and its attendant Moore's Law explaining the doubling of processing capacity with every new generation of electronics technology), the internet and mobile technology.

The steepness of the graph is our interpretation of the relative contribution of the invention to the human condition.

Analytics and Decision-Making in Business

SAIEE PRESIDENTIAL ADDRESS

ENGINEERING DEFINED

We are primarily engineers, so I thought I should take us on a journey of the origins of engineering.

The Britannica Dictionary defines an Engineer as a person who has scientific training and designs and builds complicated products, machines, systems, or structures: a person who specialises in a branch of engineering.

Design engineers are working on ways to make the cars run more efficiently.

- mechanical/civil/electrical engineer
- software engineer

A person in charge of an engine in an aeroplane, a ship, etc.

- flight engineer

A person who drives a train.

- engineer

A person who is trained to repair electrical or mechanical equipment.

- The telephone engineer [=(US) repairman]

A soldier who builds roads, bridges, etc.

- Army engineers.

WIKI

The word engineer (Latin *ingeniator*) is derived from the Latin words *ingeniare* ("to create, generate, contrive, devise") and *Ingenium* ("cleverness").

EARLY ENGINEERING

Early engineering infrastructure projects include Rome's aqueduct water reticulation system (4th century BC). In the 15th century, there were designs of military fortifications using mathematics and constructed by artisans. The 1800s saw formalised engineering training in military academies covering specific disciplines more recently.

In 1865, MIT introduced engineering training. Advancements continued until the 20th century, when the most outstanding achievement was Electrification (National Academy of Engineering (NAE)).

NEW GRAND CHALLENGES

We are facing new engineering grand challenges, some of which are:

- nuclear electricity from fusion
- food in the light of urbanisation
- clean water
- clean energy/ clean electricity
- enhancing augmented reality towards true reality
- advancing personalised learning *(I see these are threats to your lecturing jobs)*. I've learnt that there is, in fact, in the US, a committee on Engineering Grand Challenges under the NAE.

Engineering has fundamentally been about practitioners leading in providing necessary services to civilian populations: roads, bridges, water, heating and cooling, electricity and many others.

Until today, every decent army has a Military Corp of Engineers.

Today, most states have utility companies that provide these necessary civilian services (roads, water, electricity, telecommunications, etc.). Of course, there are massive changes in the direction of deregulation/ privatisation – a topic for another day.

It is worth noting that a large part of engineering practice today is about pursuing commercial interests for profit.

ENGINEERING & DECISIONS

I have explained engineering as a civil service. Engineering is not science; we are interested more in applying scientific principles in logically structured ways, always to provide a civil service. So that confirms then that there is a service to be provided, most importantly.

These services are produced using engineering and business processes.

ENGINEERING PROCESSES

Several examples of engineering processes that utilise information and analytics are:

- Manufacturing, such as vehicle

plants – from components, sub-assembly, main assembly
- Textile mills - raw material/ cotton, spinning/ thread, weaving/ cloth, dyeing/ pattern printing/ finishing, garment manufacturing
- Potable water treatment plants – raw water in dams, coagulation, flocculation, sedimentation, clarification, filtration, disinfection (chlorination, ozone, UV), hardness and taste balancing
- Electricity production in thermal plants – primary energy handling (coal, nuclear), water handling, steam handling, turbine plant, generation

At every stage of these processes, instruments take measurements and inform plant operators of the acceptability of input and output parameters.

DECISIONS AND ENGINEERING

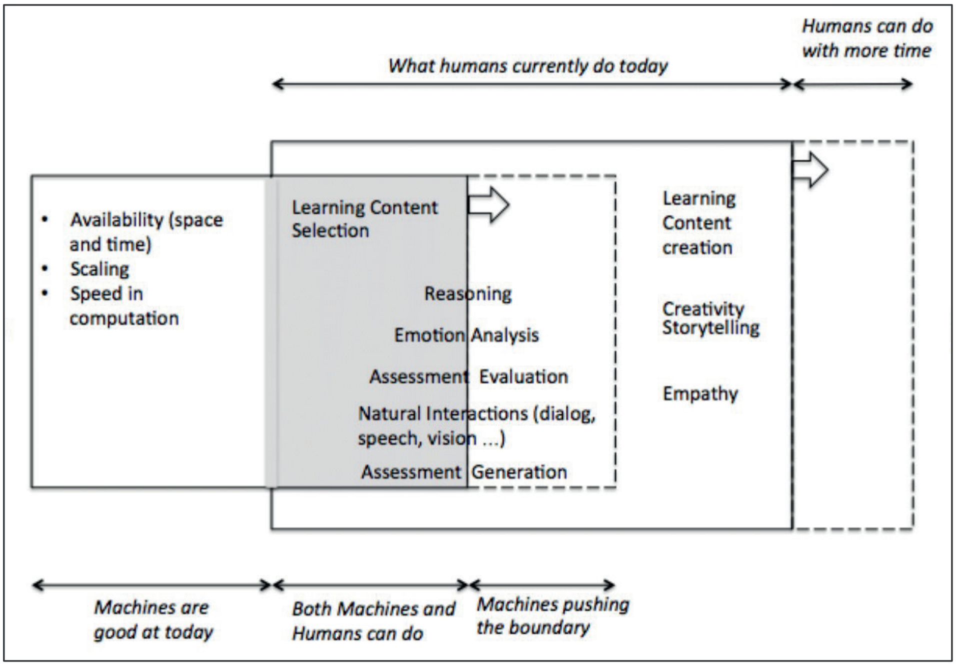
At the peak of its practice, engineering is about managing business systems and processes after applying specialist analytical skills to allocate resources informed.

DECLINING HUMAN SKILLS

Business skills are generally declining. For South Africa, this is particularly so in traditional brick and mortar trades.

HUMAN VS MACHINE

The fundamental skills for engineering practice include creativity, analytical thinking and embracing change. In their 2018 article, Augmenting Classrooms with AI for Personalized Education, Kokku, Sundarajan, Dey, and Sengupta emphasise this point by differentiating the capabilities of machines and humans. Machines are much more available. They are capable of processing large amounts of information fast. On the other hand, humans better recall events from long-term memory. They are more creative and have empathy. Machines are pushing the boundary of human capability.



Augmenting Classrooms with AI for Personalized Education, Kokku, et al

MORE REAL EXAMPLES

More real examples include automation of tasks, which has spread to artificial intelligence (AI) and machine learning (ML), end of life determination as it affects re-investment decisions.

An exciting case study is currently happening on the inspection of overhead powerlines. Remotely piloted aircraft systems are being deployed to undertake thermal scanning of hot spots, corona/air breakdown activity with ultraviolet (UV) cameras, high-definition video, and 3D point cloud images. More advanced applications are venturing into autonomous flight in what are termed beyond visual line of sight (BVLOS).

The attraction in the above case could be remotely piloted aircraft. Still, the software that powers the analysis of these images efficiently to give engineering recommendations is also a marvel on its own.

OPPORTUNITIES

The SAIEE has a marvellous opportunity to get involved and influence positive social change through technology.

MANUFACTURING GDP: Firstly, we must get the basics of traditional manufacturing right. SA manufacturing GDP has grown in absolute terms, but since 1990 its share of GDP has halved to about 11,5%.

ENGAGING SAIEE MEMBERS: The second area of opportunity is to step up the engagement of SAIEE members. The institute has achieved a lot in this area. Our specialist sections have grown from 4 to 7 and specialist chapters from 4 to 30. We have seen an explosion in technical webinars, with the SAIEE hosting 62 webinars last year, with a total attendance of 3582. The SAIEE TV channels have diverse content made up of approximately 150 videos. It has reached 775 subscribers so far and 1175 public watch hours. We can only grow from strength to strength.

ALIGNING RESOURCES WITH NATIONAL PRIORITIES: Thirdly, SAIEE environmental, social, and governance (ESG) initiatives must align with the country's priorities of poverty and unemployment. We must partner with universities, government departments and corporate social investment programmes to create and deliver relevant content for capacity building. Have we partnered with the department of science, technology & innovation? Department of Defence?

HOW MANY JOBS HAVE WE CREATED? Are we conceding that our youth are less creative or intelligent than those from the western or southeast Asian worlds?

DRIVING ENTREPRENEURSHIP: The US has an agency called the Defence Advanced Research Projects Agency (DARPA). DARPA was launched in 1958 by US President Dwight Eisenhower in response to Russia's successful Sputnik program. Its mission is to "prevent technological surprises for the US; create technological surprises for our enemies". DARPA is funded at a level of US$3,5Bn per annum. It is described as "prodigious" in its generating of technology enterprises. It can claim at least partial credit for the Moderna COVID-19 vaccine, weather satellites, GPS, drones, stealth technology, the PC, internet, etc. One of DARPA's current projects is neural implants for soldiers. This brings images of the 1989 movie, Cyborg, starring Jean Claude van Damme. With DARPA's track record, this brings to question how much longer a cybernetic super being will remain fictional.

THE WORD IS SUBSTITUTION: In the article The World's Largest Tech Giants, WEF & VisualCapitalist, 2018, it is clear that most of these enterprises that have become commonplace to us have achieved success by substituting an existing traditional product or service.

- Apple substituted a host of products and services with the smart mobile phone;
- Amazon moved the bookstore to the internet;
- Alphabet with Google took the search for information to mobile devices;
- Facebook revolutionised social contact amongst "friends";
- Netflix is replacing the movie theatre;
- Uber is a substitute for traditional taxis and public transport; and
- Airbnb has substituted hotels and formalised lodges.

It is true that with substitution being the theme, the following technological product or service is right under our noses.

MOBILE APPS: The Mobile App Download and Usage Statistics by BuildFire Blog share the facts below about mobile apps:

- With 6,3Bn smartphones and 1,14Bn tablets;
- users interact with their devices every 5.5min;
- 80% of time spent on these devices is spent on apps;
- An average mobile device owner has 80 apps installed, Millennials have up to 100;
- There are 1,96M apps on Apple Store and 2.87M on Google Store. They are a mixture of free, paid enterprise apps garnering estimated revenues of US$935Bn in FY23.

TECH DEVELOPMENTS AND QUALIFICATIONS: A review of the backgrounds of leading tech entrepreneurs shows that the result is a mix. We have a group that did not need tertiary qualifications (Microsoft's Bill Gates, Facebook's Mark Zuckerberg). Another group diverted from graduate (post-graduate) school academic research to commercialisation, such as Google's Sergei Brin and Larry Page. Another group comprises well-educated individuals who left formal employment to pursue a business idea, such as Amazon's Jeff Bezos, Mark Shuttleworth of Canonical and Kim Reid of takealot.com.

SAIEE RESPONSE

In summary, the SAIEE response to this opportunity for information analytics and decision-making in business should involve:

- Strengthening the existing Sections and Specialist Chapters bodies – we must launch more, particularly in the tech space.
- Identifying strategic collaborations for breakthrough research – partner with universities, DSTI, DoD, DSBD (Department of Small Business Development), tech incubation hubs
- Align CSI/ESG initiatives with entrepreneurship
- Our preoccupation should be to create technical solutions while also creating jobs.

A recent example of initiatives making a difference is the 15-year-old African Leadership Group (ALG). The group has an ALG platform ("The Room") that aims to match 2 million young Africans to global work opportunities. One partnership focuses on mentorship and establishing relationships with global leaders (Amazon Web Services). Another focuses on developing tech skills – software engineering, digital marketing, cybersecurity, machine learning, virtual reality, and app factory learnership (Samsung). Yet another is looking at establishing 10,000 start-ups through its self-service Founders Hub (Microsoft).

The OECD reports that Africa has 640 tech hubs, and they attract less than 1% of global investment in tech.

Finally, there is an initiative to support women entrepreneurs (Google)

WILL THE ENGINEER BECOME EXTINCT?

I explore this question very briefly, based on the human vs machine model that was presented earlier. My observations are that:

- There is still a lot of room for the human touch. Machines are not likely to attain human capabilities of learning and drawing on experience or applying intuition based on learned boundary parameters.
- There are apparent differences between humans and (even learning) machines, as seen in Kokku et al.
- New technological start-ups and unicorns will be launched, but the threat to engineering jobs is minor. The definition and skill set of the traditional engineer are changing rapidly but will not be overtaken.
- Traditional utility services such as electricity supply and water services will remain.

SUMMARY

Engineering is a civil service – we exist to provide technological solutions for the advancement of humankind.
Analytics and decision-making are found in business processes, particularly during analytics for insights, improvement in processes and development of new products and services.
There are many opportunities for technology to contribute to business and alleviate social challenges such as unemployment.

We are the ones that SA has been waiting for. We stand a chance to contribute to a new hub of technology solutions that introduce greater efficiencies based on smart analytics of data in business. We must create a new hub of technology capabilities and companies. The information age is upon us. wn

P Moyo | SAIEE President 2022
Pr. Eng | FSAIEE

SAIEE INAUGURATES 2022 SAIEE PRESIDENT

The 24th of March saw the SAIEE inaugurating a new SAIEE President and electing its 2022 Council members at the Annual General Meeting, a hybrid event. View the proceedings here.

Mr Leanetse Matutoane, the SAIEE CEO, welcomed all guests in attendance to the annual general meeting. "It is such a pleasure to see you all for the first time in two years, face-to-face, and I'm looking forward to more of these events ". Leanetse introduced Prof Sunil Maharaj, the outgoing SAIEE President, who welcomed all in attendance, declared the meeting open and worked through the proceedings."The SAIEE was very innovative in the last year. When you look at the offerings, the SAIEE produced over 60 webinars in the past year on various topics, which created a lot of excitement and interest. That was our way to innovate and have the online platform and grow our membership".

Prof Maharaj introduced the Honorary Treasurer, Mr Stan Bridgen, to deliver the financial statements for 2021. "Following an unprecedented period under audit, the SAIEE, as a non-profit company, has survived and come through well financially, on the other downside of the Covid pandemic. Some positives became apparent in the forced changes that had to be made, albeit a contraction in volume in line with the macro business environment has been endured. The impact, primarily detrimental, was felt in almost every activity within the organisation, "he said.

After the conclusion of the financial statement, Prof Maharaj introduced the incoming SAIEE President, Mr Prince Moyo, handing the baton over to him and wishing him well in his term of office.

Prince Moyo asked Mrs Sy Gourrah, Past President, to give a vote of thanks to Prof Sunil Maharaj. "I am happy to pass the Immediate Past President baton over to you and would like to thank you for your very challenging year as SAIEE President during COVID. I'd like to express my gratitude to you for your leadership, dedication and contribution to the SAIEE. With the support of the SAIEE Staff, Council and Office Bearers, it is an outstanding achievement to turn the SAIEE financially around for future sustainability," Sy said.

Prince Moyo introduced the 2022 SAIEE Office Bearers as:

- Deputy President, Prof Jan de Kock;
- Senior Vice President, Mr Pascal Motsoasele;
- Junior Vice President, Mr Veer Ramnarain;
- Honorary Treasurer, Mr Jacob Machinjike;
- Immediate Past President, Prof Sunil Maharaj; and
- Honorary Vice President, Mrs Jane Buisson-Street.

After the conclusion of the meeting proceedings, Prof Jan de Kock, Deputy President, introduced Prince Moyo for his inaugural address. He said: "It is my privilege to introduce our new president with his inaugural talk on "Decision making and Business Analytics". Read his inaugural address on page 6.

Please visit pages 68 & 69 for the 2022 Council Members, Chapter and Section chairpersons.

Page 70 will introduce you to the new SAIEE Centre Chairpersons.

After the meeting concluded, members joined SAIEE President Moyo for cocktails and networking. wn

SAIEE Past Presidents, from left Dr Angus Hay and Dr Hendri Geldenhuys.

From left Leanetse Matutoane, SAIEE CEO and Prof Sunil Maharaj, SAIEE Immediate Past President.

From left Jane Buisson-Street, Honorary Vice President, and Gerda Geyer, Executive Secretary.

Members of the Central Gauteng Centre with SAIEE President, Prince Moyo.

The Varsity TV Team

From left: Prince Moyo, SAIEE President, and André Hoffmann, Past President.

Sy Gourrah, SAIEE Past President with guests.

Guests

From left: Prince and Nontokozo Moyo.

From left: Leanetse Matutoane, Minx Avrabos, Prince Moyo, Gerda Geyer and Prof Jan de Kock.

The Old Mutual Team who donated a Golf Bag in a lucky draw!

The SAIEE announced the

2022 Office Bearers

DEPUTY PRESIDENT
PROF JAN DE KOCK

Prof de Kock (FSAIEE) has served on council for the last four years. He became an SAIEE Member in 1986.

Jan de Kock received his B Eng, M Eng and PhD in electrical engineering from Stellenbosch University. He is a registered Professional Engineer in the South Africa.
In 2001 he was appointed Professor in Electrical Engineering at North-West University. From 2005 to 2015 he was the Director of the School of Electrical Engineering and has previously acted as Dean of Engineering for 14 months. He has taught power electronics, electrical machines and final year project to undergraduate students, and advanced protection and power system dynamics courses to postgraduate students. Since January 2016 he has returned to being a lecturer and researcher within the School of Electrical Engineering.

SENIOR VICE PRESIDENT
PASCAL MOTSOASELE

Pascal is a Fellow of the Institute, and has been a member for 22 years. He is a member of Council for 6 consecutive years, and an Exco member for 3 consecutive years.

Previously he served as Chair of Events & Marketing Committee, and Chair of the Power & Energy Section. He is the Institute's Engineer of the Year 2018. Pascal is a Consultant Engineer and currently the Acting Automation Asset Manager at Rand Water's Strategic Asset Management division. His academic qualifications include a BSc(Eng) degree from University of Cape Town, MEng degree from Wits University, an Innovation Management Development Programme (IMDP) from the Da Vinci Institute for Technology Management, the Management Advancement Programme (MAP) from the Wits Business School (WBS), and is currently enrolled for the MBA with Unicaf University.

JUNIOR VICE PRESIDENT
VEER RAMNARAIN

Veer Ramnarain, a Fellow of the SAIEE, became a Member in 1993. He is a registered Profession Engineer with the Engineering Council of South Africa (ECSA).

He has a Government Certificate of Competency and completed his management qualifications with a Diploma in Engineering Business Management from the University of Warwick and an MBA from the UKZN. Veer is the Past-Chairman of the KZN Center in 2018. He conducts professional registration reviews for ECSA and serves on the Engineering Discipline Advisory Boards of KwaZulu-Natal University and the Durban University of Technology. He is an external examiner at UKZN and served on the SA National Committee of IEC, the Executive Board of CIGRE and Chairman of NRS ManCom. He is currently an EXCO member of AMEU and SAIEE.

IMMEDIATE PAST PRESIDENT
PROF SUNIL MAHARAJ

Prof Sunil Maharaj became an SAIEE member in 1996.

He completed his Bachelor of Science: Engineering (Electronic) and Master of Science Engineering (Electronic) at the University of Natal. In 2005 he was instrumental in establishing the Sentech Chair in Broadband Wireless Multimedia Communications at the University of Pretoria. He has supervised and mentored many students from Honours, Masters, Doctor of Philosophy to Post-Doctoral level. Since May 2011, Sunil has been the Head of Department of Electrical, Electronic and Computer Engineering at the University of Pretoria and has served on various national and international technical committees related to the ICT arena. Sunil is currently the Dean of the Faculty of Engineering, Built Environment and IT (EBIT) at the University of Pretoria.

TREASURER
JACOB MACHINJIKE

Jacob joined the SAIEE in 1996 as a Senior Member. He became a fellow in 2002 and served as a Council member from 2001 to 2006 and then again from 2011. Jacob was the 2017 SAIEE President and served on various council committees, including membership, professional development, finance, restructuring and policies and Exco.

He is the General Manager at Eskom, responsible for the upkeep of Transmission Grid assets. He represents Eskom on the Governing Board of the GO15 (an international organisation of extensive power grid operators).

Jacob is passionate about leadership, developing people, and coaching and mentoring for the sustainability and growth of the industry.

HONORARY VICE PRESIDENT
JABE BUISSON-STREET

Jane Buisson-Street was born in England and studied Power Engineering at TWR, Computer Science and Statistics at UNISA and received her MEng in Information Engineering from Wits in 2005. Her working experiences include working underground in South African goldmines commissioning mine winders and conveyors, lecturing to being a Head of Department.

Jane has been involved with SAIEE for several years as a Senior Member and upgraded to a Fellow Member. She currently serves on SAIEE EXCO, Publications & Membership Committees, and the Historical Section.

Jane is hardworking, diligent and completes any task with utmost vigour – and still manages to find the fun in any project. Jane serves with integrity and passion and has a fantastic insight into problems and situations that others would not usually see. wn

2021 SAIEE ANNUAL AWARDS - CELEBRATING SUCCESS!

The South African Institute of Electrical Engineers hosted their Annual Awards recently at an auspicious event in Johannesburg.

The physical event was well-attended, and members, guests and sponsors had an elected time seeing each other for the first time since the outbreak of Covid-19, which forced most people to work remotely.

The Master of Ceremonies, Minx Avrabos, welcomed all the guests and introduced SAIEE President, Prof Sunil Maharaj. "It's been a long time since we saw each other, and I'm happy to see everyone here - I can feel the 'electricity' in the air!" he said.

Our keynote speaker, Dr Antonio Fourie, gave us a short talk, "The treasure in every wreck - a simple conversation". Watch it here.

The winners of the 2021 SAIEE Annual Awards are:

SAIEE PRESIDENT'S AWARD:
PROF LEENTA GROBLER

From left, Prof Sunil Maharaj, 2021 SAIEE President and Prof Leenta Grobler, 2021 SAIEE President's Award recipient.

This prestigious award recognises significant contributions in any sector of electrical,electronic,telecommunications and computer engineering in South Africa. Prof Leenta Grobler, director for business development and stakeholder engagement in the Faculty of Engineering at the North-West University (NWU), is a true trailblazer. Not even the Covid-19 pandemic can hold her back.

She was recently announced as a semi-finalist in the category Public and Private Service of the annual Accenture Rising Star Awards which aim to recognise, celebrate and connect young South African professionals who display extraordinary leadership qualities and strive towards achievement, success making a difference.

SAIEE ENGINEER OF THE YEAR AWARD:
PROF DAVID NICHOLLS

From Left: Mr Mervyn Naidoo, ACTOM (PTY) Ltd, Prof David Nicholls, SAIEE Engineer of the Year Award winner and Prof Sunil Maharaj, 2021 SAIEE President.

This award, sponsored by ACTOM (Pty) Ltd, recognises an SAIEE member who has energetically and voluntarily worked towards promoting electrical science and its applications for the benefit of its members and the Southern African community.

Prof David Nicholls is a Fellow of the SAIEE, who became a member in 2019 has been nominated for his leadership in launching and leading the SAIEE Nuclear Chapter, which consists of six active study committees in Science & Technology, Electricity Generation, Medical Applications, Environmental Impact, Nexus of Applications for Local Industrialisation and Manufacturing and Education. The Chapter has formed the foundation for the Senate-approved new Nuclear Research Centre at the University of Johannesburg.

