THE MAGAZINE FOR INDUSTRIAL VEHICLE TECHNOLOGY, DESIGN & ENGINEERING

iVT Industrial Vehicle Technology International

NOVEMBER 2018 VOL. 26 No. 4

www.iVTinternational.com

Published by UKi Media & Events

NOVEMBER 2018

iVT INTERNATIONAL INDUSTRIAL

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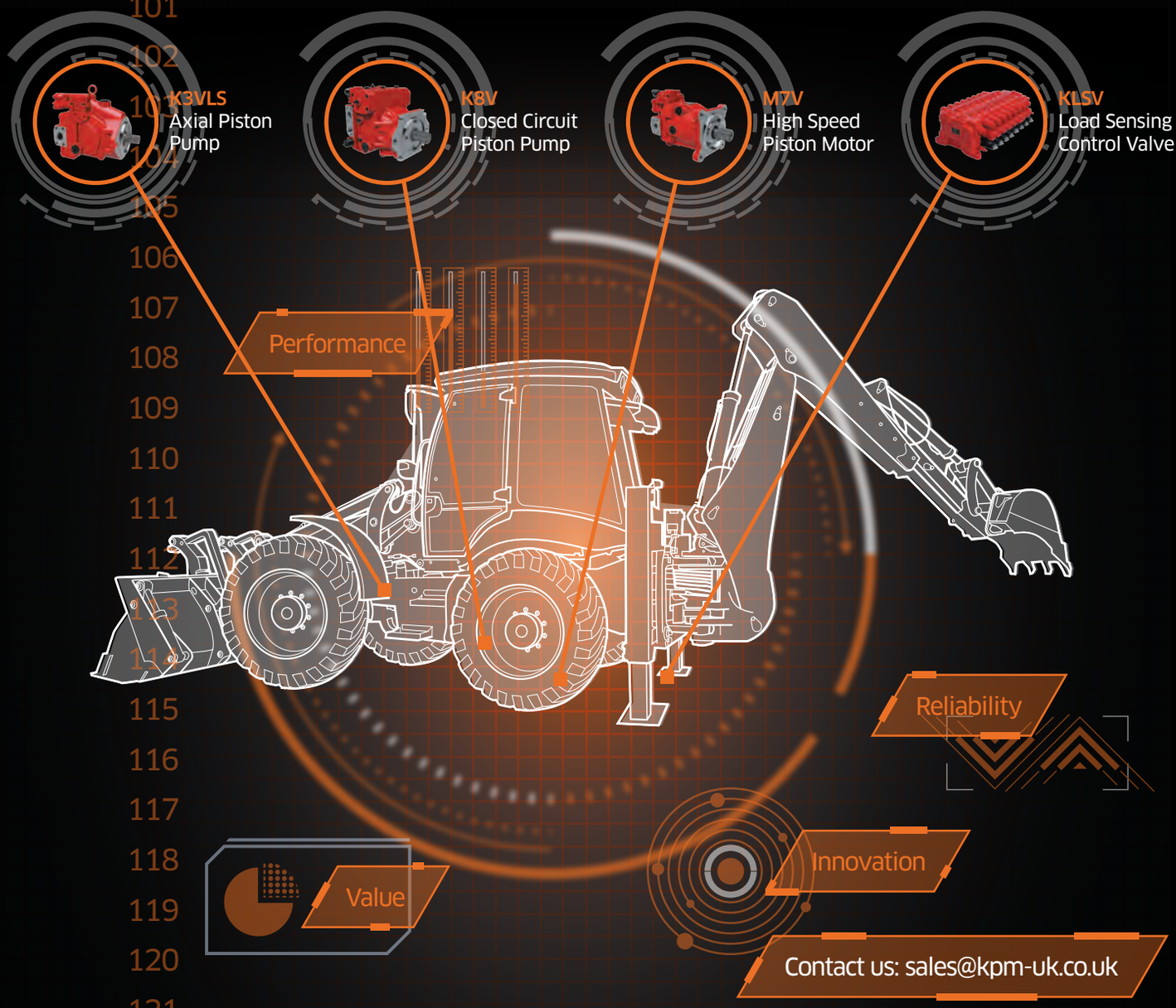

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iVT International USPS 018-627 is published quarterly, in February, June, September and November. Annual subscription price is US$110/£85.
Airfreight and mailing in the USA by agent named Air Business Ltd, c/o Worldnet Shipping USA Inc, 155-11 146th St, Jamaica, NY 11434.
Periodicals postage paid at Jamaica, NY 11431.
US Postmaster: send address changes to *iVT International* c/o Air Business Ltd, c/o Worldnet Shipping USA Inc, 155-11 146th Street, Jamaica, NY, 11434.
Subscription records are held at UKi Media & Events, Abinger House, Church St, Dorking, Surrey, RH4 1DF, UK. Air Business is acting as our mailing agent.

ISSN 1471-115X (Print)
ISSN 2397-6349 (Online)

Published by UKi MEDIA & EVENTS
UKi Media & Events,
Abinger House, Church Street,
Dorking, Surrey, RH4 1DF, UK
Tel: +44 1306 743744
Fax: +44 1306 742525
Ed. fax: +44 1306 887546

UKi Media & Events is a division of UKIP Media & Events Ltd

Printed by William Gibbons, Willenhall, West Midlands, WV13 3XT, UK
Average net circulation for the period January 1 to December 31, 2017: 10,303.

Member of the Audit Bureau of Circulations

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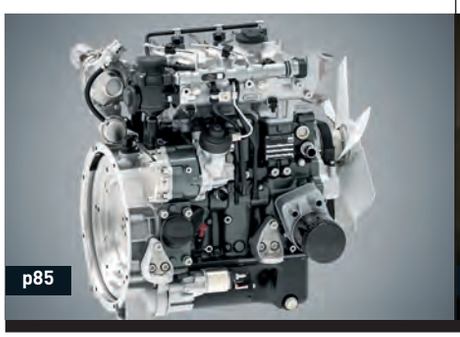
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FOREWORD

We are now entering the fourth industrial revolution – sometimes termed Industry 4.0. In this era, it is predicted that all the digital technology that has been developed over the past few decades (during the computer and automation revolution) will become increasingly connected. And, of course, we can see it already happening all around us. No longer is it adequate for technology to function and exist in isolation; increasingly, the expectation is that it will be connected with everything else around it. Communication is the key.

While this time of rapid change is extremely exciting and the possibilities it opens up seem almost endless, in fact there is nothing especially new about the basic concepts behind it. Communication has always been the key. The very beginnings of human civilization came about thanks to our ability to communicate with one another; and as this communication has become more sophisticated, our society has become more advanced. Now we have actually succeeded in building machines that communicate with each other, are we now, in fact, on the cusp of creating an entirely new society? A society of machines? As artificial intelligence advances, the possibility of this feels more real by the day.

And yet, no matter how advanced our creations are, there is still nothing in the modern world that compares with the 'data exchange' that can occur between two people. Or even better, among a roomful of people debating topics from different viewpoints. It is still by far the best way for technological advancements to be made quickly and efficiently. And it is in this spirit of communication that iVT Expo is being launched in Cologne, Germany, this February 13-14. Built upon the success of two existing events (iVT's Electric & Hybrid Industrial Vehicle and Autonomous Industrial Vehicle symposiums), the conference is now growing to include new topics (Cab Design and Powertrains) as well as giving birth to a free-to-attend exhibition, which will run alongside. It is a unique opportunity within the industry for OEM vehicle designers and decision makers to gather together and really drill down into the challenges that face the industry as we move forward – and to discover solutions that may be entirely new. Turn to page 16 for a full preview of the event.

Elsewhere in this issue, you'll find some of the key topics from iVT Expo discussed in even more depth. In the year that the EU's Stage V emissions regulations come into force, we take a look at exactly what they mean for the industry, as well as predicting where such legislation will go next, both in Europe and around the world (p32). There's also a look at some of the latest cab designs (p38), and much else besides. But all we really have to do is make sure we keep talking.

Tom Stone, editor

Coming up in the March 2019 issue of *iVT*

Construction Special • Exclusive Bauma Munich 2019 preview • New vehicle launches • How to build an industrial vehicle Part 2 • World exclusive OEM interview • And much more...

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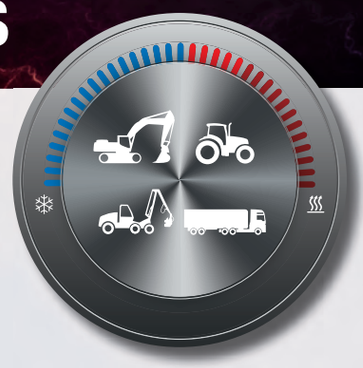

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WHAT'S NEW

India's time to shine

WITH A BOOMING CONSTRUCTION INDUSTRY IN THE COUNTRY, THE BIENNIAL BAUMA CONEXPO INDIA, WHICH TAKES PLACE THIS DECEMBER 11-14, IS EXPECTED TO BE BIGGER AND BETTER THAN EVER BEFORE

LEFT: **The Bobcat B730 entered the Indian backhoe loader market this year – the first factory producing it in the country opened in June 2018**

bauma CONEXPO INDIA

Following on from the success of the event two years ago and the explosive growth that the Indian construction industry is experiencing, Bauma ConExpo India 2018 promises to be a significant event for the off-highway segment – not just in the subcontinent, but also globally.

Last time out, the 2016 event saw 657 exhibitors from 30 different countries exhibiting across 150,000m² of floor space. The most up-to-date figures for the 2018 show indicate that 30% more space has been registered and more national pavilions across the site are planned, making it an even bigger occasion than two years ago.

LEFT: **Hyundai's R110 Smart excavator, which has an operating weight of 11.8 metric tons, is a popular machine in India**

Preparations for Bauma ConExpo India got a boost in November, with predictions that the country's construction industry will grow twice as fast as China's between now and 2030.

Citing its current low ranking in infrastructure quality (63 out of 140 countries) and a growing urbanized middle class, London-based construction analysts Global Construction Perspectives said the subcontinent to be the third-largest construction market within the next three years.

The construction think-tank believes 200 million rural Indians will relocate to cities by 2030, while 100 million extra families in the country will start earning at least US$35,000 over the same period.

Combining these factors with the country's low debt to gross domestic product ratio, the director at Global Construction Perspectives, Graham Robinson, tells iVT, "These factors are really driving growth in India, whereas in China, many of these same drivers are going in reverse.

"We expect India to grow at an average of 7.4% annually, while China is growing at a very much lower rate, currently 4% – but the expectation is getting more pessimistic by the day. By 2030, the subcontinent's construction market is projected to be over US$1tn, almost 40% larger than current third-placed Japan.

"India's huge growth over the next 12 years will reach the point where it will actually significantly shape the world economy," adds Robinson.

Pollution challenges

For the market to grow sustainably, however, India will have to address its chronic air pollution. The extent of the problem is illustrated in New Delhi. The country's capital is considered a megacity at 19 million people, and is expected to become the largest in the world by 2028. But it was also recently given the unwanted title of the world's most polluted megacity by the World Health Organization.

In an attempt to reduce the smog that blights the city, a range of emergency measures have been introduced by authorities. These include temporary bans on construction activity when particulate matter readings exceed predefined levels. Such measures are clearly inadequate and point to the likelihood of India gravitating toward cleaner engine technologies.

With this environmental focus, both alternative powertrain solutions and more efficient diesel engines will become increasingly important for the country's construction industry, and examples of both will be represented at Bauma ConExpo India.

Taking place from December 11-14, in New Delhi, many of the world's major industry players will be showcasing their solutions, with Case, Caterpillar, JCB, Kobelco, Volvo, Doosan Bobcat, Hyundai and Manitou among them.

"We are pleased with the high level of interest," says Bauma ConExpo India's CEO, Bhupinder Singh. "We already have 30% more space registered than for the previous event two years ago."

As well as local companies, representatives from China, Germany, Spain and North America are among those exhibiting. Kaeser Kompressoren, a German manufacturer of compressed air products and services, and India's Tata Hitachi, are among new faces.

For the second time, Bauma ConExpo India will be held at the HUDA ground in Gurgaon/Delhi. **iVT**

INITIAL STAGES

AS THE CELEBRATIONS FOR *iVT*'S 25TH ANNIVERSARY YEAR DRAW TO A CLOSE, WE DECIDED TO TAKE A LOOK BACK TO WHEN STAGE I EMISSIONS REGULATIONS HAD JUST COME INTO FORCE, AND STAGE II WAS BEING DEBATED

Coinciding with Stage I and II emissions regulations, there was a growing concern in the industry about engine noise outputs

"In addition to 'clean' combustion, offered particularly by natural gas, the argument concerning noise emission is also important"

1999

25 YEARS

"Research has shown that the exhaust gases from older diesel engines have, by a wide margin, the greatest cancer-causing potential"

Stage	Engine class (kW)	NOx (g/kWh)	CO (g/kWh)	Particulates (g/kWh)	Brought into operation after
1	37–75	9.2	6.5	0.85	Dec 1998
	75–130	9.2	5.0	0.70	Dec 1998
	130–560	9.2	5.0	0.54	March 1999
2	18–37	8.0	5.5	0.80	Dec 2000
	37–75	7.0	5.0	0.40	Dec 2001
	75–130	6.0	5.0	0.30	Dec 2002
	130–560	6.0	3.5	020	Dec 2003

From January 2019, diesel industrial vehicle engines made in the EU will have to comply with Stage V standards, meaning they will emit fewer toxins than ever before.

Since the first *iVT* magazine was issued in 1993, we have been keeping readers up-to-date with the latest industry news – and in 1999 we reported on Stage I regulations when they first came into play.

In our October 1999 issue, longtime *iVT* contributor Gerald Scheffels wrote, "In Europe, the exhaust gas emissions for industrial motors are being limited in two stages [see table, left]. Stage I is already applicable, Stage II will follow – depending on engine power – from January 2000 to January 2003. So what happens when Stage II arrives? Naturally, the new engines satisfy all the requirements of Stage I. However, with regard to Stage II, the formulations are fairly 'woolly'. The requirements are applicable from 2001 to 2004 'if necessary' and 'insofar that the certification of the engine should be required'. In short, additional measures are then going to become necessary."

So how do the 2019 regulations compare with their 20-year-old predecessors? Stage V is certainly not 'woolly' and will only permit a very small amount – just 3-4% – of the emissions that were allowed from Stage I-compliant engines.

Since 1999, great progress has been made in reducing NO_X and particulate matter emitted by off-highway engines. But now the focus is increasingly turning to CO_2. The ultimate goal must be the one set out by the recent UN Intergovernmental Panel on Climate Change (IPCC) – for industry to become carbon neutral by 2050. It's not going to be easy, but through innovation and collaboration we must collectively continue to strive for a cleaner future. **iVT**

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Prototype **power**

TWO NEW TELEHANDLER PROTOTYPES BOAST HYBRID AND FULLY ELECTRIC POWER CAPABILITIES

Manitou and Deutz have collaborated to create two prototype MT 1135 telehandlers – one model that is fully electric and another that is a hybrid.

