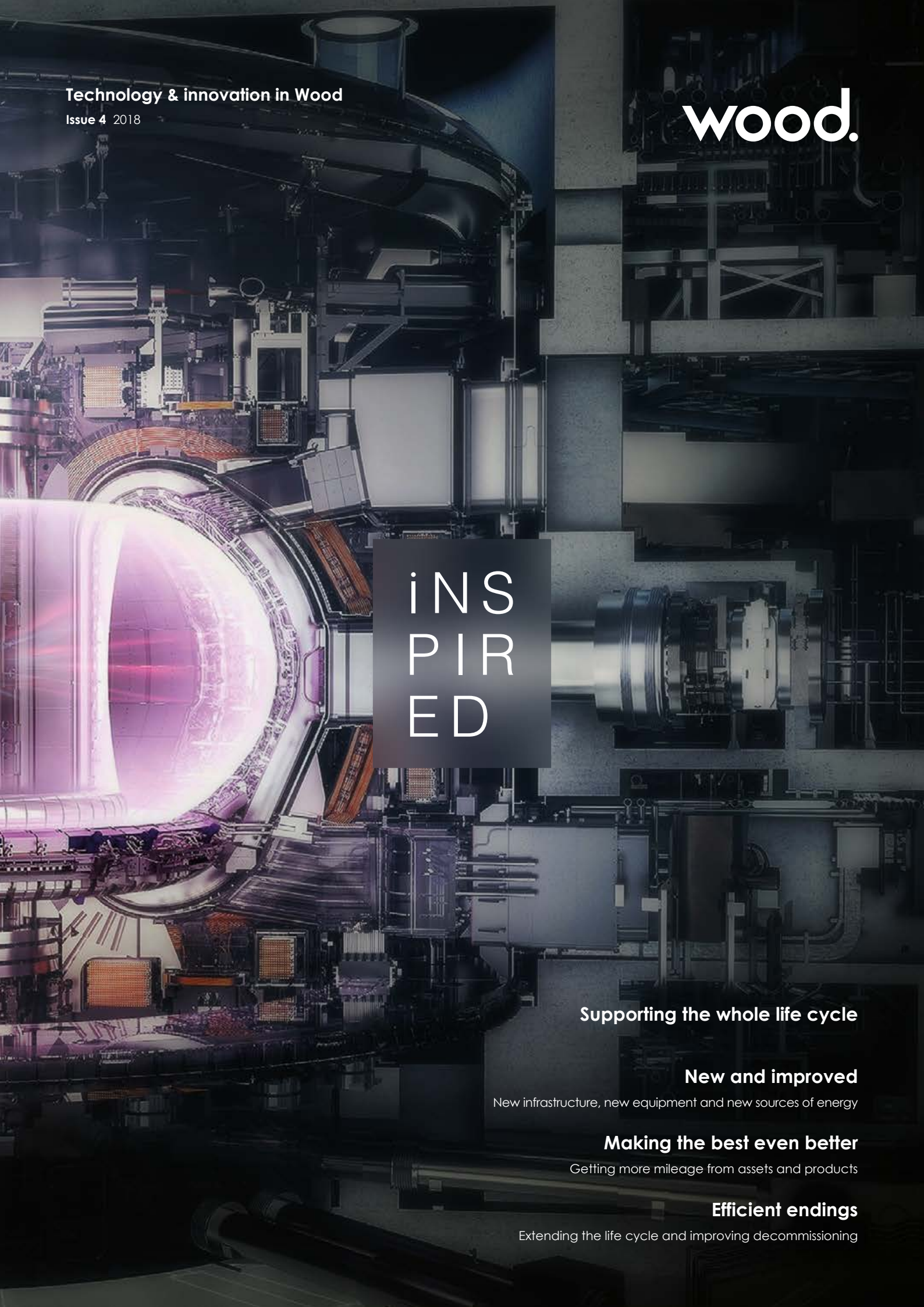

Technology & innovation in Wood

Issue 4 2018

wood.

iNSPIRED

Supporting the whole life cycle

New and improved

New infrastructure, new equipment and new sources of energy

Making the best even better

Getting more mileage from assets and products

Efficient endings

Extending the life cycle and improving decommissioning

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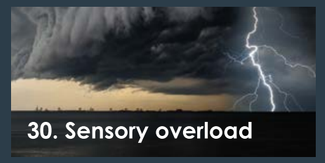

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Welcome:

A sunny outlook

Jeff Reilly
Executive President,
Strategy and Development

Our sun has been shining for 4.5 billion years and is likely to keep blazing away in its present state for another 5 billion. This certainly puts a different perspective on our own ideas of sustainability!

In this issue we are exploring our work at every point in the asset life cycle; we are working on some ground breaking new projects, keeping the current crop of assets operational and taking older facilities well beyond their original design life. It's what we do; delivering great assets and getting the most out of them for our customers.

This is our first issue as a completely new business. Wood has a significantly expanded range of services and supports a much broader spread of markets in more locations around the world. This dramatic increase in range is already bringing together some fascinating worlds, sparking new ideas and breeding a competitive ingenuity that will see many more innovations in future.

Wood continues to invest heavily in technology and development across all areas of our business. We are pushing the boundaries of data analytics on a number of fronts, from meteorology to production monitoring. We are pioneering virtual and augmented reality for safety training, impact modelling and asset operations.

There are innovative new well pad designs and engineering workflows that dramatically cut development costs, and new damper systems that reduce vibration in pipework to keep equipment functioning for longer. We are combining software and hardware to create advanced working solutions that drastically reduce time and eliminate logistical costs, and blending applications across industries to solve complex data and integrity issues.

Many of these projects are already in deployment, adding value for our customers and growing our business.

I'm thrilled to bring you this new issue and I hope you will be inspired by it. Please get in touch if you are interested in any of the projects, people and technologies we are showcasing. We would love to hear from your world, and perhaps your project will feature in a future issue.

inspired@woodplc.com

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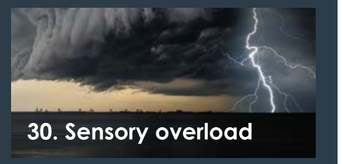

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News in brief

We're pioneering new ideas and technologies in many different markets, here are a few of our latest accomplishments:

Cutting a dash

Typically, we get the best results when we take a holistic approach to a project, looking at the whole process to identify and remove bottlenecks and highlight areas for improvement. We can scale this for specific tasks though and our discrete event simulation tool allows us to develop and refine solutions without affecting production.

Production lines are faster and more automated than ever, often running non-stop, day and night. With business models built around this capability, companies are rightly concerned about stopping production for anything, even to make changes to improve production.

Customers coming to us were asking for solutions that could be implemented with minimum shutdown or stoppage times.

In one example, a customer wanted us to look at part of a car production line that made the dashboards. They wanted production to be improved from 30 units per hour to 50. Midway through the project, they increased this to 60 units per hour.

Our discrete event simulation allowed us to model the production line and run it hundreds of times to identify bottlenecks. One key area we identified was in a place the customer had not considered. After a full analysis, we were able to remove the bottlenecks and run simulations to prove the new system would work.

Our improvements gave a simulated performance of 58 units per hour, just short of the target but good enough to give the customer confidence that real gains could be made. With the new process in place, the production line has managed to meet the new 60-unit target.

Discrete event simulation helped us mock up the actual scenario and quickly run multiple scenarios to test options and stress the system without getting in the way of production. We can test different layouts and control systems, and determine the best way to implement any changes to keep disruption to a minimum.

This solution has saved our customers hundreds of hours of testing, removed the need for actual production downtime until the correct upgrades are identified, and streamlined the upgrade process to minimise outages.

To find out more, contact: **gareth.henry@woodplc.com**

Fast tracking a FAT

In the latest of a line of new deployment ideas we sent the eXpert system to a remote location in Norway to help our customer complete factory acceptance testing of fire suppression equipment for use on a North Sea platform. Without testing and subsequent installation of the new equipment flights to the offshore installation would be restricted.