SAIEE KEITH PLOWDEN YOUNG ACHIEVERS AWARD:
NEO MAPAPANYANE

From left: Mluleki Hlatshwayo, SGB-SMIT Power Matla, Neo Mapapanyane, 2021 Keith Plowden Young Achieve Award winner and Prof Sunil Maharaj, 2021 SAIEE President.

This award, sponsored by SGB-SMIT Power Matla, awards the most outstanding young achiever of the year in Electrical/electronic engineering. What counts in this person's favour is their spirit of achievement, creativity and leadership in the workplace. Innovative, entrepreneurial actions and infectious enthusiasm for success are the qualities exhibited by young achievers.

Neo Mapapanyane joined the SAIEE in 2020 as a member and committee member of the Central Gauteng Centre (CGC). She served under the SAIEE CGC as a Corporate and Social Investment (CSI) portfolio leader. In March 2020, the President of the Republic of South Africa declared the country to lockdown alert level 5 and with the challenges that the education system faced, she rose above the circumstances and organised online career guidance in July 2020 for the grade 12 learners who were interested in Electrical Engineering Career. The main reason for hosting this career guidance was to promote and increase the interest of an Electrical Engineering career in previously disadvantaged communities and equip the learners with all the information they needed to know before following this career path.

SAIEE ENGINEERING EXCELLENCE AWARD

MOYAHABO MAGEMBA

From left: Moyahabo Magemba, Engineering Excellence Award recipient and Prof Sunil Maharaj, 2021 SAIEE President.

The SAIEE Engineering Excellence Award is awarded to a person who has excelled in Electrical Engineering and their personal capacity that supports and mentors those with whom they interact in the workplace.

Moyahabo Magemba has been working at Eskom and then later joined a municipality where her contributions and dedication in developing technical standards, specifications and guidelines for primary and secondary equipment and ensuring compliance has been instrumental in standardising the equipment and the interchangeability of components. She has been a driver of solution-driven technologies. She mentors people at her workplace and is involved in Women in Engineering at the AMEU, where she has contributed to mentoring women empowerment.

SAIEE WOMEN IN ENGINEERING AWARD

REFILWE BUTHELEZI

Refilwe Buthelezi, SAIEE Women in Engineering Award recipient.

The SAIEE Women in Engineering Award recognises a female SAIEE Member, Senior Member, Fellow or Council Member who has excelled in Electrical Engineering. She demonstrates above-average involvement in supporting the SAIEE with her aims and objectives and her capacity to support and mentor colleagues. Her peers and competitive counterparts have high regard for her integrity in all her engineering business dealings. This woman is a role model of the highest calibre.

Refilwe Buthelezi has over 15 years of business leadership experience in diverse water and power utility environments. She holds BEng and MEng degrees and a Master's in Business Leadership. During her career, she has built a reputation for operational excellence, digital technology, corporate governance, innovative strategic thinking, working with the highest level of integrity, accountability, and passionate commitment to sustainability, environmental, social and governance. She is passionate about women's empowerment and has used her various roles as a champion of transformation to elevate the role of many women in the industry.

SAIEE CENTRE OF THE YEAR AWARD

KWAZULU NATAL CENTRE

Pic 6: From left: Prof Sunil Maharaj, 2021 SAIEE President and Shepherd Nkosi, Chairman, SAIEE KwaZulu Natal Centre.

SAIEE Centres are evaluated against a set of agreed KPIs, including events organised, membership increase, centre membership activity as gauged by the attendance of events organised, monthly reporting to head office, and corporate social investment initiatives. The winning centre held ten events over the reporting period with a combined total of 464 attendees and submitted reports to head office on time during 2021.

INDUSTRY AFFAIRS

2021 SAIEE ANNUAL AWARDS - continuous

The SAIEE Annual Awards would not have been possible, without the outstanding support from our sponsors.

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SAIEE APPOINTS CHIEF EXECUTIVE OFFICER

The South African Institute of Electrical Engineers (SAIEE) has appointed a new Chief Executive Officer at the last council meeting, which took place on Friday 1 April 2022.

The SAIEE welcomes the appointment of Mr Leanetse Matutoane as the SAIEE Chief Executive Officer from 1 April 2022. Leanetse Paul Matutoane was born in Evaton, on the southern border of the Gauteng province of South Africa. He holds a National Diploma in Electrical Engineering (Heavy Current) from the Vaal University of Technology and an MBA degree from Rhodes University. He has been active in the technical, automotive, and engineering consulting operations management industries for a significant part of his career. He received a Chairman's Award for his role in the start-up operations for the HUMMER H3 with General Motors in 2007. Leanetse joined the SAIEE in the role of Operations Manager of the South African Institute of Electrical Engineers (SAIEE) in June 2018 and was appointed Acting CEO in January 2021. Leanetse is a Senior Member of the SAIEE.

His appointment came a week after the inauguration of Mr Prince Moyo as the 2022 SAIEE President, at the SAIEE Annual General Meeting, which took place at the SAIEE Head Offices on the 24th of March 2022.

Leanetse Matutoane
SAIEE Chief Executive Officer

"We welcome Mr Leanetse Matutoane to his new role as CEO of SAIEE. He has been part of the administration for a few years now, contributing to the achievement of positive results. With an approved strategic plan and clear targets, we are confident that SAIEE Office Bearers, Council and general membership will support him to reach greater heights," he concluded. wn

Electrical auctioneering safety checks

Some research before entering into a transaction with an auctioneering company can avert disappointment and problems through dealings with unprofessional or unscrupulous auctioneers.

Electrical companies should note that rather than jumping headlong into the bidding process or putting up assets for auction, Sonja Styger, chief administration officer of the South African Institute of Auctioneers (SAIA), recommends a quick check to establish whether the company selected is legitimate and a member of the association.

SAIA is the industry's professional body and provides oversight and guidelines for the industry. It also acts on indiscretions by member companies and can be called upon to mediate in the event of disputes. Members must also uphold a strict code of conduct and ethical behaviour in dealing with the public.

"I can think of not one good reason why a potential seller or buyer would choose to use an unregistered auctioneer.

There is no cost-benefit, nor is there safety in not knowing the credentials of an auctioneer. "That is why we have gone to great lengths to make SAIA member lists easily available on the web, social media, in-office, or a simple phone call to our office. When listing assets that are potentially worth a lot of money or buying goods with their hard-earned cash, we always advise people to take the time to contact SAIA and be safe rather than sorry," says Sonja. wn

Sonja Styger
Chief Administration Officer | SAIA

Prioritise the People Aspect In PDS Installations, Urges Booyco

Booyco Electronics is at the forefront of fit-for-purpose proximity detection technology.

As the implementation of proximity detection systems (PDS) takes centre stage at surface mining operations ahead of the yet-to-be-announced compliance deadline, leading PDS and CPS developer Booyco Electronics has encouraged mining companies to give equal impetus to both vehicle-to-vehicle and vehicle-to-people installations.

According to Anton Lourens, CEO of Booyco Electronics, traffic management planning has come under the spotlight recently as requirements for PDS and effective risk management interventions are set to become enforceable under the provisions of the Mine Health and Safety Chapter 8 MHSA Act 29 of 1996.

Despite the uncertainty around the exact compliance deadline surface mines have, in recent years, advanced their risk assessments and installation of PDS technology, where significant risk exists. However, Lourens is concerned about the seemingly one-sided focus on vehicle-to-vehicle installations, at the expense of equally important vehicle-to-people installations.

"Out of the enquiries we get, we have observed that there is limited assumed risk on people detection," says Lourens. "We see a big focus on vehicle-to-vehicle risk, with limited requests for the people protection aspect of PDS installations. We are not sure if the approach is informed by internal risk assessments or the fact that mines have put in place measures to separate people from machines."

As part of their risk assessments, several operations have, as an example, implemented pedestrian walkways as a means of separating people from moving machinery. While Lourens acknowledges that PDS technology is not a silver bullet on the quest for Zero Harm, he believes that, as an engineering control system, the technology has proven its mettle in mitigating risk at mines.

"We have seen operations opting for fixed barriers as part of their traffic management plans to separate people from machinery," says Lourens. "Separating people from moving machinery only mitigates part of the risk, yet the PDS can warn against possible collisions (Level 7), identify corrective paths (Level 8), or implement a 'slow-down and stop' intervention together with 'motion inhibit' (Level 9), which makes it a better solution than physical barriers." wn

The Booyco CXS is a comprehensive integrated response to Level 7, Level 8 and Level 9 safety levels as defined by EMESRT.

INDUSTRYAFFAIRS

SAIEE Visit to Wilec Olifantsfontein

SAIEE Members attended the Wilec site visit.

The Wilec Team
From left: Paul Senior, Nene Mathebula (CEO), Danford Mugadza (Deputy CEO), Ronel van Straaten, Howard Eldridge and Christo Smit.

On 9 March, SAIEE members visited Wilec's conductor facility in Olifantsfontein.

The factory, producing products under the Transwire brand, was founded in 1975 and is the leading manufacturer of enamelled and covered conductors in sub-Saharan Africa.

The vertically integrated facility manufactures high-quality oxygen-free copper rods (Cu-OFC) by employing the well-known upcast process. The rod is produced from a pure grade copper cathode, and the quality is verified by regular spectrographic analysis and mechanical testing in the on-site laboratory.

Copper and aluminium rod are further converted to produce either round or rectangular enamelled conductors, conforming to the IEC 60317 standard.

Recent investment into high-speed enamelling machines ensures the efficient production of the best quality product. In the bare and covered conductor division, copper and aluminium rod are extruded using the Conform process. The bare conductors can be covered with Kraft or thermally upgraded paper for oil-filled transformer applications and Nomex®, mica, polyimide film and glass for high-temperature applications.

A substantial investment recently into Wilec aided us completed into a continuously transposed conductor (CTC) manufacturing plant. CTC is used to manufacture and repair large power transformers, and this is the first facility of its kind on the African continent.

In this process, multiple strands of rectangular enamelled conductions are combined and transposed before being covered with multiple layers of insulating paper in a continuous process. wn

The photovoltaic installation comprises almost 1,400 solar panels and will generate 726 kW of power for the site.

Bentley Park Goes Green with its own Solar Farm

Taking forward its sustainability agenda while safeguarding operational performance, Murray & Roberts Cementation is now powering its Bentley Park site near Carletonville using solar energy.

The move puts the multi-purpose training and engineering facility on a stable and reliable energy platform, according to Murray & Roberts Cementation engineering services executive Hercilus Harmse. It is also in line with the company's strategic aim of reducing its carbon footprint.

"In recent years, the case for a more sustainable energy supply has grown – especially with ongoing load shedding and power outages due to cable theft," says Harmse. "This solution allows the leveraging of solar energy to protect the facility against the direct and indirect disruption caused by unreliable electricity supply."

The solution is a hybrid system using solar energy for most of the site's requirements, with lithium batteries providing continuous electricity in the case of outages. The existing backup diesel generating system adds another level of redundancy.

"This comprehensive design assures customers that we can continue to deliver our training and refurbishment services irrespective of the threats facing our national energy network," he says.

The photovoltaic installation comprises almost 1,400 solar panels and will generate 726 kW of power for the site. Securely situated adjacent to Bentley Park's offices, training rooms, workshops and other infrastructure, the solar farm comprises about a hectare of north-facing, ground-mounted photovoltaic panels at an efficient 12-degree angle. These also feed into 800 kWh of battery capacity, which provide uninterrupted flow to the range of sophisticated electrical and electronic equipment on site.

"As our operational technology at Bentley Park advances, there is steadily more risk posed by unplanned outages," Harmse notes. "Our training equipment, for instance, today includes sensitive and costly computerised tools such as simulators, which ideally require constant and controlled energy supply."

These risks add to the time and opportunities lost when outages prevent training being conducted according to plan, or refurbishments and other engineering work being completed on time. He argues that the direct and indirect costs of power failures made the decision to invest in renewable energy a "no-brainer". The board approval of the project's budget allowed work to proceed from mid-2021, with the installation starting in November 2021 and commissioning was completed at end-January 2022. It is estimated that the investment will pay itself back through direct savings in just seven years.

Prior to starting, the project required extensive data collection and analysis to identify electricity usage patterns and peaks – leading to the most effective strategy. Harmse says the renewable power project forms part of a broader sustainability strategy at Bentley Park, which includes environmental initiatives related to water, recycling and the reduced use of hydrocarbons in energy generation.

"This bold step into a renewable future puts us on a firm footing where customers can feel confident about our commitment to sustainability and our ability to deliver," he says. wn

Infobip scoops Service Provider Of The Year Award at inaugural WASPIES Awards

From left: Sizo Nkosi, Regional Operator Partnerships Manager; Katlego Kapari, Operator Partnerships Account Manager; and Andrew Egan, Sales Director.

Infobip, a global cloud communication company for businesses and a leader in omnichannel customer engagement, is proud to announce that it was a category winner at the recent inaugural WASPIES Awards.

Hosted by the Wireless Application Service Providers' Association (WASPA), the WASPIES is a peer recognition awards ceremony and networking event that celebrates the association's members by recognising those that make stellar contributions to the industry.

Infobip was nominated by industry peers for the service provider of the year award. This award acknowledges the excellence in service delivery within the community - a staple champion and advocate of the ecosystem.

Nominations for this category expand across all sectors within the mobile ecosystem and includes technologies, solutions, services or products that ensure the advancement of the WASP industry through smart business and partnerships. This partner need not be a WASPA member.

GREAT HONOUR

Sizo Nkosi, Regional Operator Partnership Manager at Infobip, says that winning the award is a great honour for the company, as it recognises the strong and continuous contribution that Infobip is making to the South African market.

"It is very encouraging to see that Infobip's uniqueness is being recognised. Our company culture is to bring the world together virtually and seamlessly, meaning that as a company we strive to always keep up with industry standards and ensure that innovation is a priority," he says.

Nkosi explains that after initially being nominated by industry peers, Infobip received votes from WASPA members through the voting process, before undergoing a further adjudication process. The winner of each WASPIES category was the finalist that received the most votes from WASPA members by the closing date for voting.

INDUSTRY LEADER

"Winning the Service Provider Of The Year Award strongly affirms our status as an industry leader in this space. Apart from being a leading platform service provider, Infobip has also demonstrated its economic contribution by creating many jobs, both in the African market and globally," says Nkosi.

"This is indeed a very proud moment for Infobip. To be recognised by WASPA at its first WASPIES event shows that the efforts that we have put into structuring our business in South Africa, as well as marketing and launching our products, are finally paying off."

Nkosi notes that with more than 700 direct global telco connections across six continents, Infobip is the number one choice to globally scale enterprises' customer communications – over the world most popular channels.

This is the second high-profile award that Infobip has won this year. In January, the company received the Top Employer certification for 2021 by the Top Employer Institution, which recognises excellence in people practices. wn

SEMIKRON and Danfoss Silicon Power join forces to establish the ultimate partner in Power Electronics

Executives from Danfoss and Semikron including (from left to right): Claus A. Petersen, General Manager, Danfoss Silicon Power GmbH; Dominik Heilbronner, Shareholder, SEMIKRON International GmbH; Karl, Heinz Gaubatz, CEO/CTO, SEMIKRON International GmbH; Jorgen Mads Clausen, Shareholder, Former Chairman of Danfoss A/S; Bettina Martin, Shareholder, SEMIKRON International GmbH; Dr. Felix Hechtel, Head of Supervisory Board, SEMIKRON International GmbH and Kim Fausing, President and CEO, Danfoss A/S.

SEMIKRON and Danfoss Silicon Power have announced a merger to create a joint business specialised in Power Electronics focusing on power semiconductor modules.

With an existing workforce of more than 3,500 dedicated power electronic specialists, the new SEMIKRON-Danfoss will provide world-class technology expertise as the leading partner in Power Electronics. The merger comes with a firm commitment to future investments, paving the way for green growth and a more sustainable, energy-efficient and decarbonised future. SEMIKRON-Danfoss will be a central enabler of this transition.

Electrical power will be in the future the most essential energy source. The power semiconductor module is at the heart of all electronic power solutions. The module is built of power semiconductors that make it possible to convert and control electrical power. With the rise of e-mobility, the demand for electric vehicles is expected to increase by 30% each year over the following years (BloombergNEF, EVO 2021). This speaks to the enormous growth potential of power modules as they are a vital component for powering electric motor and vehicle chargers.

Industrial motors consume 50% of electrical energy globally. Only 20% of these motors are equipped with variable speed motor controls, leaving a significant untapped potential to improve energy efficiency and reduce CO2 emissions. The power module is the key component in any variable speed control for electric motors.

The ongoing global transition aiming at replacing fossil fuels by improving energy efficiency and the ambitious use of renewables also increases the demand for power modules. The power module is critical in all solar installations and all wind turbines to enable the power conversion to grids and energy storage.

SEMIKRON-Danfoss will leverage its strong core business in industrial- and renewable power module applications and utilise the partnership to target a leading position in Automotive power modules. SEMIKRON-Danfoss will set the trend and drive the technology shift into Silicon Carbide solutions in industrial and automotive applications.

The newly formed SEMIKRON-Danfoss joint business will be owned by the current owner-families of SEMIKRON and the Danfoss Group, with Danfoss being the majority owner.

Danfoss President & CEO Kim Fausing said: "The new SEMIKRON-Danfoss builds on a strong long-term partnership and more than 90 years of combined technology leadership in Power Module packaging, innovation, and customer application expertise.

With electrification driving the green transition, SEMIKRON-Danfoss aims to become the preferred decarbonising partner for customers. We have the passion, competencies and technologies to double our business in five years."

SEMIKRON CEO Karl-Heinz Gaubatz added: "This is an exciting moment. Based on close, trusting conversations over the last months, we have identified that SEMIKRON and Danfoss are a unique fit with complementing assets, a strong team and shared values.

By combining SEMIKRON's expertise as a pioneer for semiconductor technology with more than 70 years of experience in the development of top-class power modules and systems and the strength, innovativeness and fast-paced operations of Danfoss Silicon Power and the Danfoss Group, we are positioned ideally to become one of the strongest players in power electronics." **wn**

UKZN Congratulates Recipients Of The National Batho Pele Excellence Awards

The University of KwaZulu-Natal congratulates three members of the University community who received the 2022 National Batho Pele Excellence Awards (NBPEA) announced on Thursday, 24th of March 2022, in Gauteng.

The Minister for Public Service and Administration, Ms Ayanda Dlodlo, conferred awards on several eminent South Africans. The awards recognise their outstanding efforts that have contributed to improving public service.

Among the award recipients were UKZN academics and researchers, namely:

DVC for Research and Innovation, **PROFESSOR MOSA MOSHABELA**; Director of the KwaZulu-Natal Research Innovation and Sequencing Platform (KRISP), Professor Tulio de Oliveira PhD candidate and Laboratory Supervisor, Mr Sandile Cele from the Africa Health Research Institute.

They were awarded the Ministerial COVID-19 Special Award for their distinguished research into COVID-19.

Professor Moshabela, who was among the first to establish COVID-19 response teams, was recognised for outstanding service to the public through his COVID-19 science communication efforts.

PROFESSOR DE OLIVEIRA is a Director of the KwaZulu-Natal Research and Innovation Sequencing Platform (KRISP) at UKZN and a Professor of Bioinformatics at the School for Data Science and Computational Thinking at Stellenbosch University. Recently received the South African Medical Research Council's Gold Medal for Scientific Excellence. Professor De Oliveira played a crucial role in identifying the Beta and Omicron variants. Through the Ministerial Advisory Committee, he contributed to guiding the country's response to COVID-19.

MR CELE, a PhD candidate and laboratory supervisor at Africa Health Research Institute (AHRI), recently led some of the research on COVID-19, including studies that were the first to isolate and characterise the live Beta variant. With the Sigal group, he was the first to report the immune escape of

Beta and Omicron. He also led a study describing how variants could evolve in Sub-Saharan Africa. His research output has helped put South Africa at the forefront of COVID-19 research.

Vice-Chancellor and Principal Professor Nana Poku said: "Not only has their body of work and ground-breaking research kept the UKZN flag flying high, but they have contributed immensely to the world's understanding of the COVID-19 pandemic.

"Through these and other research undertakings, many lives were saved as authorities were able to put in place pharmaceutical, non-pharmaceutical and policy interventions informed by science.

"Their research findings inform the global response to the COVID-19 pandemic. The University is proud of these achievements and the awards conferred on our staff members."

We salute our academics for their research endeavours. wn

SGB-SMIT POWER MATLA (SSPM) achieves a Phoenix milestone event

SGB-SMIT POWER MATLA is proud to celebrate a significant milestone marking the commissioning and operation of the on-site testing facility since the fire accident at the Pretoria power manufacturing plant in March 2021. In the newly built on-site test facility, the team successfully manufactured and tested a 45MVA 88/11kV double-wound three-phase transformer manufactured for a local utility on 8 March 2022.

This achievement is a momentous occasion, marking the first anniversary of the unfortunate fire accident and is a testament to the excellent and focused efforts and teamwork of everyone involved in the rebuilding project.

The rebuild project to reconstruct the fire-damaged plant and equipment is progressing well and remains on schedule. The company is taking full advantage of this rise from the ashes opportunity to modernize and improve the plant and equipment and deliver best-in-class manufacturing and testing facilities.

The Factory Acceptance Testing (FAT) commenced on 28 February 2022 and concluded on 8 March 2022 and included full-wave Lighting Impulses of 450kV on the HV, and 170kV on the HV Neutral, 95kV on the LV line terminals and Neutral. The Applied Voltage (Separate Source), LTAC induced voltage, induced voltage withstand and induced voltage with partial discharge measurements for 1-hour were also successfully conducted.

The unit successfully passed all required transformer tests.

The Pretoria plant has a manufacturing capacity from 5 MVA 66kV up to and including 800 MVA 420 kV and incorporates power and specialized transformers (such as but not limited to the furnace, rectifier, traction transformers, shunt reactors and related equipment). All transformers manufactured are tested according to international standards (IEC 60076). wn

SAIEE Museum renamed to the "Max Clarke Museum"

From left: Prof Sunil Maharaj, SAIEE President & Janet Hogg, Max Clarke's Daughter

The 24th of March was quite an emotional day for SAIEE Council members and staff. An SAIEE stalwart, Max Clarke, passed away in November 2021. He masterminded the creation of the museum and a library within the SAIEE circa 1990. In recognition of his work, SAIEE Council resolved on the 3rd of December 2021 to name the museum "The Max Clarke Museum".

The concept of collecting and restoring electrical engineering artefacts and books started long before 1990 by doyen members such as Dirk Vermeulen, Duncan Baker, Alan Meyer, Stan Bridgens and Mike Crouch.

Over the years of its existence, SAIEE members have collected and stored numerous artefacts, books, and Institute transactions. Artefacts were actively collected by Max Clarke and stored at various municipal and Eskom depots as there was no storage space at the SAIEE headquarters. Max Clarke had unofficial and gentlemen agreements with many senior managers at these entities to keep these valuable artefacts safe and secure until he had made other arrangements for collection.

Max Clarke, an extremely active member, took the lead and headed up a "historical committee "composed originally of members Dirk Vermeulen, Alan Meyer, Les James and Stan Bridgens.

