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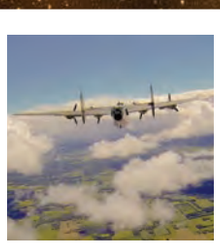
Star quality

The German reactor that could bring fusion power a step closer »16

Brain trust

How advances in metrology lead to cutting-edge neurosurgery »19



War footing

Today's engineers need to invoke the Blitz spirit, says Dr Hugh Hunt »21

Careers section

The latest engineering vacancies from leading employers in the sector »23

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inthisissue

Volume 296 Issue No.7870 | Established 1856

News

04 **Technology** Research looks at safer, more reliable helicopter blades

06 **Technology** New manufacturing centres come into existence

07 **Technology** Laparoscopic equipment the size of a small suitcase

08 **Technology** Security tool offers users pictures from underneath their cars

26 **Digest** This issue's crossword, plus a look through the archives

Opinion

10 **Viewpoint** Garry Rogerson, Perpetual Engineering Partnerships

12 **Mailbox** Your letters to the editor

14 **Paul Jackson** Weighing up the impact of the Autumn Statement

21 **Interview** Dr Hugh Hunt, Cambridge University

Features

16 **Cover story** The Wendelstein 7-X stellarator could bring nuclear fusion one step closer

19 **Feature** The Neuromate robot is helping brain surgeons in an arena where precision and steadiness are vital assets

inouropinion

Fusion power on the near horizon

You've probably all heard the joke: commercial-scale fusion power is 20 years away and it always will be.

But it's a measure of how optimistic the scientific community is about its ultimate potential that this constant shifting of the horizon hasn't dented their enthusiasm.

In this issue, we take a look at one of the most exciting projects in the ongoing effort to develop commercially and technically feasible fusion: the snappily named Wendelstein 7-X fusion stellarator (page 16).

At the time of writing, this incredibly complex – and, it has to be said, aesthetically beautiful device – was due to be fired up for the very first time on 10 December.

Its development is as much a testament to great precision engineering (the focus of our article) as it is to cutting-edge physics. If the project is successful, those involved believe it could actually stop that 20-year horizon from slipping out of reach.

> **"Throughout his work, Dr Hunt draws attention to the way in which conflict has acted as a constant spur for innovation**

Perhaps fusion research might also benefit from the mindset espoused by the subject of this issue's interview (page 22): Cambridge University's Dr Hugh Hunt.

This lecturer and researcher is also a maker of numerous television documentaries, including *Dambusters: Building the Bouncing Bomb*, *Attack of the Zeppelins* and, more recently, *Building Hitler's Supergun*.

Throughout his work, Dr Hunt draws attention to the way in which throughout history conflict has acted as a spur for innovation and how many innovations forged in the furnace of war have actually gone on to change our world in positive ways.

If we're to meet the challenges that have been created by some of today's most pressing problems, such as climate change, he argues, we need to summon up some of that 'Blitz' spirit pretty urgently.

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AEROSPACE

Project looks sharp for helicopter blade health

Government funding also looks at lightweight armour protection

BY HELEN KNIGHT

Safer, more reliable helicopter blades, and more lightweight armour protection for the aircraft are being developed by UK researchers.

Airbus Helicopters UK, based at Oxford Airport, is taking part in two government-funded projects to develop technologies for blade health monitoring and armour protection.

The first of the two projects, worth £2m and part-funded by the Aerospace Technology Institute, will develop technologies to measure blade deformations in flight.

The project, which also involves Cranfield University under the leadership of PhD student Simone Weber, BHR Group and SME Helitune, will develop a tool to constantly monitor rotorcraft blades during flight, and to measure their performance under different conditions, according to Richard Atack, head of design and engineering at Airbus Helicopters UK.

"The goal of the project is to implement a health and usage monitoring system," he said. "So you would monitor the blades throughout the duration of the flight, and then the data would be downloaded to record any anomalies."

That will allow operators to better understand how the blades fly, and ultimately therefore to extend the periods between maintenance and reduce costs.

The system will consist of a Fiber Bragg Grating, or a fibre-optic cable with a series of sensors down its length. This will be laid onto the rotor blade, although in the future it may be possible to build it into the blade itself, said Atack. "This would then sense the stress and strain on the blade while it is deflecting in flight, and that would be recorded and matched against a mathematical model to compare how the blade should fly and how it is actually flying," he said.

By better understanding how the blade performs under different conditions, it should also allow operators to optimise their flight paths and thereby reduce travel times, according to the company.

The second project, worth £1.2m and supported by the Advanced Manufacturing Supply Chain Initiative, will develop lower-weight, lower-cost helicopter armour. The project, which will be led by partner NetComposites under the Dual Use Technology Exploitation (DUTE) cluster, will aim to develop armour that can be produced at an increased rate, and to enable more flexibility in military helicopter design.

The team will use a radio-frequency tooling technique to mould woven composite armour into different shapes, allowing them to make better use of the material than with existing flat panels, said Atack.

The technique allows the material to be heated and cooled at different points. In this way the material can be moulded into shape when cool, and then heated at that specific point in order to solidify it.

"So if you wanted to build seat [armour], for example, you would typically use a back plate and two side plates, whereas this technique can produce one integral formed panel," he said. "This would sit around the seat, so you wouldn't have any weak points."

The project will mature existing technologies, reducing their time to market from up to 15 years to three.

The technology could also be used in areas such as personal protection and body armour, a global market estimated to be worth £2.4bn in 2013. "Body armour typically consists of flat plates that sit on the chest, and the aim is to develop armour that is able to mould around the body," Atack said.

Sheffield Hallam University researchers will investigate the ergonomics of the human form, to understand how a mouldable material would work with the body.

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inbrief

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Carbon withdrawal
Government funding to support the development of carbon capture and storage (CCS) technology has been withdrawn, a move that could lock industries into paying higher carbon taxes. In a regulatory note to the London Stock Exchange, the government said: "Following the chancellor's Autumn Statement, HM Government confirms that the £1bn ring-fenced capital budget for the Carbon Capture and Storage Competition is no longer available."

Doubled up
Jaguar Land Rover is doubling the size of its Engine Manufacturing Centre in Wolverhampton as part of a £450m expansion programme. The plant, which was opened in October 2014, has so far received £1bn worth of investment and produced over 50,000 low-emission Ingenium engines used in the Jaguar XE and Discovery Sport.

Energy for the Humber
DONG Energy will invest £6bn in the Humber region over the period of 2013-19, a new report has shown. The report – *Impact of DONG Energy Investments in the Humber Area* – reveals that between 2015 and 2020, the company will support an average of 1,600 construction jobs per year in the Humber, and up to 500 long-term jobs could be created in the company's operations and maintenance from 2020.

Robots on parade
The first-ever UK Robotics Week is set to take place from 25 June to 1 July 2016, with the aim of highlighting UK robotics innovation and engaging young people through competitions. Robotics is one of the eight technologies identified as key to future UK growth and it is estimated that the global market for service and industrial robots will reach US$59.5bn by 2020.

MANUFACTURING

Hubs get set for future focus

New manufacturing centres established with £20m funding

BY HELEN KNIGHT

Cars built almost entirely from recycled metals and new manufacturing processes for emerging optoelectronics technologies are just some of the targets of two £10m research centres being created in the UK.

The two new manufacturing research hubs are being established with £20m of funding from EPSRC. The hubs, based at Southampton and Brunel universities, will also be backed by an additional £58m from industry.

The hubs are being backed with further funding from industry

The new EPSRC Manufacturing Hub in Future Liquid Metal Engineering at Brunel University, for example, which will be led by Prof Zhongyun Fan, will focus on challenges in the metallic materials industry. These include increasing energy and materials costs, tightening environmental regulations and skills shortages.

The hub, which will be supported by researchers at Oxford, Leeds, Manchester and Imperial College, will focus on automotive and, later, the wider transportation sector.

It will act as a technology proving ground and help to shorten lead times from concept to production, according to Dr Robert Felstead, senior manager for manufacturing in the Manufacturing the Future theme at the EPSRC.

"The hub's long-term vision is for the global demand for metallic materials to be met by full circulation of secondary metals, with only the occasional addition of primary metals each year," he said.

The researchers will be developing methods to enhance and control a process known as nucleation-based solidification, in which the atoms of molten metals bond to form crystals.

They will initially demonstrate the technology in light metals such as aluminium, and then extend it to other metals in the longer term, Felstead said.

The EPSRC National Hub in High Value Photonic Manufacturing at Southampton University, led by Prof Sir David Payne, meanwhile, will support the UK photonics industry. The hub will help companies to improve their manufacturing processes for the production of photonics components, build prototype parts and sub-systems, and act as a one-stop-shop for trialling user ideas and developing new manufacturing processes. The hub will also develop new photonics manufacturing processes that will enable rapid commercialisation of emerging technologies.

ELECTRONICS

Partnering for graphene

Firm and institute will investigate electronic applications

BY HELEN KNIGHT

Cheaper, more reliable electronics devices could be developed using graphene components, thanks to a new research partnership.

Alpha, a US-based company that manufactures soldering and bonding materials for the electronics industry, has begun a partnership with the National Graphene Institute at Manchester University.

Graphene, a one-atom-thick form of graphite, is the world's thinnest and most conductive material, and is expected to revolutionise industries such as the energy sector.

The partnership will investigate new applications for graphene within electronics, where the material's ability to manage heat and act as a barrier to liquid could be beneficial, according to James Baker, graphene business director at Manchester University.

"Electronic devices produce heat, and that heat can make them less efficient or cause packaging or reliability issues," he said. "So any component, whether that is a plastic component or a paste or ink, which can provide better thermal management, could potentially reduce the cost or energy consumption of the component, and improve its reliability."