The electric Manitou MT 1135 prototype is equipped with a 360V vehicle power supply and a 60kW electric motor. The battery, with a generous 30kWh capacity, ensures that the energy delivered meets the challenging off-highway applications expected of the vehicle.

In the hybrid prototype, the 75kW Deutz TCD 3.6 engine has been replaced by a Deutz TCD 2.2 – which generates 55kW (74hp) – and a 20kW electric motor. The on-board electric system is provided with 48V.

Manitou president and CEO, Michel Denis, said, "Thanks to Deutz, this is the first fully electric construction telehandler prototype that we have made, and we are proud to work in this explorative phase alongside such a competent supplier.

"The integration of electric drives into our telehandlers is very encouraging for the future. Deutz has rapidly assumed a pioneering role in electrification. It has the necessary expertise and knows our applications' special requirements. Innovation is a part of Manitou Group's DNA, and electrification enables us to match our CSR approach with our customers' expectations."

Dr Frank Hiller, chairman of the Deutz board of management, added, "These joint studies reinforce our belief that we can provide the market with the right solutions and position ourselves as the market leader for innovative drive systems."

There are currently no plans to bring the hybrid and fully electric MT 1135 models into production. **iVT**

Don't miss the iVT Electric & Hybrid Industrial Vehicle Technology symposium, part of iVT Expo. Turn to page 16 for more, or visit ***ivtexpo.com***

iVT electric & hybrid industrial vehicle technology

ELECTRIC TAKEOVER

AVANT e5

This fully electric compact wheel loader has a 11.5kW battery capacity, which enables it to run for up to three hours, depending on the intensity of the work it's carrying out. It is also equipped with two separate electric motors – 6kW to drive the machine and 2kW for boom operation and hydraulics. The e5 was released in 2017 at a cost of €35,000 (US$41,300).

KRAMER 5055e

With its 80V battery pack, this all-electric wheel loader can operate for up to five hours at a time, following up to six hours of charging. It has a stacking payload of 1,750kg. The 5055e has been available on the market since 2017 at approximately €55,000 (US$63,157).

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Robotics in the field

AUTONOMOUS VEHICLES AND MACHINES ARE BECOMING EVERMORE COMMON IN INDUSTRIAL SECTORS SUCH AS AGRICULTURE AND MATERIAL HANDLING

ENHANCED TRACTOR TECHNOLOGY

In September 2018 Yanmar launched two tractors with autonomous features: the Auto Tractor (YT488A / 498A / 4104A / 5113A); and the Robot Tractor (YT488A / 498A / 4104A / 5113A).

The Robot Tractor model offers completely unmanned operation, while the Auto Tractor offers minimal operator input. Both machines rely on Yanmar's unique Information and Communications Technology (ICT), which combines advances in industrial robotics with precise positioning data.

Control of the new vehicles can be carried out via a waterproof, rugged 10in tablet that enables one person to operate both tractors simultaneously.

The positioning is based on RTK-GNSS (real-time kinematic global navigation satellite systems), which can use two signals from multiple GNSS. An additional base station helps to provide positioning information with pinpoint accuracy.

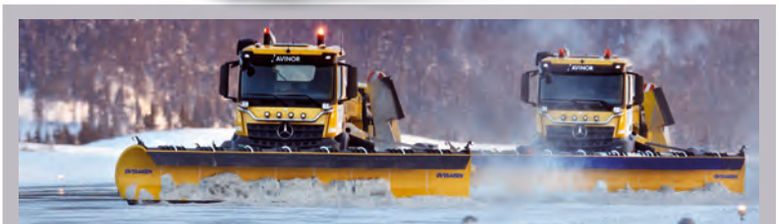
MATERIAL HANDLING

In a bid to provide machines that improve productivity in the warehouse without being too costly, the European arm of Yale has developed three automated machines: a low-level order picker (MO25), a tow tractor (MO50-70T) and a counterbalance truck (MC10-15).

Balyo geo-guidance navigation technology enables the robotic trucks to operate autonomously without the need for any wires, magnets or reflectors.

"We recognized that a major hurdle to introducing robotics in warehouses and production lines is the installation of dedicated infrastructure," explained Ron Farr, warehouse solutions manager for Yale. "By collaborating with Balyo, we've been able to produce a range of trucks that use existing structural features to generate their own map, enabling them to self-locate and navigate in real time."

The vehicles can automate a variety of repetitive load transportation tasks, from servicing production lines, transporting loads between stations, and conducting milk-run production loops, to carrying empty pallets to a palletizing machine.



SNOW-FREE SURFACES

Autonomous Semcon snowplows are being deployed at Norway's Oslo Airport this winter, following a successful trial at a smaller Norwegian airport. The Oslo Airport trials will begin in January 2019 with a fleet of 10 of the autonomous machines deployed to keep the runways clear of snow.

Jointly run by Semcon and Øveraasen, Yeti Snow Technology is the first project of its kind to adapt such large machines for autonomous operations in conditions that are particularly harsh and wintry.

Measuring 20m (65.5ft) long and 5.5m (18ft) wide, the autonomous snowplows are expected to increase efficiency and reduce snow-related delays at the airport.

The self-driving vehicles are capable of clearing 357,500m^2 (3,848,100ft^2) of snow per hour and can perform in formation for even greater efficiency.

John Emil Halden, project manager at Semcon, said, "Our aim is to complete 40 operations to ensure that the system is working as intended and see how we can develop it further. We are then hoping that more world airports will be interested in this technology." The autonomous technology could also eventually be transferred to other off-highway machines.

SHOWCASING THE COMPONENTS, SERVICES AND TECHNOLOGIES THAT GO INTO MAKING THE NEXT GENERATION OF INDUSTRIAL VEHICLES

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This February, the off-highway vehicle industry will descend on Cologne, Germany, for a brand-new event – iVT Expo, which consists not only of an exhibition, but also a full conference program with four individual streams addressing the issues that matter today.

This is not an event for farmers, contractors or casual vehicle fans. There will be no vehicles on display, or for sale. It will exclusively cater for those who build the machines, by showcasing the new components and technologies they need and connecting them with peers.

Regular readers will be familiar with two of the four symposiums at iVT Expo. The iVT Electric & Hybrid Industrial Vehicle Technology Symposium and the iVT Autonomous Industrial Vehicle Technology Symposium hosted their first events in Cologne back in 2016 and 2017 respectively. Both were instant hits and have been growing in importance and prominence since.

Running the new Cab Design & Technology and the Powertrain Technology events alongside the two already-established conference streams is expanding the range of experts delivering presentations, and the number and diversity of off-highway designers and decision makers who are attending in order to exchange ideas.

Furthermore, with so many important OEM thought-leaders in one place, key Tier 1 suppliers have the ideal opportunity to present their latest technology to the people who matter, in a brand-new, free exhibition. And so iVT Expo is born.

Over the next 14 pages, you will meet some of the key speakers and we'll take you through just some of the other highlights you won't want to miss. **iVT**

SEAL-FREE ELECTRIC WATER PUMP

With the proliferation of electrified powertrains in off-highway vehicles comes the need to keep the specialized components cool. To cater to this market, Avid Technology has developed its first-ever electric water pump that does not need seals. It uses the company's existing high-performance permanent magnet DC motor technology and high-performance electronics platform. The pump is available in 24V and 48V variants. Thanks to its cast-aluminum design, it has a low weight of 2.95kg (6.5 lb), but boasts a maximum flow rate of 110 liters (24 gallons) per minute. The pump is already being used for a wide range of applications, including – but not limited to – hybrid and electric vehicle powertrains.

Avid Technology
Stand: 2005
avidtp.com

2.95kg
The weight of Avid's seal-free electric water pump (6.5 lb)

IoT Cloud Service hardware

During the inaugural iVT Expo in Cologne, TTControl will exhibit the recently launched IoT connectivity solution, TTConnect Cloud Service, which includes the ruggedized gateway TTConnect Wave (pictured), in addition to the cloud service itself. The IoT solution enables both manufacturers and fleet owners to connect and manage vehicles and entire fleet pools. TTControl will also be demonstrating the fully customizable web portal to the IoT solution with its intuitive front-end providing cloud access to users.

Furthermore, the company will be bringing its TTConnect 616 advanced connectivity platform to the show. This off-highway-proven Ethernet switch combines and manages all in-vehicle interfaces such as CAN-FD, Flexray, LIN and Ethernet. The platform also features advanced traffic management software and support for Time-Sensitive Networking protocols.

In addition to new products, TTControl will present a number of recent product upgrades. The ECU HY-TTC32S is now available with EN 13849 PL d safety certification and will replace the previous HY-TTC 32S PL c variant. Also, the HY-TTC 500 product family is now available with SAFERTOS integration, enabling it to provide higher levels of robustness and responsiveness.

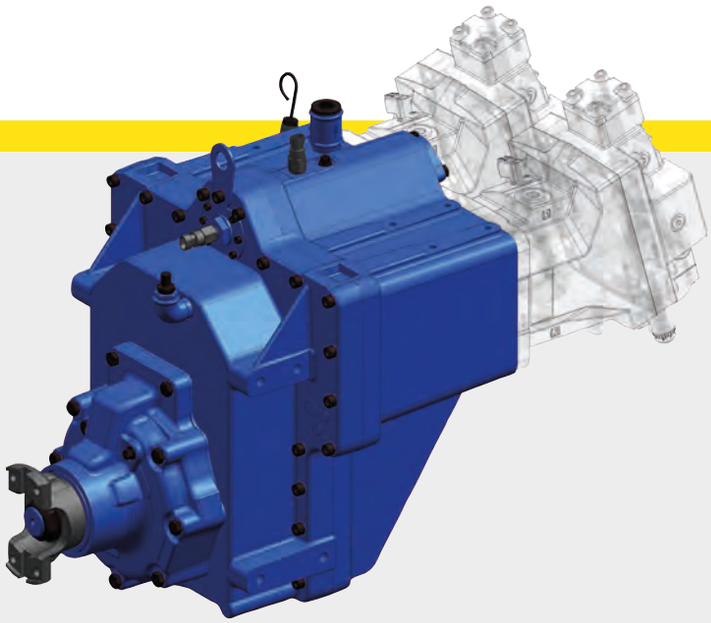
TTControl
Stand 2045
www.ttcontrol.com

ERGONOMIC OPERATOR SEATS

Visitors looking for ways to increase comfort and ergonomics in vehicle cabins should check out KAB Seating's latest Sciox seat range for both construction and agricultural vehicles. The seat range is the result of user feedback and extensive research and testing. It has been engineered to offer both good value and high durability, while also maintaining comfort throughout the day. To this end, it uses sculpted cushions and a low-frequency air suspension system that does not require additional air reservoirs, but still shields the driver from harmful vibrations and resulting injuries.

Already available for the agricultural sector, Sciox seats will be released for the construction sector by 2019. They can be ordered in a number of trim levels and can be specified with either low or high seatbacks. Additionally, 'premium' models offer heating and ventilation, in addition to a progressive variable damping system that protects the operator from injury.

KAB Seating
Stand: 3005
www.kabseating.com



DUAL-MOTOR CVT CONCEPT

Attendees in search of innovative drive concepts should visit NAF, which will be presenting its new CVT solution that combines two hydraulic motors for excellent precision and high tractive power at low speed; and reduced fuel consumption at high driving speeds. The DualSync system is already used in forestry applications up to 200kW, but it is suitable for many other machines as well.

The DualSync hydrostatic CVT is driven by two motors. One motor reaches its maximum RPM at 30% of the maximum vehicle speed and is then deactivated and disconnected from the drivetrain by a synchronizer, while the other motor drives the vehicle up to its top speed.

The company claims that the advantages of this concept include fuel savings, reliability and improved machine control compared with torque converter systems. What's more, the system ensures that the diesel engine is mainly driven in its most efficient speed range. Finally, with no stepped gear changes, the system ensures a smooth drive with no interruptions.

NAF Neunkirchener Achsenfabrik
Stand: 2025
www.nafaxles.com

CAN-compatible throttle

Visitors to MCS's stand can view the company's range of electronic throttle-control products. As electrified powertrains become evermore popular and an increasing number of electronic governors require throttle control through CAN, MCS has developed a range of CAN J1939-compatible throttle controls. The line-up includes a throttle pedal, a hand throttle, a rotary throttle and throttle position sensors. Although slightly more expensive than traditional analog models, CAN-compatible models offer simplicity of installation, as well as accuracy and reliability, thanks to their insensitivity to noise.

MCS Controls SA
Stand: 2010
www.mcs-belgium.com

iVT EXPO

FEBRUARY 13-14, 2019 – COLOGNE, GERMANY

ALSO EXHIBITING...

In addition to the companies featured opposite and over the next six pages, at the time of going to press the following suppliers were also confirmed for the iVT Expo exhibition hall with more names being added daily...