By sending the collaboration hardware to the site we were able to connect the required experts without the additional travel logistics for the 2-3 people normally required at site. Use of the system enabled us to respond faster and eliminate the coordination effort for getting parties in different locations to the site. Not only that, we were able to get more eyes on the test, allowing those normally involved in adjacent operations to witness and input to the testing, giving us more expertise, with more focus, for far less cost. In this case we saved £2400-£3600 on logistics costs, and between 20 and 30 hours of non-productive time.

The real-time nature of the system allowed us to resolve concerns immediately and record relevant sections of the test to provide a future audit trail.

The equipment passed the test and so did eXpert!

To put eXpert to work on your project, contact: **eworking@woodplc.com**

Below the waves

We have developed a new solution to enhance project and cost efficiency for the subsea sector, combining the benefits of standardised designs and supply chain independence.

Wood's engineering, procurement and fabrication (EPF) service uses standardised designs, streamlined procurement and pre-qualified vendors, integrating a number of service offerings to simplify delivery, reduce cost, accelerate schedule and remove interfaces.

The service is built on extensive experience in all areas of EPF, where we have delivered significant efficiencies. For instance, we recently saved a major operator more than 50% of the cost for quayside delivery of a riser umbilical and associated hardware.

Where previously Wood might have provided a design package for a subsea manifold, with some tendering, procurement and fabrication support and supervision, we now offer a complete turnkey solution from design to delivery at the quayside.

Based on standardised designs that cross reference industry standards for all key subsea equipment and construction aspects, EPF provides a simplified baseline that can be scaled to suit each project. Central to the EPF approach is solution independence. Wood is not commercially tied to any equipment suppliers and therefore able to consider all possibilities to find the best options and vendors for the project.

"We have always focused on simplifying complex technical problems," John Butler, business acquisition manager, says. "When it comes to subsea hardware design and engineering, we have successfully delivered all the elements of what we now term 'EPF' for a number of years across many geographical locations. This offering combines our expertise in engineering, procurement and fabrication to give a full, seamlessly integrated service."

To learn more about this service contact: **john.butler@woodplc.com**

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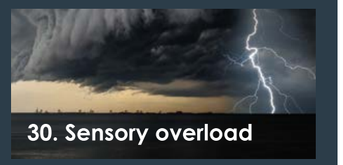
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Runway success

Heathrow is one of the world's busiest airports. Operating at almost full capacity it is managing more than 470,000 flight movements per year.

Expanding this facility is a major undertaking and our technologies are helping to minimise the disruption with VR audio simulations and advanced project planning.

To cope with increasing demand from a growing customer base and the next generation of aircraft the new runway is expected to raise traffic to 740,000 flight movements per year, a throughput of some 130 million passengers.

Before we get to work on those numbers there are the complexities of making this happen: politics, planning, project management, public consultations, compulsory purchases, river diversions, noise and air quality impacts. Getting this project off the ground will be an impressive achievement.

We began in 2012 with a range of environmental consultancy work, including supporting Heathrow's proposal to the Airports Commission. While this was important work, in many ways we were just taxiing for the take-off.

Project director Toby Gibbs is helping to pilot the work. "The scale and complexities of the project are exciting, challenging and daunting in equal measure. To be an integral player in one of the UK's largest ever infrastructure projects is something we're very proud of."

We are working with Heathrow to bring in innovative auralisation and visualisation tools. Technologies we have developed like our Listenin software can be used to inform the impact assessment and support the consultation and engagement exercises, conducting noise modelling through an immersive virtual reality (VR) system. This portable VR system can show stakeholders what a new development, such as an airport or windfarm, will sound like rather than relying on their understanding of decibel figures. The ambition of this work is to reduce the number of people significantly affected by noise.

Public greenspace will surround the airport, reducing flood risk, improving air quality, protecting biodiversity and creating enjoyable experiences for the community.

Five connecting railway lines and a terminal expansion will seamlessly accommodate 194 destinations served. We are proud to lead the way on these endeavours with a management role on the Integrated Design Team, alongside six other global consultants.

The Heathrow expansion is expected to bring £211 billion in economic benefit to Britain.

"It is a unique experience working closely with so many prominent consultancies as one collaborative organisation" said Alanna Marsh, associate director of infrastructure.

For more information, please contact **toby.gibbs@woodplc.com**

Wood already leads on five key parts of this mega project:

1. Ready for take-off – as the first construction activity on site, our engineering surveys will assess more than 1,000 individual locations.
2. Cruising altitude – our sustainability and environmental impact assessments will study impacts on noise, air quality, biodiversity and water.
3. The final approach – our landscape design will create new green spaces to benefit both the environment and local stakeholders.
4. Preparing to land – the river and flood engineering, and airfield drainage will necessitate moving major watercourses and creation of new flood plains.
5. Taxiing for arrival – our consultation services will provide the non-statutory and statutory consultation activity, likely to be the UK's biggest consultation exercise.

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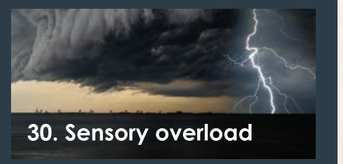

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Mobile mining

Wood subsidiary Terra Nova Technologies (TNT) has more than 20 years at the leading edge of mining equipment.

For most of us portable means something you can put in your pocket or carry around easily. In mining our Super Portable® concept refers to an 80 metre long modular conveyor unit that can move up to 10,000 tons of material per hour.

Getting to the good stuff

Extracting the various precious metals to make today's products involves processing large quantities of material to separate the commercial substances. Crushed ore is piled onto large pads that are sprayed with chemicals. The chemicals help break down and separate the precious metals from the waste material. The process, known as heap leach stacking, requires a big operational area and depends on large volumes of material to extract the metals in useful quantities.

Early heap leach systems used portable conveyors or 'grasshoppers' progressively linked together and feeding a mobile radial stacker to build the pad from a fixed conveyor running alongside. Equipment was repurposed from the aggregate industry, but could not handle heavy-duty mining, running 24/7. Our early success came from offering more robust and reliable mining equipment.

Problems stacking up

Copper followed the trend in gold mining of using heap leaching techniques, allowing operators to develop mines to quickly process low-grade oxide ores for less capital investment. Copper mines were more numerous, but required higher tonnage rates to be feasible. In a heap leach pad, ore is stacked in strips or 'cells' determined by the reach of the radial stacker and the number of portable conveyors extending from the overland conveyor to the far edge of the pad. As tonnage rates rose, the speed at which the equipment had to move and the rate at which new portable conveyors had to be removed from the main chain of conveyors on the pad increased.

To solve this problem, we developed new longer conveyors. The radial stacker grew in length from 36-40 metres to 64-70 metres. Portable conveyors grew from 38 metres to 76 metres, too big to be easily moved. The new designs had to be self-propelled and independently manoeuvrable so we developed and patented the Super Portable conveyor and stacking systems. The backbone of a Super Portable conveyor is its heavy-duty truss structure, optimised for high structural weight efficiency. The ends of the central truss are mounted on crawler vehicles driven by electric motors / on-board diesel generators. With this system, Super Portable conveyors can climb and operate up to 10 degree grades.

Moving along

The Super Portable concept created new potential for heap leaching. The 5,000 ton per hour barrier was broken with the first full system supplied to a large copper mine in Arizona running at up to 6,600 tons per hour. A system was installed in Chile and raised the bar again increasing the tonnage another 35%. With all 23 conveyors in operation, this system can stretch up to 1.8 kilometres across the pad and stack more than 130,000 tons per day.

We see potential for other applications beyond heap leaching. The units can be used for dry stack tailings, an emerging trend for reducing water use in mining. Dry stack tailings systems dewater the waste stream; the tailings are then conveyed and stacked rather than being pumping into a tailings pond. This method of depositing tailings mitigates the risk of dam failures. We installed the largest dry stack tailings system to date in Saudi Arabia, which has been operating successfully since 2011.

It is also possible to integrate overland conveyors and Super Portable conveyors to transport and stack waste rock or mix waste rock and filtered tailings to be deposited together, saving precious water, removing the risk of retaining dams and stabilising the waste/tailings pad. Major operators in copper, gold and oil-sands are all looking at these concepts.