Later Max recruited other engineers and members who made significant contributions to the cause. It is essential to acknowledge Peter Heim, Arnot Hepburn, Jane Buisson-Street, Oliver Gerondeanos, Richard Dismore and Jerry Kobyzsky.

Max enthused these active members, who later became members of the newly created Historical Section with his vision and passion for creating a museum and library. The so-called "outbuildings" adjacent to Innes House were initially a CSIR simulator facility used to train heavy duty drivers. When the SAIEE acquired Innes House, this double volume simulator room was part of the property transfer.

For years (circa 1990 -1996), Max promoted the renovation and alteration

Stan Bridgens and Janet Hogg

Mike Crouch and Prof Sunil Maharaj

MAX CLARKE
1926 - 2021

Foyer view

Radio room

Mervyn Emss Room

Historical Light Bulbs

Historical Light Bulbs

of the CSIR Simulator to house all the accumulated artefacts without success. However, he managed to secure funds to alter the building and equip it to create a library for all the SAIEE transactions and books. Max arranged to rent a 12-metre shipping container to house some but not all of the accumulated artefacts. This was the brilliance of Max's scheme – it created an eyesore on the property but, more importantly - a firm commitment in perpetuity by the SAIEE to establish a store for electrical artefacts.

In May 2008, Council approved the recommendation of an "SAIEE due diligence workshop" to build a new head office for the SAIEE on the Observatory site. This was after about five years of deliberation!

Max was a very active member of the Building Committee formed to execute the mandate to build a new head office. He thus ensured space was made in the new complex to store the artefacts. This was essential if the eyesore of the shipping container was ever to be removed! In addition, he promoted the concept of displaying renovated artefacts in the vacated Innes House. Max seized the opportunity to realise his vision of displaying the collection of artefacts, and his dream of creating a museum was one step closer.

Max was the leading proponent and activist for restoring Innes House and converting the lower level for display areas. In addition to his contribution to the Building Committee for the new head office, Max worked tirelessly to create a sound library in the outbuildings. Each room has a different theme with appropriate display cabinets.

Max Clarke submitted numerous documents to Council from 2008 to 2011 requesting/motivating funds for becoming a Museum in Innes House, a restorative workshop and a library in the outbuildings.

As the Chairman of the Historical Section, Max managed a small team of dedicated members and non-members of SAIEE to seek, procure, and donate artefacts far and wide. He enthused, encouraged and led many members to create what the SAIEE has today - a unique Museum and Library of electrical engineering in South Africa.

Cummins enables the advancement of female talent

Cummins employees come from diverse backgrounds and experiences and aspire to be workforce representatives at every level of the communities it operates globally. In celebration of International Women's Day (IWD) on 8 March, three female employees from South Africa, Morocco and Nigeria reflect on how having diverse, equitable, and inclusive workplaces allow Cummins to attract and retain a truly global workforce. The IWD 2022 campaign theme is #BreakTheBias: Imagine a gender-equal world.

Cummins has made great strides in the career advancement of females within the company both globally and locally, according to Avonisha Parsotham from South Africa. She is Business Transformation Director – Africa Middle East (AME), responsible for business strategy, quality, and sales functional excellence in the AME region.

"Seeing talented and admirable female employees recognised for their efforts and elevated to roles of senior responsibility makes me feel proudly-Cummins. The various initiatives and affinity groups within Cummins demonstrate the support and dedication the company has to enable our female talent to achieve more," says Avonisha.

Through its corporate responsibility initiatives, Cummins is at the forefront of efforts to uplift and develop female talent both within and outside the company. "I feel in general that across all organisations, there is always a need to provide coaching and mentorship to females at various levels, focusing on career development planning, skills development, and preparation for the next career step. This is how we can build confidence and readiness for talented women to grow their careers successfully," says Avonisha.

Israre Marjan from Morocco joined Cummins as Area Sales Manager within the Filtration Business Unit and then transitioned to Territory Manager within the New and ReCon Parts Business, responsible for North, West, and Central African customers. "Cummins is a great place to work because of its values that resonate with me, one of them being diversity and inclusion," says Israre. Company initiatives include a Women's Employee Resource Group and women's development programmes to build business acumen.

Israre leads by example, significantly to demonstrate to female technicians that nothing is impossible at Cummins. "I started my career as a technician in Morocco, where I was the only female in my class at college. I have often heard that 'There is no job at Cummins that a woman cannot do.' I try to show females starting in traditionally male-dominated roles that this is indeed true."

Avonisha Parsotham, Business Transformation Director

Israre Marjan, Territory Manager, New and ReCon Parts Business

Key to this approach is assessing competencies and skills on their merit and not based on gender. "We need to let women know they can work across various roles and industries, reinforcing their self-confidence and increasing their visibility. Cummins is one of the rare places in Morocco that encourages and supports women in all roles," says Israre.

Doris Okeyide is a Regional Manager (Sales and Services) in Cummins West Africa Ltd. in Nigeria. Her role entails selling Cummins products and services while maintaining a high level of customer service. Before her current role, she was the Workshop Manager in the Rebuild Centre for two years. "I started my career in a male-dominated engineering company. I remained focused and did not allow anyone to look down on me. My advice to women is to be confident in their skills and abilities and not to let others make them doubt themselves. Be diligent in all you do and look out for mentors.

"I believe that Cummins has done amazingly well to achieve gender equality in all regions. Deliberate efforts are in place to bring in more women without compromising on qualifications while giving everyone equal opportunities. In terms of female empowerment, I am glad to see women moving into higher roles, which instils confidence in others." She adds that she has had the privilege of being mentored by female leaders in Cummins, which has broadened her on-the-job knowledge and built her career path. "On a personal level, it has helped me become better in parenting and stronger both at work and in my personal life." wn

Doris Okeyide , Regional Manager (Sales and Services), Cummins

The ReBeL of automation: smart igus cobot

igus is accelerating Low-Cost Automation with the world's first cobot plastic gearbox and a digital ecosystem - 20 projects per week already

Effective immediately, igus offers the ReBeL service robot as an intelligent version. At €4,970 and only around 8 kilogrammes, the plug-and-play variant is one of the lightest cobots on the market. Digital services such as the RBTXpert and new online offerings enable customers to create complete automation solutions that don't break the bank in just a few days.

With the ReBeL, igus relies entirely on its motion plastics expertise: plastic makes the robot, whose net weight is 8.2 kilogrammes, the lightest service robot with cobot function in its class.

Without exception, igus develops and manufactures all mechanical components that make up the ReBeL. Its payload is 2 kilogrammes, and its reach amounts to 664 millimetres. Repeatability is +/-1 millimetre at seven picks per minute. The world's first industrial-grade cobot gearbox is at its core made of plastic. "Behind these numbers are 1,041 tests conducted in our in-house laboratory since 2019, including tribological and thermodynamic tests on 15 material combinations and tolerance chains.

A particularly great challenge was the heat generation in the fully integrated strain wave gear units, thermally influenced by the motor. In the development phase, we also focussed on larger motors and better efficiency to significantly reduce heat generation", says Alexander Mühlens, Head of the Low-Cost Automation Business Unit at igus. "This enabled us to improve continuously and ultimately quintuple the number of cycles to two million, equivalent to a normal service life of two years."

smart plastics - full transparency in operation for preventive maintenance

igus has also applied its motion plastics know-how to power electronics and, for the first time, developed an encoder using conductive plastic tracks. This allows the temperature, current and number of rotations, cycles and iterations to be measured precisely. A dashboard displays all generated data live thanks to a cloud connection with a webcam. This gives customers complete transparency of their ReBeL during operation in the form of critical indicators such as wear, cycle time and quantities.

INEXPENSIVE COMPLETE SOLUTION, QUICK TO INTEGRATE

The smart ReBeL is available in two variants: an open-source version without a robot control system, power supply unit or software for €3,900 for one item; the other is a plug-and-play variant with a robot, control software and power supply unit for €4,970 for one item.

In line with the igus "build or buy" approach, customers can, in addition to the complete system, choose from the individual ReBeL strain wave gears (diameters of 80 and 105 millimetres).

Torque is 3Nm (80) or 25Nm (105) at 6rpm, with a transmission ratio of 50:1.

The ReBeL is available on the RBTX online marketplace. Here, users can find individual components, integration support as well as hardware and software from more than 40 partners - with the assurance that everything is 100% compatible with everything else; this includes a wide variety of robot kinematics, cameras, software, grippers, power electronics, motors, sensors and control systems.

The RBTXpert is available to customers for integration via online consulting with a fixed-price guarantee: In a 400-square-meter customer testing area, experts advise customers daily via live video and send solution proposals within hours. Without integration, typical hardware costs start at €8,500, and complete solutions are available from €12,500.

"We feel that we are making automation even more accessible since we provide advice for more than 20 customer projects per week in Germany alone with our RBTXpert service. Therefore, we are expanding the service, adding ten more online consultants by the end of March. Internationally, the service is already available in seven countries, with another 14 in the pipeline", says Mühlens. "These positive experiences, the many projects implemented, and the numerous customer discussions give rise to an exciting ecosystem of further services."

LOW-COST AUTOMATION UNIVERSE

In this Low-Cost Automation universe, everything revolves around the individual customer application. The goal is to further simplify integration with new offerings and business models.

"We will provide an app store where Low-Cost Automation vendors and free software developers can contribute their software ideas. By leveraging existing software, users can implement their automation even faster. They can connect the robots to digital services such as IFTTT or smart assistants like Alexa or Siri.

Visitors can then engage in ordering their favourite coffee in a coffee bar by voice, which the robot then serves. This gives rise to entirely new business models, such as pay-per-pick, where users don't pay for the robot but only for its services. These new capabilities will permanently change the robotics market, and everyday life with it", says Mühlens. "We want to give them a home in the Low-Cost Automation universe." wn

PCI'S Wastewater Plant Expansion Relies on WEG Motors

Water purification specialist PCI Africa has expanded the treatment capacity of a wastewater plant south of Johannesburg, installing over 65 WEG motors for optimal performance, reliability and energy efficiency.

The project involved the addition of an extra module to the existing wastewater treatment plant, allowing it to treat another 50,000 cubic metres of water each day. Ongoing urban migration and development in the area demand that the region's wastewater treatment facilities continue to increase their capacity.

According to Lebo Rathebe, proposals manager at PCI Africa, the mechanical portion of the contract included the inlet works, 25-metre diameter primary settling tanks (PSTs), a biological reactor, secondary settling tanks and dewatering facilities.

"We added a sixth module to the plant, which included the installation of two screw pumps to feed the PSTs, with four front rake screens and hydro-conveyors," says Rathebe. "The PSTs were fitted with 30-metre long half-bridges and two recycle pumps per tank."

He explains that the new module treats water using a three-stage process for the biological removal of nitrogen and phosphorous. Influent – the incoming stream to the plant – first enters an anaerobic reactor before reaching an anoxic and aerobic reactor.

"Recycle pumps transfer part of the stream from the anoxic reactor back to the anaerobic reactor to preserve microbiological matter and keep the solution homogenous," he says. "There are also recycle pumps to move some of the streams from the aerobic reactor to the anoxic reactor."

The WEG W22 motors, supplied by Zest WEG for this project, mainly power the numerous pumps on the site and the mixers and agitators, says Dillon Govender, Zest WEG's sector specialist for public sector business development.

The motors on this site range mainly from 30 kW to 90 kW flange-mounted units and include pad foot-mounted motors from 1,5 kW to 37 kW.

"WEG motors are installed in all major processes, from screening, de-gritting, primary settling biological nutrient removal reactors, secondary settling and waste sludge thickening up to dewatering," says Govender. "Our role in this project demonstrates our growing contribution to South Africa's wastewater sector and the continent generally."

In this project, WEG motors also drive the pumps for return activated sludge and waste activated sludge. He highlights the demanding nature of wastewater applications, given the high levels of corrosion that can occur if the equipment is not suitably designed and manufactured.

"The Class H insulation on these WEG motors enhances their durability and lifespan, allowing them to withstand a higher temperature rise," he says. "The


A water recycling installation driven by WEG motors.

contract also specified including anti-condensation heaters for all motors of 4 kW and above. Our motors on-site also boast paint plan 212P and IP66 ingress protection to help keep them free of moisture or dust."

With the rising cost of electricity, it was vital for the motors to run at high efficiencies to control the plant's operating costs. Zest WEG supplied its IE3 top premium efficiency motors to satisfy the client's specifications and ensure the owner achieves the lowest cost of ownership. Govender notes that Zest WEG also offers IE4 motors, the next efficiency level.

Rathebe emphasises the advantage of having Zest WEG supply almost all the motors on the project, making life easier for both the contractor and the end-user.

"In terms of an ongoing operation, the plant owner can economise on the spares they carry and be assured of responsive after-sales support," he says. "As the contractor executing this project, it was easier for us to have one source of responsibility when dealing with the supplier." Govender concludes that the quality, robustness, and efficiency of WEG motors allow Zest WEG to offer a five-year guarantee, giving customers value for money and peace of mind that unexpected stoppages will not disrupt operations. wn


A return activated sludge pump station with power provided by WEG motors.

Marthinusen & Coutts' fault finding and redesign rectify synchronous motor vibration problem

In early-2020, a prominent South African petrochemical company asked Marthinusen & Coutts (M&C) to establish the cause of excessive vibration in a 17MW 11kV 4-pole synchronous motor that is used to drive a gas compressor.

By Rob Melaia
Engineering & Technical Executive
Marthinusen & Coutts

The motor, designed and manufactured by a reputable Europe-based OEM, had been in operation for 13 years. No vibration problems had occurred in the early stages of its operation but first became noticeable about five years ago and deteriorated in subsequent years. Eventually, it became so severe that the motor could no longer be used and was sent to M&C for investigation and repair.

RESONANCE ANOMALY

The investigation started with several non-destructive tests, but these failed to indicate the cause of the problem.

Subsequent investigations, however, showed a resonance anomaly, as the motor's resonance frequency was found through specialised resonance test procedures to be extremely close to the motor's operating speed, even to the extent of impinging into that range at times – depending on ambient conditions.

The motor's originally intended speed range was 1200 to 1500rpm, whereas the resonance frequency reading was between 1200 and 1300rpm. This clearly could not have been the intention of the OEM at the time of manufacture, as the resonance frequency of a motor is required to be well clear of its operating speed. In addition, the resonance frequency is supposed to be higher than the motor's rated speed, which would mean around 1800rpm or more.

While conducting the investigations and tests that revealed the abovementioned irregularity in the motor's resonance frequency against its operating speed, M&C also identified during testing a looseness of the stator core supports to the main stator enclosure, which was not supposed to be present in a healthy motor.

The next step the M&C team took was to remove the inspection covers of the motor for a close examination of the stator and its support structure to the main enclosure. A fundamental discovery was finding that the OEM had applied a highly unorthodox method of

fixing the stator to the mainframe. Instead of following the standard procedure of employing a heat-shrink interference fit to bond the complete outer diameter of the stator to the frame, they used about eight small welded brackets.

We deduced that the OEM, having discovered that the required resonance frequency could not be achieved if the stator was firmly fixed to the frame in the usual way. Instead, we installed the brackets as a more flexible way to change the resonance frequency to ensure that it would not coincide with the motor's rated speed. The applied measure failed to fix the resonance frequency higher than the motor's speed range. Still, it at least achieved the necessary objective of fixing sufficiently below the rated speed not to cause operational problems.

The motor was fortunately never operated under its originally intended variable speed capability.

MACHINE DESIGN FAULT

We deduced that the OEM failed to achieve the desired resonance frequency using the proper fixing procedure due to a design flaw in the motor. However, the method the OEM adopted to circumvent this problem revealed its shortcomings over time.

During our investigations into the problem, an additional discovery was that there were cracks in the support structure between the stator and the mainframe.

We deduced that the cracks in the support structure – which, as stated above, consisted of the small welded brackets used as an improvised solution to address the resonance problem the OEM had encountered during manufacture – had been caused by the welds of the brackets having been subjected to excessive strain during years of operation.

We then carried out the necessary repairs to return the motor to service. These had to be done with the customer's express permission since they were, of necessity, a compromise – as was the case with the original manufacture of the motor.

We welded up new sections on the stator support structure because we couldn't access many of the cracked sections to weld them.

After re-assembling the motor, we verified that the vibration had substantially improved but that the resonance frequency was very close to the rated speed due to the increased stiffness we had added to the structure.

On our test base, we proved that with the resonance located lower than running speed, no problems would occur on-site since the site base is more flexible than our test base.

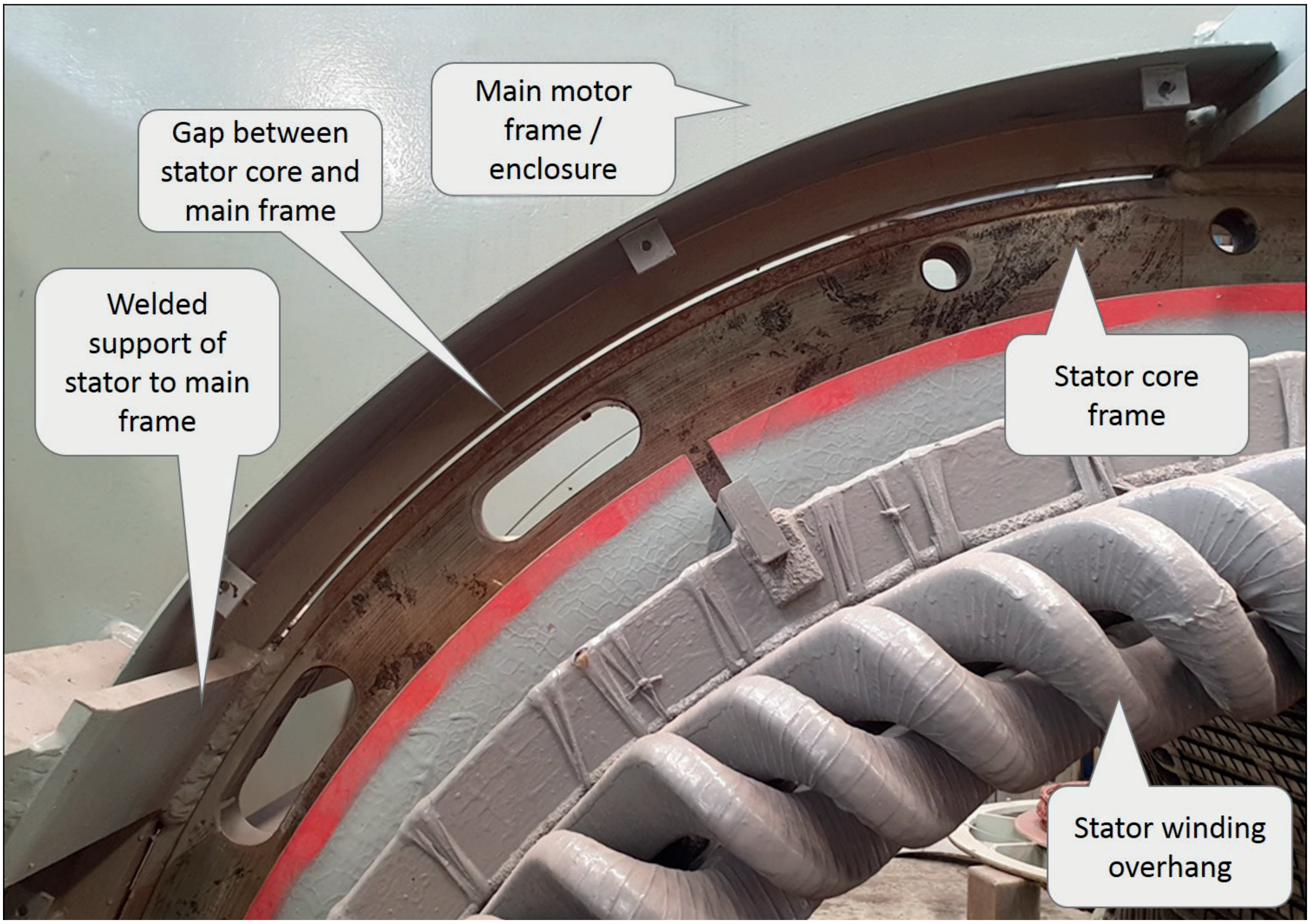
OFFBEAT ADD-ON SOLUTION

The client asked if any further measures could be taken to assure a full guarantee of successful operation the first time on site. Our response was to offer a thoroughly offbeat add-on solution, which enabled us to provide the assurance the client sought when tested and proven practical. This being a compromise solution, we could not provide a 100% guarantee of reliability on the work done.

The add-on solution provided a made-to-measure removable 7.5t mass of steel temporarily fitted onto the top of the motor. This mass further reduced the motor's vibration and lowered its resonance frequency by a small but sufficient margin to guarantee correct operation on site. It was made removable because the customer wanted first to try running the motor without this additional measure.

The success of all this work was proven when the motor was put into service after an unplanned breakdown. It operated with lower vibrations than it had for over a decade – and this without the 7.5t mass added! wn

For more information, visit www.mandc.co.za



Main motor frame / enclosure
Gap between stator core and main frame
Welded support of stator to main frame
Stator core frame
Stator winding overhang

Predictive Maintenance of Rotating Equipment - The Way Forward

Rotating equipment is used across industries and is mission-critical in manufacturing. From compressors to pumps to motors, plant profitability revolves around equipment productivity. Reliability is essential. To ensure reliability, operators of rotating equipment seek to keep factors like alignment and balance at peak potential.

While this legacy equipment is built to withstand considerable pressure forces, constant stress on machinery components poses a constant threat of failure and downtime. Rotating equipment users employ condition monitoring strategies to observe the health of machinery components and keep unexpected breakdowns to a minimum by making repairs or replacements before failure occurs.

The next generation of condition monitoring goes beyond 'preventing' failures to 'predicting' failures. Predictive maintenance strategies take advantage of modern sensor technology combined with artificial intelligence technology to offer the user unprecedented insight and predictive analysis.

A holistic predictive maintenance implementation with root cause identification gives the operator a complete picture of the entire system - allowing a deeper level of prediction and analysis that can save on exponential levels of potential financial losses. This shift in thinking from capital and investment to operation and service (CAPEX to OPEX) defines the modern era of manufacturing technology.

The realisation that service and maintenance in the life of rotating equipment contain far more value than initial capital investment has prompted the emergence of the subscription or Equipment-as-a-Service (EaaS) model.

EaaS promises to revolutionise the industrial landscape and empower the users of rotating equipment by externalising the risks and costs around equipment service to specialists.

MAINTENANCE AND SERVICE CHALLENGES OF ROTATING EQUIPMENT

Reliability is the ultimate goal of keeping rotating machinery at peak production, but ensuring reliability is a constant challenge for many reasons. Considering the scope of pressure points and torsional stress points involved at every connection of rotating equipment, it comes as little surprise that proper maintenance is a priority in keeping runtimes steady and uninterrupted.

With high pressure and intense rotational power at the core of these technologies, stress points are focused on the seals, belts, brakes and bearings that connect the moving parts of a rotating machinery asset.