ABB Oy (Stand 2098, abb.com) • **Addtech Nordic AB (Stand 2010, addtech.se)** • Adigo Drives AB (Stand 2010, adigoab.com) • **Agco Power Inc (Stand 4020, agcopower.com)** • Alders Electronic GmbH (Stand 5010, alders.de) • **Allied Vision (Stand IVT13, alliedvision.com)** • Altra Industrial Motion (Stand 2068, altramotion.com) • **ARADEX AG (Stand IVT4, aradex.de)** • ATE Antriebstechnik + Entwicklungs GmbH + Co KG (Stand 5085, ate-system.de) • **ATG Tyres (Stand 3030, atgtire.com)** • Atlantex Manufacturing Corp (Stand 4055, atlantexmfg.com) • **ATP adhesive systems AG (Stand 3055, atp-ag.com)** • Avid Technologies Limited (Stand 2005, avidtp.com) • **AVL Deutschland GmbH (Stand IVT11 & IVT1, avl.com)** • AxleTech International (Stand IVT7, axletech.com) • b-plus GmbH (Stand 5090, b-plus.com) • **Blachford Uk Ltd (Stand 3010, blachforduk.com)** • BPS Cooperative UA (Stand IVT6) • **Denso Marston Ltd (Stand 4010, denso.com)** • Denso Thermal Systems SPA (Stand 4010, denso-ts.com) • **Deutz AG (Stand 2060, deutz.com)** • Diabatix NV (Stand 5000, diabatix.com) • **DIS Sensors (Stand 1088, dis-sensors.com)** • dSpace (Stand IVT14, dspace.com) • **EAS Batteries GmbH (Stand 4035, eas-batteries.com)** • Ebco Rubber Limited (Stand 4040, ebcoltd.ie) • **EBV Elektronik GmbH (Stand 2055, avnet.com)** • Elektrobit Automotive GmbH (Stand 1015, elektrobit.com) • **FB Chain Ltd (Stand 2010, fbchain.com)** • Fortaco Group OY (Stand 4025, fortacogroup.com) • **HBM Prenscia (Stand 2095, hbmprenscia.com)** • Hottinger Baldwin Messtechnik GmbH (Stand 2095, hbmprenscia.com) • **I.M.M. Hydraulics Spa (Stand 3051, imm-hydraulics.it)** • Infineon Technologies (Stand 2055, infineon.com) • **Interpump Fluid Solutions (Stand 3050, interpumpfluidsolutions.com)** • J.W. Speaker Corporation (Stand 4060, jwspeaker.com) • **Lion Smart GmbH (Stand IVT8, lionsmart.com)** • Opal-RT Technologies Europe (Stand IVT5, opal-rt.com) • **REFU Elektronik GmbH (Stand IVT2, refu.com)** • Rima Spa (Stand 6070, rimaspa.com) • **Rögelberg Getriebe GmbH & Co.KG (Stand 4005, roegelberg-getriebe.de)** • S.E.A Datentechnik (Stand IVT12, sea-gmbh.com) • **Sensor-Technik Wiedemann GmbH (Stand 2035, stw-mobile-machines.com)** • Sittab AB (Stand 2010, sittab.se) • **Super B (Stand IVT9, super-b.com)** • Thermamax Hochtemperaturdammungen GmbH (Stand 4070, thermamax.com) • **Topcon (Stand 2065, topcon-electronics.de)** • Voss Fluid GmbH & Co KG (Stand 4065, voss.de) • **Walvoil S.p.A. (Stand 3050, walvoil.com)** • Würth Elektronik (Stand 3020, we-online.com)

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iVT electric & hybrid industrial vehicle technology

KEYNOTE SPEAKER SPOTLIGHT

Bill Van Amburg,
executive vice-president, Calstart, the USA's industry association working to develop cleaner, more efficient transportation solutions

Can you tell us why you feel iVT Expo is important to the industry?
It's about both goodwill and good engineering, but it's also much more than that. It's an opportunity to innovate and start the process of creating new products. It's the opportunity to share ideas and meet potential partners. Down the years I've met some great, innovative companies at events such as this, that we've been able to develop projects with.

What main issues will the conference address?
The big elephant in the room is climate change, and that's what we have to address over the next couple of decades through great product design, engineering and creative thinking. The question is: how do we do the work needed for society without destroying society? It requires a new generation of thinking and the conference is where we can get those creative juices flowing. The issues we need to solve also require more progressive thinking about aspects such as connected technology, augmented technology and efficiency, so this is an opportunity to discuss how we can address those issues – and then address them.

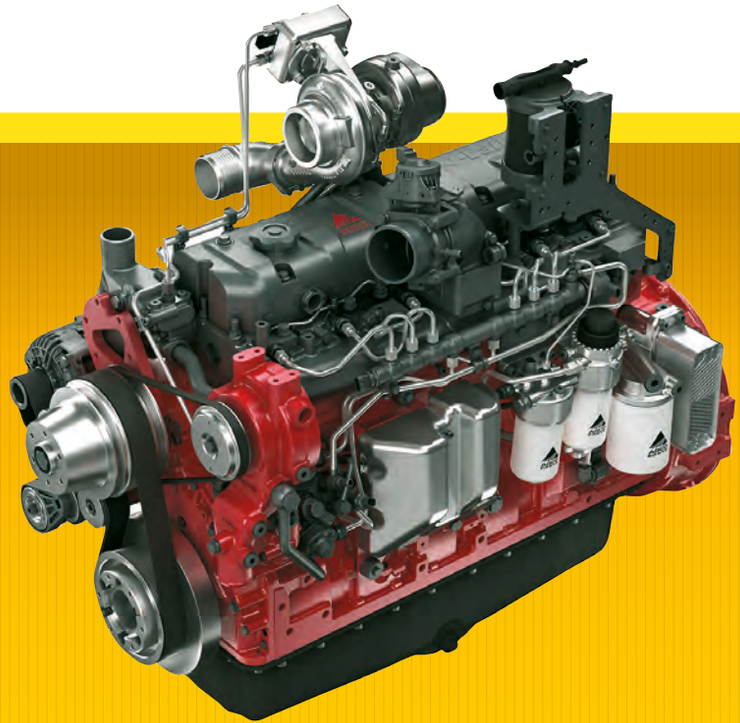
So what will you be addressing when you're there?
One of the big topics for me this year is expanding markets. We've been developing a new strategy with our industrial partners in the USA that we describe as a 'beachhead strategy': establish a first application of success for a product, then move across to adjacent and maybe larger markets. In automotive terms, this covers electrification and knock reduction. With larger vehicles the big success story has been buses, so the next challenge is to integrate that technology into vehicles such as yard tractors, industrial lifts and medium-duty trucks. It turns out we can transfer technology more laterally than we once thought possible.

What do you expect to come out of the event?
One thing I hope to find again is that great nugget – a company working out of the box. I'll be scouting for the next best-in-class player who's redefining expectations. This could be in areas like smaller, more efficient electric motors, or new applications for existing technology.

Given the environmental issues and technological challenges we face, is it more important than ever to meet up annually on an ongoing basis?
If it weren't for the logistics, it would be great to meet twice a year! The pace of change is so fast, and there is so much new thinking all the time, that this sort of opportunity to meet and share ideas is only going to get more important. For me, the key will be integration. We tend to stay in our own 'lanes', so we need to break down those barriers between us and open up new pathways for greater integration and more connected technology to make us more efficient. We have to keep looking ahead.

Bill Van Amberg will give a keynote presentation entitled ***Beachheads for change – the global urban drive to zero and its impact on industrial vehicles*** at iVT Expo. For more from Van Amberg, commenting on EU Stage V emissions regulations and what the future holds in this area, turn to page 32.

For a full program and registration details visit iVTexpo.com NOW!



STAGE V-READY ENGINES

Stage V emissions regulations are coming and iVT Expo is the place to discover engine suppliers that will make compliance easy. Case in point is AGCO Power, which offers a range of nine Stage V-ready power units. In particular, there is the 3.3-liter, heavy-duty, three-cylinder engine that is manufactured in Finland. The 3.3LFTN engine meets the requirements even without an EGR system. It is already in use in the Fendt 211, which won the 'Specialized' category at the 2018 Tractor of the Year awards. The outright winner at the same awards was also powered by an AGCO engine – the 7.4-liter in-line-six engine, as fitted to the Valtra T254. This will also be compliant when Stage V emissions regulations come into force.

AGCO Power Inc
Stand: 4020
www.agcopower.com

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3.3 l
The size of AGCO's 3.3LFTN engine, which meets Stage V requirements even without EGR

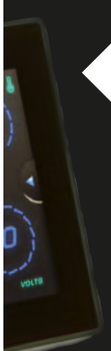
New controls for demanding applications

The new G3-C Universal Contour Grip is the latest addition to Otto's G3 family of ergonomically designed universal grips. The G3 series grips can be easily and quickly customized, both for top-of-the-line machines that require high switch counts, or to provide basic control functions on lower tier models. Available as a center, left-handed, or right-handed grip, the G3-C offers 15 standard faceplate configurations and a variety of custom mounting and termination options. The grip was developed for use with Otto's standard push buttons, rockers, toggles and Hall-effect switches, and can be easily mounted on a JH or JHM series Hall-effect joystick.

The P6-4 series switches are commercial grade limit switches that are watertight and sealed to IP68S and IP69K. Using a stainless steel housing, they stand up to extreme temperatures and harsh environments. These switches are available with either ball- or roller-plunger actuation. In addition, they can be configured as single-pole or double-pole; and both as single-throw or double-throw. The P6-4 switches offer three connection methods: solder terminal, screw terminal, or flying wire leads.

Otto
Stand: 5010
www.otto-controls.com

RUGGEDIZED TOUCHSCREENS

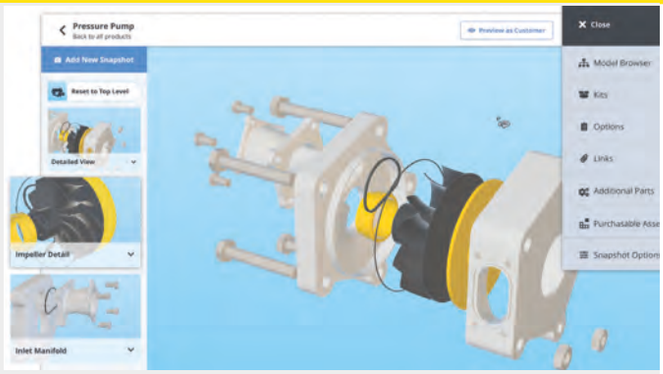


Stop by at CANtronik's stand to find out about the company's latest display – a 7in slimline touchscreen with a new high-performance processor and the option of an external CAN keypad and joystick.

CANtronik's product line-up includes embedded HMI displays and gauges with CANbus connectivity, ruggedized for the needs of off-highway vehicles. Screen sizes range from 2.3in to 7in, with analog and digital input options to support numerous sensors and senders.

To enable IoT and telematics, the display has built-in connectivity features. Combined with the internal storage and datalogging capability, the connectivity allows for complete control and monitoring of the machinery. The display hardware also comes with a software development environment that includes extensive J1939 libraries to enable the development of bespoke software applications.

CANtronik
Stand: 2075
www.cantronik.com



Easier spare parts ordering

Fully maintenance-free off-highway vehicles are, at the moment, still a dream, and ordering spare parts can often be an ordeal. Visit CADshare's stand to find out how the company can make finding and ordering the right parts much easier for your customers, thus improving their experience and building brand loyalty. The startup's solution is a cloud-based platform that offers a user-friendly inventory of spare parts with 3D CAD drawings, removing the need to hunt for part numbers in cumbersome – and possibly outdated – catalogs. The platform is already being used by OEMs such as Multihog and NC Engineering.

To reduce the friction in the part-ordering process even further, CADshare is launching a number of tools to grow customers' basket sizes. One such feature is the introduction of 'kits'. Based on already selected parts, the software will suggest other components that may be needed to complete a certain maintenance procedure.

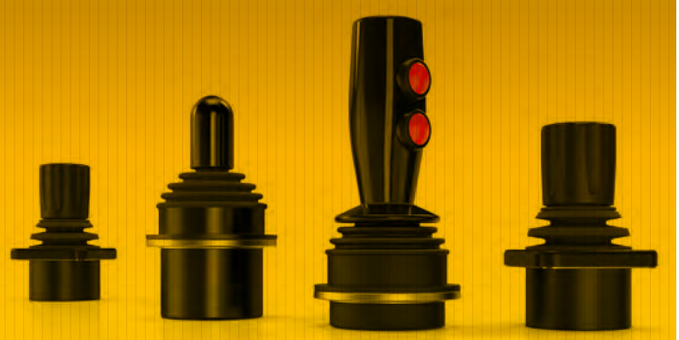
CADshare
Stand: 2093
www.cadshare.com

NEW CONTROL GRIP

At Industrial Vehicle Technology Expo, Caldaro will present the latest version of its Viper joystick grip – the XT. The Viper joystick is designed to be ergonomic, allowing for variable grip positions and preventing stress on the wrist. Steering is performed with a thumbstick, while other buttons can be customized for the specific application.

The XT offers up to three analog controls, of which two can be used simultaneously. This new version was a response to a request from a major manufacturer of construction machines. The manufacturer asked for steering control to be integrated into the handle, which was solved with a proportional lever on the front of the device. The steering lever and the proportional thumb rocker button for controlling the hydraulic attachments can be used simultaneously. This means the operator can let go of the wheel and put their hands on the joysticks to drive the machine, while remaining in control of the attachments.

Caldaro
Stand: 2010
www.caldaro.com



JOYSTICKS

EAO will showcase its Series 09 joysticks for off-highway vehicles. The range includes 10 standard models, with customized solutions available for specialized applications. The joysticks are available with IP65 or IP67 ingress protection ratings, with a maximum loading of 18,000Nmm and a choice of one, two or three axes; with soft, rigid or no cross guidance.

In addition, the joysticks feature a self-resetting, reliable interlocking mechanism, momentary or maintained action and a choice of more than 10 different handles. Hall-effect or conductive plastic sensors enable back panel depths of less than 20mm, while the units can be specified with standard or customer-specific output signals, plug-in terminals and cables, to allow for the widest possible range of applications.

EAO
Stand: 5040
eao.com

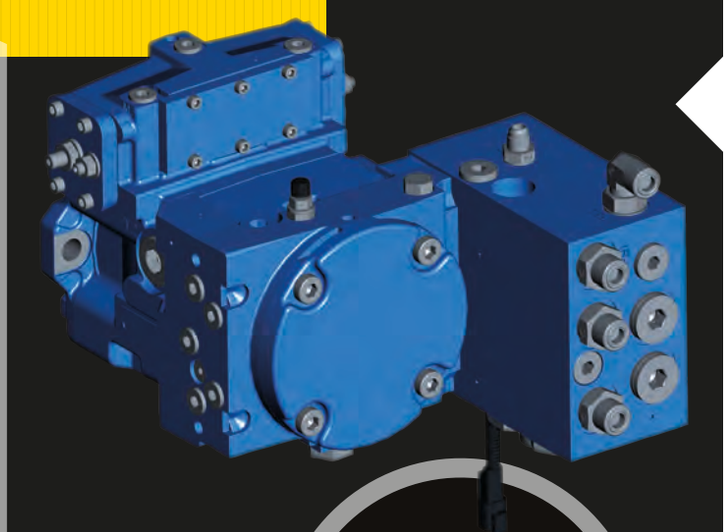
10
The number of different standard joystick models in EAO's Series 09 range

IoT and connectivity solutions

At iVT Expo, Finnish control unit specialist Epec will showcase its safety system and its IoT solution. The company will unveil a new hardware unit for the IoT solution. The Epec SC52 is a flexible controller for software-based safety function implementation in mobile machinery. With the controller, Epec offers a set of pre-certified PLCopen application libraries that help customers to develop safety-related software. Thanks to this, a considerable portion of an application can be created without the need to write code.

Meanwhile, Epec's GlobE solution is a remote management platform that allows fleet owners to customize functions, for example for fleet management and condition monitoring. It is integrated with the company's control systems, allowing for a short time-to-market and reduced project costs. It can also be combined with integrated display solutions such as the Epec 6000.

Epec Oy
Stand: 6060
www.epec.fi



RATIONALIZING HYDRAULICS

To make the integration of the many hydraulic components in modern vehicles easier, Poclain is presenting its hydraulics package at Industrial Vehicle Technology Expo. With the different components perfectly tuned into each other, the hydraulics package can fit in a tighter space, while also being easier to service.