Graphene can also act as either a barrier to water or as a perfect membrane, and the researchers will investigate applications for this property within electronics.

The partnership will fund a core team of academics, while Alpha will bring in its own applications engineers to work alongside them, Baker said. This should help to accelerate some of the applications of graphene, he added.

"Alpha brings the market, production, and volume application knowledge, while the university brings the fundamental science and graphene know-how," said Baker.

The surgery system could be used in developing countries

MEDICAL

Suitcase surgery

Laparoscopic equipment in a small package

BY HELEN KNIGHT

Minimally invasive surgery carries less risk to patients than conventional procedures, and reduces recovery times.

But the cost of the laparoscopic equipment needed to carry out such procedures puts them out of reach of many hospitals in the developing world.

Now a concept system the size of a small suitcase could showcase the future of surgery in developing countries such as India and China.

The Ekano laparoscopic surgery system, developed by Cambridge Consultants, could be used by surgeons in developing countries to perform operations via small incisions in the abdomen.

Conventional laparoscopy equipment can cost more than £100,000, while the Ekano system would cost around a quarter of the price, according to Rahul Sathe, head of surgical innovation for emerging markets at Cambridge Consultants.

The system creates its own WiFi hotspot that allows the surgical team to upload pre-operative images to help them plan the procedure, or to share data wirelessly with colleagues. The portable system can also be mounted on an IV pole in the required operating theatre.

Instead of using three-chip camera sensors, the system uses a cheaper single-chip sensor equipped with optical filtering and image processing, to allow it to enhance the pictures produced to ensure they are of comparable quality.

"In interviewing surgeons we found that in most basic procedures the key need was to visualise anatomy clearly, so that the surgeon can then make his or her own decision about what to do," said Sathe. "So as long as they can see tissue in the right depth of field, with the right light, they can then manipulate tissue, dissect it or perform a procedure."

The large and expensive xenon light sources typically used in theatres in the developed world, which require frequent maintenance, are also replaced with a compact LED array.

The system can be used with interchangeable tool tips, to allow the surgeon to use it for different types of procedures, according to Sathe. "In emerging markets there is huge emphasis on total cost of ownership, so surgeons and hospitals prefer not to use disposable devices, but rather to pay more for a reusable device and be able to use it over multiple cases," he said.

AUTOMOTIVE

Low-cost power

Generators could boost downsized engines

BY HELEN KNIGHT

The fuel consumption and greenhouse gas emissions of vehicles could be cut by over a quarter without the need for costly high-voltage plug-in hybrid systems, according to a UK company.

Controlled Power Technologies (CPT) is investigating the use of two low-voltage motor generators, mounted at different points on the vehicle, to provide a power boost to downsized engines at a much lower cost than plug-in hybrid technologies.

The two switched-reluctance motor-generators would act in tandem to provide electric boosting, according to Nick Pascoe, chief executive of CPT.

"In this way you have no range-anxiety issues because you still have a base engine, but you can use the electric machine to accelerate," he said. "That means you can retain the same vehicle architecture, and continue to use petrol or diesel to drive it, but you can make that vehicle a lot more fuel efficient than it is today, by assisting it with intelligent electrification."

The company is exploring the use of a newly developed 10kW axle-mounted SpeedTorq unit, to be used in tandem with its existing 10kW engine-mounted SpeedStart unit, to provide energy recuperation during braking and torque assist during acceleration.

The combination of two low-voltage electrical machines represents a cost-effective intermediate step between conventional vehicles powered solely by internal combustion engines, and expensive plug-in hybrids with their larger traction units and costly high-voltage battery systems.

The car industry is considering moving from the use of 12V electrical systems in vehicles to 48V. This will increase the energy available for the range of vehicle control and safety systems within modern vehicles, but without the expense of moving above the 60V threshold, beyond which electrical systems require additional safety restrictions, said Pascoe.

AUTOMOTIVE

Electric avenue

Pods could provide public transport

A project aimed at bringing automated, driverless pod cars to the streets of the UK has won the 2015 Society of Motor Manufacturers and Traders (SMMT) Automotive Award for Innovation.

Led by the UK's Transport Systems Catapult, the Low-carbon Urban Transport Zone (LUTZ) Pathfinder project has developed two-seater autonomous electric-powered 'pods' that could provide public transport along pedestrian routes.

In trials that are expected to begin next year, a number of pods will operate along predetermined pedestrian routes in Milton Keynes. Findings from the project will then be fed into the larger-scale UK Autodrive programme that is set to deploy a larger fleet of 40 pods along with 'regular' road-based cars.

The battery-powered, four-wheeled pod developed by the team seats two people, can travel at a maximum speed of 15mph and has a range of 40 miles. Rather than relying on GPS to find its way around, the vehicle uses information from an array of different sensors to work out where it is within a pre-mapped environment. ***JE***

SECURITY

Below the radar

Tool offers users high-definition pictures from underneath vehicles

BY JASON FORD

In just under a year, UK engineers have designed and produced V-Guard, a new security tool that gives users high-definition images from the underside of vehicles.

Designed for permanent or temporary deployment, the V-Guard mobile checkpoint comes with a fully integrated numberplate recognition package and optional day/night IR overview camera to help identify vehicles and their occupants.

"We spotted a gap in the market for a product that is highly portable, could fit into something the size of a briefcase, that can be put on the ground very quickly and is very simple to operate – including the graphical user interface (GUI) – and is ruggedised," said Andy Johnson, project manager at CMCA (UK).

The battery- or mains-operated system is connected to a tablet via secure wireless or 3G link but can be used with any wireless Windows-based device in order to display – and allow interaction with – information generated by the system.

"So that can be a ruggedised tablet, a laptop or it could be hard-wired across to any other computer system, so a desktop computer in an office or security station," said Johnson. "The information we're feeding into the GUI is drawn from the cameras, so the under-vehicle camera does the 1,080p HD [full HD] and that's gathered as the vehicle drives over the system."

V-Guard's road surface-mounted, 360˚ HD camera is housed inside strengthened semi-transparent resin along with an LED control system.

"Its visual, there's no active intelligence," said Johnson, "there's no X-ray type backscatter, it's a visual-only system."

"We don't have a stitched image because we're using a semi-fish eye," he added.

"We looked at our initial stitching and thought: let's concentrate on the video imagery, lets make that completely controllable so that we can cycle through the frames – forward and backwards – with the swipe of a finger over the GUI, which means we get the parallax associated with the image so that we can look into spaces from multiple angles rather than having a flat image and trying to enhance it."

CMCA (UK) took its V-Guard tool to DSEI 2015 in September and has since received several enquiries from interested Middle Eastern countries.

MANUFACTURING

The price is right

New additive technology could be cheaper

BY HELEN KNIGHT

A metal 3D-printing technology costing a fraction of the price of existing additive manufacturing machines could be launched next year.

London-based company IT IS 3D is working with researchers at Cranfield University to develop the metal 3D-printing system, based on wire deposition technology.

Existing additive manufacturing machines cost between £200,000 and £1m. While still in licencing negotiations with the university, IT IS 3D hopes to launch the technology by the end of 2016, for prices starting at under £50,000.

That would make the technology accessible to far more companies, said Martin Stevens, CEO of IT IS 3D. "We hope to take this sophisticated technology and turn it into something that is affordable to a large range of companies, to provide them with a means of prototyping or creating low-volume, special-purpose parts, using metal 3D printing," he said.

The wire deposition process, also known as wire and arc additive manufacturing (WAAM), uses a robot to deposit layers of molten metal from a wire through a welding head onto a surface. It is being explored by the aerospace and defence industries as it can produce large components more rapidly than powder and laser deposition processes.

However, the technique typically involves expensive robots such as those used in automotive and costly welding generators, said Stevens.

"We and Cranfield University plan to look at much lower-cost, probably cartesian (linear) robots," he said. "When used alongside lower cost welding systems – and we're investigating those at the moment to see which can produce the best results – we believe we can get the cost down to a level that no other technology can reach at the moment."

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ROBOTICS

An inside job

System inspects and repairs live gas mains from inside the pipes

UK gas distribution network SGN and US-based ULC Robotics have developed a new robotic system for inspecting and repairing live gas mains from inside the pipes.

The Cast Iron Robotic Repair Inspection System, or CIRRIS, consists of two complimentary robots.

CIRRIS XI carries out inspection, collating data on the condition of large diameter metallic mains while travelling through the pipes.

The robotic sensors monitor corrosion levels, wall thickness and the stress the pipe is under. SGN claims that this level of analysis is a world first.

CIRRIS XR acts as the repair robot. It injects sealant into the walls and joints of the piping, repairing leaks and helping to prevent future damage.

According to SGN, the system can inspect and repair hundreds of metres of live gas main from one small excavation, helping to improve safety and minimising disruption to road users and gas customers.