Firstly, maintaining alignment is crucial for collinear shafts to ensure minimal stress on bearings, couplings, shafts and other machine components. Angular misalignment of just 0.08 of a degree (or more) has been shown to cut the life of a bearing in half. Laser alignment is employed to keep misalignment as low as possible. Keeping the cyclical forces on bearings, shafts and equipment structure under control requires maintaining a balanced standard such as ISO 21940-11 (rotor balancing). If a rotor is out of balance (or falling out of balance), it will impose high strain levels on bearings and severely diminish their lifespan. Unbalance can be measured (and corrected) by looking at vibration data from sensors attached to the bearing locations.

By comparing "natural" frequencies with "unbalanced" frequencies, data from these sensors can be continually monitored (condition monitoring) to signal any balance changes that would otherwise be amplified by resonance and potentially lead to further stress problems. To keep resistance minimal, bearings and gears in rotating equipment require appropriate and continual lubrication.

Studies show that mistakes in cleaning, tightening and lubrication are the root cause for some 70% of mechanical failures in rotating machinery.

Dirt, oil and debris in oil sumps and bearings are frequently the cause of premature failure. Bearing life can be maximised by proper lubrication and assuring that lubricants are free of contaminants and have the correct viscosity.

Improper lubrication is frequently identified as a root cause of mechanical failure in rotating equipment. Distressed connections can also be identified via the correct implementation of temperature and shock sensors. Temperature, vibration and shock measurements from IIoT sensors delivered to cloud interfaces can be analysed and identified by machine operators using AI analysis. The more sophisticated the system, the earlier potential problem areas can be isolated and corrected before more costly damage occurs.

CONDITION MONITORING IN ROTATING MACHINERY MAINTENANCE

Early warning systems are essential in rotating equipment to escape cascading damage chains that lead to exponential damage, repair costs, and failure. Maximising efficiencies while minimising downtimes is the name of the game. Condition monitoring and its skilful application make the difference between maximum productivity and extensive downtime. Identifying mechanical faults is a constant challenge for operators of rotating machinery such as engines, motors, turbines, pumps, conveyors, compressors, gearboxes and the like. Experts say most faults are detectable, though the appropriate sensor technology and IIoT interface are not permanently installed.

Having the right condition monitoring system in place with the right digital solution (AI) gives operators the tools to identify the root causes of mechanical failure and boost reliability to its highest

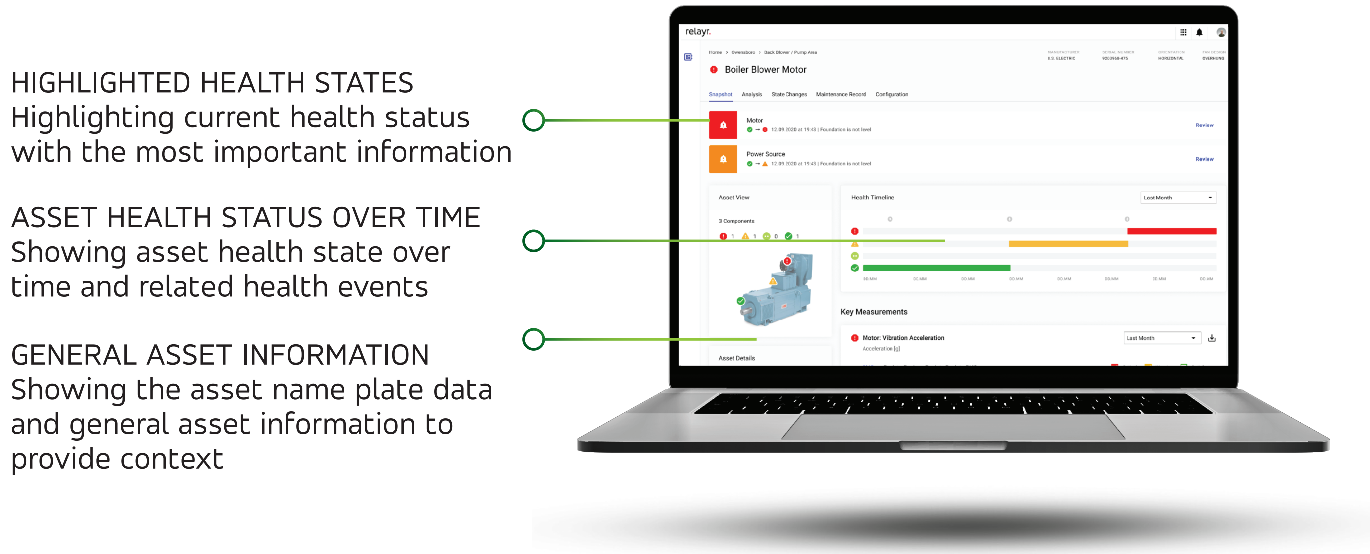


FIGURE 1: Condition Monitoring Example.

possible level. Root causes of failure can be identified with sufficiently advanced condition monitoring, whether they be factors of misalignment, unbalance, under lubrication, looseness, etc. Early warning with condition monitoring and eliminating root causes can ensure users of rotational equipment the longest possible life and value on their initial investment (ROI).

CONDITION MONITORING EXAMPLE

Condition monitoring facilitates a remote review of the assets' health status. It also enables a clear view of the sensor readings associated with the health status. See Figure 1.

THE THREE MODES OF MAINTENANCE

The necessity of maintenance is unassailable in keeping equipment running as long and as uninterrupted as possible. There are three important strategies or philosophies for maintaining equipment assets within the industrial equipment sphere.

These three approaches to maintenance can be categorised into these modes: reactive, preventative, and predictive. See Figure 2.

REACTIVE MAINTENANCE is the 'strategy of reaction' or deciding to repair or replace a part only after it has broken or become worn down to failure. Reactive maintenance is perhaps the most basic mode of maintenance.

It can technically require the least amount of work with the highest utilisation, all other things being equal. Maintaining by reacting to problems as they arise can create new externalities that become more costly. Unexpected breakdowns created by parts breaking, overheating, or vibrating can cause damage to other equipment parts.

Furthermore, unexpected downtimes that stop production can create cascading financial losses that could have been avoided with a more holistic maintenance strategy. Finally, this strategy often leads to service providers focusing on fixing symptoms rather than addressing the core problem. This can mean that a part is repeatedly replaced or repaired after being worn down when the root cause of its wear could have been identified and managed before the endless repair loop even began.

PREVENTIVE MAINTENANCE (also sometimes known as 'planned maintenance') describes the strategy of implementing scheduled service tasks over a defined period while the equipment is still in regular operation to avoid unexpected part breakdowns (and their extra costs) in future operations over the lifetime of a piece of equipment. In this model, equipment assets are temporarily taken off-line at predefined time intervals where maintenance and replacement tasks are carried out.

The main intention of a preventive maintenance strategy is the avoidance of unexpected downtimes and breakdowns to extend the lifetime of an asset while also increasing its productivity and efficiency. Filters are changed, seals are replaced, lubrication is applied, etc. at regular time intervals regardless of the actual state of
the component.

Preventive maintenance models are designed to keep parts that break down from reaching the point of failure and avoid costlier and potentially wider-reaching replacement costs.

FIGURE 2: The three modes of Maintenance.

Studies show that preventive strategies can provide cost savings of 12-18% on average compared to reactive strategies. In this sense, preventive maintenance is more cost-effective than reactive maintenance. However, it can sometimes be more challenging to justify to management as the initial costs of regular part replacement can exceed replacement costs if parts are only replaced when they fail. Preventive maintenance is also based on the theoretical rate of failure rather than real-life equipment performance, meaning that parts may be replaced prematurely, i.e. when they have plenty of utility and production power left. Planned downtimes can also create extra costs in production loss compared to the irregular downtimes of reactive maintenance.

PREDICTIVE MAINTENANCE (PdM) is one of the newest iterations of maintenance strategy, given its reliance on modern digital technology methods and IIoT implementation. And yet it is one of the fastest-growing modes of maintenance strategy, given its long-term financial benefits. This mode of maintenance utilises the advancements of modern analysis (AI) derived from data provided by implemented sensors and historical data.

By actively monitoring the performance of equipment and its many parts with comparative analytics, equipment managers can make predictions about when and where an asset will fail, thus allowing service professionals to take steps to correct an issue before it reaches the point of failure. When properly implemented, predictive maintenance strategies are superior to reactive and preventive strategies in that equipment is neither run to failure (as in the former) nor are parts unnecessarily replaced (as in the latter).

Ideally, a smart predictive maintenance implementation will allow companies to make maintenance operations at the opportune time, not too early (thus wasting parts) or too late (missing root causes). A data-forward model of predictive maintenance enables a holistic overview of interconnected technologies and assets rather than a fragmented one where symptoms are repaired instead of addressing core problems. Studies have shown average cost savings of 8-12% in predictive strategies compared to preventive ones. However, there is plenty of evidence that the upside advantages are even greater when considered over the entire lifecycle of a piece of equipment, especially in combination with an EaaS model.

Upfront investment in a well-orchestrated predictive maintenance strategy is probably the most significant barrier for companies to overcome in justifying a move to predictive methods. The costs of implementing the correct technology and training employees can dissuade some companies from considering the long-term advantages that pay back the initial investment many times over. Yet, the numbers are convincing. Independent industry studies have shown that average predictive versus preventive implementation savings are considerable.

The US Department of Energy report on "Achieving Operational Efficiency" has revealed that average ROI is up to 10 times higher in predictive versus preventive measures. Reduction in maintenance costs ranges from 25-30% higher. Elimination of breakdowns is especially impressive at 70-75% higher than preventive strategies. Downtimes are reduced by 35-45%, and production levels are increased by 20-25% using predictive methods and technologies rather than preventive ones.

An initial investment in IIoT and digital solutions can be relatively easy to justify when the long term savings in damage avoidance and minimised replacement costs are considered.

IIoT solutions that can be applied to rotating equipment, depending on the requirement, include vibration measurement, temperature measurement, ultrasonic testing, power quality measurement, oil sampling, torque monitoring using strain gage technology, thermal imaging cameras and laser alignment equipment (among many others).

HOLISTIC SYSTEM MAINTENANCE IN ROTATING MACHINERY

As opposed to an individualistic and fragmented maintenance solution, systems experts recommend users of rotating equipment seek to create holistic service systems that enable maintenance staff to find root causes earlier and with better precision. For instance, in a pump system used in a hydrocarbon processing plant, a wide range of complex, interconnected assets need to be considered for interdependencies rather than their singular function alone.

A pump system, for one example, is operated via numerous interlinking components, including elements such as pipework, impellers, pipe seals and valves, all of which depend on each other to function correctly and reliably. Depending on the installation, adverse effects such as high temperatures and thermal expansion in one part can lead to rippling damage effects in other parts. Mechanical reliability in rotating machinery can be best ensured by providing operators with a complete overview of the entire system and allowing users to identify potential problem areas before they develop into more severe problems. Sometimes, a combination of planned and predictive maintenance in such systems is the best configuration whereby essential components are continually replaced. In contrast, longer-life components can be submitted to long-term analysis via sensors and IIoT installations.

The advantage of a holistic predictive maintenance solution is in its custom application. Individual components are assessed for their value in the entire production chain, and sensors are applied accordingly.

A holistic approach has been shown to ensure the maximum potential for early warning analysis and root cause identification in rotary equipment systems.

IIOT-BASED CONDITION MONITORING FOR AIR COMPRESSORS

Air compressors are one of the most commonly used pieces of industrial machinery. They can be found in nearly every industrial sector, particularly in the oil, gas, chemical and petrochemical industries, where reciprocating air compressors are commonplace. Such compressors often need to stay in operation around the clock without interruption, so efficiency and maximum uptime are paramount. Unexpected breakdowns can be disastrous, creating rippling financial and production losses and potential environmental damage and plant safety issues. In some scenarios, machine malfunctions have even been known to destroy entire machine trains.

Any potential fault in a piece of equipment needs to be detected and identified as early as possible, thereby minimising any downtime and consequential revenue loss.

The operators of air compressors can rely on condition monitoring implementation to have continual status updates of the health of compressor components and, even more importantly, isolate and predict problem areas before they turn into a breakdown. A typical reciprocating air compressor has several interconnecting parts where breakdowns are most likely to occur, including the bull gear, pinion gear, thrust bearing, thrust collars and compressor stage. Considering the range of applications involving air compressors, the demands placed on their components differ widely from plant to plant.

But nearly every application involves high-pressure levels with multiple points of potential failure. Possible disruptions, faults or failures include split shafts, misalignments, roller bearing damage, cracked blades and cavitation. Such areas include the bearing house and the foundation bed of the compressor or pump, but the sensors can be placed virtually anywhere they are required.

IIoT sensors placed throughout the compressor can measure vibration, temperature, noise, magnetic fields or any other relevant metric on these components. Sensors can be mounted anywhere that operating parameters like vibration or temperature will be fluctuating.

In a typical example, a MEMS accelerometer sensor to measure vibration might be placed near a pressure point on the compressor. The sensor would be linked to a central gateway (often by wireless internet connection) that coordinates data gathering from every other sensor on the compressor. Sophisticated data analysis of these

vibration waveforms and comparison to ‘normal’ wave patterns allow the AI software to identify any problematic variations in vibration measurements on the broader condition monitoring system. A predictive maintenance alert would then notify operators about a potential area of concern, allowing a component to be inspected, repaired or replaced before the failure occurs, thus avoiding a costly breakdown and keeping operations at peak performance.

IIOT-BASED CONDITION MONITORING FOR ELECTRIC MOTORS

Motors and engines are at the core of the industrial production chain. Given their role in power generation, they are at the heart of reliable machinery operation. Manufacturers who need their motors in continual operation with minimum downtime are increasingly moving from preventative maintenance to predictive maintenance solutions with IIoT sensors and artificial intelligence analysis.

Industry surveys show that over 90% of rotating machinery
in industrial and commercial applications use rolling-element bearings, and in cases of electric motors, the majority of failure incidents (41%) occur at the bearings.

The other central problem area in motor failure is the stator, the element that creates the magnetic field driving the rotating armature in the motor. After bearing failure, malfunction in the stator is the most significant cause of motor breakdown, with 27% of failures at stator insulation and another 10% of failures defined as ‘other’ stator faults. Predictive maintenance (PdM) solutions are crucial to monitoring motor components’ health and maximising the lifespan of an industrial motor.

Modern industrial motors are designed to work for up to 20 years in constant operation. However, they often fail to run through an expected lifecycle for several reasons, many with improper or ill-timed maintenance. Lack of investment in proper PdM implementation, in many cases, can be blamed for premature motor failure. IIoT sensors deployed correctly in a motor PdM system allow early prediction of machine faults.

They can help operators repair motor inefficiencies that will ultimately boost the motor’s overall performance, productivity, asset availability, and lifetime. Systems experts agree that the ideal PdM implementation efficiently uses as many sensors and methods as possible to analyse a motor’s potential fault areas from as many angles as possible.

There is a multitude of sensors available to measure motor parameters. Still, a few of them include Piezo and MEMS accelerometers to measure vibration, ultrasonic microphones to measure sound pressure, shunt sensors to measure current, magnetometers to measure the magnetic field, and RTD sensors to measure temperature and particle sensors to measure oil quality. This array of measurements, when routed through a gateway, this array of measurements analysed by a predictive algorithm and displayed on a user interface. It is a powerful overview of motor health and potential problem areas, allowing early failure prediction and maximum operational efficiency.

SERVICE STRATEGIES WITH DIGITAL TRANSFORMATION AND EAAS

Maintenance schemes in rotating machinery have continually evolved over the decades from the beginning of the industrial revolution to today’s modern digital era. Owners and operators of rotating equipment, be it engines, generators, pumps, compressors, gearboxes, conveyors, or any other machine with rotating parts, have continually reconsidered the technology at their disposal to ensure that their equipment operates at maximum capacity with minimum downtime. Maintenance plans have thus, understandably, moved from reactive to preventive to predictive or perhaps some hybrid combination of these three schools of thought.

Asset managers have come to realise that costs over the lifecycle of a piece of machinery weighs heavily to the side of operation and service costs rather than the initial cost of the equipment itself, roughly speaking at a ratio of 20:80 with the majority side in service, depending on the machinery and its expected lifespan.

With this growing emphasis on the service and maintenance side of equipment operation, machinery operators have seen an entirely new economy guarantee uptime and provide new analytical services for their clients. These services can be ideally provided by modern data analysis (aided by AI and machine learning) that exploits the data gathered along with the IIoT/sensor array of a particular equipment setup. With data now at the core of maintenance considerations, the operation has superseded ownership as an essential element in a rotating machinery system’s value and financial longevity.

In recent years, a new model has emerged that has seen adoption accelerate year on year. As such, the service package around a piece of equipment now holds more value than the physical cost of the asset itself. This shift from ownership to operation (as part of the movement shorthand “Industry 4.0”) is sometimes described as a shift in focus on expenditures from capital (CAPEX) to operating (OPEX).

This new service model is alternately known as Equipment-as-a-Service (Eaas) or subscription model. OEMs who see the benefits and unlocked value in EaaS have been able to externalise costs around service, maintenance, operations, finance, warranties and invoicing (among other areas) and offer a new range of previously unavailable services to their clients.

Both manufacturers and users of rotating equipment are utilising IIoT implementation combined with digital solutions (such as system interfaces and operational analysis) to maximise uptime and minimise failure rates in their machinery operations.

The subscription model for rotating equipment has much to recommend it. Early adopters of this holistic equipment strategy find that the digital services they can offer their clients provide them both a competitive market edge. New revenue streams as the data-derived insights from their customised digital solutions make them more attractive to a growing client base.

The pay-per-use model and its consultative approach allow an unprecedented level of flexibility for all parties involved in rotating equipment, whether they be manufacturers, users, or service professionals.

ONE-STOP SHOP

As Equipment-as-a-Service models gain critical mass in manufacturing, there is no doubt that digital transformation becomes a stepping stone to success. When adopting digital technologies, it's best to find great technological solutions. In other words, the business should drive the technology and not vice versa.

Adopting a holistic approach that encompasses business strategy, leadership commitment, talent, and strong partnerships, paves the way for a successful transformation of the entire business model. wn

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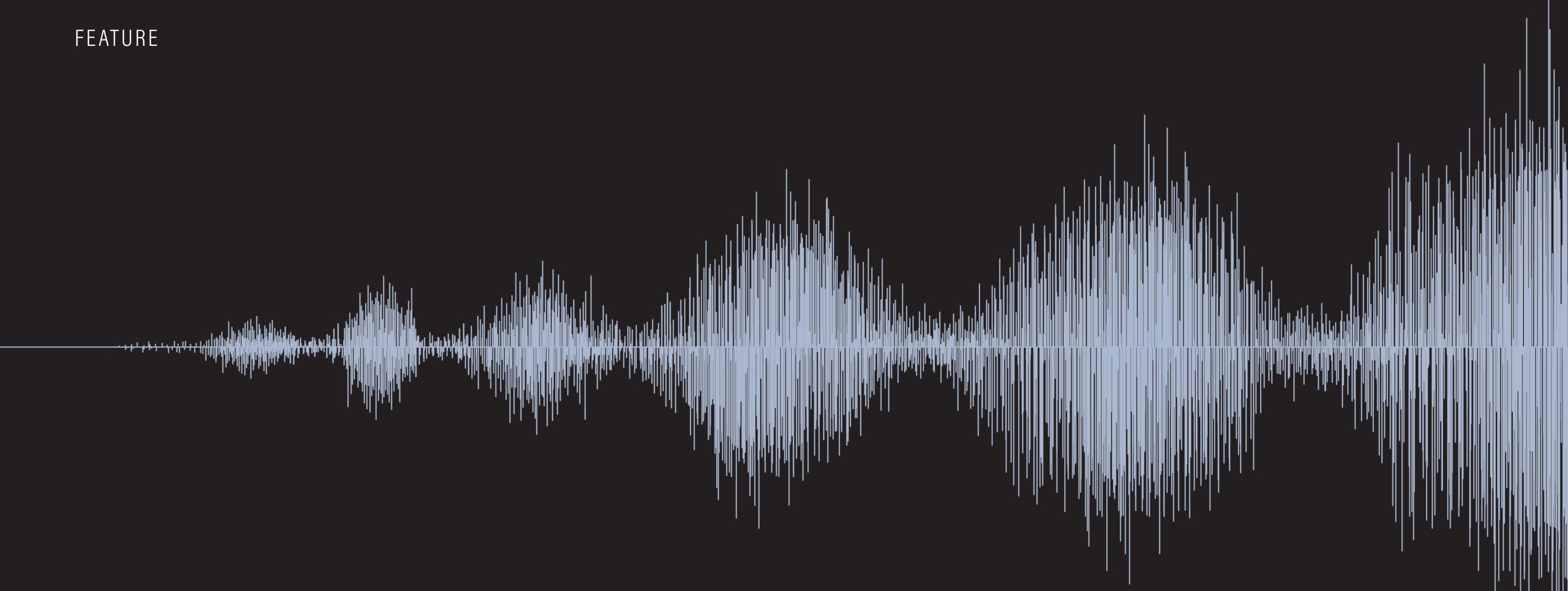


6 Common Equipment Failures Vibration Sensors

Condition monitoring is a process where equipment is monitored for early signs of deterioration to better plan maintenance activity, reducing downtime and costs. This is particularly important in continuous process and manufacturing plants, where failure and downtime can be extremely costly. The monitoring of vibration, temperature, voltage or current is most common.

Vibration is the most widely used measurement for condition monitoring and can be used to identify several faults in rotating machinery (see below).

Vibration monitoring can detect and diagnose problems and potentially give a prognosis, i.e. the remaining useful life and possible failure mode of the machine. However, the prognosis is much more complex. It often relies on the continued monitoring of the fault to determine a suitable time when the equipment can be taken out of service or on known experience with similar problems.

This paper introduces the type of problems your machinery can exhibit and reviews the basic measurements you can make to identify these trends. When monitoring these measurements over time, you can identify and prioritize machines showing signs of potential failure and schedule your maintenance crews appropriately.

6 COMMON FAILURES IN MACHINERY

Several conditions can arise in rotating machinery that, if left unchecked, can lead to breakdowns or catastrophic damage. Some of the most common are:

- Bearing Defects - Wear and tear on bearings such as abrasion, pressure damage, corrosion, and electrical damage (fluting)
- Cavitation - Cavities (air bubbles) form in the liquid inside of a pressurized pump, causing imbalances between suction and impeller sections
- Gear Wear - Removal or displacing material on the surface of gear teeth due to mechanical, chemical, or electrical action. Misalignment or insufficient lubrication can lead to abrasion, adhesion, or polishing effects and damage
- Misalignment - Misalignment of shaft centre lines between driver and machines are not aligned in the vertical or horizontal planes
- Structural Resonance - Excessive vibration of machine base or supporting structure
- Unbalance - Uneven distribution of mass around a rotating axis commonly caused by the build of

you can Detect with Wireless

foreign matter, broken blades or missing fasteners.

COMMON VIBRATION MEASUREMENTS TO IDENTIFY POTENTIAL FAILURES

The Swift Sensors Predictive Vibration Sensor measures Vpeak-to-peak, VRMS, and Crest Factor. These measurements provide insight into many of the failure conditions listed above from just a few basic measurements of vibration waveform characteristics. See Figure 1.