Mining the future

We are working with other equipment manufacturers and operators to use Super Portable conveyors with in-pit crushing and conveying (IPCC) systems. When faced with ever decreasing grades and higher strip ratios in hard rock mines, IPCC systems can use the highly mobile Super Portable conveyors to directly link a shovel and mobile crusher to high capacity overland conveyors extending out of the mine to reduce haulage costs.

Focusing the mine layout around conveyors instead of trucks is critical for effective IPCC solutions. IPCC systems are made to fit into existing mine plans, and lack the flexibility to adapt as the mine changes. The Super Portable conveyor, combining high mobility with high tonnage overland conveyors may be the next step in the evolution. We are developing systems for tonnages over 200% of today's typical production rates for open pit conveyors, using new 'megawatt' class conveyor drive technologies.

If you're interested in improving production in a way that's flexible and easily controlled, get in touch:
ron.kelly@tntinc.com

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The innovative Super Portable conveyor improves production and operating efficiency.

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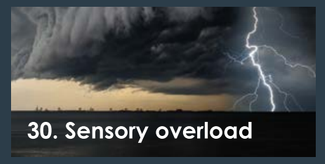
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Engines of ingenuity

Ingenuity is one of the key principles at Wood; our chief executive explains why it is so important.

For me, innovation has a number of facets. There are the small improvements we make every day, evolving our processes and making our operations more efficient; the technologies we apply to change discrete areas of our business for the better. Then there are the major innovations, disruptive moves that bring about a step change in performance.

Our ingenuity goes beyond cutting edge technologies and complex software. It is rooted in the thoughtful, progressive attitudes of our people, and a drive to improve, find better methods and generate greater value for our customers. It's a part of our culture I am extremely proud of.

A lot of our operations are incredibly complicated, sometimes with millions of moving parts. Our success lies in ensuring the solutions are no more complex than they need to be, helping customers understand their problems in the simplest terms and devising answers that are elegant in their simplicity.

The integration we are going through to create Wood really is a major innovation, and the step change is occurring on a number of fronts.

Firstly, it moves our strategy a giant leap forward, executing a vision we originally mapped across a five to ten-year horizon in just six months. We would have been positioning for a new stage of growth, now we have more than doubled the size of our business.

Secondly, we aimed to move into new markets to create greater stability and security as a platform to support our employees and our customers. That balance has already shifted to a much broader spread of markets and sectors, with the opportunity to develop these further in future.

I see this new mix of capabilities as a catalyst, accelerating our potential and creating a fertile platform for new ideas with a far greater range of technical ability, specialist viewpoints and industry perspectives to draw from.

I have never been more excited about the future of our business.

Robin Watson
Chief executive, Wood

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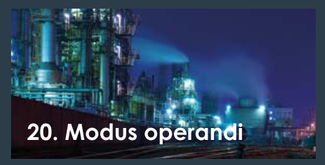

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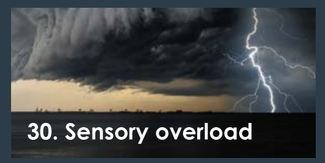

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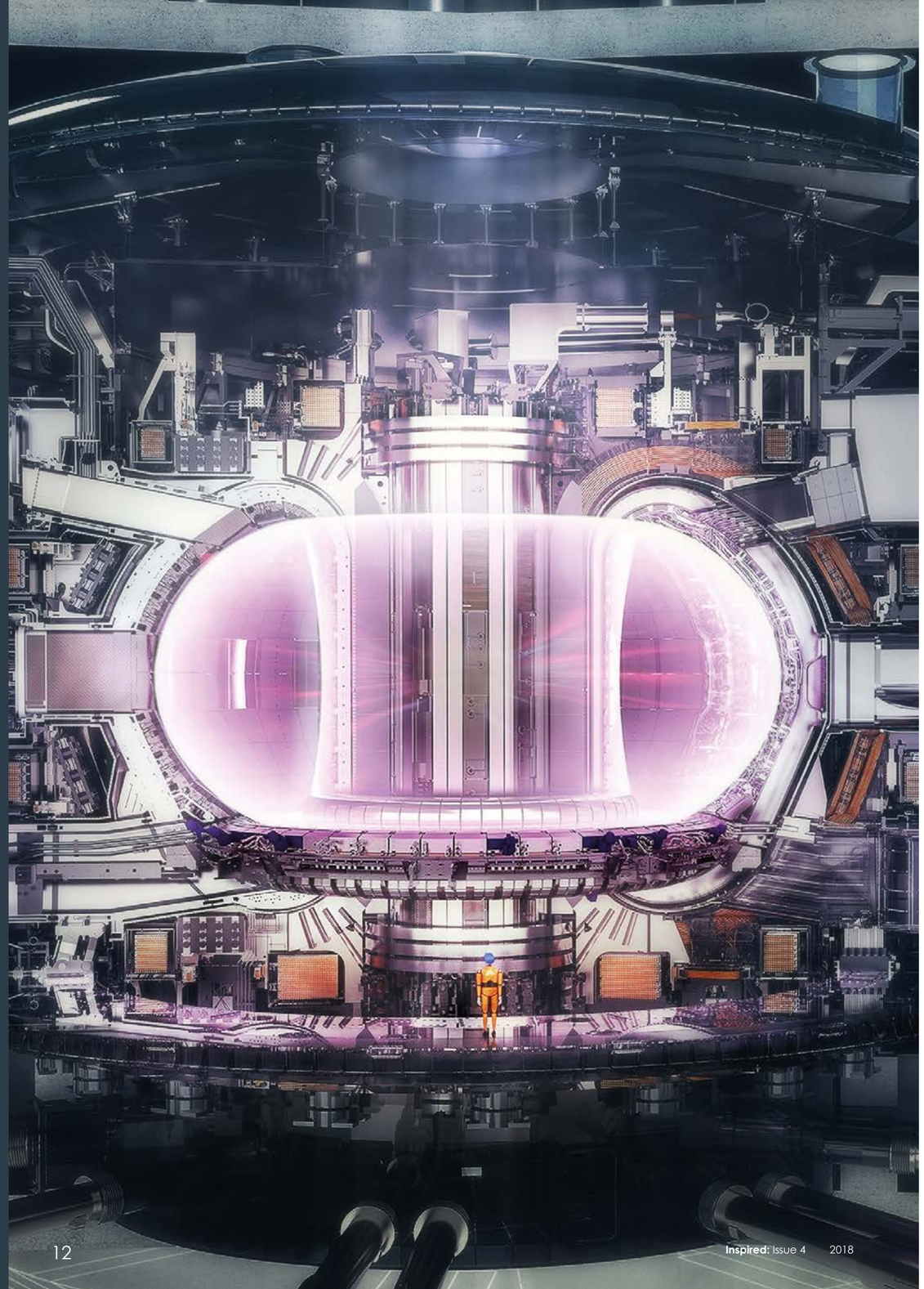

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From fiction to fact

Nuclear science is a highly complex discipline and exploiting the immense energies involved is a major challenge. So far, attempts to harness this power have focused on the fission process, breaking atoms apart to release energy. This is the relatively straightforward method...

Throughout this issue we have looked at different developments with the potential to create a step change in performance. Moving from a fission process to a fusion one would also deliver a step change. The energy output from successful fusion is potentially many times greater than the energy we create with fission. Beyond the increased energy output, the fusion process has the advantage of using more easily available fuels and the waste products are significantly lower with shorter half-lives, making it an even cleaner and more sustainable energy source.

A long-term project with long-term goals
Nuclear fusion has been pursued for more than 60 years, the key goal being a sustainable reaction. The tremendous energies involved – fusion essentially recreates the reactions that occur at the heart of our sun – mean that both powering and engineering the process is a huge challenge. The ITER project, an international nuclear fusion megaproject, aims to prove the feasibility of fusion as a large scale carbon-free source of energy. Construction of the ITER facility is scheduled to complete in 2025 with early experiments beginning in a four-stage process over the ensuing 10 years.

The whole facility is a testbed for the methods and technologies needed to achieve a stable source of power with fusion.