CIRRIS is currently being trialled in South London, with roll-out across the network planned for spring 2016. ***AW***

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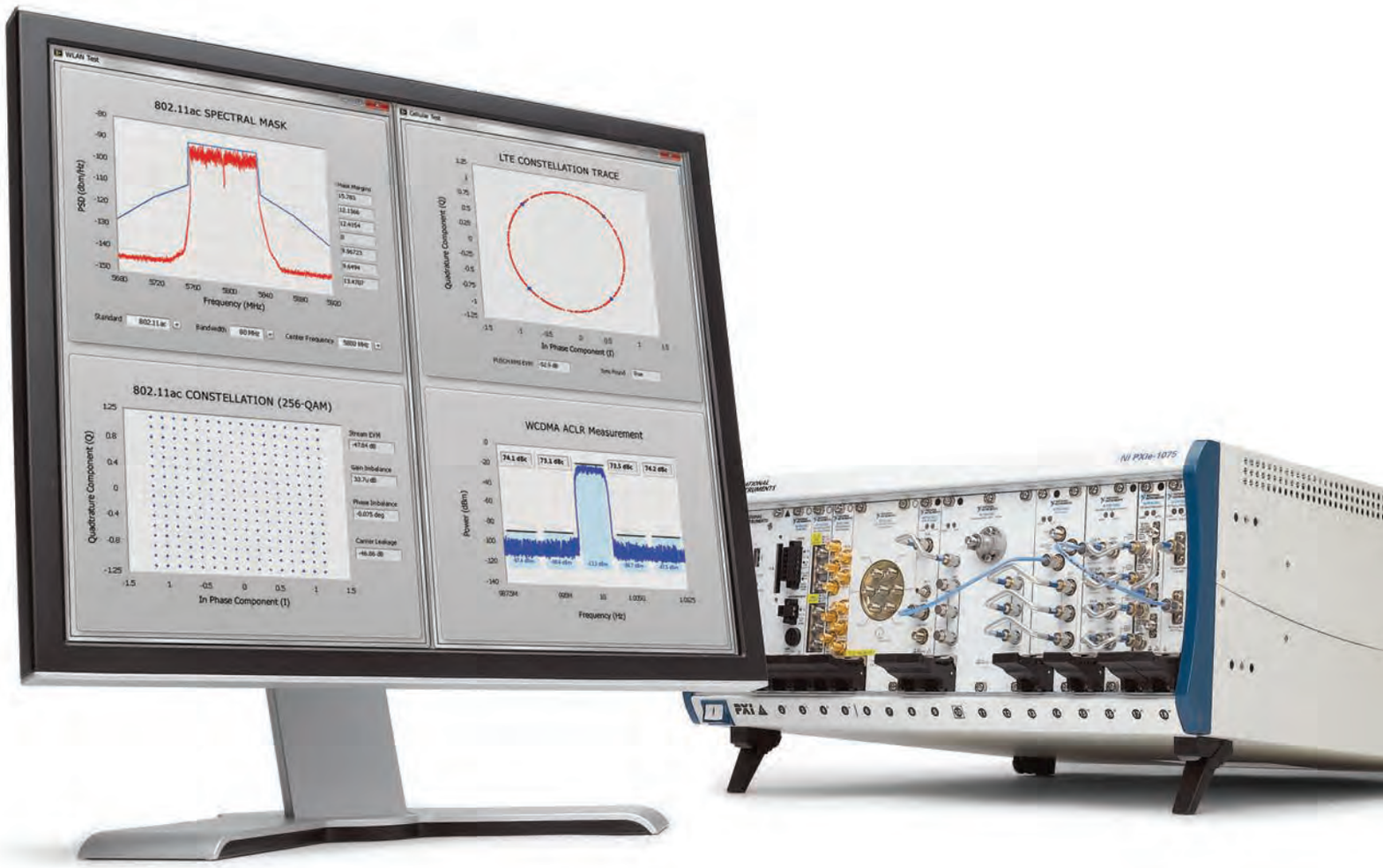

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NATIONAL INSTRUMENTS

Think bigger and go small

Small firms are offering candidates unique opportunities to work with professionals across engineering disciplines

Latest labour market figures show demand for job candidates continues to outstrip supply, and growth in permanent engineering placements has ground to its slowest rate of increase in over two years.

With competition for quality graduates and experienced engineers forcing up pay and bonuses, smaller firms risk losing out in the race for talent to those with bigger budgets. The challenge for SMEs is to be seen to be offering a truly better career alternative to the bigger companies.

And yet when it comes to finding solutions that bridge the skills gap and advance engineering as a rewarding career, the SME market has long been recognised as a rich source of innovative ideas and practical strategies. For engineers motivated by the prospect of a dynamic and varied career path, for example, many small firms are giving their larger rivals a run for their money.

Unbound by steep and rigid hierarchical structures, small firms are offering candidates unique opportunities to work closely with professionals across engineering disciplines and with regular access to managers and directors. The divide between the coal face and top leadership is typically narrower in smaller firms, so employees get a clearer view of the bigger picture, better awareness of the part they play in helping the organisation to achieve its goals, and a realistic understanding of the opportunities available to them to develop their own careers. These are all features of the working environment that we know translate into improved levels of professional contentment, loyalty and performance.

As a result, career progression in small firms can be extremely fast with considerable flexibility to adapt an individual's role and make the most of their talents. Small companies with ambitious growth plans can offer incredible career progression for motivated engineers at all levels. A firm with plans to grow from a turnover of £40m to £100m in three years, for example, can only achieve its objectives by recruiting and developing people with drive and ambition.

Engineering firms across the board are often criticised for not doing enough to regenerate skills from the bottom. And with many specialist engineers approaching retirement, and large pools of expertise moving from one industry to another – as has been the case in recent months in the oil and gas sector, which has lost significant numbers of professionals to other industries, including nuclear – concern surrounding the loss of skills has reached fever pitch.

Here, too, the SME sector is stealing a march with practical schemes designed to nurture thriving teams of new talent and stem the flow of knowledge out of some areas of the industry. In some firms, this means systematically underpinning senior or specialist engineering appointments with graduate appointments, so creating clear routes for important skills to pass through the business. At the same time, junior engineers who join these programmes are being shaped into experienced specialists with the right skill sets and cultural fit to succeed in their organisations.

A major difficulty for small firms is getting their voices heard in the candidate market, particularly amid the clamour of the graduate recruitment season, and alongside glossy, big-budget campaigns afforded by larger players. Many candidates will always be seduced by status, but a greater understanding of the unique advantages of working in small engineering firms is needed if we are to go some way towards levelling the playing field.

This has motivated a movement of small firms based in the north west of England to collaborate with each other; combining marketing budgets, time and people power to generate a louder voice and a clearer message to appeal to graduates. Their objective is to generate a wider pool of quality candidates from which they can select those with the right mix of skills and aspirations to work well in their businesses.

In my experience, the SME sector is home to some of the most passionate, charismatic and inspirational leaders in the industry, and the energy with which they lead is one of the most appealing factors in attracting and retaining talent. By creating a platform for their leaders' voices to be heard by the candidate market, SME businesses can go a long way to setting themselves apart from the competition.

Garry Rogerson is managing director of specialist technical recruitment company Perpetual Engineering Partnerships

Join the debate at **theengineer.co.uk**

thehottopic

Women still hampered by misconceptions

Last issue's special focus on women in engineering attracted a broad range of comments

I am a female chemical engineer who has worked for 30 years in the chemical manufacturing sector. It's incredibly dispiriting to see virtually no progress in the portion of women at all levels in this field. Engineering is a well-recognised gateway to significant leadership roles in organisations. Aside from failing to make use of almost half of the talent available in the workforce, women not taking up engineering careers is a major impediment to them being represented in many influential positions.
Anonymous

Not a week goes by, sometimes not a day, when I don't experience some form of sexism at work, (suggestive comments, nude calenders of women, or just being singled out, in some way, for being female). Still, we do our best. The problem definitely lies in schools and media. I had (among others) a maths teacher, and an Ofsted inspector both discourage me from studying engineering at university. At the same time there are initiatives encouraging girls to study. It's a very mixed message.
Sally

Engineering should be open to all. If anything, women entering engineering enjoy positive discrimination already. I have two daughters. I have tried to show them what a great career engineering is and encourage them to pursue this path. But they are just not in the slightest bit interested. Engineering is suffering a skills shortage and we need to raise the profile for all young people and not spend time over promoting to just one demographic.
Anonymous

Engineering companies and the education system can do as much as they like to promote women in engineering but as long as a plumber and electrician can call themselves 'engineers' we are never going to dispel the misconceptions about our profession. Whenever I tell the average person on the street I'm a mechanical engineer they ask if I can fix their car. Why would a school-age girl who is good at STEM subjects aspire to be a car mechanic? In Germany and many other countries engineer is a title similar to doctor or architect – they don't have our skill-shortage problems.
Alex Freeman

I am a managing director of a small electronic CEM, and have always had an interest in how manufacturing is perceived within a diverse community. In our local area, manufacturing was traditionally a part of every person's daily experience, and young people of both sexes saw manufacturing as an normal employment option i.e. it was always part of most youngster's range of choices. The manufacturing base disappeared from our area in the 1990s, and now, I find, it is not even on the radar of any young person and of any of their teachers. Without a broad manufacturing base it will be much more difficult to get any young person, let alone women, believing that there is an open door into that world.
C Swallow

inyouropinion

Returntobase

Many readers agreed that the science and research base needs more help from the UK government

■ I think the best way to fathom if science is doing well in a given nation is by how many patents it registers per year.
Anonymous

■ We should not restrict our scientific research purely on economics. However, to be able to invest more we have to be better when we do commercialise. By this I mean we are not very good at keeping the commercial benefits of our innovation primarily in the UK. When seeking industrial partners they are too often overseas companies; we outsource too much manufacturing when we should be looking to manufacture locally and export. And too many growing companies are sold to overseas investors. We never seem to fully exploit all our great inventions. Fix that and we can have an abundance of money for scientific research.
Mike

■ Globalisation discourages innovation, particularly in the energy sector. Established industries modify their technologies rather than allowing newcomers to break into their markets. Government does not want to upset the status quo as it relies upon existing jobs for revenues. PR programmes have persuaded people to think that the consumer society is better than the creator society and the UK's abundant fossil-fuel supplies in the past 40 years have further encouraged this belief. Engineers developing new energy technologies are largely ignored.
Jean Aldous

Jaguarroars?