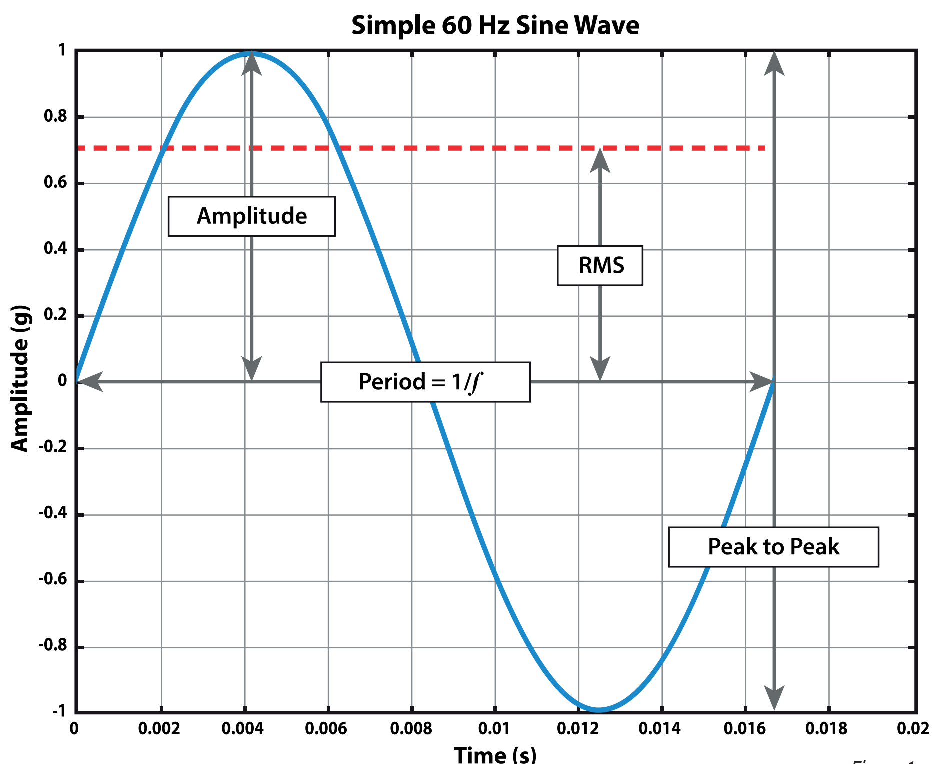


Figure 1

- The peak-to-peak value measures the signal's overall positive and negative displacement (Amplitude). This is valuable for shock events, but it doesn't take into account the time duration and thus the energy in the event
- The RMS (root mean square) value is generally more helpful because it is directly related to the vibration profile's energy content and thus the vibration's destructive capability. RMS also takes into account the time history of the waveform.
- The crest factor is a ratio between the Amplitude (peak) of the signal and the RMS value for the signal. This indicates the "spike-i-iness" of the signal: the higher the Crest Factor, the more abrupt or violent the vibration.

The blue signal is a smooth, relatively flat sine wave if you compare the two signals below. The crest factor is low for this signal (the peak voltage and RMS are similar, giving a factor in the range of 1.5). The red signal has a much higher peak but a similar calculated RMS value. The Crest Factor for this signal will be much higher (perhaps in the range of 5). This illustrates the importance of the individual peak-to-peak and RMS measurements and the combined crest factor measurement in vibration analysis. See Figure 2.

When applied to an actual vibration signal, you might see a rising trend in these measurements over time that suggests potential problems.

Setting thresholds on crest factor or Vpeak-to-peak can trigger notifications for further investigation, applying to regulations, and enhancing their business performance. See Figure 3.

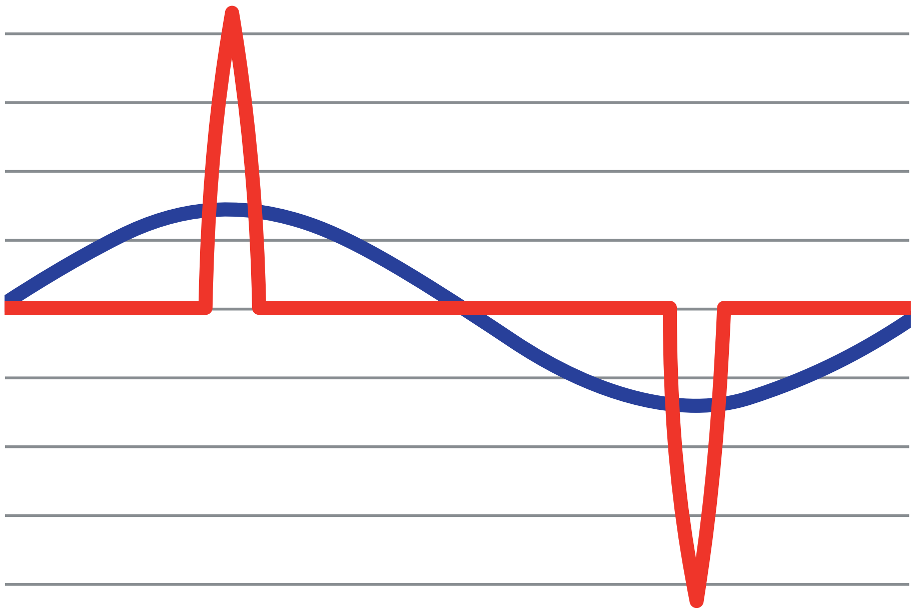


Figure 2

VIBRATION IS ONLY THE BEGINNING

Vibration is the most common measurement used in predictive maintenance for rotating machinery, but there are many other remote measurements you can make to monitor the condition of your equipment:

TEMPERATURE: For checking refrigeration, freezers, and coolers storing valuable perishable inventory in food processing, laboratories and pharmacies, and restaurants. Industrial machinery may also show wear and pending failure through friction-induced temperature increases.

PRESSURE/FLOW: Pumping systems, injection machines, extruders, and painting/coating process equipment can show rapid changes or slow degradation in pressure or flow rate that indicates trouble.

VOLTAGE/CURRENT: Measuring the voltage or current levels in power sources provided for your equipment can indicate the efficiency and reliability of your power distribution system.

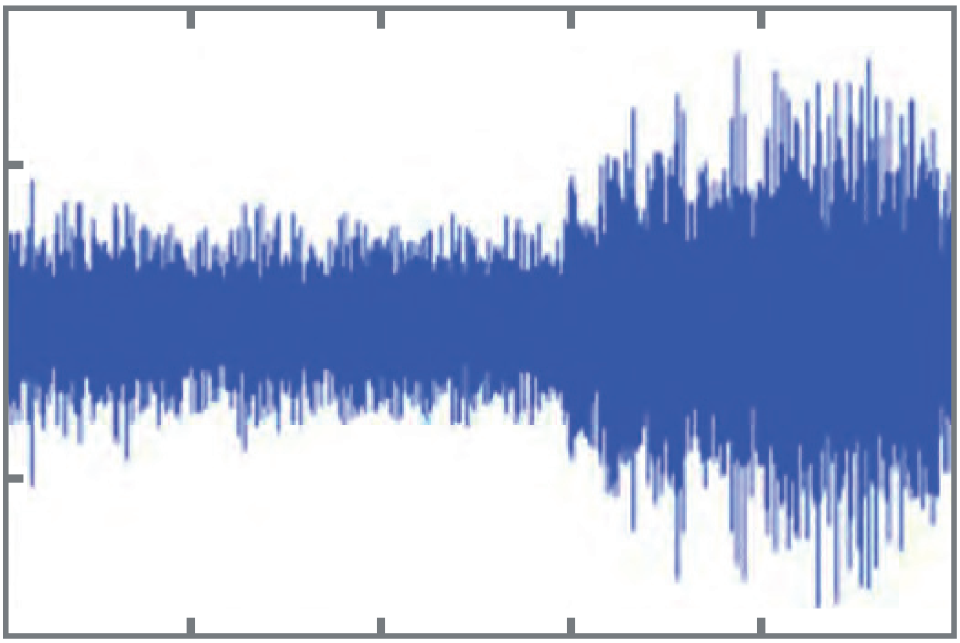
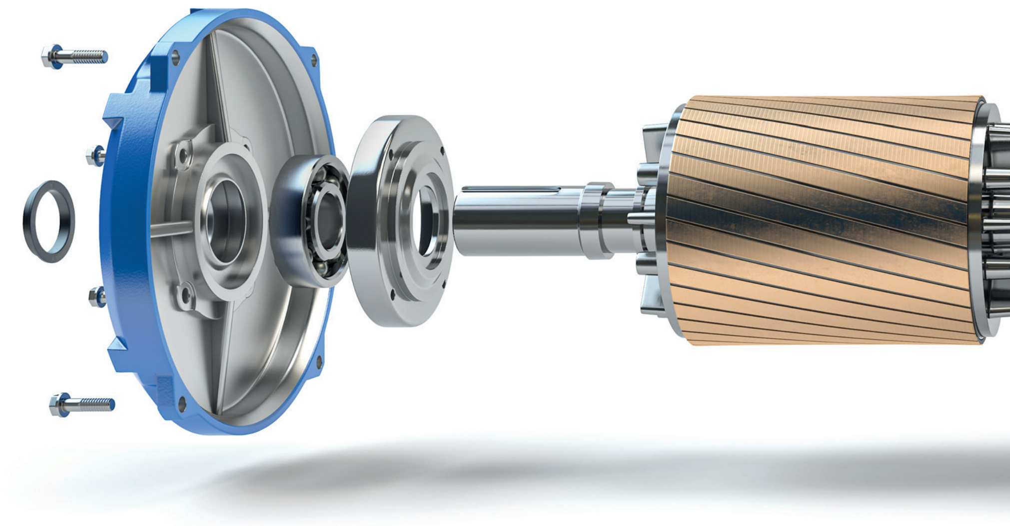


Figure 3

COUNTER/TIMERS: Digital counters can measure the rotating speed of various components in your
equipment, giving you an indication of the health and efficiency of these devices.

CONTACT/SWITCHES: Dry Contact sensors can determine the open/close state of switches or activators within your equipment to determine if it is running or not for efficiency and yield measurements. wn

Induction Motor Rotor Testing



How often do you experience induction motor rotor problems? Because squirrel cage motor can operate with a problem such as broken rotor bars, shorted laminations, and mechanical (misalignment or imbalance.), it can cause catastrophic damage.

By Hendry du Preez

General Electric in the USA did some failure investigations and found that rotor failure, based on research in 1980, accounted for 10% of motor failures.

What are the most catastrophic rotor defects? The first thing that comes to mind is broken rotor bars. Induction motors can operate with broken rotor bars. The operation is not up to standard, and the starting could be seriously affected.

The same defect in two identical motors can act completely different when placed in separate applications.

The defects in the rotor can and are often invisible to the naked eye yet can be catastrophic to the motor.

There are many different designs for induction (squirrel cage) motor rotors, including Copper bar cages, double cage rotors (copper and brass cages), and die-cast aluminium cages with or without the centre rotor cast end-rings, aluminium Bar rotors. Some rotors may have skewed rotor bars, or half the rotor bars off set half a slot pitch. The shorting rings at the end or in the centre of the core are commonly referred to as end rings.

MOTOR ROTOR FAILURES

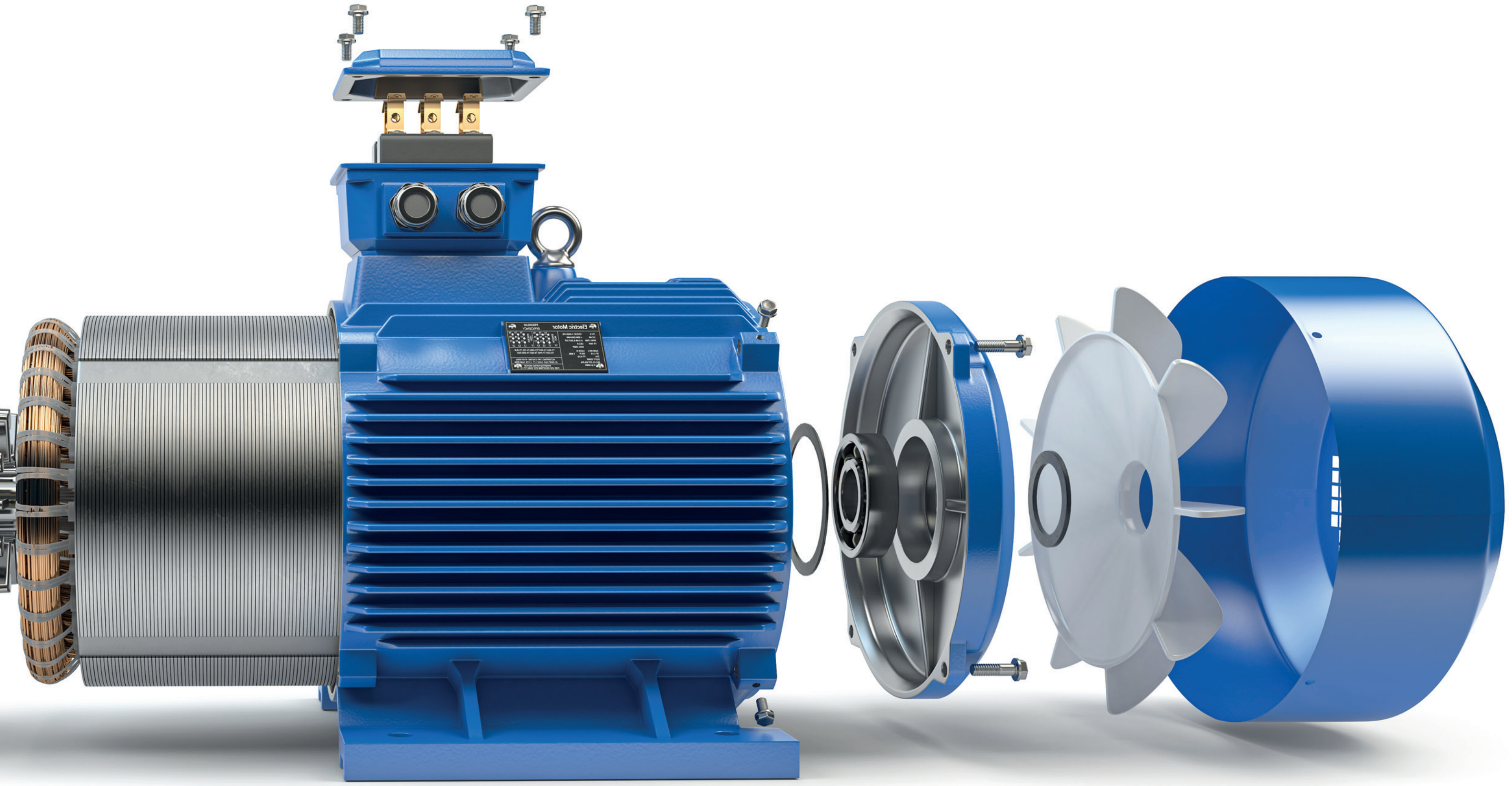
Induction motors can operate with one or more fractured bars. The performance will be impaired. Starting could be sluggish etc. the danger here is if the bar lifts, it could damage the stator and stator winding.

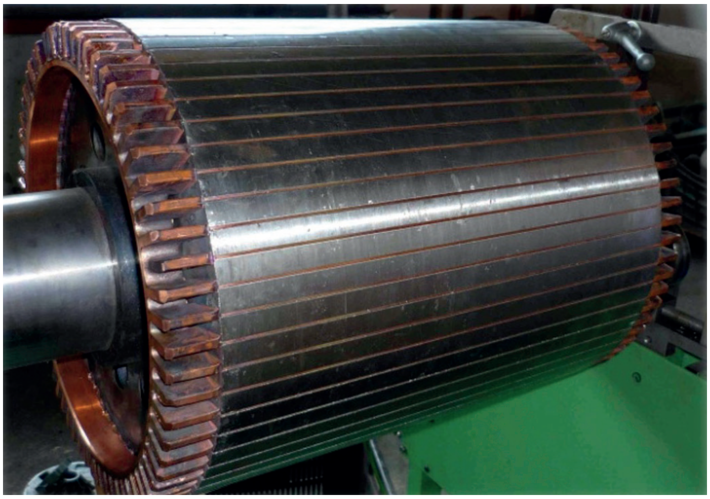
Porosity is more common in cast rotors, which is one of the effects invisible to the naked eye. The slot could be closed (see photograph 2), or the porosity could be due to overheating or faults in the manufacturing casting of the aluminium. Porosity has a significant amount of influence on the overall resistance of the rotor circuit and then will have some level of influence on the operation of the motor.

This also depends on the operation and application of the motor. A motor that has numerous starts and stops or operates under various load conditions may be affected more than a motor that operates under a steady load for long periods.

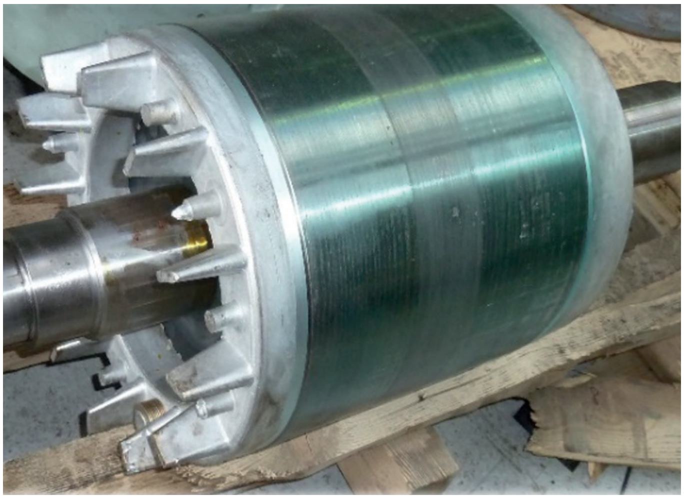
During starting and stopping or load variations, the magnetic flux generated by the rotor is developed from different parts of the rotor bars than that of a motor running at a steady state.

The current distribution in the bars can be pushed to the outer edges of the bar or deeper in the bar towards the shaft, depending on the application. This effect can affect the life of the rotor bars. This can also cause flux variations due to the rotor magnetic structure's porosity





1. Bar wound induction motor rotor.



2. Die Cast Aluminium Rotor.

3. Double Cage Bar Wound Motor Rotor.

4. Aluminium Bar Wound Rotor .

5. Aluminium Rotor bars brassed to Aluminium end rings.

6. Cage Bar Wound Induction Motor Rotor Failure.

7. Aluminium Bar welding Failure.

8. Cast Aluminium Rotor Failure.

9. Rotor Lamination Core burning due to fracture bar.

10. Rotor bar fractured and lifted damaging the stator winding.

and variations due to the rotor field's imbalance. The result of this could cause vibration and shorten the bearing life.

Broken or cracked rotor bars will develop more severe high resistance connections than porosity in the aluminium die-cast rotor bars.

These high resistance connections caused by cracked or broken rotor bars require the nearby rotor bars to carry the excess current than they were designed for and result in the lamination core carrying current and burning. (See photograph 9).

During starting, these cracked or broken rotor bars cause excessive current in adjacent bars and rotor core—the lamination to overheat and burn away, resulting in the bar lifting and damaging the stator winding.

During start-up, these very high currents will cause excessive temperatures resulting in thermal expansion of the copper or aluminium, which can change the severity of the defect.

DAMAGED ROTOR LAMINATIONS ARE A DEFECT THAT CAN BE CATASTROPHIC TO THE MOTOR

Damage can result from numerous causes, mechanical handling (dropping them during handling), rotor/stator rub, overheating during a locked rotor condition, and rotor bar damage.

The lamination on either side of the air ducts on the larger rotors can be forced out, blocking the cooling effect but restricting the airflow through the stator resulting in stator heating shortening the stator insulation life.

General damage from the overheating of a broken rotor bar, manufacturing flaws or overloading is less obvious.

Individual rotor laminations are insulated from each other and are designed to prevent excessive I2R losses. High currents can flow through the iron when this insulation is damaged, doing no actual work but creating heat. These high iron temperatures lead to abnormal expansion (thermal growth), creating imbalances and, in the worst-case, rotor/stator rubbing.

TESTING THE ROTOR OF AN INDUCTION MOTOR

Testing the rotor of a disassembled AC induction motor has certain advantages.

1) Is the ability to see the rotor. The rotor's ability to physically view has advantages as apparent faults can be seen, such as a cracked or fracture rotor bar.
2) Tests can be applied directly to the rotor. There are times when faults cannot be seen directly, such as porosity, crack, or breaks in the die-cast rotor, as the rotor bars are often inside a closed slot.
3) Generally, copper bar/double cage (Brass/copper) rotor bars can be seen and, from time to time burning on the lamination due to cracked/ broken bars.

TESTING FOR BROKEN ROTOR BARS

Growler Testing is one of the most popular ways of testing for broken or cracked rotor bars.

The old method used an AC induced voltage into the bar and used a hacksaw blade to feel for vibrations.

Modern growlers use a growler AC induced current in the rotor bad and a pick-up coil to check the voltage induced into it at the other end of the bar, measuring each bad in turn and comparing the readings. This method gives a measurement that can estimate the extent of porosity, crack or broken bars in the core of the rotor.

"Core Loss/ Infrared" Testing. This testing method uses a core lose tester as a power supply or any other adjustable AC low voltage current supply and an infrared camera for the test.

By connecting the current supply to either end of the shaft and adjusting the current to a suitable level, the current will also flow through the rotor bars. Broken or cracked rotor bars (Copper, Brass or Aluminium) and shorted laminations will cause heat variations easily identified with an infrared camera.

Other methods for checking for rotor bar faults do not indicate lamination shorts and show these clearly.

ALTERNATIVE ROTOR TESTS

Alternative test for rotor faults, but these tests do not all indicate any lamination shorting.

GROWLER

The growler induces a current in the rotor bar, which is placed on the rotor laminations at one end, and an induced voltage is measured with a pick-up coil at the other end of the bar. This is repeated for each bar and compared.

The volt reading on all the bars should be similar. There is an alternative way of comparing the bars, which all should give similar results. This test is best done with the rotor warm.

SINGLE-PHASE ROTOR TEST

This test requires the motor to be assembled with a single-phase low voltage supply connected (ensure reasonable current supplied). An analogue ammeter is in series with the single-phase supply. The rotor turned slowly, noting fluctuations in current. If the current decreases, that indicates a cracked or fractured rotor bar. The test is best done with the motor/rotor hot.

HIGH CURRENT ROTOR TEST

A method preferred as this test also indicates lamination short. When using an infrared camera.

In this test, a significant current low (voltage supply) is connected to either end of the shaft. A calculation is recommended to calculate the voltage across the shaft to obtain a reasonable flux level in the core.

Using an infrared camera and hot spot can show fractured or cracked rotor bars and shorted lamination.

CURRENT SPECTRUM ANALYSIS

This test requires the motor to be run under partial load conditions.

VIBRATION SPECTRUM ANALYSIS

This also requires to be carried out with the motor operating on load.