Creating energy with energy
The reactor will create plasma, a molten mass of electrically charged gas heated to temperatures of about 150 million degrees Celsius and contained within a specially shielded, doughnut-shaped container called a tokamak. ITER's tokamak will be the world's largest magnetic plasma confinement experiment, more than ten times larger than the largest existing model. The aim of ITER is to build the first reactor capable of generating a 'burning plasma', meaning a plasma that is largely self-heating, generating approximately 10 times more thermal energy output than the thermal input required to power the plasma reaction.

World-leading collaboration
35 nations are working together on this ground-breaking project with thousands of engineers contributing to the design. Wood is the largest industrial contributor from the UK and we have supported this project for decades. Our current work includes:

- Developing blanket first wall panels (FWPs) to protect the chamber from the extreme heat of the plasma
- Remote handling systems for the neutral beam, which heats the fuel in the tokamak, and for maintenance of other parts of the reactor
- An integrated plant simulator covering multiple systems
- A concept-level study into dismantling the ITER facility when it comes to the end of its life as an experimental research platform
- A contract lasting up to 10 years for construction management-as-agent, supervising the assembly of millions of components on the ITER site

To find out more, contact **peter.stalker@woodplc.com**

ITER is one of the world's largest experiments, with the potential to transform our energy future. Find out more at **www.iter.org**

Fusion is only part of Wood's work on future nuclear technologies. Our involvement in research into high-temperature Generation IV reactors ranges from materials testing to the application of virtual reality design techniques, and we have also designed the cores for small modular reactors. These technologies have the potential to meet the world's energy needs in a safe and cost-effective way, a combination that remains a challenge for today's fission reactors.

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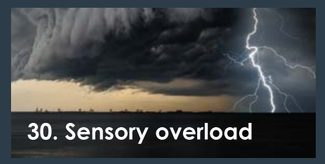
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Raising the bar on barrier testing

Real-time monitoring software is helping our customers test their valves more effectively.

Last issue we showcased how our Virtuoso software is being used to monitor thousands of remote well pads with simulation environments and models that help rapidly test various configurations to get the best performance from each well (Well, well, well. Inspired Issue 3).

The software is highly adaptable and is also being used to monitor pipelines, model flowrates and identify likely corrosion points. For wells, we have adapted the software to analyse barrier tests of safety-critical valves.

Barrier testing builds pressure behind the safety valves of a well to prove their effectiveness. There are many elements to the well that can lead to false results in the test unless properly accounted for. The only way round this is to be very rigorous, conduct tests over an extended period, and allow time for well fluids to cool and settle.

Until now.

Failed valves lead to shutdowns, false predictions lead to shutdowns, and proper testing requires a shutdown. So the best option is to test effectively, and test quickly.

Our Intelligent Operations team has worked with well pad operators to monitor production for nearly twenty years; over this time we have built a comprehensive understanding of the dynamic properties of well fluids, using the data to refine our models.

Our testing features rigorous thermo-dynamics (leak rate calculations are affected by fluid expansion or compression) and parameters that must be factored against the overall results to determine if the leak is real. Valve leak rates are estimated beyond a simple pass/fail output to give qualified results with defined uncertainty parameters so it is easier to verify and understand the possible causes.

Tracking these results over time helps to build a far more accurate picture of the well profile and determine which results indicate a false leak and which should be acted on.

We lead the industry in real-time performance monitoring. Our product line incorporates multiphase flow, heat-transfer and advanced thermodynamic calculation technology, all delivered through a user-friendly interface that is optimised for field use while allowing detailed analysis of the calculations by engineers.

Standard approximations are not enough to make reliable predictions across so many variables so our rigorous modelling covers the complete real-life operation to solve the full physics of the problem.

To find out more, contact:
pradeep.dhoorjaty@woodplc.com

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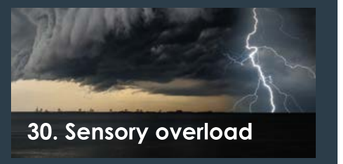
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Beta vibes

A lot can change in half a century. After 50 successful years our vibration, dynamics and noise team has a rich heritage of experience, skills and hairstyles to draw from.

In 2017, Wood's vibration, dynamics and noise team celebrated its 50th anniversary. BETA Machinery Analysis, a speciality mechanical engineering consultancy originating in Calgary, Canada, was purchased by Wood in 2015, bringing a unique range of niche technical support covering the whole spectrum of noise- and vibration-related integrity issues.

It's hard to imagine how vibration concerns were tackled in 1967, but back then our engineers had to solve complex problems without any of the computers, analysis software and advanced sensor capabilities that we use widely today.

The founders of BETA were truly pioneers in their field. They built their own sensors and designed new electronic test equipment to understand the root cause of vibration and performance problems on compressors and pumps. They then had to find innovative solutions, resulting in novel software simulations and patents.

Dave Schuh founded BETA, and Brian Howes and Bryan Long came on board soon after. Through their passion and focus, the company became a market leader in vibration and pulsation analysis.

Brian Howes joined fresh out of university in May 1972, and has had experiences with machinery of all kinds over his long career: "The work we did on large integral reciprocating compressors, gas turbines, centrifugal compressors and other equipment led us to better understand the modes of failure and some of the sources of problems in machinery. We were then able to design better tools for solving the problems. Our computer models were greatly enhanced by the continuous feedback from field work we undertook.

"We are still always learning. Recently, at a refinery in Spain, I was presented with a situation involving a blower that occasionally had a failure of the stub shaft. The result was the coupling hub and stub shaft bouncing around inside the noise enclosure. Operators were rightly afraid to enter the enclosure when the unit was running. We were able to identify a lateral critical speed that could be changed with the relatively simple addition of a carefully chosen mass on the coupling hub - a very satisfying result for everyone. Helping people prevent problems with machinery and fix issues when they do arise has always been our reason for existing."

Bryan Long joined BETA in November 1973: "I met Dave Schuh when he was looking for someone to lead the development of a digital simulation reciprocating compressor pulsation service. Work like this was being carried out on analogue computers but there were obvious advantages to transitioning to digital technology. This was pioneering work. MAPAK, our mechanical acoustical simulation software, was developed and launched commercially in 1975. Over the years the service evolved and became very successful through ongoing research and development. Still called MAPAK, it really has been the foundation of our success. These days it is a very different technology from when we launched it, but it's been state-of-the-art every step of the way. MAPAK enabled us to become a dominant presence and industry leader in the speciality of reciprocating compressor and pump vibration analysis.

"Overall, I believe there are four reasons why we have been so successful: ongoing innovation as the foundation, our drive for excellence, being selectively opportunistic and our commitment to customer satisfaction, which became part of our culture.

"I have enjoyed working here for the past 44 years and I see a positive future with additional global opportunities as part of Wood. Previously, the vast majority of our work was in Canada and the US, with some work in South-East Asia. Now our opportunities have increased in these areas and throughout the world."

Shelley Greenfield, service line manager of the machinery analysis division, was hired in 1985 to help set up a technical library: "Very quickly I started working on pulsation studies.

"Over the years I have touched on a few of our other services, but my main focus has been pulsation and mechanical studies.

"It has been very interesting to watch the reciprocating compressor industry advance. When I started, a large separable compressor was about 1200 horsepower running at 900rpm, which is relatively small by today's standards. As industry developed larger, faster compressors, the analysis world also had to change. A group of world-class engineers and a strong field services team has helped us stay at the leading edge of technology. The evolution of computing power has also helped us succeed in our continual drive for more accurate results and efficient modelling tools.

"We have always promoted a culture of continuous improvement and customer focus. It has been very rewarding to be part of such a dynamic organisation."

Another long-serving employee is Kelly Eberle, principal consultant, who is approaching his 30th anniversary with the business: "I've been incredibly lucky to be involved in almost every service area, from machinery design and field troubleshooting work, pulsation studies and finite element analysis, to research and development, and delivering courses for customers.

"I believe our success is down to the people. You have to have the right people in place to understand the technology and keep pushing it forward, to strive for improvements and advancements.

"There were only around 20 employees when I joined in 1988. It felt like a small team, but when I started travelling, I realised that there were pockets of people in far flung places round the world who knew our reputation. It was inspiring to know what a significant impact was being made to people, customers and the industry as a whole.