News of Jaguar Land Rover's expansion in Wolverhampton received a mixed response from readers

■ In my opinion, a dinosaur company, directed by yesterday's management, manufacturing poor technology that belongs in the last century. Missed opportunities galore here. Those who can afford to spend £50,000 on a car have a moral obligation to be 'first movers' in the adoption of technologies that do no harm to others. It's time they put consumer pressure on JLR to get its act together.
Dave Smart

■ No one has a "moral obligation" to adopt technology! It is personal choice and freedom. This is a draconian mindset dressed up as progressive one.
Anonymous

■ Dave Smart shows that he is out of touch when he talks of "a dinosaur company, directed by yesterday's management". Anyone who has looked at JLR recently will know that yesterday's management got the boot years ago, when those real losers Ford and BMW fumbled with the ball. Tata is a very different beast. As to "poor technology that belongs in the last century", that's another sign of a less-than-smart analysis. It takes time to turn around a large enterprise, but, as *The Engineer* has pointed out, JLR hasn't done too badly with its new engine plant and the switch to aluminium. By the way, you won't get much Jaguar, or even a Land Rover, for £50,000.
Michael Kenward

■ On the contrary, Michael, investing in the future of British manufacturing is a very smart idea, and overpowered, overpriced cars designed with technology overkill are really very stupid. All sections of the car industry

Human nature, male and female brains, inherent aptitudes and other similar arguments are nonsense and never proven scientifically. The discrimination against women in engineering and, in general, is a social construct, most probably built and maintained by those men, stuck in adolescence, with their puerile calendars.
I am a mechanical engineer. I did not think of an inability to pull ropes with my teeth or around my neck or lifting heavy stuff as an impediment to become one. Thanks to all engineers and many other people before my generation, raw human power is the least necessary to make or move stuff. Sally and all the rest: do not let yourselves be intimidated or discouraged. Disregard the pathetic fools who harass and offend you, and go and show your competence: run the machine; draw the tool; design a product or a process; know what you are talking about; and do what you love to do with confidence. When I started, a long time ago, I worked as a process engineer for a large manufacturer. My male boss asked me to work on a project to keep me busy, confident that as a woman and a 'fluff' that I didn't know anything. Do you think he was right? No. He admitted with embarrassment what he thought about me initially and apologised. It so happens that I was, and still am, a better engineer than him.
Silvia Leahu-Aluas

thesecretengineer

Our anonymous blogger reflects on the sacrifices made by those working in industry during the Second World War

There was a programme a while back about women involved in the aircraft industry during the Second World War. One woman in particular had been a welder, and I'd guess in her late teens at the time in question. Along with many others she'd found herself in an alien world doing a technical job under difficult circumstances.

With an air of regret that still obviously cut deep, even after 70-odd years, she related how her hair had caught fire because of a stray spark one day and how after that she would constantly weep in fear behind her mask while carrying out her duties.

That is until, inevitably, she had to give it up. I got the distinct impression that she was ashamed of what she saw as her weakness, her failure to contribute as others did. In reality, clearly, she had pushed herself beyond endurance and to the point of breakdown. Courage is not an absence of fear; it is being afraid and yet still continuing. For this I thought of her during the two-minute silence on Remembrance Day.

In September 1940 the Supermarine factory was bombed twice. Being the home of Britain's most capable fighter at the time and on the south coast, the employees must have known that it was a primary target. Despite the factory being destroyed the main machine tools were serviceable and subsequently dispersed out to workshops, bus depots and garages. A local web of production sites was established and new Spitfires were being delivered again after only a few weeks.

This was the result of unwavering determination and fierce commitment. For the staff to have achieved this when the air raids had killed 140 of their colleagues is deeply admirable. For this I thought of the workers at Supermarine, those who had fallen and those who had survived, during the two-minute silence on Remembrance Day.

Chilwell, near Nottingham, was the site of a large shell-filling factory set up in 1915. The predominantly female workforce were called 'canary girls' as exposure to the chemicals turned their skin yellow.

Worse was to come though in July 1918. For reasons yet to be fully explained an explosion ripped the factory apart leaving 134 dead with another 250 injured. The blast was heard 20 miles away such was its ferocity. Yet the workers returned the next day and then beat their production record within a month. Systematically poisoned, blown up and then not only continuing but pushing harder. For this I thought of Chilwell's workers during the two-minute silence on Remembrance Day.

It is right and proper that on 11 November we primarily mourn those fallen in battle. However, I think we should also look to our own – we have a duty to make sure that they too are never forgotten.

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suffer from inertia to change, that's perfectly understandable, but the hubris of blinkered management knows no bounds, especially in motorsport and prestige cars.
Dave Smart

Powerstruggle

The announcement by energy secretary Amber Rudd that the UK is to phase out coal-fired power stations by 2025 prompted a lively debate

■ Coal-based power generation is only non-economic due to the arbitrary Climate Change Act and other green taxes that our competitors are not saddled with. This is the other side of the subsidy-driven distortion of energy markets: penalties for arbitrary emission regulations. Coal is the lowest-cost power source available to the UK and EU.
Jack Broughton

■ Why is this decision being made by a history graduate? Our power mix is all dictated from on high by the EU. We have our own supply of coal yet we must rely on importing gas from unstable and unpleasant regimes.
Albert Ross

■ Coal is the favoured source of energy only if its emissions are disregarded in the face of scientific evidence and our country's policy. In light of this, it cannot be the best option, so a firm date for its removal is welcome.
Anonymous

■ Can anyone tell me why we are not investigating coal gasification, perhaps coupled with carbon capture and storage? Surely this would offer security and reduced emissions?
Anonymous

Festivespirit

Our seasonal look at how to spark an interest in engineering during Christmas sparked some engaged responses

■ "How do I violate the laws of causality to visit every house on Earth in 24 hours while wearing a red, hooded and fur-trimmed outfit?" Encourage the reindeer to get quantum-based sat-navs; have 3D printers to hand at the rear of your sleigh; have GCHQ interrogate all communications in advance, so that you will know what's required by each child; make what is necessary, while circling slowly above each house; and sip very small amounts from each sherry and simply crumble the mince pies to make it look as though you have eaten them.
S Claus (Mike Blamey)

■ Meccano – it doesn't matter whether metal or plastic (the plastic stuff is better for little ones). And don't forget that little kids can be given some real tools, not toy ones - e.g. junior hacksaws are much safer than any kind of sharp tool and can do a nice job on Styrofoam or balsa. For the bigger kids in your family, why not get hard-to-find-on-the-high-street components such as small electric motors or a laser? A set of chemistry clamp stands is an unusual gift that will probably get an 'ugh, what do I want that for' response initially, but then get used for 101 things over the year. What about some real tools, too? Also, don't forget a multimeter – £10 or £15 can buy something that you can measure volts, amps, resistance, frequency, temperature and lots of other things if you add a device costing pennies (e.g. a photoresistor).
Neil A Downie

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Devil in the detail

The apprenticeship levy outlined in the Autumn Statement could have some unexpected outcomes in our sector

Having had a mixed reception across the business world, the impact on our industry of the new apprenticeship levy, announced by the chancellor in his Autumn Statement, may be very different to what is seen elsewhere.

Engineering pays above-average salaries, an important detail given the criteria for the levy is not (as anticipated) the size of the company, but the size of the salary bill. With 0.4 per cent of engineering companies employing over 42 per cent of the workforce, there is a real question around whether we can be confident of getting the right capacity. Engineering is an industry dominated by SMEs: almost 80 per cent of engineering firms have fewer than five employees. However, it is the small number of large companies that generate the greatest levels of employment, resulting in a uniquely skewed distribution that brings its own challenges.

“It is the small number of large companies generating the greatest levels of employment that brings its own challenges

Will engineering firms benefit from the apprenticeship levy?

Other elements of the chancellor’s statement have been more widely welcomed by the industry, not least the capital investment in infrastructure and the protection of the science budget for the next five years. Both are vital to the prospects of the industry and both are reliant on a steady stream of new talent entering the workforce. Will engineering employers reap the benefits of the apprenticeship levy with an influx of ‘earn-as-you-learn’ recruits or simply end up subsidising other parts of the economy?

We should also be asking whether we will continue to see the same investment in research and development and innovation in business once Research UK subsumes Innovate UK, and the shift from grants to loans is complete. Almost every industry supported by Innovate UK relies on engineering expertise, either directly or indirectly. Will a rise in the number of catapult centres balance out the change and will Research UK offer the same platform for collaboration and innovation?

At EngineeringUK we have received direct support from Innovate UK for our Knowledge Transfer Partnership with the University of Bristol. This joint activity will support engineering companies throughout the UK in becoming more sophisticated customers and supporters of educational engagement, which should, in turn, support the development of the industry’s talent pipeline.

While we continue to have an annual shortfall of engineers and technicians in the tens of thousands, that talent pipeline is not restricted to those working in engineering roles. As things stand we do not have the teachers and academics in further and/or higher education to deliver the rate of qualified workers the industry so desperately needs.

The introduction of maintenance grants for part-time students and greater access to loans for anyone looking to do a second degree in a STEM subject could push up the numbers interested in engineering qualifications. But are universities and FE colleges in a position to take on more students in these subjects? Are we taking seriously enough the need to build capacity to deliver the required change?

Government investment is a boon for any industry but, as ever, the devil is in the detail. We will need time to really take stock and see how much engineering will gain from this latest review.