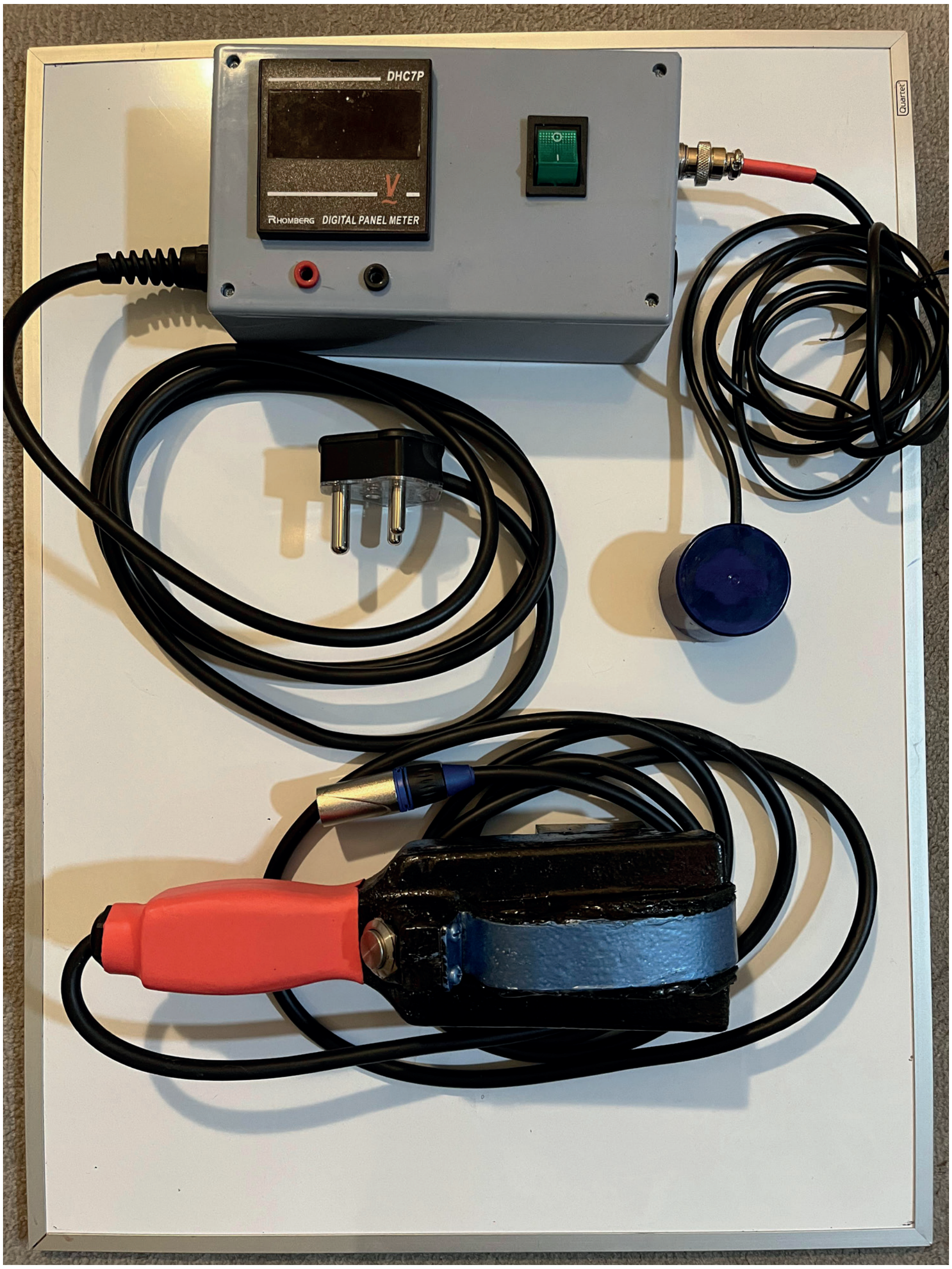
ELCID

A current is passed through the shaft, and each slot is scanned with a Shattock coil for bar current and short-circuited laminations when looking at the quadrature component.

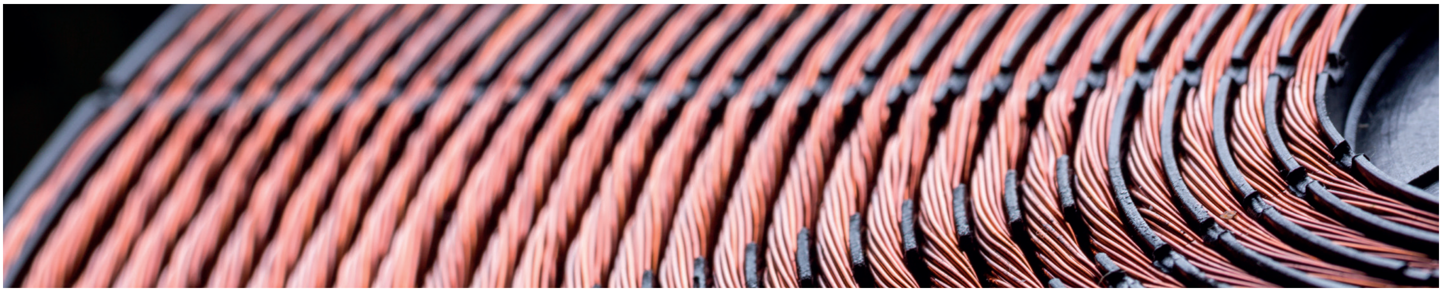
CONCLUSION

The high current through the shaft and an infrared camera should be considered the most cost-effective and beneficial way to test a rotor.

It is easy to perform the tests and accurate as infrared cameras are susceptible and can show slight temperature differences. The photographs can be printed and recorded for reference. wn



Growler with Power Supply, Voltmeter and Pick-up Coil.



Axial Magnetic Flux Rotating Machines

Axial flux machines are not a new innovation – Michael Faraday's original demonstration of 200 years ago was a DC electric generator of axial flux design.

By Dudley Basson

Axial flux and reluctance machines have lain dormant for nearly two centuries primarily due to the unavailability of AC supply and variable frequency power electronics. This is about to change dramatically.

Axial flux technology was researched and patented by Nikola Tesla back in 1889.

Reluctance motors have become the motor of choice over induction motors for electric vehicles, but these may only be a pre-cursor to axial flux machines. Axial flux motors do not imply a particular type of motor – axial flux designs can be applied to AC synchronous motors and brushless DC machines. The efficiency of these machines can be significantly improved by using rare-earth permanent magnets.

Axial flux motors have several advantageous properties, making them suitable for use in aircraft propulsion and road vehicles, including motorcycles. Notable features of axial flux motors are:

- Excellent power to weight ratio.
- High starting torque.
- Short magnetic flux circuit.
- No back iron.
- No slotted conductor overhang, reducing I2R losses and mass.
- Low rotational inertia allows fast acceleration.
- Very short length – described as flat or pancake motor.
- Can conveniently drive vehicles and aircraft directly without the use of gear trains.
- These are the only motors considered for use in electric aircraft propulsion.
- It can be air-cooled, but oil cooling has been used to its advantage.

WATCH the video for a comparison between radial and axial flux motors (6:35 mins.).

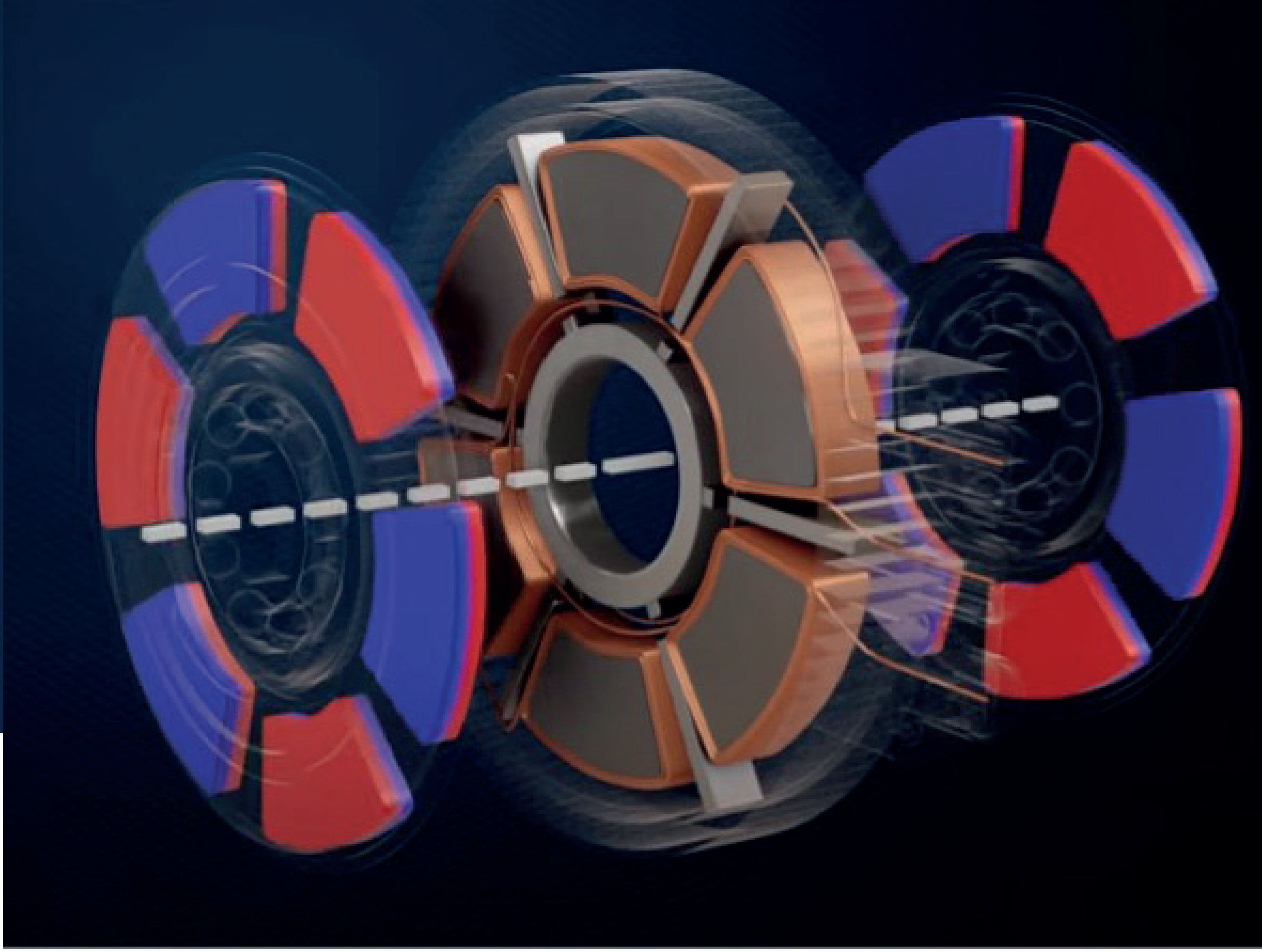
WATCH the description of axial flux motors in aviation, see (6:56 mins.).

SOME CONSIDERATIONS IN AXIAL FLUX MOTOR DESIGN

The primary axial motor consists of a stator carrying the electromagnets sandwiched between two rotor discs carrying the permanent magnets. It is a design challenge to accurately maintain the small air gaps between the strongly attracting permanent magnets.

The stator needs air cooling. However, continuous run performance has been dramatically improved by using oil cooling.

Efficiency is improved by using oriented steel for the electromagnet cores and square conductors for the windings. Core laminations can be flat or spiral,



Axial flux motor components - The rotors with permanent magnets will usually be fixed to the shaft, and the stator with windings fixed to the housing The hinted ball bearings in this illustration indicate a direct drive vehicle motor with rotating housing and power supply through the stationary shaft.

then welded and machined to the final shape.

WATCH this clip of the manufacture of a stamped single spiral axial flux stator core.

WATCH this link for lamination manufacture and soft composite magnetic material.

The power supply must be designed for minimum torque ripple to provide smooth output.

Using Halbach Array magnets on the rotors can suppress air-gap flux density harmonics.

Large scale use of rare-earth permanent magnets may cause supply chain problems.

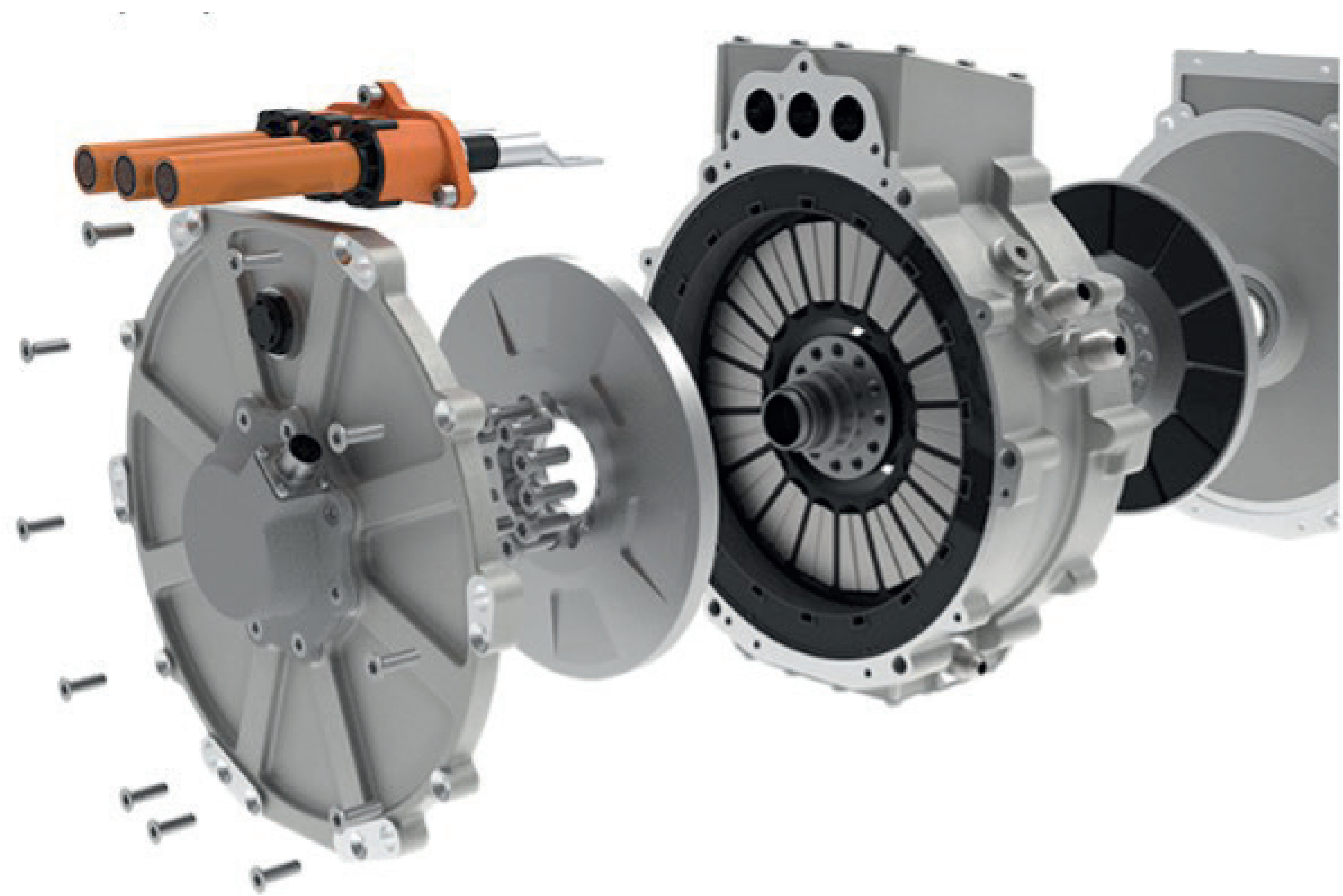
There are various configurations for axial flux motors regarding the number of fixed and rotating parts.

A rotating housing and stationary shaft and electromagnets will be required for direct drive vehicles with wheel-mounted motors.

Wheel-mounted motors are not a foregone conclusion, as the motors will not be carried by the vehicle's suspension system and will place extra dynamic strain on the tyres.

When using an electric motor for aircraft propulsion, the rotational speed will be constant, like a piston engine. The aircraft speed will be controlled using variable pitch propellers and motor power. The rotational speed will typically be less than 2000 rpm, as at higher speeds, the propeller will become ineffective due to a process similar to cavitation.

The front fan and rear turbine will typically run at 2500 to 4000 rpm and the compressor at a higher speed on a turbofan jet engine. A turboprop jet engine is quite different to a turbofan engine, including back to front airflow, and may run at 37000 rpm, which will require a gear train to drive the propeller at a lower speed.



Exploded view of an axial flux motor showing 18 electromagnet stator cores mounted in housing and two permanent magnet carrying rotors which can be bolted to the shaft. Note the 3-phase connecting box at top of housing and cooling air connections at side.

Reluctance and induction motors of modern electric vehicles run at a very high speed requiring a centralised gear train and differential for two-wheel drive.

A vehicle driven at 120 km/h and using 65 cm tyres will have a roadwheel rotational speed of 1061 rpm. This is a convenient speed for direct-drive motors, which can be attached without gear trains or differential and will suit four-wheel propulsion.

READ: For more info on axial flux motors

This website includes several links to other axial motor materials.

READ: Turncircles for scalable and stackable axial flux motors.

WATCH this excellent video on developments in electric aircraft propulsion (42:30 mins.).

WATCH this video of the development of the record-breaking Rolls Royce "Spirit of Innovation", see (13:45 mins.).

The Rolls Royce "Spirit of Innovation" is powered by a YASA 400 kW axial flux motor.

The power train included the most power-dense battery pack ever assembled for an aircraft.

The electrification industry has historically depended on radial motors – a legacy first developed more than fifty years ago. Oxford-based YASA was founded to commercialise an innovative new approach to the design of electric motors.

YASA power density has improved yearly at a rate of 15% per year and continues to improve as the technology has multiple avenues for optimisation rapidly.

The continuous-run performance of YASA machines has been improved by introducing oil cooling for the stator. Much work is also being done on hydrogen fuel-cell electrical power. wn

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Wireless on the 'White Train"

– RADIO COMMUNICATIONS DURING THE ROYAL VISIT OF 1947

Soon after the Second World War, the most notable event occurred in South Africa. On 17 February 1947, the largest battleship in the Royal Navy, HMS Vanguard, berthed at Duncan Dock in Cape Town. Onboard was Britain's - and South Africa's - Royal Family, King George VI, his wife Queen Elizabeth and the two Princesses, Elizabeth and Margaret. They had arrived for their visit to southern Africa.

By | Dr Brian Austin

It happened because South Africa's Prime Minister, Field Marshal J.C. Smuts, had invited them. It was a visit regarded with much expectation by some South Africans, with disdain and even hostility by others and curiosity by the majority. And the King wished, personally, to thank the youngest Dominion in the British Empire for its excellent service during the World War that had come to an end less than two years before.

The Royal party would travel more than 17,000 km across South Africa and some of the surrounding British Protectorates for two months. Most of that journey took place on a specially constructed train – of quite some grandiosity - known as the White Train, in the company of two others that provided all the essentials to make the Royal Visit a success. Over the intervening 75 years, what was, ironically, to become South Africa's swansong with the British Empire has largely been forgotten for an assortment of reasons which any student of South African history (both old and new) will not find hard to discern. But that is a story that has been well-told by many writers and commentators, so it will not detain us here.

However, one aspect of that epic journey was probably almost unknown, even in 1947 when the tour was at its height, and it is undoubtedly unknown today: the story of the design, installation and operation of the unique telecommunications system that was installed in those trains. Its purpose was to guarantee the Royal party's safety and ensure the success of their visit by providing continuous communication even when on the move. As well as His Majesty's need to be in constant contact with his government back in England, there was the travelling contingent of newspaper reporters who all had deadlines to meet. None could afford to wait until the train pulled into a station to file their copy; it had to be on

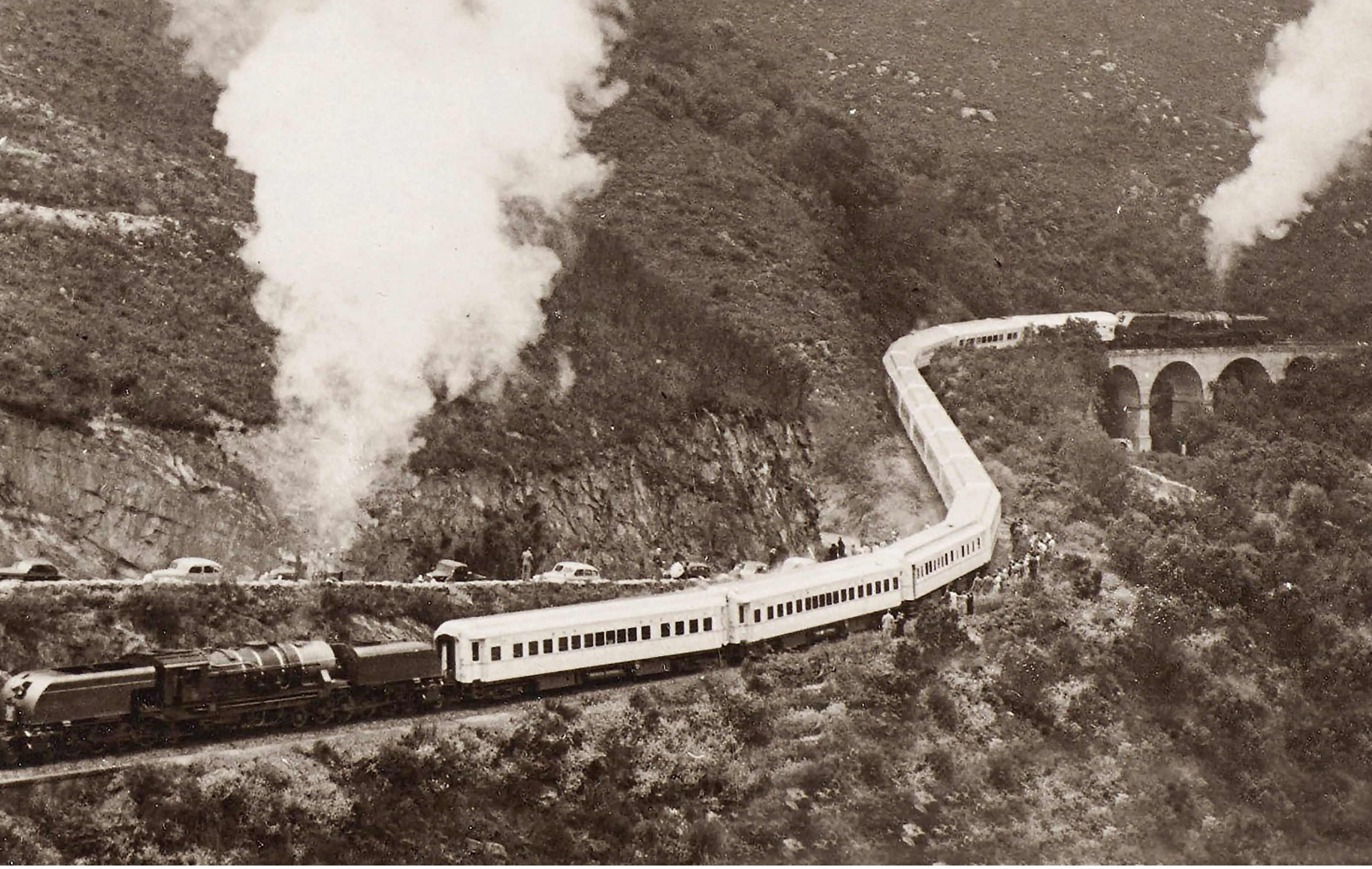

Figure 1: HMS Vanguard at anchor in Cape Town

its way to an editor, somewhere around the world, as soon as they had typed it. That telephone, telegraph and radio equipment, which only arrived from England in the first week of December 1946, was installed in the workshops of the South African Railways in Pretoria. Thankfully, for posterity's sake and the accumulation of technical knowledge, The SAIEE recorded the details of that massive engineering enterprise soon afterwards in the pages of its Transactions. And thankfully too, those bound volumes have been digitised and are available for consultation by engineering historians and other interested readers. For this, we have to thank the foresight of the SAIEE's senior officers and the dedication of its administrative staff.