The package is composed of a 52cc PM50 axial piston pump with hydraulic servo control and an FD-M3 three-way flow divider that carries out traction control. Together, they take up only 216 x 306 x 322mm (8.5 x 12 x 12.7in).

Apart from the space efficiency and serviceability, flanging the components has a number of other benefits: fewer hoses are needed; assembly time is reduced; the risk of leakage is lower; and there is a smaller pressure drop, which improves performance.

Poclain Hydraulics Industrie
Stand: 5075
www.poclain-hydraulics.com

Rugged radio control

NBB Controls + Components' stand will feature the company's range of radio remote controls. The devices can be specified with push buttons or joysticks and they feature a replaceable battery to ensure continuous operation, even in extreme circumstances. They support different fieldbus systems to make data transfer as seamless as possible.

NBB's remote controls are made to be sturdy and highly resistant to dust and moisture ingress. For that reason, they are constructed with glass-fiber-reinforced plastic cores or rubber-coated cases. If needed, joysticks and buttons can also be changed without any requirement to open the case, thus preventing potential contamination of the electronics inside.

NBB Controls + Components
Stand: 3000
www.nbbcontrols.de

MODULAR COOLING SYSTEMS

Manufacturer of customized cooling systems Ymer will present a modular and scalable thermal management system for hybrid and fully electric machines. This system manages the cooling of the battery and of all electric and hydraulic driveline components, in addition to managing cabin temperature. It saves energy by using waste heat to reduce the load on electric heaters and compressors. By using standardized basic components, Ymer can bring down development costs for OEMs.

The cooling systems will be produced in Ymer's brand-new production location in Ljungby, Sweden. The company has also invested more than €5m (US$5.75m) in a new production facility for bar-and-plate coolers at the same location.

Ymer Technology GmbH
Stand: 2040
www.ymer.com

iVT AUTONOMOUS Industrial Vehicle Technology

SPEAKER SPOTLIGHT

Mel Torrie
founder and CEO of Autonomous Solutions Inc, previews his presentation on how the company is already automating today's off-highway vehicles

What will your presentation be about?
Autonomous Solutions Inc. (ASI) is a leader in commercial ground vehicle autonomy. Our technology is revolutionizing industries like mining, agriculture, automotive, and material handling. My presentation will focus on ASI's recent developments in these areas and what kind of an impact automation is having on these industries, including off-highway-specific vehicles and operations.

What is the focus of your work in autonomous off-highway vehicles?
ASI's technology is universal and OEM-agnostic, meaning it can be applied to just about any vehicle in just about any industry. Our focus in off-highway vehicles is on automating highly repetitive tasks, highly dangerous tasks, and highly boring tasks. There are many opportunities and great use cases in the mining industry, construction, and agriculture, and others, where automation can offer great returns and a smarter, safer way to perform the job at hand.

Which areas of off-highway vehicles are most suitable for automation?
We've made great strides with the technology and its application to off-highway vehicles. Mobius, the command and control software that we have been developing for over 18 years, enables companies to simply automate these processes and offers complete control of multiple vehicles by a single operator. This software is an enabler to incorporate higher levels of safety, repeatability, accuracy and efficiency.

How far has Autonomous Solutions come with the automation of off-highway vehicles and how is it already changing the vehicles of today?
It's our intention to deliver a safe and simple-to-use product and so our customers have found that Mobius doesn't require a highly technical engineer to operate the system. In fact, many of our customers are using technicians to become operators within Mobius to oversee the vehicles and their operation. We see human operators always playing an important and necessary role in operating Mobius. The technology just provides one more layer of safety to ensure the work is carried out properly and always gives the technician the final say, ensuring the correct response when notifications come back from the vehicles in the field.

Automation in these fields is only in its infancy, but is already having a great impact. As more and more companies adopt automation, the technology and capabilities will continue to mature. The possibilities truly are nearly endless!

Mel Torrie will give a presentation entitled ***State-of-the-art technology for driverless industrial vehicles*** as part of the Autonomous Industrial Vehicle Technology symposium at iVT Expo

For a full program and registration details visit iVTexpo.com NOW!

iVT EXPO

FEBRUARY 13-14, 2019 – COLOGNE, GERMANY

MAKING THE MOST OF COLOGNE

The German city is well worth visiting in its own right. Here are some of the best things to do, should you find yourself with some free time

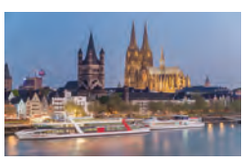
1 Cologne Cathedral

Cologne Cathedral is not just the city's most iconic site, it is also the most visited attraction in the whole of Germany, with around six million visitors every year. The Gothic church is the largest of its kind in northern Europe. The twin spires of the World Heritage site stand at 157m (515ft) tall, contributing to the building having the largest façade of any church in the world.

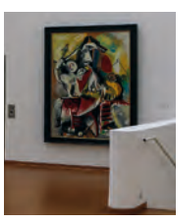
2 The Chocolate Museum

A must-do experience for all chocolate lovers. The museum takes you through cocoa's cultural history, as well as showing how modern chocolate production is done. A walk-through greenhouse containing real cocoa trees and a 3m-high (10ft) chocolate fountain are among the museum's most popular attractions, and yes, free chocolate is included with the entrance price.

3 Rhine River cruise



Various cruises are available for visitors to view the picturesque city from the Rhine River that almost perfectly dissects Cologne in two. Among the many sights clearly seen from the river is the city's famous cathedral, while guides are on hand to provide interesting facts about the buildings and monuments as they glide past.

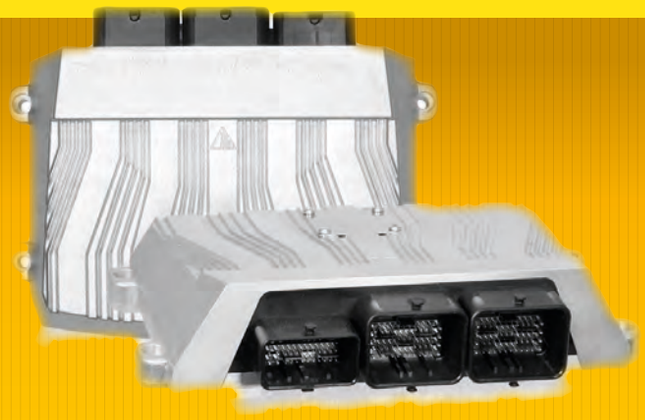


4 Ludwig art gallery

Cologne is host to some of the most important modern artworks in the world. Works from Picasso, as well as from American pop art proponents Warhol and Lichtenstein, are on display, while the abstract collection includes contributions from Rothko and Pollock. Examples of German expressionism are also on show.

5 Old town

After a busy day at iVT Expo, what better way to unwind than to spend the evening in a hall of a different variety? The distinctive historical charm of the of Cologne's historic quarter is enhanced by the many beer halls dotted around its rustic narrow streets. Hugging the Rhine, the scenic neighborhood is a pleasant place to get a bite to eat and enjoy a stein or two.

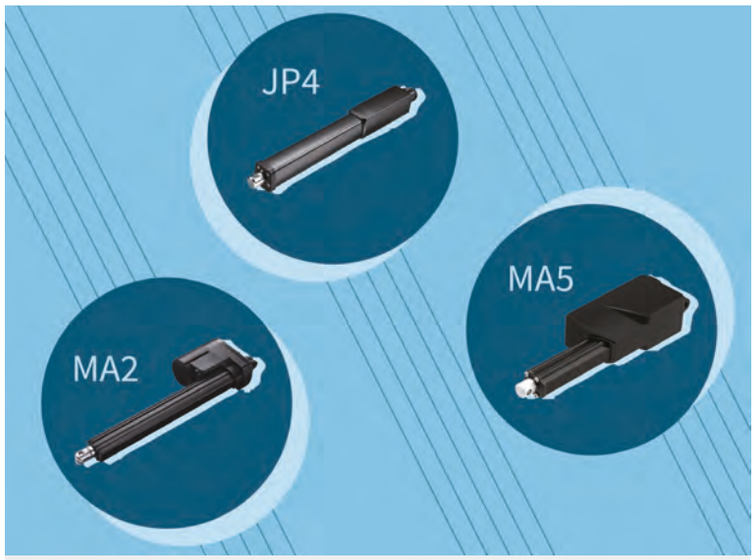


AUTOSAR AND DIAGNOSTICS

The eSys-SVx series are Sontheim's latest control units for safety applications in mobile machines. The ASIL-C control units are available in four different versions, with additional configuration options and a wide range of applications optional. The controllers boast up to four CAN interfaces and a LIN interface, as well as up to 89 different inputs and outputs. An acceleration sensor is optional. The 32-bit, dual-core 160MHz processor with floating point unit ensures a sufficient performance and a fast processing. Sontheim offers the user a number of software packages, including quality management software, ASIL-D, and AUTOSAR-compliant software.

In addition to the control series, Sontheim has also developed a new software tool, the Modular Diagnostic Tool 2.0, to access diagnostic data in a standardized way. The MDT 2.0 tool helps to create, structure and run diagnostic workflows using the OTX industry standard.

Sontheim Industrie Elektronik
Stand: 4050
www.sontheim-industrie-elektronik.de



Compact electric actuator

TiMotion's latest electric actuator, the MA5, is designed for the harsh working environments of vehicles such as harvesters, grain handlers, scrubbers, backhoe loaders and tractors. The powerful actuator is capable of up to 3,500N and duty cycles of up to 25%. Its short retracted length ensures it can easily be integrated in most applications where space is tight.

It features IP69K ingress protection thanks to the inner tube and optional grease chamber. This construction also offers the MA5 excellent protection against corrosion due to chemicals. To further extend the longevity of the product, it can be ordered with a grease nipple so that users can directly add grease when required. The MA5 also incorporates the company's integrated Hall-sensor or potentiometer sensors for positioning feedback.

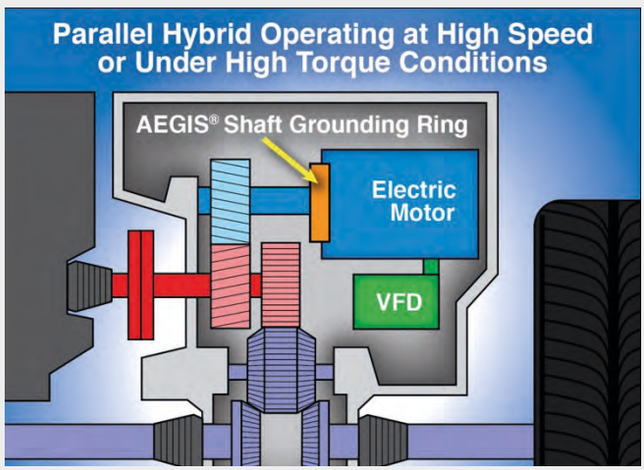
TiMotionEurope
Stand: 4030
www.timotion.com

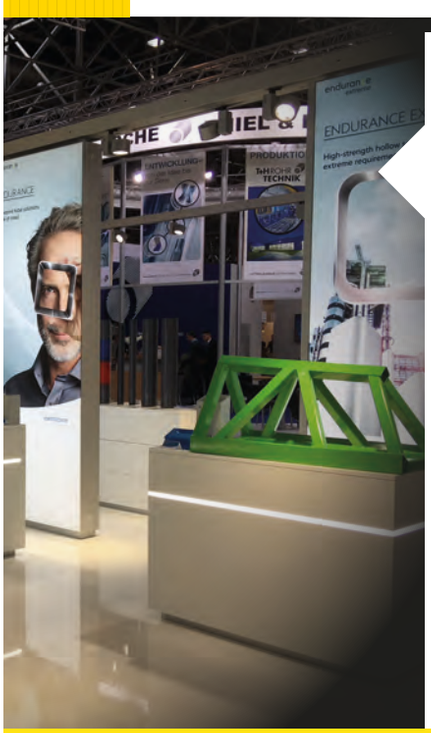
Shaft grounding rings

To prevent bearing damage caused by motor shaft voltages in applications where inverters or variable frequency drives are used, Aegis has developed a range of shaft grounding rings. These rings channel harmful inverter-induced voltages away from wheel bearings, and bearings in traction motors, transmissions and engines.

This way, damaging shaft voltages are avoided, and motor bearings and other drivetrain components are protected. In addition, EMI and RFI are reduced or completely eliminated, avoiding unwanted influence on onboard computers, wireless sensors and communications equipment. Rings are available for shaft diameters between 7.89mm and 762mm.

AEGIS dba Electro Static Technology
Stand: IVT10
www.est-aegis.com





STRONGER STEEL

Off-highway vehicles need to be able to endure extreme stresses, so Voestalpine is introducing a new cold-formed steel hollow section that combines the strength of hot-formed, seamless hollow sections with the lower cost of cold forming.

Thanks to a micro-alloyed and thermo-mechanically rolled steel with a high degree of purity (ReH of 355-550MPa), the material resists cracking for longer, even under constant vibrations. This allows for tighter bends in the metal and makes it suitable for a larger variety of applications.

Instead of defaulting to hot-formed hollow sections, customer requirements can often be met by Voestalpine's Endurance Dynamic material, allowing for cost savings thanks to the less expensive manufacturing process. The new material is available in three versions, with a choice of rectangular and square sections.

Voestalpine Krems
Stand: 2050
www.voestalpine.com

THERMOFORMED PANELS

Vitalo will showcase its automated bonding process for thermoformed body panels that was used in the John Deere Cassiopeia project. Thanks to the in-house plasma/glue treatment and use of flexible 2K glue, Vitalo claims its bonding process is precise, consistent and highly resistant to vibrations. The thermoplastics themselves boast good UV stability and scratch resistance of the high-gloss topcoat, with no sink marks or surface deflection after gluing. The ABS plastic is formulated for excellent recyclability and is also made from largely recycled material.

Vitalo Industries
Stand: 3015
www.vitalo.net

For a full program and registration details visit **iVTexpo.com** NOW!

Zero in

Additional speaker highlights in **Electric & Hybrid Industrial Vehicle Technology**

Dr Terry Alger, director, spark ignited engine R&D, powertrain engineering division, Southwest Research Institute, USA

Opportunities to use V2X to improve fuel economy in hybrid applications

Jean Heren, system advanced engineering manager, Poclain Hydraulics, France

Powertrain optimization using an electrohydraulic system

Ignacy Puszkiewicz, senior director, advanced technology and industrial design, JLG Industries, USA

Electric and hybrid powertrain solutions for the access industry

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SPEAKER SPOTLIGHT

Willem Nieuwland project leader for Hyster's zero-emissions Laden Container Handler, discusses the challenges and possibilities of electrification and the relative merits of batteries and hydrogen

What are the challenges in electrifying a big truck and how do they compare with electrifying smaller lift trucks?
Although Hyster can offer lithium-ion (Li-ion) batteries on many trucks, the use of Li-ion power will be more limited in electrifying container handling trucks. Battery capacity is not sufficient for the most intense applications if there are no suitable opportunities to recharge during the shift.