If the investment in infrastructure and the aerospace, automotive and energy sectors is accompanied by a strong programme of innovation and a system that supports the development of new talent, then we may be onto a winner.

Paul Jackson is chief executive of EngineeringUK

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Star quality

The Wendelstein 7-X stellarator is set to bring the concept of nuclear fusion to fruition. Andrew Wade reports

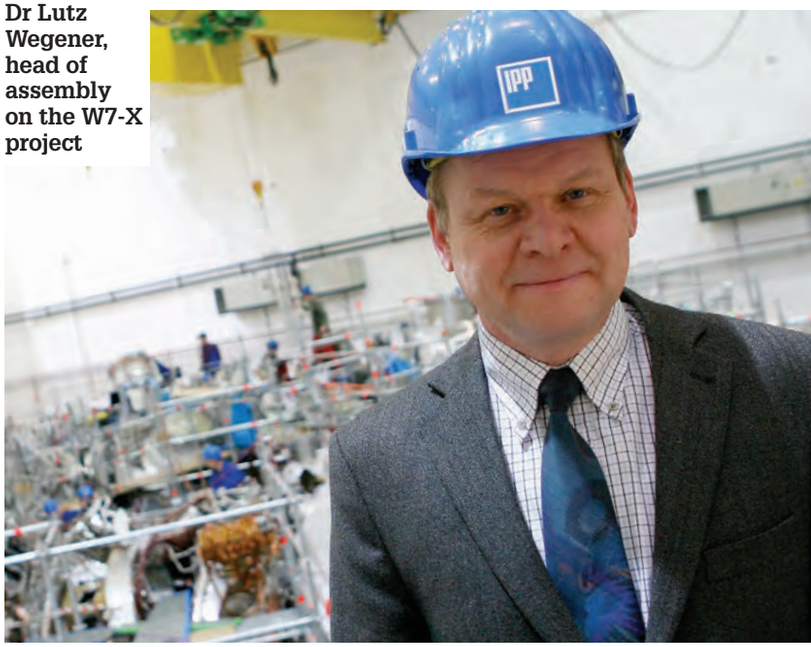
By the time you're reading this, the world could be one step closer to clean, limitless energy. Some time in early December 2015, the Wendelstein 7-X fusion stellarator will be powered up, super-heating plasma to millions of degrees for the very first time. Known as W7-X, it is the largest stellarator ever built, a two-decade labour of love undertaken by the Max Planck Institute for Plasma Physics (IPP) at its Greifswald branch in north-east Germany.

For decades, nuclear fusion has been hyped as a potential solution to humanity's energy needs. Replicating the same process that fuels the sun, the reactors aim to fuse hydrogen isotopes (deuterium and tritium) together to form helium, releasing huge amounts of neutron energy. Fusion in the sun takes place at extreme pressures, with temperatures of around 10 million degrees Kelvin (K). On Earth, where those pressures can't be replicated, the temperatures required are about 100 million K. Naturally, that means a massive energy input, and current fusion reactors suck up more energy than they create. It's a hugely promising technology, but one that remains commercially unviable, the old line being that it is always 20 years away, forever out of reach.

First conceived of in the 1950s by US physicist Lyman Spitzer, stellarators are a particular type of fusion reactor that confine the super-hot plasma using twisted magnetic fields. The premise is similar to the more well-established technology of tokamak reactors, where plasma is fired around a magnetically confined toroid, aided by an internal current. However, stellarators aim to create a natural plasma path solely using external magnets, but this requires precision engineering and calculations that can only be carried out by supercomputers.

This level of complexity is one of the main reasons stellarators lag behind tokamaks in development. But W7-X could help change all that. Its 50 non-planar and superconducting magnet coils are 3.5m high, and with their enclosure weigh about 425 metric tonnes. They are cooled using liquid helium for maximum efficiency, an intricate cryostatic system adding yet another layer of difficulty to the build. The machine also contains another 20 planar coils, as well as 254 ports. In total, construction of W7-X took over one million hours of labour. When testing began last year, it was simply a case of checking one subsystem after another, according to Dr Lutz Wegener, head of assembly on the W7-X.

"Thousands of welds have been made. All of them need to be helium tight. That means perfect
Dr Lutz Wegener



Dr Lutz Wegener, head of assembly on the W7-X project

"First, you need a good vacuum," he told *The Engineer*. "That means thousands of welds have been made in small pipes, in big walls, in massive structures – all of them need to be helium tight. That means perfect. There is hardly access later on. So one our first challenges and first main tests was: are the vessels tight?"

Wegener said that apart from some minor issues, these tests were all successful, with no leaks found in the sensitive interior of the device where the electromagnets are housed. The magnets themselves were then put through their paces – without the presence of any plasma, of course – and the last stages of testing on the controls and safety systems are now underway. In reality, though, the nature of these reactors means that the real testing only comes when the stellarator is powered up for its maiden plasma run. At the time of writing, this was scheduled for 10 December.

Each section of the confinement chamber is precision-engineered

As head of assembly, Wegener has been responsible for establishing build procedures on W7-X, as well as procuring tools and equipment and keeping the project on track. At the heart of the stellarator are the 50 electromagnets that guide the plasma on its journey around the 16m-long toroidal chamber. The ring formed by the contorted coils is almost sculpture-like, a swooping scientific marvel that wouldn't look out of place competing for the Turner Prize. But the aesthetics are subsidiary to the physics, supercomputers dictating the shape and flow of the magnets so they can confine the twisting plasma with sub-millimetre accuracy.

"It's more or less the standard (magnet) technology, if you like," Wegener explained. "It is a neo-titanium superconductor in a coil winding package. Then the winding package is enveloped in a steel case with a certain compression to assist the load operation. The tricky thing here is every coil of the same type has to be fabricated within really low tolerance. That means the effort is enormous to create the tooling at the manufacturer's side, to wind the coil, the process to create the coil casings, the steel pack if you like, that are supporting the winding pack during operation.

"We use very tough steels, which is appropriate for the cryogenic operation temperature. It is hard to machine, so all our contractors who were involved in that business had to learn a lot of lessons until they were able to do all these things."

These complicated construction processes arise from the unorthodox design of stellarators. Fusion energy is a tricky beast to begin with, but attempting it with a stellarator is like trying to ballet dance in stilettoes, another layer of complexity on top of an already complex task. To give some context, well over 200 tokamaks have been built throughout history, while only a handful of stellarators have ever been constructed.

One reason behind the renewed interest in stellarators is their intrinsic stability, resulting from the pure magnetic confinement of plasma. In contrast, the electrical current that tokamaks rely on to aid confinement can cause problems, leading to operational downtime and even destruction of the reactor. In a stellarator, the twisted magnetic field created by the magnets confines the plasma on its own, removing this threat.

->

indepth

Dr David Kingham argues that bigger isn't always better when it comes to fusion

Although stellarators and tokamaks were first conceived of roughly around the same time, the science around the latter is much more advanced. Dr David Kingham is the CEO of UK-based Tokamak Energy, a company that specialises in compact spherical tokamak reactors. He spoke to *The Engineer* about the stellarator, advances in tokamak technology, and why bigger isn't always better when it comes to fusion.

"It's exciting this Wendelstein stellarator coming online, and it should give some interesting plasma physics results," said Kingham. "It's a lovely concept and beautiful physics, but the engineering of it is very challenging, so it's difficult to see how it would ever scale to be a viable power plant.

"With tokamaks, the physics is pretty well understood. There are still some important details to sort out, but we see the devices as pretty much an engineering challenge."

Kingham identifies three points that indicate how tokamaks are moving to this stage, where the theory is solid and the main challenges become engineering-orientated. The first is the inherent efficiency of the spherical tokamaks that are currently being developed. Making maximum use of the available magnetic field, many believe spherical tokamaks have the potential to significantly outperform previous designs. The second indicator, according to Kingham, is the adoption of a new type of magnet for plasma confinement.

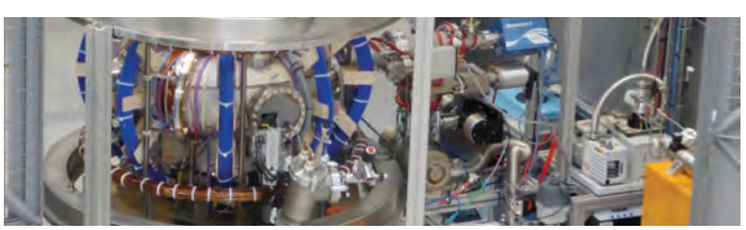
"The key to this is a new material, a high-temperature superconductor that we're using," he explained. "The top-performing tokamaks to date have all used copper magnets. We were the first, very recently, to demonstrate a tokomak with all magnets made from high-temperature superconductors.

"We're able to use the technology to hold the plasma in place for 24 hours. We can go on from that point to engineer more complicated higher-field magnets from high-temperature superconductors.

"It's a huge breakthrough for tokamaks because it not only gives higher field than possible with conventional low-temperature superconductors, it also only needs to be cooled to perhaps 20 to 30K, compared to 4K or lower. So the energy cost of cooling is much reduced, and that's important for overall energy efficiency."

The third indicator that Kingham points to is that tokamaks don't have to be huge to be powerful. His colleagues at Tokamak Energy published a paper earlier this year examining the physics underpinning the reactors. It concluded that smaller devices are viable, with multiple megawatt-scale tokamaks potentially forming modular power stations capable of producing gigawatts.

"We're aiming at 100MW devices," said Kingham. "The challenge is to make them small enough to fit on the back of a large truck, so they could be made in a factory and transported to site, rather than being built on site… We're firmly of the view that if you want to crack fusion power, it needs to be in much more compact devices."