I shall attempt in this article to tell that technical story with particular emphasis on the high-frequency radio communications equipment aboard the train. It provided virtually unbroken communications with Railway headquarters in Johannesburg from wherever the White Train and its accompanying rolling stock happened to be on that mammoth journey.

SOME BACKGROUND

A visit, anywhere, by British Royalty is always an event. Nothing is left to chance, and the accompanying pomp and circumstance are not only fundamental to its success. Still, they are demanded by the thousands of people who line up to watch the processions and the pageantry.

And so, this very significant Royal Visit to South Africa received not only the attention of the Lord Chamberlain in England, whose province was the heraldry and, some might say, the flummery of every occasion, but it became a momentous event in South Africa, too, involving various levels of the protocol in Pretoria some of it, seemingly, quite flummoxing. It was General Smuts (as he was always called in South Africa) who had extended the invitation to the King to visit the country with his family to have a holiday after the incredibly stressful times of the war. But a holiday it certainly did not turn out to be, much to Smuts's alarm and concern [1]. The combined officialdom in London and Pretoria made arrangements that left very little time for relaxation.

After a grand parade through the flag-bedecked streets of Cape Town and a State Banquet in the Cape Town City Hall, His Majesty the King officiated at the State Opening of Parliament. Bands played, the guns fired the Royal salute on Signal Hill, soldiers presented arms, and the South African Air Force put on as spectacular a flypast as it could muster. Cape Town was captivated though there were mutterings from some politicians

The King and Queen and their two daughters Princesses Elizabeth (left) and Margaret (right) with General Smuts.

who were less than well-disposed to what they saw as British imperialism on their doorstep. They believed this was an assault on their embryonic republican ideals and, as events but a year hence would reveal, those ideals had much grassroots support beyond the reaches of metropolitan South Africa. However, this was not the time for most people to show it.

On 21 February, the Royal train, the 'White Train' as it came to be known, left Cape Town on its journey across southern Africa. The Royal Visit had begun [2].

THE TRAINS

With its fourteen carriages in their ivory and gold livery, the White Train presented an impressive sight as it travelled northwards into the heart of the country. It was preceded by another train, the Pilot train, in the relatively less startling standard chocolate brown and cream colour scheme of the South African Railways (SAR). Behind was a third train, known as the "Ghost train", because of its virtual anonymity. Each had a specific and vital role in what was to become, perhaps, the most extensive railway tour ever undertaken by royalty anywhere.

Eight air-conditioned all-steel coaches, manufactured in England, especially for the Royal Visit, accommodated the Royal Family and their immediate entourage from equerries and private secretaries to Ladies of the Wardrobe, countless other folks with specifically-designated Royal duties and, of course, the King's bodyguard, as ever a detective from Scotland Yard in felt hat and raincoat.

Among them, too, was the Minister in Attendance – a South African Cabinet Minister whose function was to provide all necessary liaison with the King on behalf of his government. This was a role that was transferred between many members of the Smuts Cabinet as the tour progressed and allowed them to operate at a somewhat different level to that required when performing their usual ministerial duties. And their wives rather relished the opportunity it afforded them for some Royal hob-nobbing.

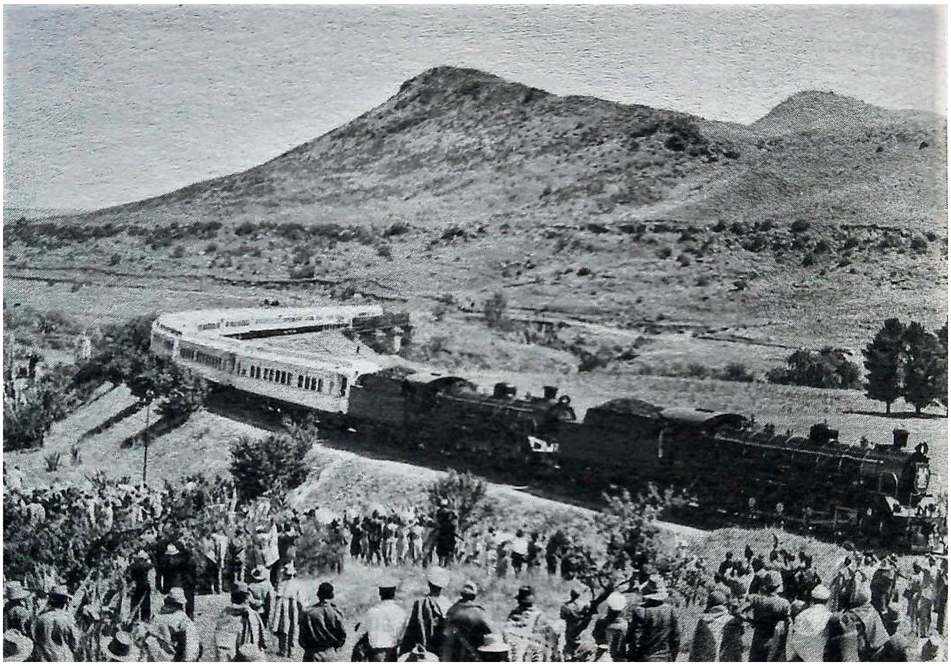

Figure 3: The White Train and a crowd of curious onlookers.

The remaining six splendid ivory and gold-hued coaches came from the SAR's luxury train, the Blue Train, mainly repainted for the occasion. For the next two months, they became the home of a seeming multitude of officials from both countries with duties to perform in direct service of the King as the tour unfolded.

Those last carriages were all of wooden construction – a crucial factor for the success of the radio communications, as will soon be revealed. Under normal circumstances, the construction of those eight steel coaches would have taken two years, but these were not normal circumstances. Smuts had committed himself to a General Election in 1948.

It was imperative, he believed, that the Royal Visit should take place well before the frequently less-than-seemly political in-fighting and, at times, outright outrightly skulduggery was unleashed on the country. British industry, along with their counterparts in South Africa, went into overdrive to deliver the necessary rolling stock in time for it to be fitted out with all the appointments required for comfort, in this extraordinary instance, for communications. The eight steel coaches were manufactured in Birmingham, with the SAR having despatched a senior electrical engineer and two draughtsmen to be involved from the outset.

The air-conditioned coaches, including the most up-to-the-minute and well-appointed dining car, were completed within nine months and arrived, by sea, in Cape Town in December 1946, a mere couple of months before the convoy of trains was to leave the city with its Royal entourage on board.

With its wooden coaches, the Pilot train made use of the usual SAR rolling stock. It too underwent a major refit at the SAR mechanical workshops in Pretoria to be able to accommodate the Administrator of the whichever Province the train was passing through and the contingent of local and overseas press and broadcasting personnel with all their paraphernalia. Should such services be needed, there was also a sizeable police contingent and medical staff. In addition, the Pilot train had its own catering and dining facilities sufficient to tend to the dietary needs of all its passengers.

The Pilot train preceded the White Train by about thirty minutes, and no other traffic was permitted on the line between them [2].

Each train had its own train manager with duties similar to those of the captain of a ship. He was responsible for the safe running and operation of his train and particularly the safety of his passengers. Upfront, on the footplate of the engine (of which the White Train always had two locomotives), in addition to the driver and the fireman was a locomotive inspector, a senior and very experienced driver charged with monitoring every aspect of the operation of those locomotives throughout the tour. Bringing up the rear was the Ghost train to transport any spare parts that may have been needed and the skilled mechanics and technicians to effect any such repairs.

Throughout the tour, the trains travelled only by day. At night the White Train was taken to a quiet station or siding remote from any towns or villages. This was all done in the interests of safety and security. In the larger centres where the King was to perform some function and meet local dignitaries (as well as ordinary folk) over a more extended period of two or three days, the Royal party and their staff were taken to an official residence set aside for their sole use. The arranging and coordinating of all these necessary actions by the various senior officials travelling on the White Train, and its all-so-important Pilot train, required good inter-communication between them at all times, even when they might be as much as 40 km apart [2]. That required radio. The press corps, meanwhile, had a copy to file, and it too had to reach an editor's desk well ahead of the

Figure 4: The Royal Family alights from the White Train somewhere.

tight deadlines of the newspaper and broadcasting industries. The reporters required radio communications to do that when on the move, but they wanted instant access to South Africa's telephone and telegraphic networks as soon as the trains came to a halt for more than a few minutes at any station anywhere. And unsurprisingly, the Royal party and their entourage had their own needs for such telecommunications services. So the South African Railways and the Post Office set out to provide them.

TELECOMMUNICATIONS TRIUMPH

As mentioned above, we have to pay tribute to the Transactions of the SAIEE (and, naturally, to the authors concerned) for providing such a complete and very detailed account of the telecommunications facilities built into both trains. Without the paper by Manson [3], a senior SAR engineer, this account would have been sparse in detail. In England and South Africa, the engineers' problems were undoubtedly not routine.

Several various items of equipment had to be accommodated in minimal space, and, where necessary, all the cabling linking them had to be laid as inconspicuously as possible. With remarkable foresight, undoubtedly based on years of experience, attention was given from the very beginning to the likelihood of interference occurring between those various systems.

Though such problems had plagued electrical communications systems since man first used the electric telegraph, understanding the mechanisms and the devising of methods to mitigate them had not yet been given a name. Today it is known as electromagnetic compatibility (EMC). A British company specialising in the field was contracted to solve all such problems as and when they arose during the installation phase of this most complicated process.

Another major item requiring attention was the power supply needed to keep all the equipment functioning. All communications equipment was to run off 220-volt 50 Hz. As soon emerged, the bulk of the communications hardware, both wired and wireless, would be placed within the Pilot train, and the power requirements were beyond the capabilities of the battery supply. A suitable prime mover and alternator were therefore required. In addition, to supplement it, a 2.5 kVA motor alternator set, operating off the train's 24-volt lighting batteries, was also provided. A similar set was all that could be accommodated on the White Train, except that in this case, all the equipment would operate off 65-volts d.c.

The most important of those items were for the entertainment of the passengers. Broadcast receivers were installed in the many lounges. At the same time, three specially-sprung radiograms that would function with the 78 rpm records of the day without, literally, missing a beat regardless of the undulations of the track and the attendant movements of the train were carefully positioned for those even inclined to dance.

The conventional broadcast receiver in His Majesty's private study was particularly important. Its quality of reproduction was to be beyond reproach! As laid down in the specification, it had to have 'good sensitivity and selectivity plus ample band-spread over the primary medium and shortwave bands.

The specifications for all the hardware were completed in April 1946, and they were passed to five British firms contracted to manufacture it. This was a mere nine months before the start of the Royal tour. Unfortunately, no doubt governed by the Institute's policy on advertising at the time, the names of those companies were never mentioned.

Still, it is reasonably easy to guess who they might have been given the prominence of the Marconi Company, Metropolitan Vickers, AEI, GEC and Reyrolle Parsons within British engineering in those days. The closest collaboration existed between them and engineers within the SAR and the South African Postal Administration. Given the rather specialised nature of some of that equipment, there was a need for a degree of research and development. And all had to be carried out under the tightest of time constraints.

THE AUTOMATIC TELEPHONE SYSTEM

All compartments on both trains were served by a telephone, the standard black BPO type for the entourage accompanying the King but a cream-coloured instrument for each Royal party. The telephone exchanges had a capacity for 68 lines, allowing automatic access to any subscriber on either train when they were interconnected. The full-extension was possible to both the SAR telephone network and the Post Office at each port of call along the route. This all went via a switchboard operator.

The "cut in on engaged" feature provided only for privileged subscribers was a curious but perhaps not surprising facility. One can well imagine who they might have been. Its operation was described thus: 'On receiving the busy tone after dialling the desired number, the subscriber would dial "0", which gave him (sic) access to the engaged circuit. The other subscribers would be informed of this intrusion by simultaneously applying a "ticking" secrecy tone to the circuit. They would then be requested to replace their handsets.' The operator at the exchange had a similar feature that made such "cut-in" possible to interrupt any conversion on receipt of a trunk call. This was no egalitarian party-line service!

The network was interconnected by a 75-pair cable running the length of each coach. Whenever the two trains were stationary for any significant period, both exchanges were linked by two tie lines. As mentioned earlier, meticulous attention was paid to the screening and filtering associated with those cables to ensure that no interference was carried along with the wanted signals.

Careful attention was also given to providing telephone communications between the respective train managers and the crew of the leading locomotive of each train. In those cases, electrical noise was not so much the problem, but the extremely high acoustic noise level was. It too was solved by using army-type loud-speaking telephones and their accompanying "power microphones", all appropriately accommodated on the footplate.

THE RADIO LINK BETWEEN THE TRAINS

For an assortment of reasons, it was necessary that the two trains were to be in radio contact throughout their journey across the country. The all-steel construction of the White Train provided many problems in this regard. In contrast, the wooden coaches of the Pilot train certainly made life a little easier for the radio engineers. In both instances, however, the placement of the appropriate antennas posed problems owing to the height of the coaches relative to the height of the tunnels which they would have to pass through en-route and, particularly, in those areas where overhead catenary wires electrified the lines. The solution to the possible noise problems from those overhead lines was to use VHF transmitters with 10 W output and frequency modulation.

The SAR engineers favoured a frequency around 150 MHz (or Mc/s as it was in those days), but their British counterparts were concerned about the alleged "optical" effects at the short wavelength. This was a strange but persistent fear among British radio engineers and physicists that had its roots lodged in wartime thinking. The Battle of Arnhem in September 1944 was a calamity for the British Army for many reasons, one of which was the inadequacy of the radio communications between its troops. British military radio doctrine at that time saw VHF as being effective over a very short-range (i.e. a few miles) because, as was claimed, 'such frequencies propagate only in straight

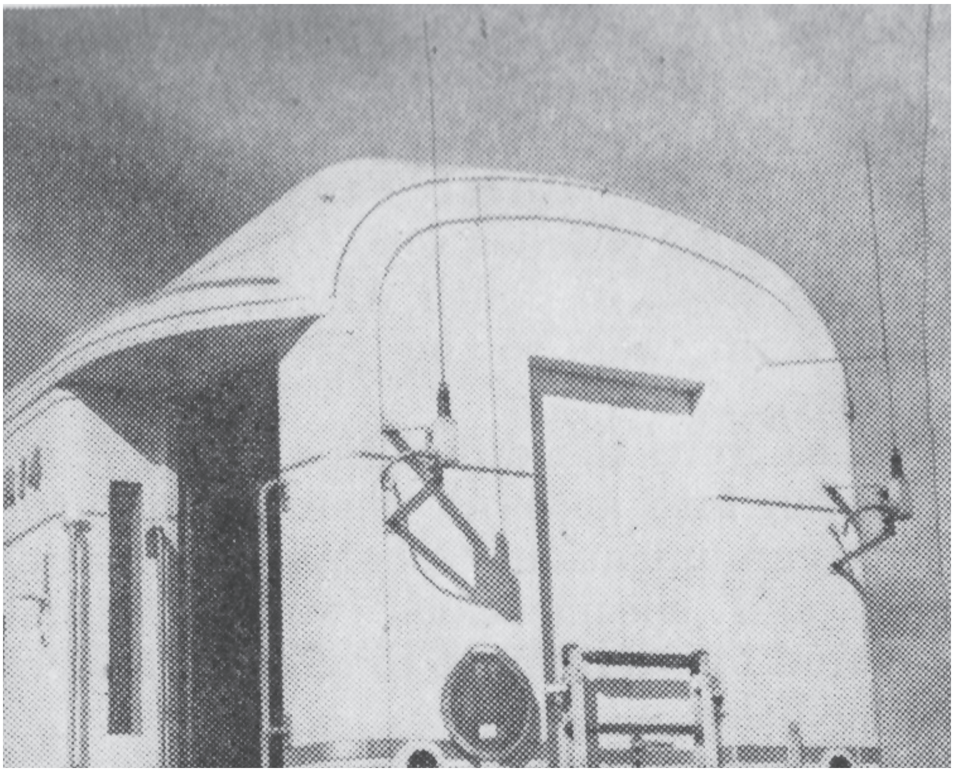

Figure 5: The extended VHF antennas on the White Train [3].

lines, old boy'. The army, therefore, used frequencies in the low MHz range, which propagated (equally poorly, as it turned out) via the ground wave. In addition, the much under-powered manpack equipment on a soldier's back used an antenna no more than two metres long. Any longer, and the unfortunate radio operator became a much sort-after target. Such short antennas were, as expected, highly inefficient radiators.

Therefore, a frequency of 80 MHz was felt to be more appropriate for distances up to the expected 40 km that could occasionally separate the two trains. That immediately meant antennas twice as long as the SAR had intended. However, a vertical quarter-wavelength whip mounted on a flexible base on the coach roof would pass through all tunnels without any difficulty. Likewise, it would be sufficiently below the overhead power lines for there to be no concern. But to be absolutely sure that this inter-train VHF never failed, two additional and somewhat longer antennas – yielding slightly more gain - were mounted at the rear of the White Train. As it transpired, the short roof-mounted antennas proved to be more than adequate throughout the journey.

LONG-DISTANCE HIGH-FREQUENCY RADIO COMMUNICATIONS

Given the vital need to protect the safety and security of the Royal party throughout their very long rail journey across southern Africa, it was a pre-requisite of all the planning that went on that the White Train should be in radio communications with one or more key SAR centres at all times. In addition, the King himself had to be kept abreast of developments on the wider international stage, should the need arise. This necessitated his being in radio contact, ultimately, with London. And then there were the other government officials travelling with him and a veritable posse of journalists. They all needed such communications facilities to carry out their duties, and only radio could achieve that. It fell, therefore, to the joint efforts of the SAR and Post Office engineers, working in very close collaboration with their British counterparts, to provide it.

In those pre-satellite days, the only means of communicating over hundreds and even thousands of kilometres was high-frequency HF (or shortwave, as it was known) radio. Given the nature of the ionosphere on which such communications depend with its variability by day, by season and by the vicissitudes of the sunspot cycle, several different radio frequencies spread across the 3 to 30 MHz HF band would be required. Such allocations were in the gift of the Post Office, and five frequencies lying between 4 and 11 MHz were allocated to the Royal trains.

As it perhaps unsurprisingly transpired, the SAR already had a sophisticated radio network across South Africa since it too needed communications over and above those provided by its own telegraph lines and those of the Post Office. This had been precipitated at the outbreak of war in 1939 by divisions within the country between those supporting the Smuts government's decision to join the Allies in their war against the Nazis and those vehemently opposed to it. Among the latter group was the Ossewabrandwag, which intended to disrupt the South African war effort by all possible means. Sabotage and the destruction of telecommunication services were among the numerous anti-war measures they deployed. The SAR radio stations that soon came into being were located in Johannesburg, Cape Town, Durban, Bloemfontein, Port Elizabeth, Kimberley, Kroonstad and Windhoek.

The most crucial radio link from the Royal train was that to Railway Headquarters in Johannesburg. They had to ensure

Figure 6: The Marconi CR-100 HF communications receiver used on the Pilot train and at Roberts Heights.

that it functioned flawlessly, particularly when sending high-speed press traffic under indifferent propagation conditions. Use was made of the Post Office radio station at Roberts Heights (actually renamed Voortrekkerhoogte in 1938 and more recently Thaba Tshwane). From there, a landline completed the circuit to Johannesburg.

At 'The Heights,' a triple-diversity scheme involving three Marconi CR-100 communications receivers of the same type as fitted on the train but fed from a single local oscillator to ensure absolute frequency commonality was used in conjunction with three widely separated receiving antennas to increase the spatial diversity between the received signals. This means any fading could be compensated for by combining all the receiver outputs. No stone was being left unturned.

The proximity of an antenna to a conducting structure significantly affects its performance. As emphasised above, the White Train was of all-steel construction. Though steel offered undoubted advantages compared to wood in a mechanical sense, any metallic conductor would be most disadvantageous from an electromagnetic point of view when it came to the siting of antennas, and never more so than at HF.

This problem was mitigated by placing the HF transmitter and receiver in the Pilot train with its wooden coaches. Still, their length of about 28 m would impose constraints on the antenna's maximum length, which should have been close to half a wavelength at the lowest frequency. Since the lowest frequency allocated to this vital mission was 4.055 MHz, the wavelength was about 74 m, making this impossible. Once again, an engineering compromise had to be made. But there was another factor too. Only a single (and relatively simple) antenna could be accommodated on a railway coach. Yet, the range of frequencies that would have to be used to cope with the changes in the ionosphere over 24 hours meant that the antenna had to have a wide bandwidth. No simple antenna structure possesses this feature. It had to be mounted on top of a railway coach and therefore relatively close to the ground. Its height above the coach roof was also severely constrained by the limitations imposed by any tunnels or power lines en route.

THE HF TRANSMITTER

The transmitter with its diesel engine and alternator, plus the necessary switch-gear, were located in two separate compartments of the Pilot train. The associated receiver and the high-speed telegraphic equipment went into two compartments in an adjacent coach. In addition, there was a particular cypher office on the train whose purpose was to handle any highly confidential radio traffic, usually intended for the King. It contained two "Typex" machines of the type made famous during the war just past when they were used to encipher all classified British military traffic. Unlike its German counterpart, the much-described Enigma machine, the messages from the "Typex" machine were never broken.

The separation that could be achieved between the transmitting and receiving antennas was of much technical importance. This turned out to be about 76 m, limited by the coaches' length. Since they would be approximately end-on to one another, the mutual coupling was reduced. This was all to the good since "paralysis" of the receiver when the transmitter was operated to be avoided at all costs. The transmitter produced an output power of 500 W under continuous wave conditions and half that when used for telephony in the form of amplitude modulation. Both the transmitter and receiver could be operated either locally or remotely, with the normal operation being under the operator's control at the receiver. A duplicate facility existed at the transmitter. When operating in telegraphic mode, the keying system of the transmitter allowed for traffic transfer of up to 200 words per minute [3]. Under normal circumstances, the coupling to the antenna of the transmitter dual tetrode power amplifier valves, operating in parallel, was using a two-wire transmission line with a characteristic impedance of 600 ohms. However, as a further example of the belt-and-braces approach adopted everywhere, the transmitter could also drive single wire antennas of either low or high impedance had the need arisen. The complete transmitter installation comprised a two-bay cabinet standing some 2m in height, a metre wide and 700 mm deep. The whole assembly weighed about 360 kg.