This is where fuel cells come in. Innovative Hyster Big Trucks are expected to be able to support continuous operation with operator-friendly recharge or quick H_2 [hydrogen fuel] refill options, delivered through our relationship with Nuvera Fuel Cells.

What prospects are there for hydrogen?
Hydrogen and grid power provide complementary solutions for ports. Where the requirements to power a fleet of electric Big Trucks are likely to exceed the power capabilities of the grid, hydrogen may provide ports with readily available energy without requiring a high-capacity charging infrastructure. The Big Truck charging challenge won't just go away, because charging one requires a large amount of energy to be drawn in a short space of time. However, given the right infrastructure, operations will be able to work around it by carefully managing charging.

The Hyster zero-emissions toploader in development has both a hydrogen fuel cell and a lithium-ion battery. This way, it has the potential to effectively support applications with higher power consumption and heavy-duty cycles: these trucks are expected to operate for a full day before requiring hydrogen refueling. As the truck can operate for longer before battery recharging is needed, this configuration also supports operations with irregular break periods, where it may not be practical to factor in battery charging throughout the day.

With hydrogen fuel cell technology, Hyster expects the Big Truck in development to offer 'clean' energy with zero local emissions, as well as a low cost of ownership and comparable performance with diesel.

Which powertrain configuration do you think is ideal?
To achieve the optimal total cost of ownership, the right power option for a truck will always depend on the specific operation. There are a number of factors that need to be considered, such as break periods, duty cycle, level of power consumption and charging infrastructure.

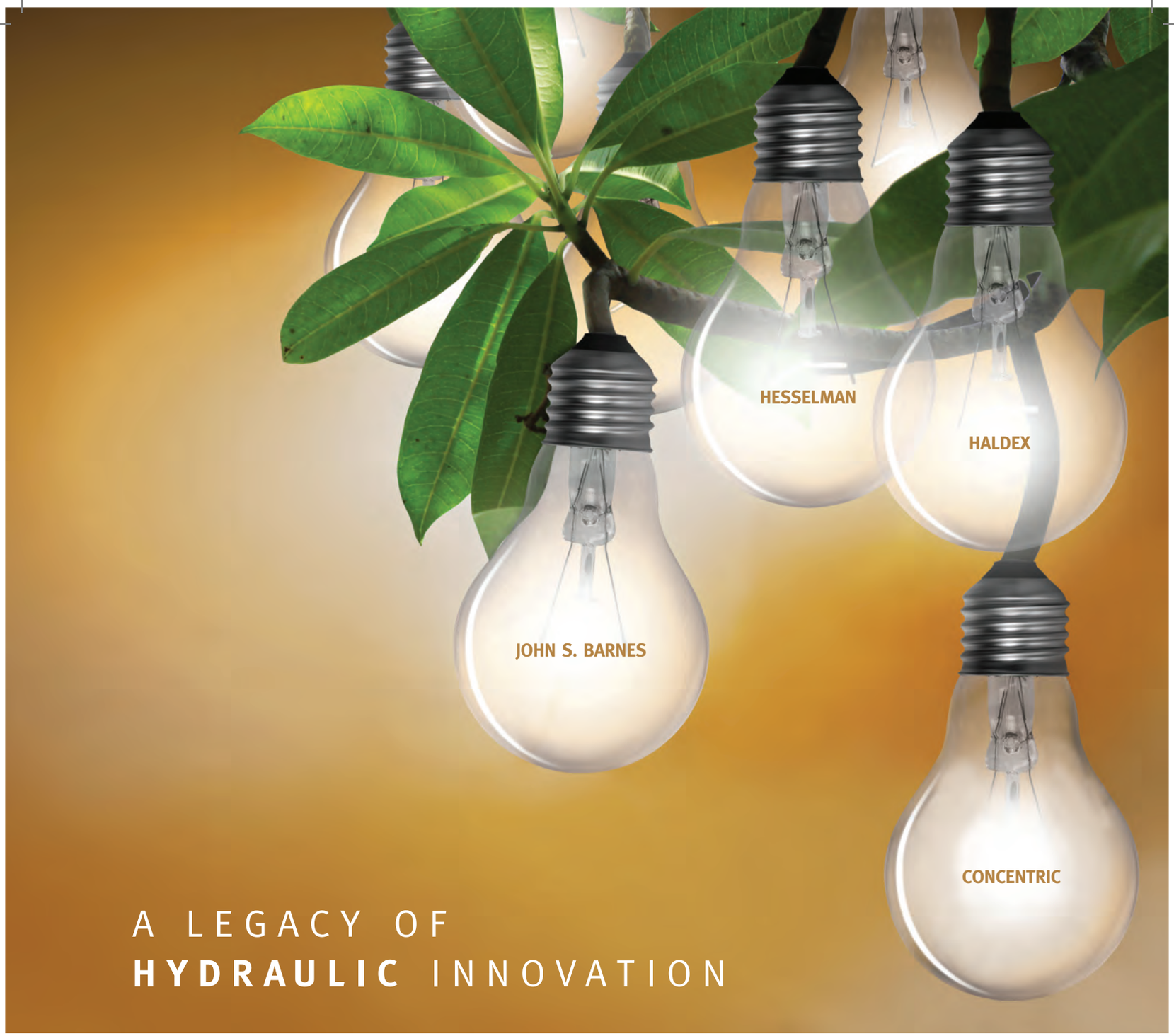
For example, an electric truck with a large battery pack and conventional charging may suit some applications, whereas others may be better suited by a truck with a medium battery pack and the capability for wireless opportunity charging. Other operations may benefit more from an electric truck with a small battery pack combined with an onboard fuel cell.

There are many future possibilities around charging for electric handling equipment within terminals, such as wireless charging options and hydrogen fuel cell refill, but there are challenges, too. In the future, standardized charging is expected to be necessary for all types of electric vehicles in an operation. Otherwise, many believe that the cost of installing and maintaining a new charging infrastructure could prove to be prohibitive.

It is expected that IC may eventually be replaced, but this is unlikely to happen quickly. Global differences in emissions requirements, trucks operating under extreme conditions, and the time needed to develop necessary infrastructure for electric vehicles, are all factors that will continue to make IC a popular power option in the short term.

*Willem Nieuwland will give a presentation entitled **Energy reduction and clean technology** as part of the Electric & Hybrid Industrial Vehicle Technology symposium*

"WITH HYDROGEN FUEL CELL TECHNOLOGY, HYSTER EXPECTS THE BIG TRUCK IN DEVELOPMENT TO OFFER 'CLEAN' ENERGY WITH ZERO LOCAL EMISSIONS"



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"AUTONOMOUS CONTROL IS ABOUT MORE THAN JUST REMOVING THE OPERATOR FROM THE CAB"

Ben Holter, hydraulic automation systems manager, Husco

Future assist

Additional speaker highlights in **Autonomous Industrial Vehicle Technology**

Brett McClelland, autonomous vehicles product owner, CNH Industrial, USA

Challenges and opportunities for automation in agriculture

Dominique Seydel, research engineer, Fraunhofer ESK, Germany

Resilient software architectures for autonomous systems

Dr Elza Marisa Paiva de Figueiredo, autonomous system manager for Europe, Danfoss Power Solutions, Denmark

Introduction to off-highway autonomous machine design

Yann Roussel, business manager OEM GNSS and mobile mapping, Topcon Positioning Group, France

High-accuracy guidance of autonomous vehicles

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SPEAKER SPOTLIGHT

Ben Holter, hydraulic automation systems manager, and **Simon Yardley**, manager and director of strategic business development, Husco, discuss the current and future possibilities of automation in off-highway vehicles

What technology will you be presenting at the Autonomous Industrial Vehicle Technology Symposium?

Simon Yardley: We will be presenting a study on the application and results of a new approach to enabling autonomous functions on hydraulic pilot-controlled off-highway equipment. The study details the components and control used to automate a 21 metric ton excavator without modifying any of the factory-fitted control systems.

We will discuss how receiving pilot feedback and controlling the hydraulic system as a subsystem of the machine control allows improved performance and enables automated machine control of a standard pilot-operated machine.

What are the standout features and benefits of the automation system?

SY: Husco is striving to give OEMs and machine control providers access to an easy digital-to-hydraulic interface on both new and existing pilot-operated machines. An important feature is the versatility of the system: it is adaptable to a wide range of machines and types of hydraulic control systems, such as PCLS/LUDV, Open Center, negative control and positive control. This adaptability also makes the system relatively simple and quick to install on any regular, pilot-operated mobile machine, thanks to a fully integrated manifold and controller system with onboard diagnostics and feedback.

What are its potential uses and how close are we to fully autonomous vehicles?

Ben Holter: Autonomous control is about more than just removing the operator from the cab. At the moment, the value of the technology lies mostly in automating certain functions, augmenting the skills of the operator, and enabling remote control.

For example, certain repetitive sequences, such as returning to the trench, can be automated. More importantly, the technology can make the operator's actions safer. When connected to 3D models, the technology can avoid accidental contact with hazards such as high-power cables or underground services because the machine will stop the function before a collision can happen. Potentially unsafe situations, such as a person walking into the path of the machine, can be automatically observed and acted upon.

Such augmentation potential can make a good operator great, or 'upskill' an inexperienced operator – a great help when contractors are short on skilled operators. The result is increased productivity and precision, which means less overrun on projects, less time backfilling on overdug portions, and lower emissions per project.

Another benefit of automation is that it allows more precise documentation when integrating with Building Information Modeling (BIM) systems. For instance, when you dig a foundation or lay a drainage trench, you will know exactly where it was excavated, in case future maintenance, repair or other digging is needed. Today, this is only possible though manual surveying and recording of the data, which is time-consuming and reliant on surveyor competence.

Finally, automation can play a role when it comes to hazardous operations. This can be done either through remote control or through full autonomous operation. For the near future, it is likely that fully driverless machines will be restricted to such situations due to the unpredictable environments of current standard worksites.

How is automation already changing off-highway vehicles of today?

BH: With today's technology, we are already seeing increased productivity, improved safety and the enabling of machine learning via integral machine feedback with the system.

SY: In combination with the correct sensors and data, automated machines can stop a function before an accident happens. The technology can improve an operator's precision and productivity by lowering the cognitive load and reducing fatigue. Finally, behind the scenes, the electronics can automatically document the worksite through machine-connected BIM systems.

*Ben Holter will give a presentation entitled **Enabling autonomous electrohydraulic control of pilot operated off-highway machines** as part of the iVT Electric & Hybrid Industrial Vehicle Technology symposium*

Inside story

SPEAKER SPOTLIGHT

Alexandra Herrmann, marketing and PR manager at Fritzmeier Systems, explains the achievements of the Cab Concept Cluster project so far

What is the Cab Concept Cluster and what's the difference between the Smart Cab and Genius Cabs you have developed?
The Cab Concept Cluster (CCC) is a cooperative industry association set up to push the boundaries of cab design. We launched the construction-focused Genius Cab at Bauma 2016 and the agricultural Smart Cab at Agritechnica 2017. The Genius cab is a pure concept that was never intended to be sold, but is still setting standards today. It shows the great potential of smart integration of innovations. The Smart Cab in its basic version is a serial product that Fritzmeier offers to sell. We do have high interest and we already have customers.

What is your role in the project?
My role in the Cab Concept Cluster is as the project and communication manager in bringing both innovative cab concepts to market: the CCC Genius Cab with all-new concepts for safety, comfort and system integration; and the Smart CAB focusing on x2x usability, smart and digital farming readiness, and full modularity for operator comfort, functionality and productivity.

How did the project come about, how far has it progressed, and how did it get where it is now?
To be competitive in the market, it is important to present and offer innovations to the customer at regular intervals. A successful example of this is our Cab Concept Cluster, which brings together and integrates leading OEM suppliers in a cooperation of the latest technical innovations.

What has been the response from OEMs?
We have been on a road trip and visited more than 20 different OEMS and we had several cluster meetings with cross-functional teams. The response has always been very positive. Our customers see us as a very innovative company, as a leader in our industry.

Alexandra Herrmann will make a presentation at iVT Industrial Vehicle Cab Design and Technology symposium. Herrmann and other industry experts discuss the future of off-highway vehicle cab design further on ***page 38***

"TO BE COMPETITIVE IN THE MARKET, IT IS IMPORTANT TO PRESENT AND OFFER INNOVATIONS TO THE CUSTOMER AT REGULAR INTERVALS"

Other Cab Concept Cluster partners speaking at iVT Expo include...

Prof. Jens Krzywinski, head of industrial design engineering, Technische Universität Dresden, Germany

Wanja Steinmaier, managing director, Lumod, Germany

Robert Laschober, global sales agricultural, turf, and utility machinery, Hella Group

Additional speaker highlights in **Cab Design & Technology**

Dr Rafal Sornek, SVP technology, Fortaco Group, Poland

Enhanced productivity and driver comfort in operator cabins

Jérôme Regnault, product marketing engineer, ESI Group, France

VSS: Overcome autonomous vehicle cabin challenges with virtual prototypes

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ICE man

Additional speaker highlights in **Cab Design & Powertrain Technology**

Larry Fromm, executive vice president, Achates Power, USA
Advanced engine architecture for on- and off-road reduced emissions

Ralf Plieninger, head of electrification, Deutz, Germany
The E-Deutz approach for non-highway applications

Alex Woodrow, managing director, Knibb, Gormezano and Partners, UK
Decarbonization of non-road machinery – scenarios for CO_2

Bruno Lacheteau, director – truck and bus markets, Poclain Hydraulics, France
Poclain Hydraulics AddiDrive for heavy commercial vehicles

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SPEAKER SPOTLIGHT

Colin Garner, professor of applied thermodynamics at Loughborough University, UK, dispels the idea that the internal combustion engine's days are numbered

What are some of the issues concerning the development of future off-highway powertrains?
There is a lot of misinformation in the media about internal combustion (IC) engines, IC-engined hybrids and battery-electric vehicles. An IC engine has an engine and a transmission, with a fuel tank as its primary onboard energy source. An 'engine hybrid' also has a fuel tank with an engine and a transmission that drive the wheels. That engine and transmission can bank and trade energy with a store, which is usually a battery, but could also be a flywheel or a hydraulic pack. Nevertheless, the primary onboard energy source is still fuel.

'Hybrid-electric' is a misnomer, really. Yes, it has electricity flowing around, but it's not the primary source of propulsion. In fact, every car has a battery and a flywheel on it, so every engine is a micro-hybrid anyway. I prefer the term 'engine hybrid'.