"The big advantage is that no current is necessary in a stellarator, just the pure magnetic field compresses the plasma in a stable way, in a continuous way, " said Wegener. "Running current in the plasma brings additional energy in the plasma, and the more energy you have in this instable thing, the harder it is to get it under control, or to keep it under control. In a tokamak you need a current in the plasma, otherwise you have no chance to get it confined. On the other hand, if the energy balance is disturbed, you get rid of the current immediately and all the energy goes in the walls.

Over one million hours of labour have gone into the stellarator's construction

"In stellarators, you have to trust the perfectly made magnet field. You have hardly got correction measures. There are some correction measures – additional coils can be added to the outside or inside of the machine, this is what we did as well. This gives you the possibility in the small range to increase the stability and to improve the quality of the magnetic field. But this is limited. Basic accuracy must be achieved under all circumstances to have this stable situation."

The cryogenic system used to cool the device means extremely hot and cold components are often operating within close proximity. It's vital that thermal insulation between these components is properly installed, allowing them to function within millimetres of each other.

"The main issue there is to make sure all the welds are tight, make sure all the raw material is tight, no crack in the pipes, no crack in the steel, everything must be perfectly tight," Wegener continued.

> **"Make sure that between cold and warmer components there is always a gap in between – no clashes, never**
> Dr Lutz Wegener

"Make sure that between cold and warmer components there is always a gap in between – no clashes, never. Make sure that the thermal insulation in between those components is properly installed and not squeezed. Make sure that the cryoshield – the cryoshield means that you are at about 50K, like a temperature barrier – is really closed, perfect, connected and also actively cooled as designed. This is, at the end, the main challenge you have."

The magnets and their cooling system have already been tested for hours at a time, but W7-X is designed to confine high-energy plasma for 30-minute stretches. When the switch is thrown in December for the initial run, only low-energy plasma will be used, as the IPP team gently eases the reactor online. Over the ensuing months, W7-X's capabilities will be more fully explored using higher-energy plasma.

"The more tricky thing is, if you are putting more energy in, is it still stable enough?" Wegener mused. "This is a question that can be answered more in, let's say, January and February, where there will be more time to increase the energy content a little bit.

"The most important thing is we need to complete the machine further. In the present situation the machine does not have any heat exchanger inside. Putting energy in means to some extent you have to be able to get rid of that energy; there must be a heat exchanger active to get heat out, and this is the next installation phase starting in 2016."

While W7-X won't solve the fusion conundrum single-handedly, it could be a breakthrough proof of concept on the path to viability, a stepping stone to clean, sustainable fusion power. Against the backdrop of global climate change, as well as a UK energy grid set to be squeezed to the limit this winter, events at Greifswald will be eagerly followed.

For more on this story visit **www.theengineer.co.uk**

Robotic brain trust

The Neuromate robot is helping brain surgeons in an arena where precision and steadiness are vital assets. Stuart Nathan reports

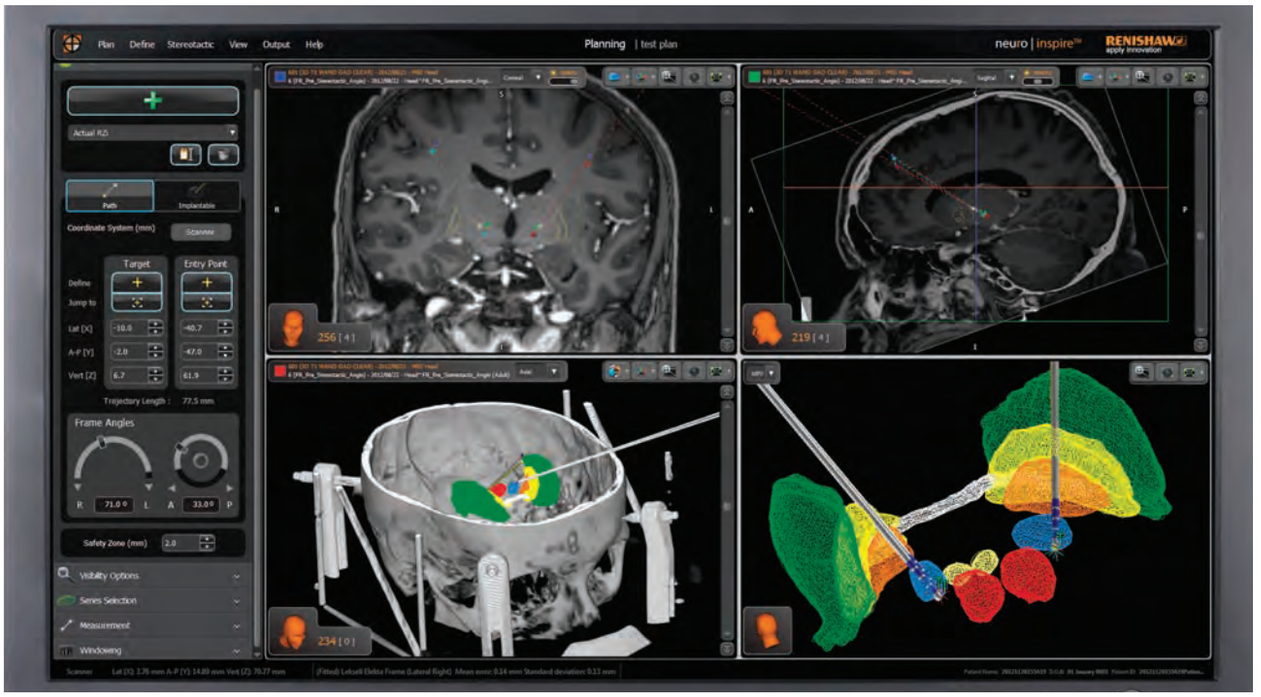
Neuromate is featuring in a number of operating theatres around the world

The precise field of industrial metrology is a vital part of the world of high-value manufacturing, helping to ensure components are the correct size and shape for their purpose and that production processes remain repeatable and within their tolerances. But one manufacturer is sending its machines into an area where precision and steadiness are even more vital: the delicate sphere of brain surgery.

Renishaw's medical business is a growing and exacting part of the Gloucestershire-based metrology specialist's business. Its best-known activity is its production of custom-designed 3D-printed surgical implants at its facility in Cardiff; it also produces the software tools that help surgeons to design them. But its Neuromate robot takes the precision it is trusted to provide in factories around the world into the operating theatre.

Brain surgery, of course, requires extreme precision. Just the task of locating the sites in the brain that require the attention of a surgeon is an art in itself. These sites encompass quite a variety of neurological phenomena: they might be tumours that require the precise positioning of an implant to deliver chemotherapy drugs, for example; they might also be sites implicated in conditions such as epilepsy, Parkinson's disease or severe depression (the latter two conditions can sometimes be treated using a technique called deep-brain stimulation, where an implanted electrode delivers an electric charge to a precise point in the brain).

Once the implicated site has been located, it's down to the surgeon to devise a route through the brain to position the necessary implant. This will tend to be in a straight line from a hole drilled in the skull, but has to avoid damaging any vital structure on the way. This is a matter of finding a suitable angle to go into the brain, minimising potential damage. ->



Neuromate allows placement of electrodes with an accuracy of 0.78mm

Surgeons do this by locating the operation site using 3D scans of the brain and mapping these onto the patient's head, then using fixed supports to guide their instruments; first, the drill used to access the brain, and then the implant itself. Conventionally, this is done by hand, by fixing the patient's head onto the operating table using a device called a stereotactic frame; and then using arc-shaped measuring scales, also fixed to the table, to position supports for the operating instruments. But this is exacting work, subject to the always slightly uncertain vagaries of human skill at the time of the surgery. It also increases the amount of time the patient needs to be under anaesthetic, which carries risk. Moreover, the frame itself can cause trauma; in some cases it is attached using surgically affixed pins.

Neuromate avoids these problems. It is a robotic arm tipped with a mount for surgical instruments. The arm has six swivelling joints to position the mount in precisely the correct position for the surgery planned. It can be used with or without a stereotactic frame, and is equipped with software to help devise and programme in the surgical plan to get implants into the right place.

Although precision movement is a cornerstone technology for Renishaw; for example, in its coordinate measuring machines and Equator gauging devices, Neuromate is not adapted from an industrial metrology device but was designed specifically for surgery.

One procedure for which Neuromate is proving particularly useful is stereoelectroencephalography (SEEG). This is a method for providing an accurate identification of the locations in the brain where electrical disturbances cause epilepsy, for patients suffering from severe forms of the condition for which a surgical treatment might be considered. SEEG involves gaining a rough location of the epileptogenic site using techniques such as dye-tracing angiography to map blood vessels, MRI techniques to image rain structures and external electrodes on the

> **"Neuromate was not adapted from a metrology device but was designed specifically for surgery**

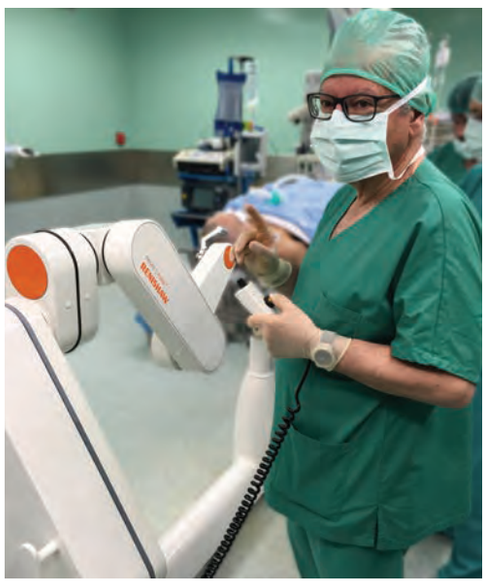
surface of the head to locate abnormal electrical activity, and then implanting electrodes within the brain tissue itself to narrow down the precise location. Unsurprisingly, it's a highly exacting process. Up to 20 electrodes are typically used, each one a semi-rigid rod bearing up to 18 electrical contacts along its length, and every single one has to be oriented precisely and inserted through the cortical area of the brain; the outer surface layer, which is dense with blood vessels that the surgeon must not disturb. Neuromate allows placement of electrodes with an accuracy of 0.78mm, according to a study derived from 81 placement operations. In the operation, Neuromate first guides the surgeon's drill to the precise position for an electrode and then guides the placement of a hollow screw into the drill hole, through which the electrode is inserted. Once the screw has been placed, the robot shifts its arm to the next position, with the whole sequence taking only seconds.