"Working within the oil & gas industry is now a major part of the business, but it wasn't until the late 1990s when we successfully completed a logistically complicated project that we started making significant inroads. We designed and commissioned seven reciprocating compressors on an FPSO operating in the Gulf of Thailand - quite an accomplishment for a small team located in the Rocky Mountains of western Canada. We developed the pulsation and mechanical design of the compressor packages for a US customer, completed the structural dynamic analysis for a customer in The Netherlands and performed on-site testing in the Singapore shipyard during construction.

"Being part of Wood gives us much greater exposure to new customers and industries; our scope of work is expanding. For example, we have tripled the size of our pump team and our US office. It's had a hugely positive impact on the business."

Russ Barss, vibration, dynamics and noise director, says: "We grew cautiously at first, but then expanded across North America and eventually into the global marketplace. In 2004, the three shareholders passed the reins over to me to help keep the momentum going.

"In 2015, we joined Wood, followed shortly by SVT Engineering Consultants, the dominant vibration team in Australia, and a group of leading vibration experts in the UK. This combined capability created the VDN team, a global leader in vibration, dynamics and noise.

"We are privileged that Brian Howes and Bryan Long continue to be actively involved in the business, providing their technical expertise and mentorship to our team. We hope this party continues for another 50 years."

The VDN team can be reached at: **info.vdn@woodplc.com**

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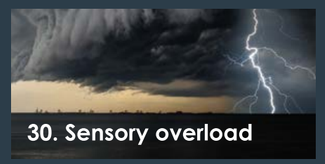

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Optimising wind farms is a breeze

Our Optimiser service effectively digitises the wind to model improvement opportunities.

Our technology has been used to optimise performance on a variety of projects worldwide.

We have used our advanced technology to extend the life and performance of more than 50 wind farms around the world.

Optimiser combines revolutionary LIDAR technology to visualise airflow, state-of-the-art computational models and real data from the turbines to extract greater performance from wind farm assets. These case studies show how we are helping our customers get the most from their investments.

Barking up the right tree

We were appointed by an operator to investigate the performance of its Swedish wind farms. The forest around these sites creates complex wind flow that reduces performance. Optimiser was used along with state-of-the-art computational modelling to suggest felling plans that would maximise windfarm production while remaining commercially and environmentally acceptable to the forestry operators.

We identified a genuine win-win with the felled areas replanted to modern standards, bringing biodiversity and other environmental benefits.

The commercial value to the customer is in the region of $25 million, an excellent gain on current production. Needless to say, the recommendations made by the clean energy team have been fully accepted and we are now managing the forestry restructuring activity on behalf of the operator.

A breath of fresh air

For a customer looking at acquiring a large wind farm portfolio of approximately $1 billion value, we provided a professional assessment to support the decision. In addition to detailed risk analysis, we looked at improving returns through performance optimisation, in this case considering measures to extend the lifetime of the assets.

The work identified substantial value enhancement potential, tens of millions of dollars, which assisted their successful bid to acquire the assets. We are now undertaking follow-on work to implement our suggestions to enhance value through life extension.

The long-term gains from incremental improvements are significant over the life of these assets and we are excited to be at the forefront of developments in this field.

To find out more, contact **alan.mortimer@woodplc.com**

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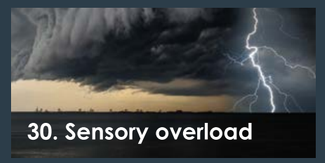

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Modus operandi

Wood and Siluria Technologies launch Modus™, the first process technology to convert low-value offgas into refinery products.

Refinery offgas streams, typically from a fluid catalytic cracker (FCC) or a delayed coking unit (DCU), are typically burned for heat or power within the refinery operation. However, these streams contain significant quantities of valuable components such as light olefins and natural gas liquids.

Conventional approaches for extracting value from the offgas use complex and capital-intensive recovery systems to separate and purify the components. Installation of these systems requires significant downtime, which can adversely impact refinery operations. In addition, refiners are then forced to enter unfamiliar markets and develop supply chain solutions for these logistically challenging products.

As a result, many refiners choose to burn the offgas as fuel, consuming a potentially high-value product for low-value energy purposes.

Jointly developed with Siluria Technologies (www.siluria.com), a leader in disruptive process technologies for the petrochemical and energy industries, Modus is an industry first technology that converts refinery offgas components into high value, fungible liquids that can easily be added to the sales pipeline. The technology offers a simple, low-cost and effective solution for maximising the value of the offgas streams and enhancing profitability.

For example, a 200,000 bpd US Gulf Coast refinery configured with an 80,000 BPD nominal-feed FCC and a 50,000 BPD nominal-feed DCU, could enhance the refinery profits by $30 million to $35 million per year after installing Modus. The payback period is also short, between 1 to 2 years, making this an attractive investment.

At the heart of Modus is a novel catalyst and reactor system that converts dilute quantities of light olefins (such as ethylene and propylene) in the offgas into high-octane, ultra-low sulfur gasoline blendstock and liquid petroleum gas (LPG).

The Modus catalyst was specially designed for compatibility with offgas streams, without requiring extensive containment, pre-treatment or purification.

Modus can be readily integrated into existing refinery operations with minimal capital investment and operating impact. Based on standard modular design and construction, Modus can be rapidly installed as a standalone upgrade during routine maintenance turnarounds or revamp projects. Modus also provides greater operational flexibility and the potential for reduced emissions, without disrupting refinery operations.

For more information about Modus contact Daniel Carter, director of global consultancy in Wood's Process Technology service:
daniel.carter@woodplc.com

or Andrew Aronson, corporate development at Sluria Technologies:
a.aronson@siluriatech.com

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Nawal Prinja, a mine of nuclear knowledge

After 37 years working for our nuclear business, technology director Nawal Prinja continues to look forward.

"The nuclear industry is changing," Nawal tells us. "That means we have to innovate. There is no way we can just carry on doing what we have always done."

Fortunately, research is one of our strengths. When the UK government wanted to create a new high-temperature facility to test materials for use in future reactors, it selected us and gave us £2 million to host it.

More government money is being invested on research into digital reactor design and new technologies for decommissioning. And there is increasing emphasis on research and technology development: the UK Government intends to increase its R&D spending to 2.4% of GDP, taking it to around £12.5 billion by 2021/22.

"We plan to develop innovative technologies that will benefit our industry," says Professor Prinja. "This is not research for the sake of research; it's innovation for growth."

These technologies include:

- SIAL, a geopolymer matrix that has many advantages over cement for encapsulating nuclear waste
- RESIST (residual stress and structural integrity studies using thermography), a non-contact, remote method for assessing stresses in welded joints by using infrared imaging
- Load-following techniques that will enable nuclear power plants to adapt to a rapidly changing world in which electricity demand is measured in fractions of a second rather than hours

Nawal is well placed to know whether a technology is truly ahead of the curve, thanks to three professorships at Aberdeen, Bolton and Brunel. These give him access to meetings of the Joint Nuclear Centres for Doctoral Training, where scores of PhD students present their work. It helps that he is an expert assessor for Innovate UK and also advises the Engineering and Physical Sciences Research Council, the International Atomic Energy Agency and the World Nuclear Association.

The UK's National Grid believes that nuclear will have to supply 31% of the country's electricity needs by 2050.

"With fossil fuels being phased out and renewables still plagued by intermittency, how else can we provide enough power to meet demand?"

Undoubtedly, the existential challenge for nuclear power is to come up with the next generation of reactor design with greater thermal efficiency and lower build costs than current gigawatt reactors.

Professor Prinja believes that this is where the UK government will focus its research funding, adding: "Future reactors are likely to be high-temperature, perhaps graphite moderated, which would play to our strengths from designing and supporting the UK's AGRs (advanced gas-cooled reactors). It is likely we will play a major role in the new reactor designs."

This was borne out last year when our team, working with Rolls-Royce on small modular reactors, rapidly increased to more than 50 people at its peak, providing support on design concepts, early stages of safety cases, plant performance, fuel route, control and instrumentation, containment building concepts, and reactor designs.

Between our ongoing services for nuclear energy in the UK, support for the ITER fusion project in France, our global decommissioning work, our leading position in wind energy and the long-term efforts to create a more sustainable future in conventional methods we have a significant stake in our global energy production, it's an exciting place to be.