Nearly everyone seems to lump hybrids and electrics together as one technology. Actually, IC engines and IC engine hybrids form one group and pure electrics another. I think that's such an important differentiation, because the media gets this wrong nearly all the time. They also often use the term 'conventional engines' and that's wrong too, because modern IC engines are extremely advanced.

What does the future look like for the IC engine?
The future of the IC engine is very strong, because it has very good capability. Oil reserves are still very high. It doesn't take a lot of energy to make, for example, diesel; you can store it very cheaply and it's easy to handle – it's high-density, so you don't need a pressurized fuel tank and you get fast fueling.

Current engines have high power. They're low cost, have good durability, and can run at extreme ambient temperatures – unlike batteries. There is a big challenge with local emissions, but these are progressively being reduced. Because of Dieselgate, people think that diesels have high emissions, but with Stage V they are actually very low. We're down to about 2% particulate matter and less than 5% NO_x compared with the levels that were allowed at Stage I.

I think there is a bit of naivety when people propose to ban IC engines. The alternative just isn't good enough yet and the outlook is limited for pure battery vehicles. People seem to underestimate how good an IC engine is and overestimate battery technology.

How far-reaching will the electrification for off-highway vehicles be?
Electrification is, without doubt, going to happen in off-highway vehicles. Electricity will be on board somehow, but I believe that most untethered applications will still have a fuel tank and an engine.

In 2017, the Automotive Council UK set a number of targets for battery technology in 2035. Even with these stretch-targets – which are optimistic, and we may not achieve them – a battery pack that stores the same amount of energy as a conventional fuel tank will cost and weigh far more: to store the equivalent amount of energy to a 150-liter diesel fuel tank, we will need a 1.77 x 10^9J (490kWh) battery, which we can estimate will still weigh 983kg (2,167 lb) and cost £17,700 (US$23,270) just for the cells. With present cell mass and costs, these work out as 1,967kg (4,336 lb) and £49,560 (US$65,167).

There will be tipping points where the battery might be advantageous and where some people will be willing to pay for that battery pack because they don't want to produce any tailpipe emissions at all. However, for many applications, the cost will remain prohibitive and IC or hybrid engine powertrains will continue to be the logical choice.

The other big issue is charging. Even with a 120kW charger, it would take over four hours to charge the 490kWh battery mentioned. You would need to build this time into the duty schedule of the machine. With electric forklift trucks, there are often one or two trucks charging while the other two are actually doing work. And then there's the access to a charger – in many off-highway applications, there simply is no access to charging facilities.

Colin Garner will give a presentation entitled ***Off-highway vehicle powertrains: What is the best energy source?*** *as part of the Industrial Vehicle Powertrain Technology symposium*

"PEOPLE SEEM TO UNDERESTIMATE HOW GOOD AN IC ENGINE IS AND OVERESTIMATE BATTERY TECHNOLOGY"

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Final stage?

WITH STAGE V EMISSIONS REGULATIONS ABOUT TO COME INTO FORCE IN THE EU, *iVT* TAKES A LOOK AT HOW FAR THE INDUSTRY HAS COME IN THE LAST 19 YEARS AND CONSIDERS HOW MUCH MORE EFFICIENT DIESEL ENGINES CAN BECOME

The EU's Stage V emissions regulations will have a profound effect on the industrial vehicle market when they take effect in January 2019. You might be forgiven for thinking that this is yet more red tape, given that diesel engines are virtually unrecognizable from even 10 years ago in terms of emissions and pollutants, but the new rules take the drive for cleaner engines to another level and put Europe at the forefront of the environmental debate.

One key area of the new regulations is the legislation for particulate matter (PM), which is so stringent that it's possible to argue that, in a sense, diesel engines are now pumping out air purer than the air they emerge into. And that begs the question: are diesel engines as clean as they're going to get, or is there still scope for development on an environmental level?

First, the catch. The implementation of Stage V doesn't mean that the supply of Stage IV-compliant products is going to dry up overnight – especially given that the regulations only cover the EU – and many manufacturers rushed Stage IV products to market in 2018 while they still had the chance.

"There will certainly still be a supply of Stage IV products to the market – they haven't been banned," says Bill Van Amburg, executive vice president of Calstart in the USA. "But how many new ones will be sold once Stage V has come into force? There's usually a carry-over period for engines coming to the market, but people do need to move into Stage V."

That may be the case, but it won't happen overnight. For one thing, there are two different deadlines for Stage V, allowing a longer Stage IV lifecycle for mid-range products between 56 and 130kW [see *The stage is set* at the end of this feature]. "No Stage IV engines can be manufactured after these deadlines but, to allow a smooth transition and proper stock management, EU regulations allow OEMs to sell off new machines adopting Stage IV-compliant engines built before the deadline," explains Federico Gaiazzi, head of global marketing at FPT Industrial. "For this reason, Stage V will be introduced progressively, and the tipping point will depend on each OEM's strategy, as we've seen in previous emission transitions."

Supply and demand

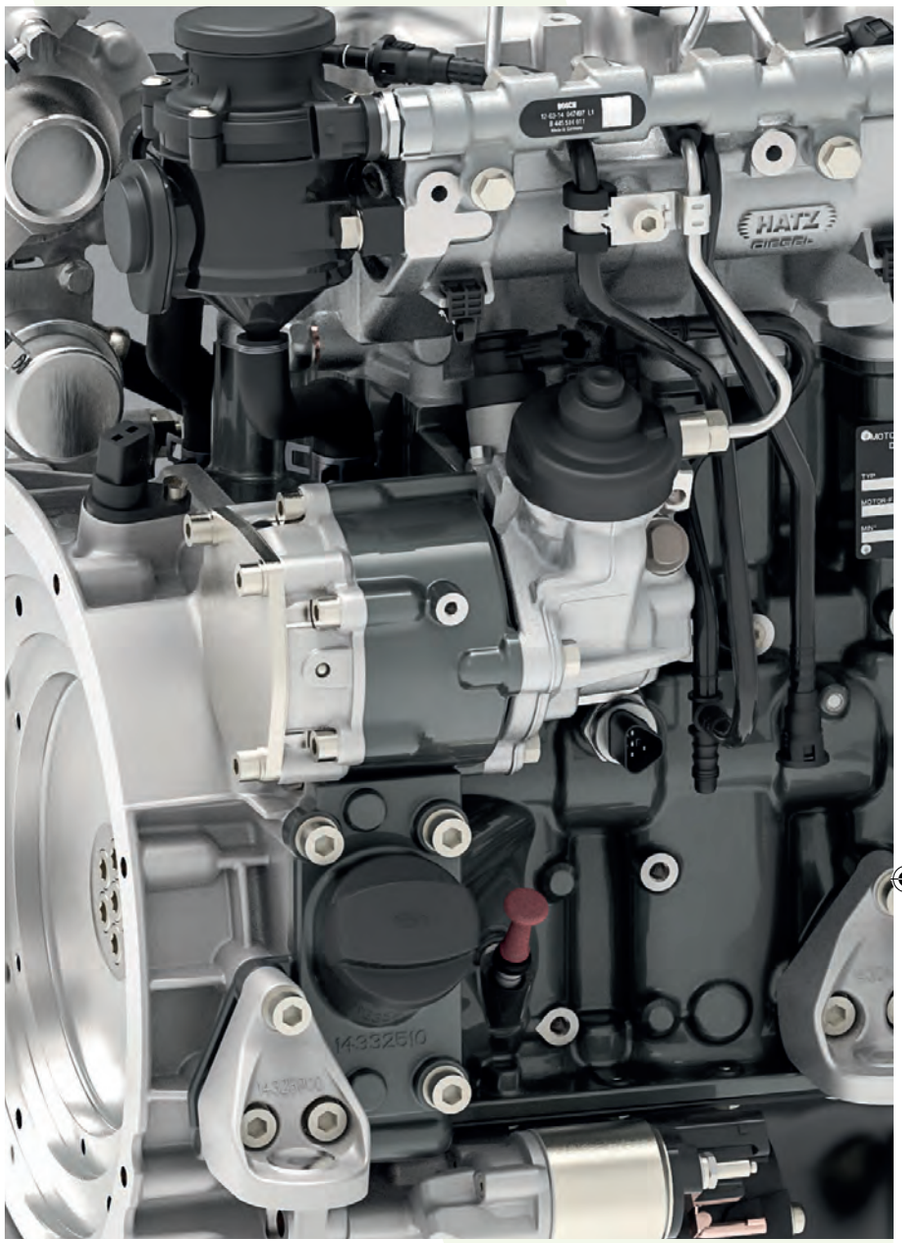
"The question of timing is a really good one," Van Amburg adds. "Usually in industrial vehicles we're not talking high volume or fast turnover, so it takes a while for new technology, or for products that meet new regulations, to displace what's already out there.

"Now that manufacturers have had to develop Stage V products, they'll want to get them out there. But there will be markets that don't adhere to Stage V and where the new products may be undercut on price by older ones, which is what we said when low-knock technology was adopted. There can also be a big issue around the packaging of components for aftermarket treatments in industrial vehicles, which can only be smoothed over once new designs are locked down."

That will have happened relatively late in product

1999
The year that Stage I emissions regulations were introduced

FPT's F36 Stage V agricultural engine



RIGHT: **The Stage V-compliant 1.5-liter 3H50T engine from Hatz**

development terms, given the tight deadlines, although Van Amburg believes the technology is already in place to make the transition smoother than it might have been.

"It's less of a technological challenge *per se*, and more of a product engineering challenge," he says. "Engines that meet the new regulations have to fit individual development parameters, and take into account aspects such as sightlines, tilting features, tight air pathways and flow patterns. Plus the reduction in particulate matter emissions has been well known for some time now, so it's about integrating rather than inventing."

"The biggest challenge has been to boost engine performance while still complying with the new standard," says Gaiazzi. "It is not easy to work on the particulate matter, especially with heavy-duty machines, and at the same time be able to develop an aftertreatment system that has to be 'for life' and EGR-free. But we did it."

"This is where the EU and USA are aligned but a little out of kilter," says Van Amburg. "The USA reduced particle emissions between 2007 and 2010, whereas the EU was more carbon-focused. Now the EU is driving on knocks and particulate matter. The bottom line is that this is a big challenge. You can reduce particulate emissions to have a cleaner engine but it might be less efficient, and if it's less efficient it's going to be emitting more carbon. If we're going to have combustion engines – and they're going to be around for a while yet – we have to reach a point where they don't affect air quality and don't emit carbon."

A cleaner future

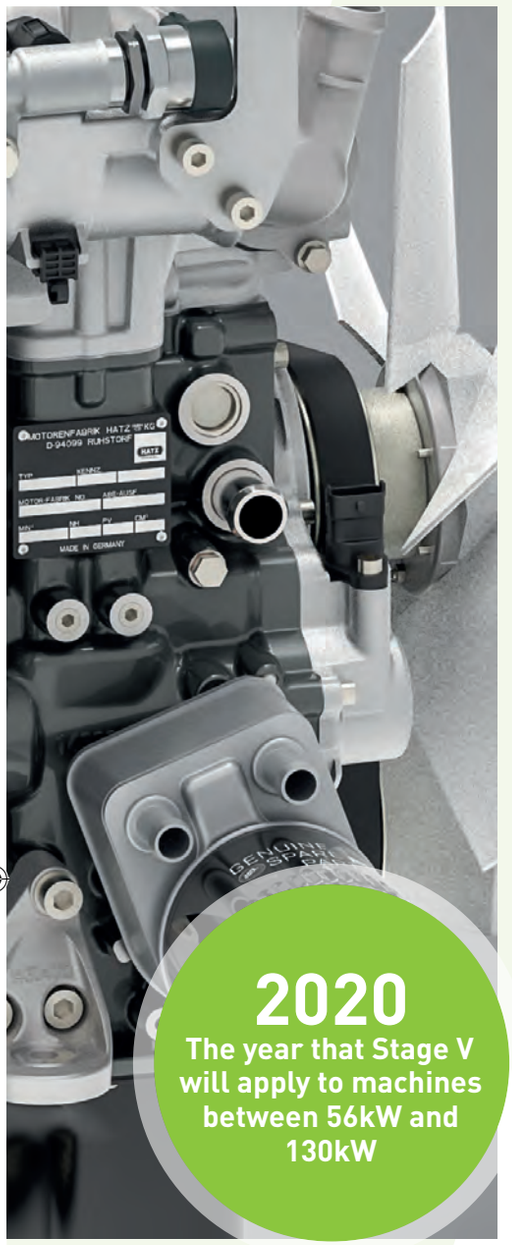
So are diesel engines as clean as they're going to get? "No, they can still get cleaner than they are," says Van Amburg. "New engine architectures will be important for the future because if you go to cities like Paris or London, they have the sort of air quality issues that we thought were restricted to the likes of LA and Shanghai. So we either need more engine regulations in the future or we need to ban engines from city centers."

"Stage V is a step toward an increasingly green diesel," agrees Gaiazzi. "With Stage V, it will take 180 compliant machines to generate the same amount of NO_x emissions as one machine in 1996. CO_2 emissions, on the other hand, are not regulated, but we are still committed to reducing them."

One fear is that increasingly stringent regulations could stifle innovation, in the sense that manufacturers won't be able to differentiate their products. It could end up a little like Formula 1, in which Red Bull designer Adrian Newey believes that an ever-expanding rulebook has robbed designers of their ability to stand out from the crowd. Yet to flip that

"WE'LL SEE MORE ELECTRIFICATION, AND THIS IS WHERE WE NEED TO BE SMART – TO USE THE POWER OF DIESEL BUT MAYBE DOWNSIZE THE ENGINE"

Bill Van Amburg, executive vice president, Calstart, USA



2020
The year that Stage V will apply to machines between 56kW and 130kW

F1 analogy on its head, Mercedes-Benz and Ferrari spend hundreds of millions of pounds developing radically different design concepts that end up producing virtually identical lap times.