SEEG monitoring generally takes five to 15 days; basically it involves waiting for the patient to have an epileptic episode and monitoring the electrical activity with the implanted equipment.

"Thanks to the use of the Neuromate system, every target can be reached with a combination of speed and submillimetric accuracy," said Francesco Cardinale, a neurosurgeon at the Ospedale Niguarda Ca'Granda in Milan. "The precision of robotic guided SEEG has revolutionised surgery to cure epilepsy, allowing us to offer cures to a whole new cohort of patients," added David Sandeman, consultant neurosurgeon at Southmead Hospital in Bristol. Dr Cardinale has been able to perform an operation on the epileptogenic site – a thermal procedure to destroy the troublesome cells – with the electrodes in position.

At the Sainte-Anne Hospital in Paris, consultant neurosurgeon Prof Bertrand Devreaux uses a Neuromate machine for SSEG, biopsies and deep brain stimulation to treat Parkinson's. "We would not consider doing these manually without Neuromate," he said. "In my opinion, it is the easiest, fastest and most precise way to perform stereotactic procedures."

One particular advantage he find is that it reduces the number of X-rays that need to be taken during surgery to check the position of electrodes, which both reduces the risk to the patient and makes the procedure faster, cutting the time under general anaesthetic.



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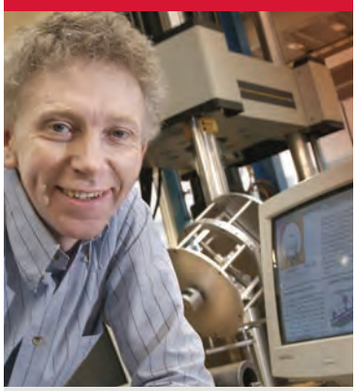
On the warpath

hugh hunt

Cambridge University, reader in mechanical engineering



Education
1984-88 Cambridge University, Engineering PhD, December 1988
1979-81 Melbourne University, Bachelor of Engineering (Mech), first class with honours and first place

Television work
2015 Channel 4 – *Hitler's V3 Supergun*
2015 Channel 4 – *Wall of Death*
2014 Scientific advisor for National Geographic series
2014 BBC – Slinky Springs, Boomerangs for *The One Show*
2014 PBS Nova (US) – *D-Day 360*
2013 Channel 4 – *Attack of the Zeppelins*
2012 Channel 4 – *Escape from Colditz*
2011 Channel 4 – *Digging the Great Escape*
2011 BBC – *Engineering Connections*
2010 Channel 4 – *Dambusters: Building the Bouncing Bomb*
2009 Channel 5 – Fifth Gear Stunt Special, *Loop-the-Loop*

A Cambridge University expert has been busy highlighting the key contribution engineers made to the Second World War. Jason Ford reports

Bombs away: **The RAF dropped 5,400kg 'Tallboy' bombs on the V3 site**

War can be hell for those taking part but such periods are guaranteed to generate ingenious innovations, and stories from conflict make compelling television.

Historians may disagree but there are those who believe engineers win wars, and Dr Hugh Hunt is one expert who advocates this, and not without good reason.

The Cambridge University reader in mechanical engineering has a CV that includes credits for his work as technical expert for documentaries, including *Attack of the Zeppelins* (2013), *Escape from Colditz* (2012) and *Digging the Great Escape* (2011).

In 2011, Dr Hunt and Windfall Films were awarded the Royal Television Society award for *Dambusters: Building the Bouncing Bomb* and in June this year he received the Royal Academy of Engineering's Rooke Award in recognition of contribution to the public promotion of engineering.

More recently, Hunt lent his engineering expertise to Channel 4's *Building Hitler's Supergun*, which investigated Hitler's plans to wreak havoc on London with V3 canons installed in a bunker dug into a chalk hill in northern France.

As the title of the show implies, the V3 marked a departure for artillery pieces with shells being forced up the barrel by a succession of explosive charges.

"This idea of the multi-charge cannon is to say, let's have a long, long barrel in which we'll fire our projectile in a normal way, but at quite low pressure, and then as the projectile moves along the barrel we'll keep injecting more hot, burning gas," said Hunt. "The design that Hitler was proposing was that with relative simplicity, he thought, you could take the… idea of gunpowder along the cannon that would self-ignite. The heat of the gas behind the projectile would cause the next lot of propellant to ignite, maintaining the pressure. It's a great idea in theory, but in practice it's quite difficult and that's what we were looking at."

In 1944 Hitler unleashed the first of his Vergeltungswaffen

Terror in the skies: **The V1 flying bomb was meant to terrorise civilians**

(vengeance) weapons onto London in the form of the V1 flying bomb, a new and odious addition to the Führer's arsenal that was used in anger a week after the D-Day landings began.

This was followed by the V2 rocket, a weapon that was virtually impossible to defend against but one that Hitler didn't favour.

"The V1 and V2 were really very successful but somehow [Hitler] had his sights set on this supergun, the V3," said Hunt. "If, in my opinion, he'd concentrated on getting the V2... perfected then that would have made a much bigger difference."

At the peak of the onslaught over 100 V1 flying bombs were launched onto London and southeast England in a day, while over 3,000 V2s in total were pointed at London and targets in Belgium. The V3, if successfully deployed, would have inflicted fresh havoc on a city that had already endured the Blitz.

Hunt said: "It's impossible to be sure what rate they could have achieved but they might have been able to achieve a round a minute onto London 24 hours a day, it really depends a little bit on how quickly they could recharge these cannons.

"The amount of explosive charge in these rounds were quite small and in the order of few tens of kg compared with bombing raids over London when they were dropping a few tons of bombs.

"These [shells] would have been completely silent and moving at the speed of sound when they were coming down onto London. Suddenly, you're sitting down having a cup of tea and one of these things comes through your roof and blows up your house."

"If Hitler had concentrated on getting the V2 perfected... that would have made a much bigger difference
Hugh Hunt

For Hunt, the Second World War shows how engineers applied their know-how in urgent and difficult circumstances to effect victory against an aggressor bent on ruling Europe through force.

On 6 June 1944 the Allies launched the world's largest seaborne invasion when around 156,000 troops landed on Normandy's beaches as part of Operation Overlord.

By the fifth day of the assault, the Allies had landed around 326,547 troops, 54,186 vehicles and 104,428 tons of supplies had been disembarked on the Normandy shoreline. Furthermore, the Allies' mechanised push east required vast amounts of fuel, which was supplied in part by PLUTO (Pipe Line Under The Ocean) from August 1944.

"The war was won by engineering," said Hunt. "It is just astonishing to think how big the Merlin engine is for the Spitfire, and who would ever think that you could have an aircraft back then, only 40 years or so since planes first flew, with such a huge, powerful engine? The whole thing is remarkable."

Humans have, of course, been successfully slaughtering one another since the end of the Second World War but for Hunt another significant and ominous threat to life on Earth comes from the effects of climate change.

"In the 1930s and 1940s the real urgency of the day was to defeat Hitler and it was a close run thing in 1940, 1941, 1942 when Hitler had the upper hand," said Hunt. "Here we are in 2015, [and] what are the crises we're facing now? There are so many: water supplies, energy supplies, climate change, rising sea levels, and flooding.

"And who is going to solve these problems? The solutions are, as ever, engineering solutions. We need engineers, we need clever engineers and one question I'd like to ponder is: supposing people such as Barnes Wallace and other astonishing engineers were alive today, how would they be approaching the problems? I think we've got plenty of astonishing engineers around [and] I think we need to create an environment where they are listened to."

Hunt said that he is working on "all sorts of weird technologies" that could help to cool the planet if CO_2 targets are not met and concedes that humanity has badly misjudged what it has to do to stabilise life on Earth.

"We've never had to ask that question," said Hunt. "It's an odd question to ask because never in the whole of human existence have we had to ask that question. But now that we're full on pushing the planet's resources to the limit we do have to ask: how do we stabilise our impact on the planet?

"On average, each person on the planet is emitting five tonnes per year of fossil CO_2. Now five tonnes per year on average, if you divide that by 365 days in a year, that's an average of 15kg of CO_2 a day. In the UK the average is more like… 40kg a day and those of us that travel to the US or Australia we're talking maybe 100kg a day of CO_2. That's ridiculous, so what do we do? Do we reduce the per capita consumption or do we reduce the population? There is no single solution."

What is clear to Hunt is the need for open, often radical discussions around mitigating climate change in an environment where ideas can be presented without fear of embarrassment or ridicule.