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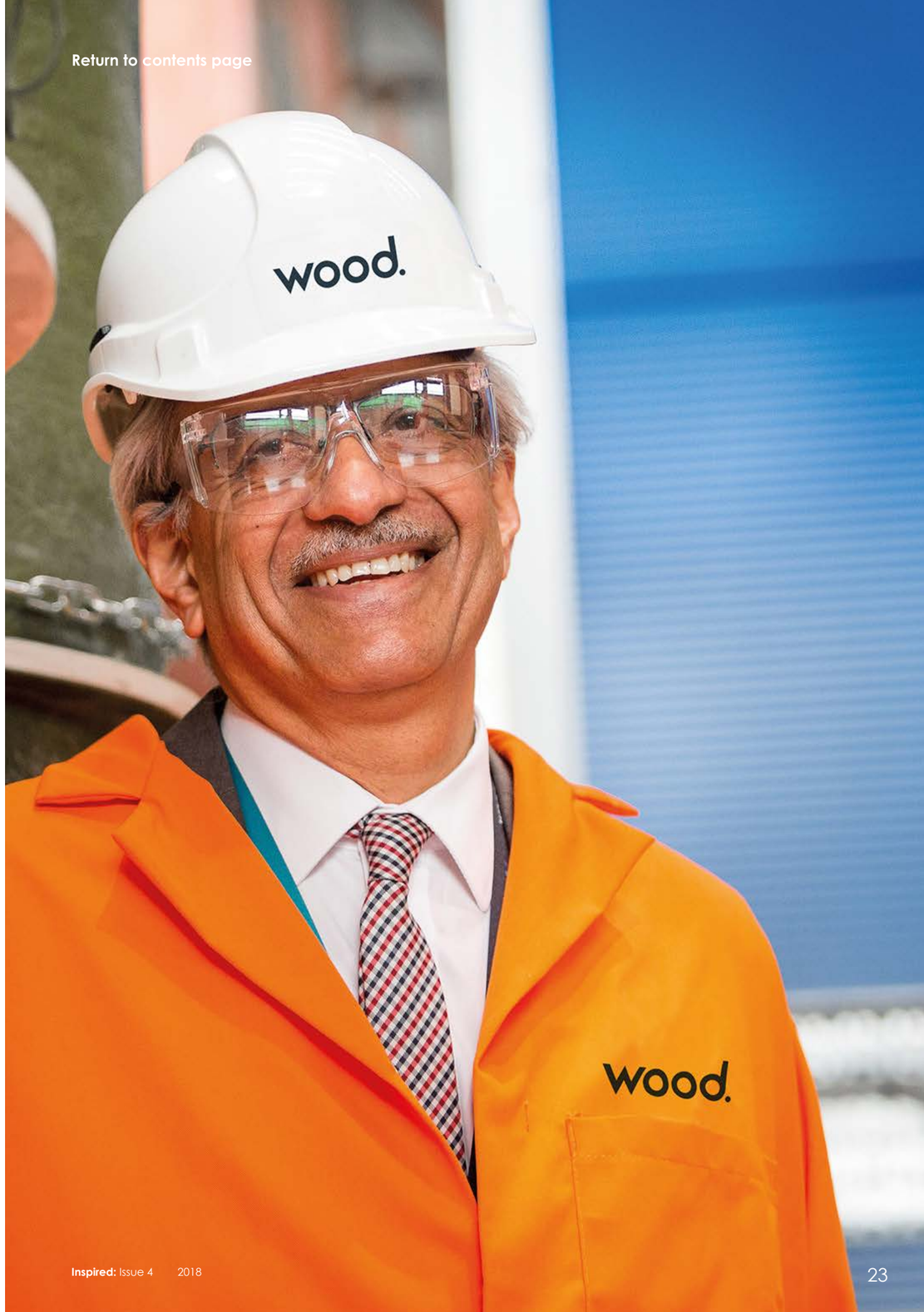

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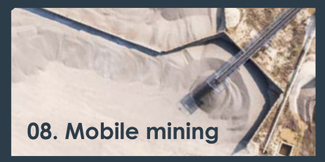
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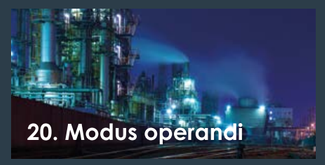
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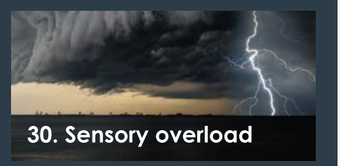
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Go with the flow

Wood's new software eliminates production constraints and increases design flow by 20%

The integrity of process piping on aging assets is a common concern for operators. Failures caused by ongoing issues such as vibration-induced fatigue can have devestating and costly effects.

An Omani-based customer had been operating its three-train LNG plant at reduced production rates because of concerns around the integrity of the main process piping. Operations personnel had reported the risk of vibration-induced fatigue failure and were worried about the ongoing condition of the piping systems. A new gas field was also planned to come on stream to supplement the existing feed, so it was imperative that future production constraints were avoided.

We started the project by working closely with our customer's site integrity team to assess the vibration integrity of the hydrocarbon process piping and identify any areas at risk of vibration-induced failure.

Our initial office-based investigations were conducted with Veridian, our digital, risk-based vibration screening tool.

We considered all typical vibration sources for the assessment, including flow-induced turbulence and pulsation, mechanical (machinery) vibration, pulsation due to reciprocating gas compressors, transient forces due to fast-acting valves, and rapidly changing fluid flows.

Changes to the existing piping system were planned, assessed and implemented prior to introduction of the new gas stream: with remaining (low-risk) anomalies identified and ranked using the software's anomaly manager feature.

Our Veridian software saved the customer hundreds of hours by accurately screening, calculating and pinpointing the areas of piping for further investigation. This enabled the operator to remove the production restrictions on the current feed gas and extend the design flow by up to 20%.

Over 2,000 main process flow lines were assessed and more than 400 had a potential vibration integrity concern that required a more detailed investigation. In addition, the customer identified specific flowlines of concern due to slugging and multiphase flow, liquid flashing, and high flow velocity vibration.

Due to the significant gas inventory associated with an LNG plant, a relatively large number of flare system gas valves were highlighted as a potential concern, requiring a more detailed integrity assessment of the flare piping. Noise control measures had been included in the original plant design, however, specific design features were identified as being a long-term integrity risk. Wood's vibration engineers worked to identify short- and long-term control measures, assessing the flare system for the risk of acoustic-induced vibration (AIV).

To more accurately quantify the vibration risk, onsite visual inspections and vibration and dynamic stress measurements were conducted on all the accessible main lines identified in the screening study, as well as the lines previously identified by our customer. The results were used to update the Veridian database and the areas of concern were included in an online anomaly tracker.

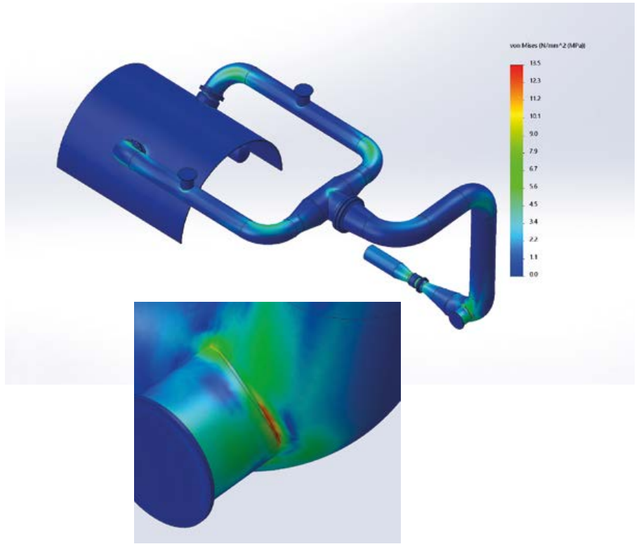
To determine whether the piping stresses were acceptable for the current and future operating ranges, detailed finite element analysis was carried out for the main flowlines with significant vibration concern. Where necessary, vibration control measures were evaluated using our computer models, and once a satisfactory solution was agreed with the customer, we provided specialist engineering support to implement the change.