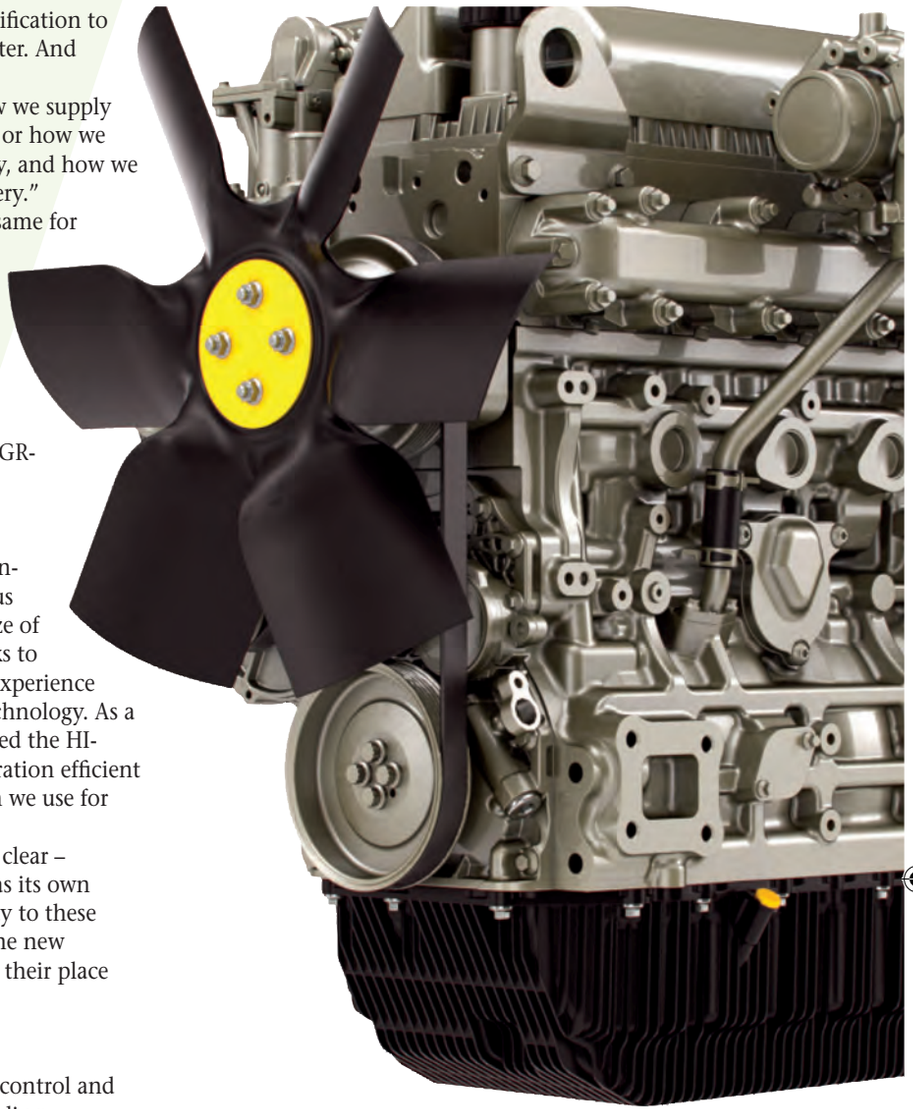
"I think manufacturers will be able to differentiate in lots of ways because new engine architectures will facilitate different approaches, whether that's how they generate power or how they reduce pumping loss," says Van Amburg. "We'll see more electrification, and this is where we need to be smart – to use the power of diesel but maybe downsize the engine, or not run it through the whole engine map, and use elements of electrification to control emissions better. And there's also scope for differentiation in how we supply torque to the wheels, or how we operate lift machinery, and how we harness energy recovery."

"The target is the same for everyone, but the strategies with which to achieve it can be different," Gaiazzi agrees. "FPT Industrial has managed to keep its heavy-duty engines EGR-free by optimizing a technology – the SCR [selective catalytic reduction] on-filter – which allows us not to increase the size of the ATS. This is thanks to more than 25 years' experience in the field of SCR technology. As a result we have patented the HI-eSCR2, the new-generation efficient aftertreatment system we use for Stage V."

The implication is clear – each manufacturer has its own strengths and will play to these to meet and exceed the new targets, and maintain their place in the market.

Hit for six?

The ongoing need to control and limit emissions, including greenhouse gases, raises the specter of – you guessed it – Stage VI emissions regulations for the EU, although as yet it's unclear what



ABOVE: **Perkins Syncro 3.6-liter Stage V engine**
RIGHT: **JCB's 3.0-liter Dieselmax 430 engine**

THE STAGE IS SET

Stage V emissions regulations for off-road vehicles come into force in January 2019 for engines below 56kW and above 130kW, and from January 2020 for all engines in between. The legislation limits harmful substances in exhaust gases from units powered by fossil fuels, including nitrogen oxides, carbon monoxide, hydrocarbons and particulate matter.

The emissions standards now cover a wider range of engines than previously. These include compression ignition engines below 19kW and all powerplants above 560kW, none of which were covered by previous legislation. The new regulations also effectively require all vehicle manufacturers to utilize diesel particulate filters to meet the stringent particulate matter targets which have been introduced.

As an example of how far the regulations have come, Stage V will only permit 3-4% of the limits that were allowed by Stage I, which was introduced in 1999.

"OUR TARGET IS TO MAKE DIESEL ENGINES 50% MORE EFFICIENT, SO THERE IS STILL PLENTY OF ROOM FOR IMPROVEMENT"

Federico Gaiazzi, head of global marketing, FPT Industrial

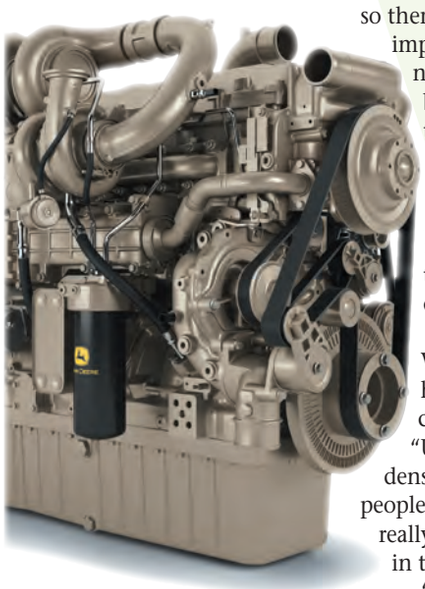
2050

The year by which industry needs to be carbon neutral, to prevent catastrophic climate change

Source: UN IPCC

ABOVE: **The Cat C9.3B 9.3-liter Stage V engine**

BELOW: **The new 13.6-liter Stage V engine from John Deere Power Systems**



form such regulations might take.

"Further reduction across the board is technically possible," says Gaiazzi. "Our target is to make diesel engines 50% more efficient, so there is still plenty of room for improvement. However, it is also necessary to evaluate the real benefit of further adding technical contents to the aftertreatment systems in terms of the real effect on pollution. A more realistic alternative would be to focus the effort on renovating the circulating fleet."

"I can't predict what Stage VI will entail, but we certainly haven't gone as far as we can," says Van Amburg. "Urban regions are growing denser and the movement of people is still increasing, so we really need vehicles to be greener in these tight spaces.

"Then there's the recent climate change report – the new goal is to be carbon neutral by 2050, so we're about to enter a 20- to 30-year cycle of innovation and improvement. We won't get there tomorrow, or by 2025, but Europe is the leader on this and some very clever people will have to put on their design hats to get us to zero emissions."

"The reduction of CO_2 emissions is not a target that can be achieved only through the creation of specific regulations," says Gaiazzi. "It must rather be a commitment that we make to the customer and the environment. We need to reduce CO_2 and improve performance. For this reason, the fundamental of engine design for FPT Industrial has always been efficiency. Efficiency means less CO_2 and greater performance, therefore respect for the environment and customer satisfaction. Yet there will be targets, and we need to find the technology to reach them for the economic sustainability of the market."

"The good news is that heavy equipment is heading toward zero – the port in Rotterdam is a good example," says Van Amburg. "We have electric cranes and gantries running through cables, batteries or both. Excavation vehicles can be tethered or untethered, depending on the work cycle. We're at the very beginning of an important journey here." **iVT**

For a full preview see page 16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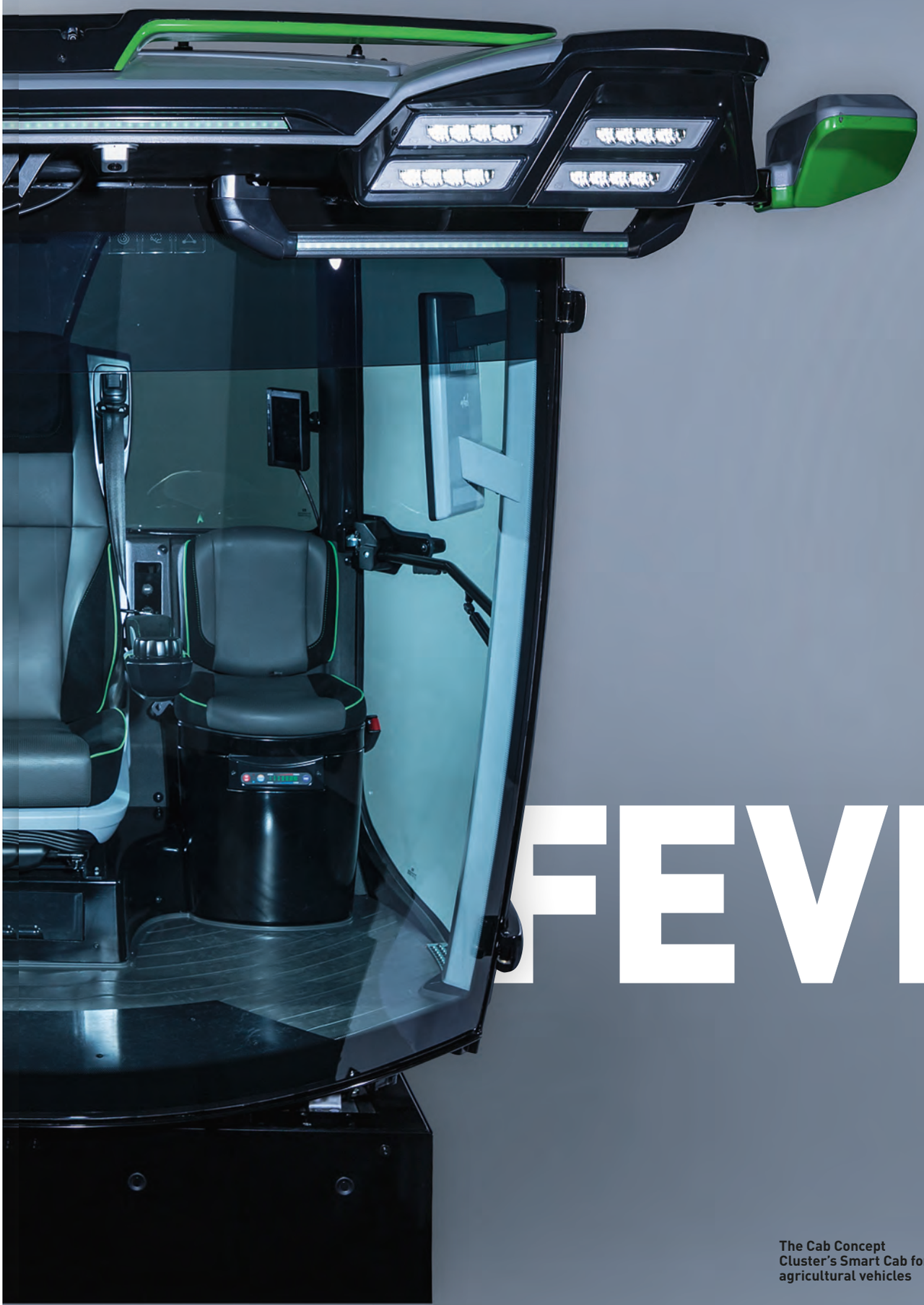
SAUL WORDSWORTH, IVT INTERNATIONAL

A KEY USP IN TODAY'S OFF-HIGHWAY VEHICLES IS CAB ERGONOMICS, WHICH IS WHY IT IS A PRIMARY FOCUS FOR INNOVATION. *iVT* MEETS THE OEM DESIGNERS AND TIER 1 SUPPLIERS WHO ARE HELPING TO DEFINE THE OPERATOR AREAS OF THE FUTURE

CABIN



FEVER

The Cab Concept Cluster's Smart Cab for agricultural vehicles

ABOVE: **JCB's CommandPlus cab, developed for the first in its X Series – the 220X excavator – has a low in-cab noise of 67dB(A)**

The challenge with cab construction today is to combine safety with reduced use of materials, functional integration, and modern, lean designs. At the same time cab companies must keep track of all standards and regulations to fulfill safety mandates, and prioritize the comfort of the driver.

"At the center of our cab design is the well-being of the operator and the desire to make their job easier," says Gustavo Guerra, design director at Volvo Construction Equipment. "We build cabs that are 'premium by purpose', meaning that we focus on enhancing safety, efficiency and comfort. We start by looking at customer needs and how the machine will be used, then design a cab that fits these requirements. Unlike the automotive industry, construction isn't about fancy features. We focus on safety, all-around visibility, comfort and easy-to-access controls."

Materials

Whether it's a construction machine, agricultural solution or forklift, manufacturers of off-highway vehicles are under great cost pressure

THE FUTURE OF CABS

In 2014 a group of experienced OEM suppliers, including Hella, Bosch and Fritzmeier Systems, linked up with renowned designers, scientific institutions, industry associations, machinery hire companies and operators to form a collective of agricultural and industrial truck manufacturers. They called themselves the Cab Concept Cluster. Four years later they are still driving the future of cab design.

"The objective of Cab Concept Cluster is to illustrate the incredible potential of efficient system integration in construction and agricultural," says Alexandra Herrmann, product manager at Fritzmeier Systems, a partner in the Cab Concept project. "Our innovative features are setting new standards in global markets in terms of safety, intuitive operation, operator comfort, maintenance and design."

The group is divided into two separate divisions: Smart Cab, for agriculture, and the Genius Cab for construction. The two divisions also differ in that Smart cabs are concept only, while a basic version of the Genius is now being marketed to OEMs across the industry.

The Smart Cab is multifunctional, designed for agri vehicles such as harvesters and field sprayers, and transfers growing trends such as serial-tested modularity and smart farming, which enables communication between vehicles, the cloud and even drones. Its was unveiled to much great acclaim at Agritechnica 2017.

Its Genius equivalent previewed concept versions of Smart technology. A mirror replacement system combining variable rearview camera surveillance with a central touchscreen interior display panel enhances visibility. Ultrasonic sensors detect hazards and obstacles in the vicinity; smart lights illuminate them. The modular exterior is constructed from welded aluminum profiles and boasts a 30% reduction in weight. Last but not least, the finished product has undeniably sleek lines and a futuristic look.

The first Genius Cab won the innovation award at Bauma in 2016. The guiding theme was 'human centered design' including a drive to maximize ergonomic comfort.

"We were very successful in the construction industry with Genius Cab as a pure concept cabin," says Herrmann. "It is still setting standards today. Even though we started it back in 2014, people consider the Genius Cab a prime

"THE HMI CLUSTER'S GOAL IS TO MAKE HMI SIMPLER AND SAFER FOR DIFFERENT MACHINES. THE FIRST RESULTS WILL BE PRESENTED AT BAUMA 2019"

Alexandra Herrmann, product manager, Fritzmeier Systems

example of how we provide a platform to integrate different functions from different suppliers.