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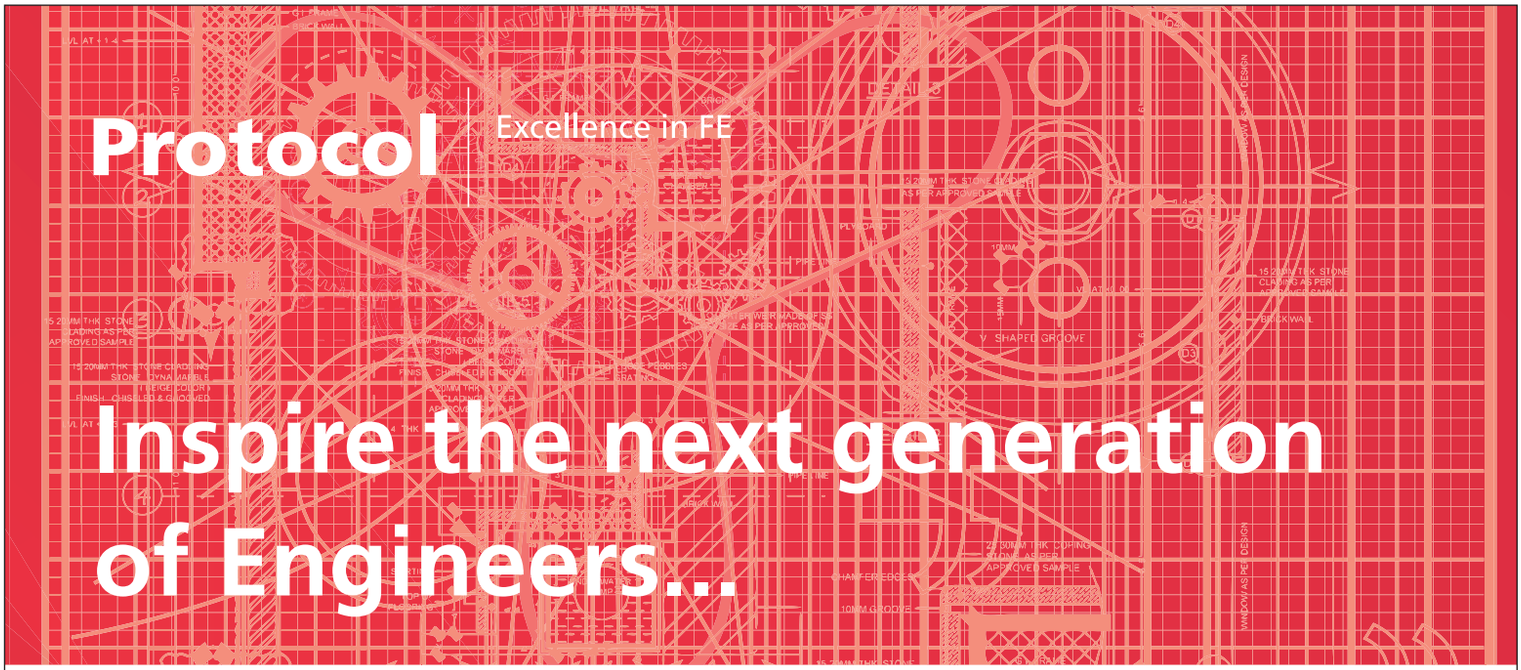

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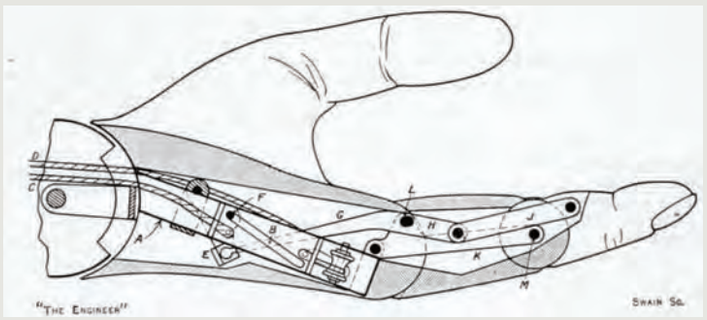
The Engineer took an interest in one of the most distressing aspects of the First World War – assisting those who had lost limbs in action



Even in the darkest days of the First World War, engineers were involved in caring for the wounded, as well as building the instruments of warfare itself.

In this article, *The Engineer* took a look at one of the most distressing consequences of the conflict from an engineer's point of view: the design and production of prosthetics for those who had lost limbs in action.

This article, written by Edward Hobbs, a prosthetics designer, describes the function of an articulated arm to replace a limb that had been amputated at the shoulder. Held on by cross-straps and a waist belt, the arm contained an arrangement of levers, bearings and cables that allowed the user to move the forearm and flex the hand using the remaining shoulder muscles. This allowed the user to lift weights up to about 2lb; enough to handle a full glass of 'liquid refreshment' (probably about a pint, we would imagine) or raise his hat.

"It had been considered impossible to do anything for a man who had lost his arm at the shoulder

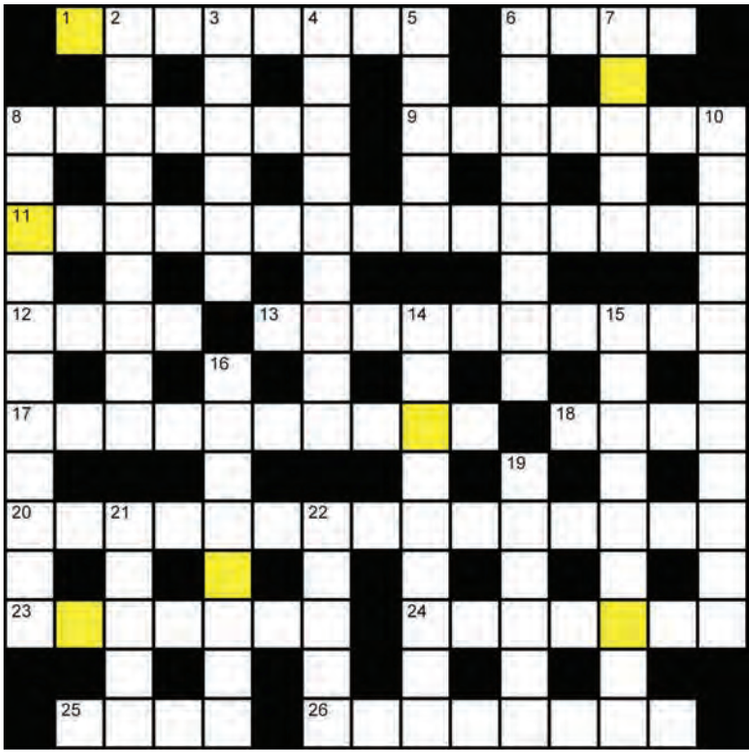
"For many years it had been considered absolutely impossible to do anything for a man who had lost his arm at the shoulder," Hobbs said, "whereas the Hobbs hand can be raised or lowered at the shoulder, flexed and extended, the wrist twisted and the hand clasped at will — without any assistance from the sound hand."

The arm came with interchangeable hands for a variety of different uses, with the 'full clasping hand' deemed the most popular and versatile. "With that hand a man can with a little training rapidly become fully proficient as a mechanical draftsman, or clerk; can handle his knife, fork and spoon; tie his necktie or his bootlaces, light his cigarette, play cards or billiards, and a thousand or one things besides," Hobbs claimed. ***SN***

For more on this story visit **www.theengineer.co.uk**

prizecrossword

When completed rearrange the highlighted squares to spell out a plant for treating lumber. The first correct answer received will win a £20 Amazon voucher. Email your answer to jon.excell@centaur.co.uk



ACROSS

1 Trade in guns (4,4)
6 Become plastic or fluid from heat (4)
8 Get on the back of (5,2)
9 Grinding with a machine (7)
11 Belief accepted as authoritative by some group (6,2,7)
12 Set of questions evaluating skill or knowledge (4)
13 Body of Swiss water (4,6)
17 Able to cause disease (10)
18 Central area of a church (4)
20 Exhibiting magnetism produced by electric charge in motion (15)
23 Raise to a higher position (7)
24 Perplexing problem (7)
25 Infection of the sebaceous gland of the eyelid (4)
26 A basis for comparison (8)

DOWN

2 Coarse plaster for the surface of external walls (9)
3 Humorous TV drama (6)
4 Use of spies to get military or political secrets (9)
5 Greatest possible degree of something (5)
6 Topple forward and down (4,4)
7 Support made of cloth or rope (5)
8 Most outstanding work of a creative artist or craftsman (11)
10 Whitish rubber that insulates electrical cables (5,6)
14 Short part of the oesophagus (9)
15 Any of various elastic materials that resemble rubber (9)
16 Written computer programs (8)
19 Bent from a vertical position (6)
21 Construct or build (5)
22 Heating appliances (5)

November's highlighted solution was Gangway. Congratulations to Keith Nuttall who provided the first correct answer.

origineering Anthony Poulton-Smith explores the origins of everyday engineering terms

Possibly our first engineering lesson came at school when the metalwork teacher introduced us to the file. Neither the tool nor its name has changed much since the Saxons referred to the feol, a word coming from the Proto-Germanic fihalo, quite literally 'cutting tool' and itself from the earlier Proto-Indo-European peig meaning 'mark by cutting' or sometimes 'an incision'. These early forms also gave some Eastern European languages with their word for 'paint'. Hence our ancestors saw the use of the file as a means to give the workpiece a good finish as much as shaping or cutting. For once, the 'file' in the office sense is completely unrelated and comes from the French file meaning 'a row'. This link between 'row' and 'documentation' came as the earliest filing saw the documents strung up on a cord or wire. This also explains why we often hear something is not 'on file', when it is clearly more accurate to say 'in file'.

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