WALKER'S CRUCIAL BROADBAND ANTENNA

It is no mean feat to produce an antenna that operates over a bandwidth of more than two octaves. And the problem is made even more challenging when that antenna has to be accommodated on the roof of a train that is underway. Though he had no clue about the Royal visit to South Africa when he first looked at this problem, G. D. Walker, a lecturer at the Witwatersrand Technical College, had some experience with wideband antennas due to the research he had been doing into the development of an ionosonde. The difficulties of war and the need for highly skilled people in specific key posts saw Walker transferred, early in 1940, to the department of the SAR's Chief Electrical Engineer in Johannesburg, where he was given responsibility for all the SAR's radio communications. Walker was no neophyte in this field. Some years before, he had designed and constructed the first ionosonde in South Africa when such instruments for measuring the features of the ionosphere were not to be found in too many other parts of the world [4]. Its first use in anger, as it were, had been planned some while before when Professor B.F.J. Schonland's Institute of geophysical research at Wits intended to observe the forthcoming total eclipse of the sun by all means possible. One of those was measuring its effects on the ionosphere, and Walker's ionosonde was just the instrument. And so, in October 1940, the ionosonde was deployed at Middleburg in the Cape to record any changes in those ionised regions up above as the sun was eclipsed by the moon [5,6]. Since an ionosonde uses swept-frequency radar techniques to measure the virtual height and critical frequencies of all the ionosphere layers, Walker was well-acquainted with the problems of radiating and receiving radio signals over the 30 MHz of the HF band.

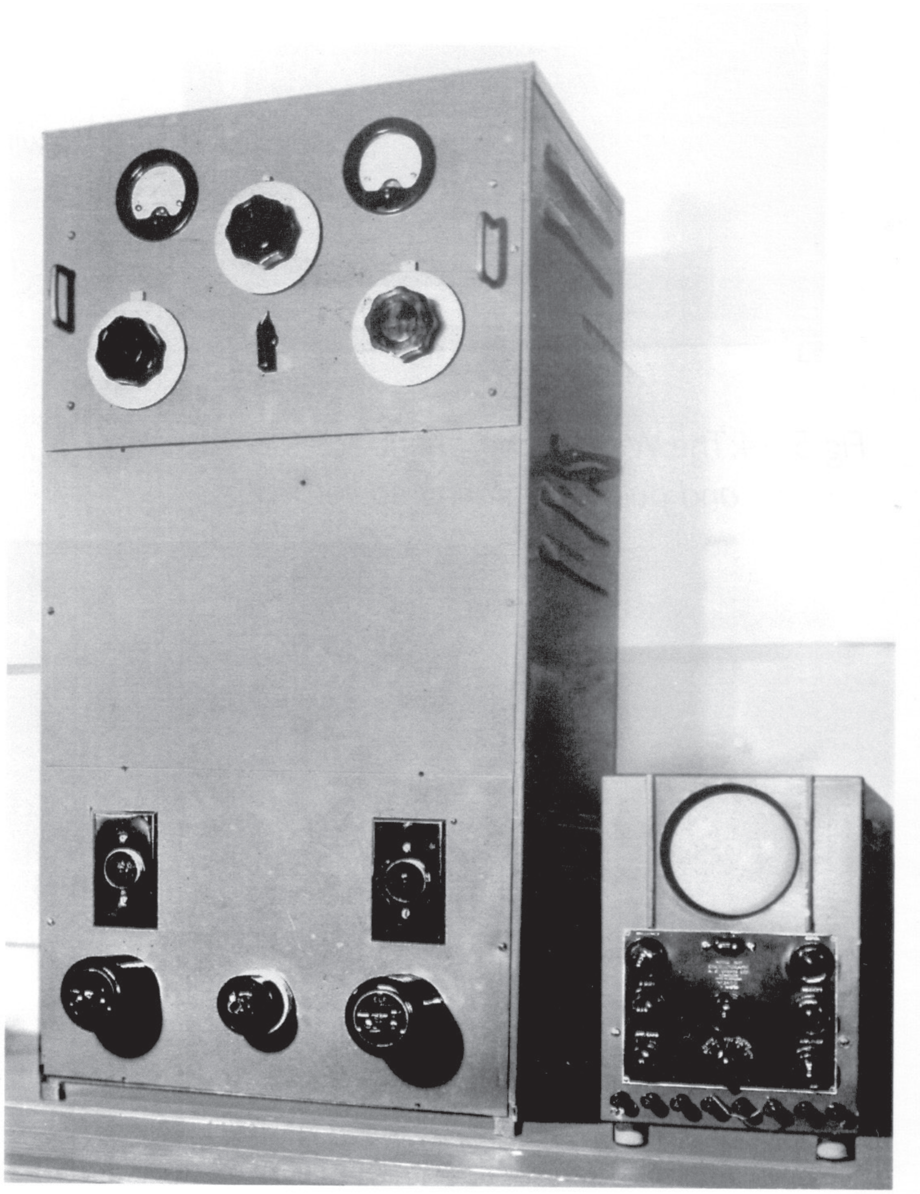

Figure 7: G.D. Walker's ionosonde that observed the effects of the solar eclipse in 1940.

In 1946 Walker published a comprehensive paper in the Transactions of the Institute in which he described the work carried out under his direction by the SAR [7]. An essential aspect of it was the type of antenna to be used at all those SAR radio communications centres. He examined and experimented with many. Since the HF radio spectrum is vast, and antennas, in general, are narrowband devices, Walker thought, initially, that some combination of dipole elements might offer a multiband capability with resonance at the specific frequencies allocated by the Post Office to that SAR radio network. However, it turned out to be a tall order because the antennas were sizeable structures. Naturally, he discussed the problem with his academic and industrial colleagues, and a suggestion of a single element antenna that might suffice was forthcoming from England. The antenna is shown in Figure 8 with the dimensions intended for use at the various SAR radio stations across the country.

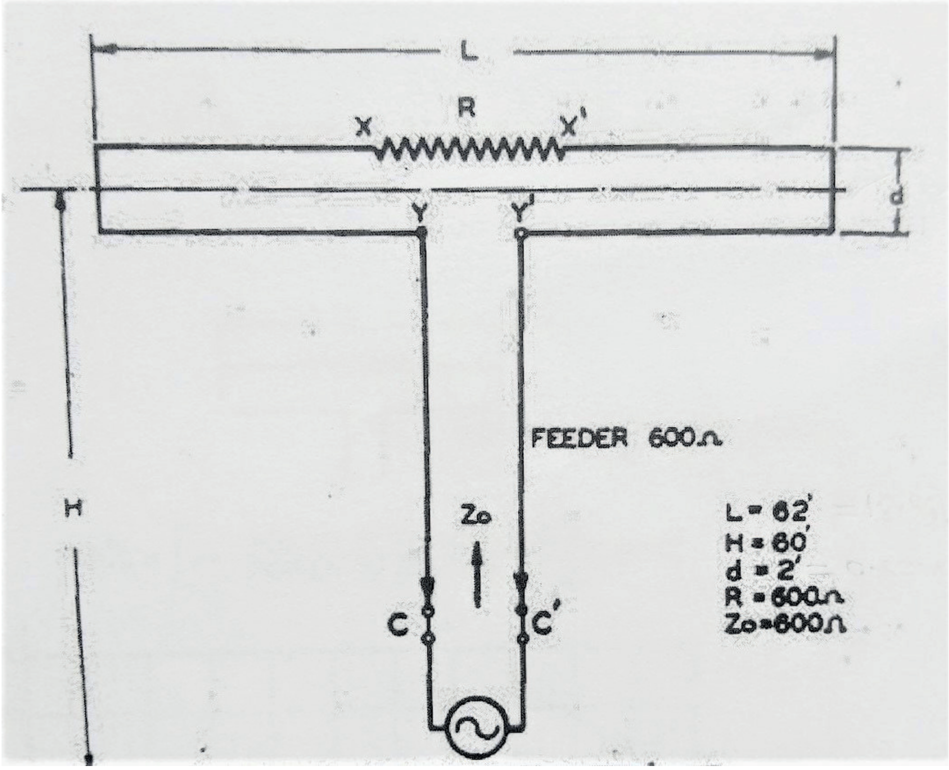

Figure 8: The resistively-loaded folded dipole antenna

Essentially, the antenna is a folded dipole with resistive loading. An unloaded antenna of that type has a bandwidth of just a few hundred kilohertz and is similar to a high-Q resonant circuit. Any added resistance will decrease the Q and increase the bandwidth - but it comes as a cost. The antenna's radiation efficiency is reduced, so there is the inevitable trade-off between bandwidth and efficiency. Walker discussed this in detail in his paper and presented measured results showing the antenna's input impedance across the HF frequency range.

He also measured the power dissipated in the loading resistor, and, from those data, he was able to get some idea of the resulting radiation efficiency. Modern antenna analysis software enables us to do this with considerably higher precision. The results show the increasing efficiency with frequency, as expected, and with numerical values similar to those that Walker had measured. However, Walker's test antenna was nearly 20m above the ground, whereas the antenna on the roof of the Pilot train would be only a few metres above terra firma. The additional ground losses would inevitably degrade the radiation efficiency further. But there were no other options, so this terminated folder dipole, as it became known, was the antenna of choice for the Royal train.

THE ANTENNA ATOP THE PILOT TRAIN

Space was limited. The size of the coach determined the antenna's dimensions, so the eventual length was just over 17m. The folded dipole was made of two 12 mm diameter nickel-plated copper rods – the nickel coating presumably prevents the copper from oxidising and thereby increases its losses. The two parallel elements of the dipole were 127 mm apart, with the whole structure being supported on porcelain stand-off insulators 150 mm above the coach's wooden roof. The terminating resistor, which had to be non-inductive, thus making a wire-wound resistor out of the question, consisted of six two 000-ohm carbon bar elements in parallel held in special clips inside the coach to protect them from the weather. The 600-ohm characteristic impedance balanced feeder from the transmitter left the coach at the same point.

Leaving nothing to chance, provision was also made to deploy a longer 24m antenna whenever the train was stationary for any reasonable length of time. Being longer and higher, though also resistively loaded, that antenna would have produced a stronger radiated signal. As it turned out, it was never needed. It was held aloft by two portable 10m masts of three sections, which could be erected quickly. A computer simulation of the train antenna's height of 3.7 m above the ground yielded adequate isotropic radiated power (EIRP) ranging from 4 to 11 MHz. Given the very short antenna length, when expressed in units of wavelength, at the lowest allocated frequency of 4.055 MHz, the EIRP was just 6.3 W. By contrast, at the highest frequency of 11.4 MHz, where the longer antenna had considerably more gain, it was as high as 740 W. Though vastly different, the EIRP is not the sole determinant of successful radio communications at HF. The ionosphere has the final say, but given its variability with the time of day, the seasons and the sunspot cycle require careful frequency selection by the operators. It is, after all, the EIRP and the noise level at the receiver which together determine the signal-to-noise ratio. To give them as many options as possible, the frequencies allocated and the two mentioned above also included 5.70, 7.52 and 8.80 MHz.

Based on his previous experience when experimenting with that antenna, Walker was confident that the set-up aboard the Pilot train would prove to be effective. However, the initial tests between Pretoria and Johannesburg proved highly unsatisfactory: signals were weak on some channels and non-existent on others. But further tests with Bloemfontein were far more successful. An explanation for this follows.

Two possible modes exist: HF radiated signals could propagate over the roughly 50 km distance between Pretoria and Johannesburg. The first is the ground wave, where the electromagnetic energy literally hugs the ground's surface as it travels away from the transmitting antenna. The other is the skywave which leaves the antenna at an oblique angle where it then encounters the ionosphere and may be reflected by one or other layers.

The radiating signal must be vertically-polarised for the ground wave to propagate over a reasonable distance. Since the antenna on the train was in a horizontal position, it radiated a horizontally polarised wave, so the ground wave was virtually non-existent. This left just the skywave. Figure 9 shows Walker's 1946 paper [7] diagram illustrating this particular case. It is somewhat over-elaborate in that it

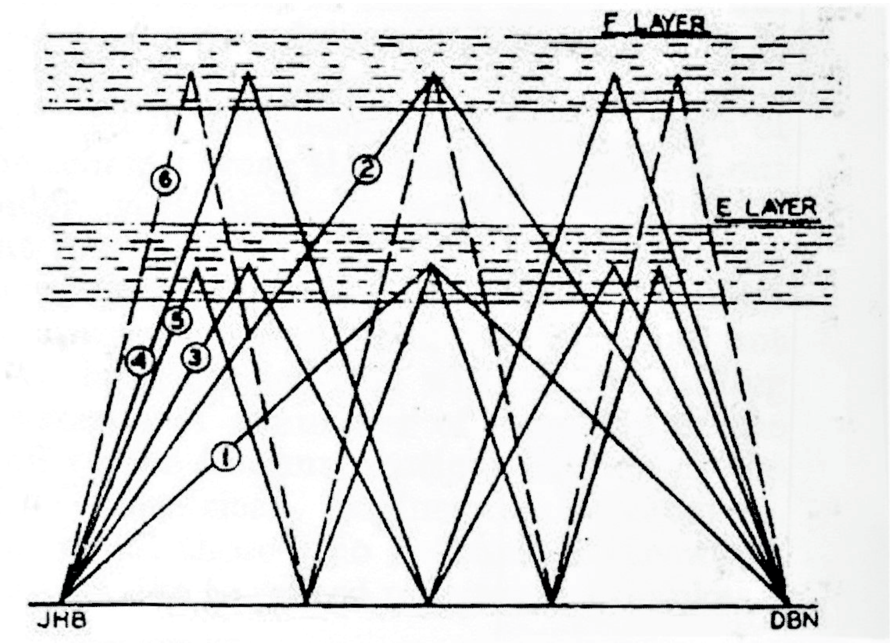

Figure 9: A stylised diagrammatic view of ionospheric propagation.

is most unlikely that so many different modes would exist over that relatively short Johannesburg to Durban path that he used as an example. The ionosphere would, most likely, support just modes 1 or 2 (and then seldom simultaneously).

At night, for example, the E layer disappears, while it may actually be dominant around midday. Most of the time, except possibly over reasonably short distances, propagation would have been via the F layer. It will be noted that there is a region between the transmitter and the point at which the reflected signal returns to earth in which there is no radio coverage. This is known as the skip zone for obvious reasons. Over the relatively short distance between Johannesburg and Pretoria (illustrated, perhaps, by rays 5 and 6), there is every likelihood that the down-coming ray only returns to earth in Vereeniging when the train in Pretoria was transmitting and in Polokwane when the headquarters station in Joburg was doing so! Thus, the two stations were within the skip zone, so no contact between them would have been possible, hence the dismay in Pretoria when the first test failed!

IONOSPHERIC PROPAGATION PREDICTIONS

Immediately after the end of the Second World War, Schonland founded the CSIR at the behest of General Smuts [6]. One of the first laboratories to be established was the Telecommunications Research Laboratory (TRL), initially based at Wits, and the majority of its engineers and scientists had been members of Schonland's wartime Special Signals Services (SSS) that had designed, constructed and operated South Africa's own radar system throughout the war.

The first director of the TRL, which subsequently underwent a name change and became the National Institute for Telecommunications Research (NITR), was F.J. Hewitt. From its inception, a vital member of the TRL was T.L. Wadley, the designer of some truly remarkable pieces of electronic equipment [6, 9, 10]. One of the areas in which the TRL immediately became involved, and Wadley played a most significant part, was a study of the ionosphere. It was Wadley who designed and constructed the ionosonde they used.

Figure 10: The TRL (NITR) staff c.1963. F.J. Hewitt in the centre of the front row; his sister Joyce is on the far left and T.L. Wadley is on Hewitt's immediate left.

Hewitt's sister, Joyce Hewitt, became the first ionospheric physicist at the TRL, and she specialised in predicting how the ionosphere would behave some short time in the future. Doing this required daily measurements of the critical frequencies and virtual heights of those ionospheric layers, which were provided by Wadley's ionosonde [8]. Figure 11 shows an ionogram displayed on the equipment in 1947 when that particular sunspot cycle reached its peak. The horizontal axis is marked in 1 MHz intervals, while the vertical axis displays the virtual heights of the layers in 50 km steps, with the lowest interval being an altitude of 50 km. The two ionograms show the almost untouched nature of the ionosphere twenty minutes apart as measured directly above Johannesburg on an indicated day of the year. From those displays, the critical frequencies when the trace turns sharply upwards, and their virtual heights, when they are approximately horizontal, can readily be measured and used in the predictive scheme implemented by Miss Hewitt.

HOW WELL DID IT ALL WORK?

On 4 February 1947, the two trains, now fully fitted with all their home comforts and the various items of technical equipment needed so that the Royal party and their entourage, plus all the attendant press corps, could be in constant contact with the world outside, left Pretoria for Cape Town. Before setting out, routine tests were carried out with all the automatic telephone equipment connected to the national telephone network, and the few faults that were found were immediately rectified. Other more persistent problems were worked on and solved during the journey south. Radio tests commenced almost immediately after departure. A schedule of calls every half hour was agreed with the Post Office station at Roberts Heights and with all the SAR radio stations around the country. It was reported that the Reef electrification system did not affect radio communications. Manson also reported that tests continued all the way to Cape Town, and 'at no time was contact with the fixed stations lost. By judicious choice of operating frequencies for different times of the day and night, the signals were in most cases at a high level.' Not only would that have been decidedly reassuring to the SAR and GPO engineers who had played such a crucial part in all of this but, equally, it was a clear vindication of the choice of the compromised broadband antenna occupying its sheltered position on the roof of coach R27 of the Pilot train.

Once the Royal tour had commenced, Manson subsequently reported that the HF radio installation was soon hard at work with the Post Office staff handling all the radio traffic. At the same time, the two trains maintained almost unbroken contact via the VHF radio link between them, such as the demand. Daily out-going traffic in telegrams and press reports, sent to the Pilot train and thence onward to the receiving station at Roberts Heights, averaged 25 000 words per day. And as soon as the trains came to a standstill, the connection was immediately made to the landline network, with the railway telegraphists becoming telephonists to route all the calls through their two switchboards. Naturally, when within tunnels and in mountainous areas of the country, there were the inevitable VHF dead spots, but these had been foreseen, and none persisted for longer than expected. In certain parts of the country, most notably between Nelspruit and Pretoria, between Mafeking and Bulawayo and between Victoria Falls and Livingstone, communications between the trains were excellent.

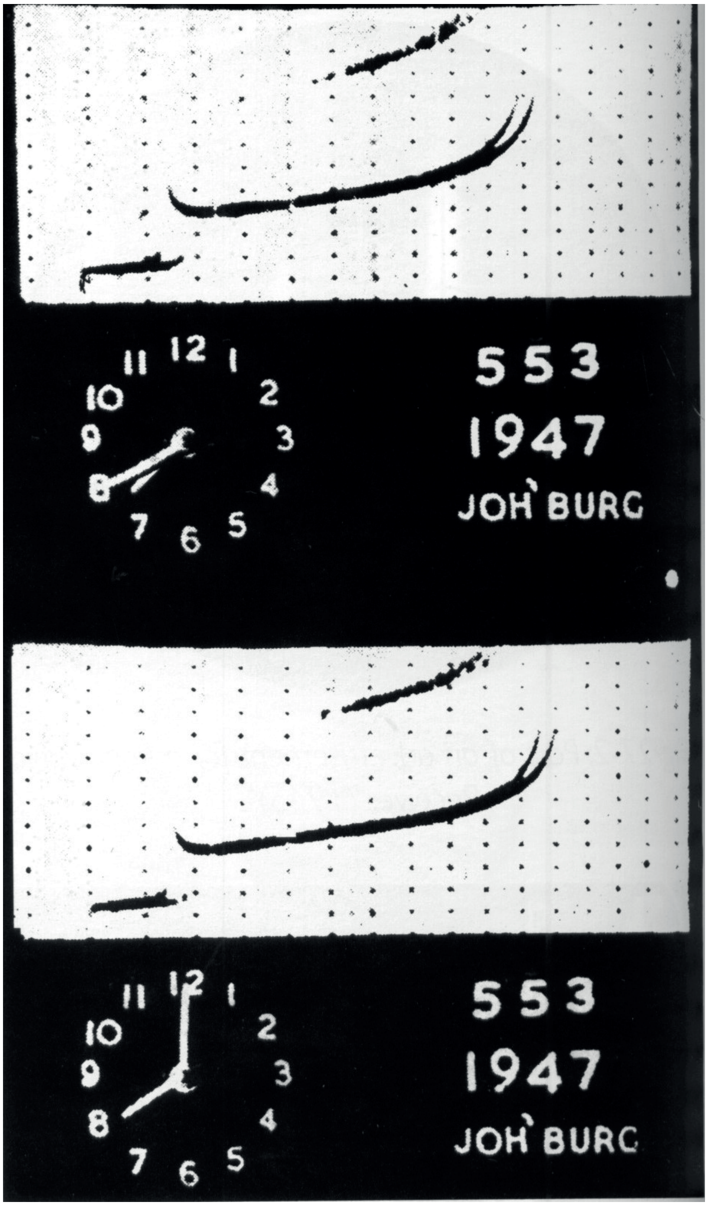

Figure 11: Two ionograms produced by the Wadley ionosonde in 1947.

IN CONCLUSION

The Royal Visit to South Africa was an unqualified success, at least in terms of its planning, the arrangements and the superhuman efforts of all who contributed so much to every aspect of the grand tour. Though usually somewhat side-lined in popular accounts and even in terse official documents, the success of the down-to-earth engineering that made so much of it possible and, most notably, the Royal trains' flawless performance cannot be overstated. In closing, Manson summed it all up as follows. 'As far as is known, communications on this scale have never before been applied to trains anywhere in the world …' [3].

This unique event would, within a year, come to be seen as possibly the final days of South Africa's very close association with Britain, its monarchy and ultimately its Empire and Commonwealth. Local politics were changing, and a very different way of viewing the world-at-large would soon become the new government's policy. That 1947 Royal Visit was a pivotal event in more ways than one. wn

ACKNOWLEDGEMENTS

South Africa's very proud engineering heritage owes much to men of their calibre and, most importantly, to journals such as the Transactions of the SAIEE for publishing, in full and very precise detail, this material that reflects so well on those men who carried it out. Without the foresight and dedication of those engineers who took it upon themselves to write detailed accounts of the communications systems on both the Royal trains and also about all the preparatory work that went into it, we, many years later, would never have known the fascinating details. I, therefore, wish to acknowledge them and pay tribute to their work. I also wish to pay tribute to Graham Viney [2] for telling such a fascinating story about the Royal Visit and all its many niche events that so captured the South Africa of all those years ago. In addition, I must thank Gerda Geyer, at the SAIEE's head office in Johannesburg, for the considerable assistance given to me when I was pulling this article together. There are also two books, relatively recently published by the SAIEE, which provide a wealth of detail relevant to this story – and to very much more besides. Both are comprehensive accounts of the history of the Institute and electrical engineering in South Africa [9,10].

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