Our vibration and acoustic mitigation methods ensured the continued safety, integrity and commercial viability of the plant's piping systems.

This approach was highly regarded by the customer, and discussions are already ongoing for using Veridian to predict and manage the integrity of future plant developments.

For more information, please contact **jonathan.baker@woodplc.com**

The colours in the model show the bands of stress within the pipework, highlighting areas of potential failure.



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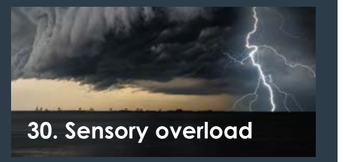

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More than a paint job

Brendan Fitzsimons has been at the leading edge of coating developments for more than 30 years. In that time he has worked on some surprising projects...

Inspired: Tell us how your career started.
I have always been involved with the corrosion and protective coatings industry. I obtained a master's degree in material engineering before becoming a Chartered Scientist. I spent eight years working as a coatings technician and adviser to a global coatings consultancy organisation. This role took me to various locations around the world looking at coating projects in the marine, offshore and petrochemical industries.

I then spent 10 years in the offshore construction industry working throughout Europe on oil and gas projects.

I now support the Industrial Services division of Wood in marine, offshore, petrochemical and construction.

Which projects are you most proud of?
I have been involved with numerous projects, from offshore platforms and windfarms; oil and gas pipelines in the UK North Sea, Canada and the Far East; to concrete dams in the Middle East.

I have worked on many military ships and vessels, and prestigious contracts such as the Forth Rail Bridge in Scotland and Tower Bridge in London.

What is the process for specifying a new coating? What do you consider?
The industry strives for innovation. Customers want innovation, yet they want a guarantee that it will work. Expert support is needed to ensure that the products have been thoroughly tested (laboratory or independent) and to ensure that the product can be applied as specified in the product data sheets.

The annualised cost of application, the product itself and lifetime maintenance have to be considered. It may be easy to find fault with a new product, however, a little bit of support or technical advice can enhance a new coating.

Are any areas typically overlooked?
Chemists and engineers are always striving to produce new products. Due to legislation, products need to have minimal solvents and fewer chemicals included in the formula. The product must be able to be stored, mixed and easily applied. Field trials are often overlooked, The value of information from field trials and long-term exposure cannot be underestimated.

What is the most unusual application you have worked on?
I have worked on a lot of unusual assets from a King's concrete jetty to a pig's sewage pipeline. I have looked through ducting on one of the world's biggest cruise liners and tried to establish why coatings have fallen off an aerial mast on top of a skyscraper. I have also climbed around a secret military radar system as the failing coating was effecting the signal.

The most unusual and extreme challenges often arise from surface preparations and coatings for application in very hot conditions such as the Middle East in August or very cold conditions like protecting ship ballast tanks in the Baltic in January.

What advice would you give to customers looking to protect their assets?
Consider the long-term implications, and engage with organisations and people who understand corrosion mitigation and planned maintenance. Coatings are not just for aesthetics. Proper maintenance of assets is the most cost-effective way to control corrosion. Develop or use specifications and standards that have been tried and tested. Listen to people in similar industries.

Don't chase corrosion, take the lead on arresting it.

Everything is possible in the coatings industry, certain coatings can withstand application in high temperature while others can dry and cure at very low temperatures.

Facilities managers can play a critical role by adopting the right philosophy that considers coatings as part of the overall integrity programme.

If you need help to protect your asset, get in touch with Brendan:
brendan.fitzsimons@woodplc.com

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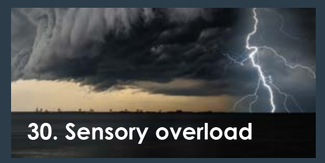

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Corrosion watch

Great ideas can seem quite obvious when you look back at them. Combining two world-leading technologies to help predict and control corrosion now seems like a completely logical step.

Corrosion is often thought of as an external agent, attacking structures and pipework from the outside. But it targets internal systems as well. Internal corrosion presents a different set of challenges since access becomes much more of an issue, involving shutdowns, suspended production and complex survey techniques.

Monitoring and predicting corrosion is a very important discipline relevant to the entire life cycle of an asset.

Pipes are simple enough in principle. However, when your pipelines are complex or extend for thousands of miles things become a little more complicated. Flow rates can be different in different areas of the pipe; hotspots focus the effects of corrosion in certain areas or allow it to develop elsewhere, and corrosion inhibitors might not reach the right areas.

Modelling the problem
Our Virtuoso software is used to model and predict flows in pipeline networks. It can operate both on- and offline, allowing predictions to be made based on historical data and confirmed in real time with live data to build increasingly accurate refinements.

Electronic Corrosion Engineer (ECE) is our specialist software that predicts corrosion rates based on temperature, pressure and flowrate conditions. There are thousands of potential combinations of conditions that lead to different levels of corrosion making it difficult to predict accurately.

A combined solution
By plugging the flow modelling data from Virtuoso into the corrosion calculations of ECE we have been able to create a really powerful tool for assessing the impact of flowrates on corrosion. In addition, when we look at mitigating corrosion with inhibitors we are able to model and predict how effective an application will be.

We have worked with Leeds University on a project to measure corrosion rates in high CO2 systems. This has provided more detailed data for our models helping us develop and test better corrosion-resistant alloys. With more vigorous data and a wide variety of test conditions we have been able to identify the components that have the greatest impact on corrosion and the best methods to reduce it.

Corrosion resistant alloys are very expensive, up to 20 times more than carbon steel. By modelling their effectiveness over the whole pipeline we can pinpoint the best areas for protection and even suggest ways to operate the pipeline to avoid using expensive alloys and extend the life of the pipe.

This is an exciting development for corrosion prevention and also for exploring the additional potential to combine our applications to create new solutions.

For more information, please contact
dale.erickson@woodgroup.com

An inside view

Selecting the most appropriate inspection methods can make a major difference to your integrity programme.

Pipeline integrity is a critical part of any integrity management program. Operators need to know each pipeline and its condition intimately because pipeline failures or unplanned shutdowns have a major impact on production targets and can have severe safety or environmental consequences. Having a clear understanding of the current and likely future condition of an infrastructure is central to effective decision making.

Pipeline inspection is normally achieved with pigging – inserting a specialised device known as a pig into the pipe and using pipeline pressure to push it along. Using a pig requires a particular set of skills and expertise - as well as a decent flow rate to move the pig along. In addition, a pipeline system may not allow the transit of inspection pigs, or there may be limitations related to aged valves or related equipment.

Performing pipeline inspection places a huge burden on OPEX with lengthy production outages, so selecting an appropriate inspection method and defining the inspection interval is paramount for assessing current and future pipeline integrity.

At Wood, we understand that no single inspection technique is appropriate for every application, so we support our customers with a comprehensive suite of pipeline integrity services, including robust analysis methods that provide accurate data on pipeline condition.

Where only partial inspection data is available, or where pigging is not possible for operational or economic reasons, we can provide internal corrosion direct assessment (ICDA) that enables integrity evaluation without having to carry out in-line inspection (ILI). Our ICDA program helps customers gain valuable insight into the integrity of their pipelines through evidenced-based assessments and analysis.

Using a process developed from the NACE industry standard practice, Wood's multidisciplinary engineering teams manage the entire pipeline integrity assessment through a simple, four-step process that provides complete confidence to proceed with ongoing pipeline integrity management.

Our ICDA provides a pipeline integrity evaluation without the need for a pigging survey. This offers significant cost and schedule savings. Our engineers and analysts review the data and carry out the indirect examination / analytical assessment. From there our teams can conduct any physical inspection and evaluation required, with a capability that covers the full range of inspection management, from external inspection by ROV or diver, deployment of partial internal / crawler tools. If pigging or isolating operations are required we can develop schedules that maximise uptime.

A recent inspection project took just six weeks to review the data and carry out the indirect assessment, which is considerably less time than it would take to develop and execute a pigging program offshore. Our approach can enable a physical inspection to be deferred, using robust analytical data to push back an ILI campaign by months or years, which helps optimise OPEX burden from maintenance budgets.

ICDA optimises external inspection programs by identifying the most critical locations. The assessment is carried out by fully integrated flow assurance and integrity engineering delivery teams, and operators will benefit from improved understanding of internal flow regimes, operational optimisation to mitigate threats, e.g. sand production and slugging / flow regime management. Where pigging is possible, ICDA can still be applied to optimise an ILI strategy, providing improved modelling and a deeper understanding of the internal threats throughout the life of the system, all of which contributes to a more robust integrity assurance program.

For further info on our IDCA service, contact: **ais@woodplc.com**

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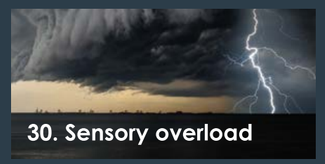
30. Sensory overload

Sensory overload

Sensors of all types tell the story of our environment; they are bringing a level of situational awareness that was unknown just a few years ago.

From phones and Fitbits, to field sensors on remote farms and unmanned probes navigating the lonely voids of space, sensors and smart devices are extending the human sensory system in remarkable ways.

At the front line of these developments we are giving individuals and teams the support needed to increase data knowledge and raise the bar on situational awareness. Self-monitoring technologies are essential, providing a truly objective account of daily events.

Wood's goal is to use context-aware technologies to help people understand how various aspects of their work and lives are influenced by rapidly changing conditions.

But to see how these smart sensors and the mountains of data they provide truly add value to our lives, we need to mine this data and build intelligent models to help us mitigate risk, and ultimately protect our assets, human or otherwise.

Wood uses an enormous array of smart sensors in many of its field programs to support individual health and safety, project work and asset management. We can interrogate this data to generate more accurate forecasting models, predicting risks across a range of scenarios with greater accuracy.

Our weather forecasting and met-ocean service reduces financial and safety risk for customers whose operations are sensitive to high-impact weather events or severe ocean conditions.

Lightning reactions

Energy companies know only too well the problems caused by adverse weather. Lightning storms can disrupt power grids and bring additional danger to an already high-risk working environment.

Smart-sensor technology is being used to notify power grid operators and the crews that work on the network. Building a more accurate picture from the live sensors, Wood combines the data with leading-edge display and notification systems to alert operators on the location, movement and density of lightning strikes, so they can better manage the supply of electricity and develop rerouting scenarios in case disaster strikes.

On a local scale repair crews receive georeferenced lightning alerts to halt work if a storm is coming, and when to return after the threat passes. In 2017, we processed over 46 million lightning strikes sending more than 100,000 alerts to keep crews out of danger.

Smart roads + smart vehicles = smart drivers

Knowing the road conditions during adverse weather is critical. Snow, freezing or heavy rain, and strong winds create major challenges for many departments, including road maintenance, traffic management, emergency services, law enforcement, and commercial vehicle operators, not to mention you, commuting to work every day.

Smart sensors are placed on roadways and vehicles to measure parameters like surface temperature, stopping friction, and road freezing conditions. The data arms departments with the right information to schedule and adapt their activities.

We operate more than 430 roadside weather stations across Canada. In the not too distant future, on-board car sensors currently used by industry will be placed in every car to give an even more detailed picture of conditions and keep drivers aware of the constantly changing road surface.

Motion in the ocean

Our offshore customers work and live in a very harsh environment, where there can be considerable risk to individuals and assets. Storms that catch operators unprepared can cause major damage to vessels, severing drill strings and causing expensive loss of productivity.

Smart sensors can be used to indicate the stability of an ocean platform, with wind and wave sensors working to provide operators with a better understanding of the health of the platform in various severe conditions. Wood provides vessel motion predictions for its offshore customers.

Smart sensor inputs combined with atmospheric and wave forecast model data are used by our meteorologists to advise platform operators and ensure a safe working environment. This combination of sensor data and forecast modelling can connect real-time monitoring of waves and observed vessel motions to automatically provide instant updates, allowing operators to take timely action and mitigate any risk to their assets.

Our world is safer and more reliable thanks to our ever-increasing ability to leverage the power of extended senses. Knowing this makes our work very rewarding.

If you need some help monitoring your operation, contact:
shawn.allan@woodplc.com

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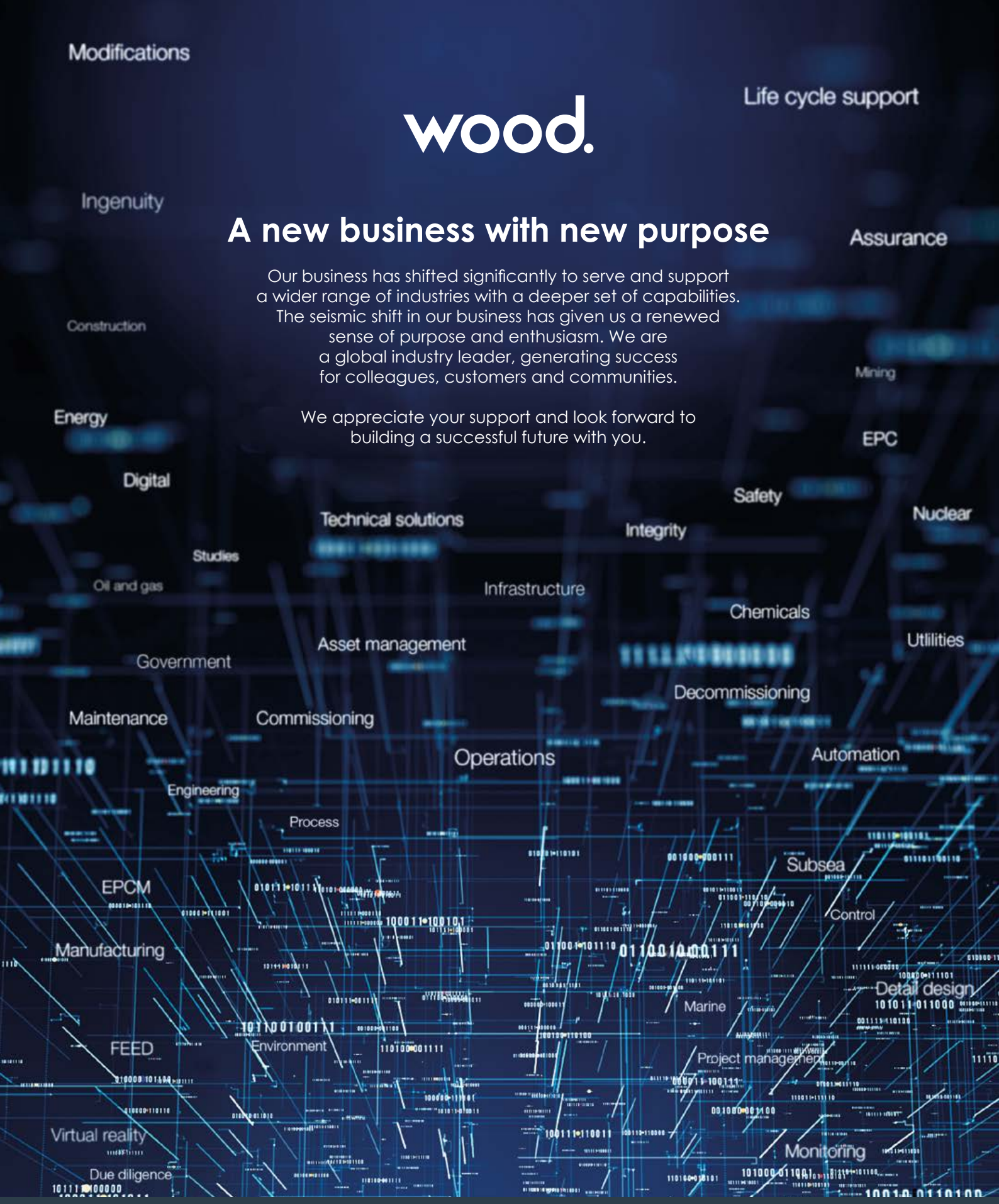

Inspired is written, edited and produced in house by the Wood marketing team.
Submissions and feedback are welcome and can be sent to: **inspired@woodplc.com**

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