"As for the hard future of cabs, human-machine interfaces [HMI] and standardization in the context of M2M communication is a very big trend topic for the future viability of the off-highway sector. The topic is becoming increasingly important in the context of driver assistance systems and meaningful use of data in particular. To this end, Fritzmeier co-founded an HMI Cluster in October 2018 with partners from the construction industry, OEMs, suppliers and universities. The HMI Cluster's goal is to make HMI simpler and safer for different machines. The first results will be presented at Bauma 2019."

ABOVE: **Genius Cabs are developed to show innovation potential, rather than sold on the market**

LEFT: **A 'human centered design' theme helped the Genius Cab win an innovation award at Bauma 2016**

£50m
The amount JCB invested into the new UK lab that will help to double its cab production (US$64m)

"ERGONOMIC SOFTWARE IS USED ON OUR DESIGNS TO ENSURE OPERATORS FROM THE 5TH TO 95TH PERCENTILE ARE ACCOMMODATED COMFORTABLY"

David Carver, general manager, JCB Cab Systems

so it is vital for cab projects to be cost-effective, whether they are manufactured from steel, aluminum or carbon fiber.

"Our cab frames are currently produced from steel, while glazing predominantly uses toughened or laminated glass," says David Carver, general manager at JCB Cab Systems.

In June JCB announced that it was investing more than £50m (US$64m) into a new UK plant that will double the production of cabs used in its machines. "Polycarbonate is also selected for certain applications," Carver explains. "There is a range of approved engineering polymers for interior and exterior trim."

"The cab is built with the frame as the base and it includes everything up to the interior design and the look and feel parts," says Guerra. "Therefore a wide range of materials is used including steel, glass and plastic."

Typically a cab frame is broken down into subassemblies. These are welded together in a main tack fixture and final welding is completed robotically. The cabs are then painted using an electrophoretic deposition (EPD) undercoat, seam sealed and powder finished. Next they are assembled with component and/or subassembly parts at different stages along a moving production line. All cabs are checked at every stage. At the end of the line they are electrically tested and water tested before final inspection and dispatch to machine business units.

Design and shape

The shape of a cab is driven by a combination of machine architecture, legislative requirements for minimum operator space and zones of reach for ergonomics. An additional focus is the need to maximize all-around visibility for the operator. Industrial design will have a large influence on the cab shape and styling, with a focus on ensuring the machine looks strong and purposeful.

ABOVE: **Approved engineering polymers are used for cabs' internal and external trims**

"The designs and the shapes we use are very much driven by usability," says Patric Klacksell, director of cabs and operator environment, Volvo CE. "Our aim is to enhance the usability of the machine. We are focused on improving the operator's experience in the cab, so we have the saying 'form follows experience' at the forefront of our minds. Everything comes back to the user experience. As for the machine's exterior, this is about integrating the cab with the entire machine and achieving unity.

ABOVE: **An operator using the Load Assist function in a Volvo CE wheel loader**

The shape needs to communicate that this is a strong, sturdy and safe machine. Of course, we also consider the aesthetic aspects as that is part of creating a comfortable and pleasant operator environment."

Driver comfort

In the past the cab was a tight spot often involving some level of physical discomfort or stress for the operator driving the machine. Now the well-being of the driver is central to cab design. This includes everything from the interior design and seat ergonomics to air quality. In terms of heating, ventilation and air-conditioning, JCB sees different requirements across its machine ranges. For applications such as agriculture and waste re-handling, due to the chemicals involved in such environments, there is an increasing demand for cabs featuring air temperature control as well as pressurized cabs.

"Excellent operator comfort is paramount on all our models and is central to all design objectives," says Carver. "Ergonomic software is used on our designs to ensure operators' comfort. Extensive user trials are carried out to evaluate and approve seat comfort. Heated and cooled options are now commonly fitted."

"The seat and air-conditioning are two critical aspects for operator comfort, and by maximizing operator comfort you improve efficiency," says Guerra. "The seat is the biggest component in the cab, so it is important that it conveys quality and comfort. Our adjustable seats are comfortable and durable. From the operator's seat, it's easy to access the ergonomically positioned controls." He explains that the HVAC system is designed for ease of use and maximum comfort.

Also in the cab, Volvo focuses on creating a relaxing environment so the operator can concentrate on the job without distraction.

"We choose colors that will help operators to focus on the task and create a good balance between hard and soft materials for different areas," notes Guerra. "For example, easy-to-clean kick panels and floor mats are designed with durability in mind."

Finished cabs are not typically built for insertion into a portfolio of other machines. A one-size-fits-all approach isn't popular because it can lead to functionality and usability compromises (though a more modular methodology may become popular in the future – see sidebar). Machines are different and have specific requirements to fulfill. Even within a single product range,

"WE CHOOSE COLORS THAT WILL HELP OPERATORS TO FOCUS ON THE TASK AND CREATE A GOOD BALANCE BETWEEN HARD AND SOFT MATERIALS FOR DIFFERENT AREAS"

Gustavo Guerra, design director, Volvo CE

"A CAB IN AN AGRICULTURAL MACHINE OFTEN BOASTS MORE COMPLEX CONTROLS AS THE MACHINES CAN BE SPECIALIZED"

Patric Klacksell, director, cabs and operator environment, Volvo CE

TOP: **The operator view from inside the Cab Concept Cluster's Smart Cab**

ABOVE: **The view from inside the Genius Cab**

the smallest machines work in very different applications to the largest. Therefore the operators have particular needs due to the task to be done and the time involved. Having said all that, companies like Volvo use their cab structure as a base platform and reuse some components and ideas.

Construction versus agriculture

What about the requirements for different verticals – in other words – how do construction vehicle demands differ from those of agricultural vehicles? First it should be noted that there are separate legislative requirements in construction (ISO 20474) to those in agriculture (EU tractor framework directive 2003/37/EC and new framework regulations 167/2013/EU).

"Large areas of construction and agriculture are very similar, but there are specific technical variations," says JCB's Carver. "We make cabs for both sectors, with our Loadall telescopic handlers for example featuring prominently in each. Construction regulations see FOPS [falling object protection systems] and ROPS [rollover protection systems] required as standard, whereas in the agricultural sector these are customer-specified options. In construction it is also possible to self-certify the tests but third-party approval is necessary in agriculture. Owner-operated equipment is more common in agriculture so there is often an expectation of higher specification cabs in terms of seats, HVAC options and the quality of interior trim. Construction machines, particularly those destined for large rental fleets, may feature less-sophisticated specifications although the highest levels are fully available."

"A cab in an agricultural machine often boasts more complex controls as the machines can be specialized," says Klacksell. "This means that the operator has a steeper learning curve and it's harder to go from operating one machine to another. However, there is more automation within agricultural machinery so there's plenty of learning the construction industry can take from this. In the future I believe the differences between machines in these two industries will decrease." **iVT**

For a full preview see page 16

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"India is a land of ENORMO opportunity

WITH VAST EXPERIENCE IN CREATING DURABLE, NO-NONSENSE MACHINES FOR THE DEMANDS OF THE CHINESE MARKET, SDLG IS WELL PLACED TO BUILD FURTHER ON ITS ALREADY CONSIDERABLE SUCCESS IN INDIA. THE OEM'S NEW HEAD OF BUSINESS IN INDIA, SURAT MEHTA, TALKS CANDIDLY ABOUT THE CHALLENGES, AND LOOKS AHEAD TO DECEMBER'S BAUMA CONEXPO INDIA EVENT

Surat Mehta is eminently qualified to tell us something of industrial vehicle markets in India, having crossed the length and breadth of this heavily populated nation during 25 years in the industry. "India is a land of enormous opportunity," he says. "Since 2014, demand for construction equipment and mining machinery has grown consistently at an annual rate of over 20%. Because of slow-downs elsewhere in the world, most of the global players have set up business in India, making the market a bit overcrowded. While demand is growing, the market has become highly competitive – but I think we have a space where almost everyone can survive. For seven or eight years, this growth story will continue."

Mehta is the recently appointed head of business in India for China's SDLG (Shandong Lingong Construction Machinery), which has rapidly gained momentum in India since first establishing a market presence in 2009. With a reputation for reliable, cost-effective and easy to operate vehicles, SDLG saw over 50% growth in wheel loader sales from 2013 to 2017 and is now one of the market leaders in the 5 metric ton wheel loader segment in India. While it manufactures a more comprehensive range of vehicles in China, including backhoe loaders and excavators, SDLG is concentrating on just two types of machine in India – wheel loaders and motor graders.

"The primary demand drivers are the road and mining sectors," Mehta explains. "The government aims to link every village in the country through a network of roads while building extra highways to connect our ports and major metro cities. There are also plans to build a lot of smart cities in order to convert people from villages to new urban centers where infrastructure is available." Road building on a subcontinental scale will ensure continuing demand for SDLG's 15 metric ton G9190 and 12 metric ton G9138 motor graders.

ABOVE: **SDLG's motor graders are playing a key role in India's extensive road-building activity**

"THE PRIMARY DEMAND DRIVERS ARE THE ROAD AND MINING SECTORS. THE GOVERNMENT AIMS TO LINK EVERY VILLAGE IN THE COUNTRY THROUGH A NETWORK OF ROADS"

Surat Mehta, head of business in India, SDLG

Meanwhile, SDLG's range of 3 to 5 metric ton wheel loaders (see *Profile of a Bestseller*, page 53) cater for both highway construction and India's colossal mining industry. "Around 60% of the country's power generation depends on thermals," says Mehta. Mine extracts include coal, limestone, copper, zinc and uranium.

Size and scale

In 2017, India's estimated population was 1.32 billion; by 2050, it is expected to be 1.66 billion, with UN projections suggesting that 17.2% of all humanity will live in India. According to Mehta, India's sheer size determines the character of the marketplace. "India has always been very cost-competitive," he says. "It's a volume-driven market wherein the customer base is huge, so most players try to bring down costs and play to the volumes. What customers value is getting a decent level of product at the lowest cost." This means a large market for value products and huge potential for growth in the value sector targeted by SDLG.

PROFILE OF A BESTSELLER

The LG958L is SDLG's bestselling vehicle in India. The largest of SDLG's wheel loader range in the country, it has an operating weight of 6.6 metric tons and a standard bucket capacity of 3m³ (105ft³), allowing it to lift 5 metric tons. Its Deutz TIER III engine provides 215hp (160kW) of power at 2,000rpm and maximum torque of 920Nm at 1,400rpm, while it features semi-automatic powershift transmission with four forward and three reverse gear speeds. SDLG's box-structure frame is designed to provide best-in-class robustness, and rear access panels allow daily maintenance checks and single joystick operation of the loader arm and bucket to facilitate simple and comfortable working. A hydraulic boom-lift time of just 6.4 seconds underwrites quick duty cycle performance, boosting overall productivity.

"Typically, the LG958L goes to several applications," explains SDLG's head of business in India, Surat Mehta. "One application is loading minerals onto railway wagons at a railway siding. A second application is tunneling. Third is the road segment. Every road requires crushed stone to be laid as the base layer, so raw stone has to be fed into the crusher, then the crushed material has to be loaded into trucks for movement to the site. The fourth application, where we are dominant, is cargo unloading and handling at ports. Our fast and reliable wheel loaders come in very handy to customers at ports, because the ship turnaround time has to be reduced."

SDLG's Indian offering also encompasses three smaller wheel loaders. These include, in the 3-ton class, the LG933 and LG936, equipped with load-sensing hydraulics and ideal for space-constrained operations and, in the 4-ton class, the versatile L946, billed as suitable for farms, small mines and town construction sites. SDLG is poised to unveil a more powerful and fuel-efficient addition to its loader range at Bauma ConExpo India, December 11-14, 2018.

215hp
Power output of SDLG's bestselling LG958L wheel loader (160kW)

"CUSTOMERS USE MOST OF OUR EQUIPMENT TO DESTRUCTION. THE SCOPE FOR REBUILDING IS LIMITED, SO THE CUSTOMER EXPECTS A LONGER FIRST LIFE FROM THE MACHINE"

Surat Mehta, head of business in India, SDLG

ABOVE: **The G9138 grader offers high-speed, high-precision and efficient performance**

When adapting its Chinese-built loaders for the Indian market, SDLG focuses on optimizing value and reliability. "For the drivelines, we use the best engines, transmissions and axles," says Mehta "These are high-cost items, but they are at the heart of the machine. Indian customers want to strike a balance between technology and costs, while reliability and lifecycle value are major factors that influence purchases." SDLG loaders offer impressive boom lift and cycle times, providing improvements in operational speed combined, according to Mehta, with low fuel consumption, driving down the overall cost per cubic meter of material handled.

Rugged and durable

In India, machines are expected to endure a longer lifecycle than elsewhere in the world. In many countries, huge markets exist for second-life machines, remanufactured and remarketed after an initial period of work. However, since a market for remanufactured equipment has yet to mature in India, vehicles have less resale value. "Customers use most of our equipment to destruction," says Mehta. "The scope for rebuilding is limited, so the customer expects a longer first life from the machine. Structures must therefore be durable as stresses continue to build, giving an uninterrupted working life."

Another reason to prioritize reliability lies in India's sheer vastness: though SDLG cites a pan-Indian presence with 16 dealerships nationwide, distances of hundreds of miles could still mean a time delay in the delivery of critical components. Simplicity of maintenance and design becomes a virtue here.

SDLG prides itself on customizing machines for the Indian market. India has a hilly and mountainous terrain, making tunneling a key activity, be it for roads, railways or irrigation. At present India has 1,190 tunnels totaling 2,223 miles (3,578km) in length, with more being built. Typically, the blasting method is used, with wheel loaders removing displaced material between successive detonations, operating within a constrained space. During his previous strategic support role for SDLG in northern India, Surat Mehta oversaw the introduction of a customized LG958L loader with side-discharge bucket. "It means that the space

"I KEEP MYSELF UP-TO-DATE WITH THE MACRO-ECONOMICS WHICH DRIVE DEMAND AND WE PLAN PROACTIVELY TO ENSURE WE HAVE A SUSTAINABLE, PROFITABLE BUSINESS FOR SDLG IN INDIA"

Surat Mehta, head of business in India, SDLG

needed is much less than for a normal wheel loader, reducing the de-mucking time," he says. "Until material is de-mucked, you cannot plan for the next blast, so the overall cycle time has been reduced."

Ready for Bauma ConExpo India

Mehta is eagerly anticipating Bauma ConExpo India, which takes place in December at Huda Ground in Gurgaon, a major financial and industrial center 20 miles (32km) southwest of New Delhi. He regards SDLG's presence as having become integral to the exhibition over recent years. Ahead of the event, he can only divulge a few particulars of the new SDLG vehicle being launched – an upgraded wheel loader, more fuel efficient and powerful than prior models. Aside from this, SDLG will focus on promoting its core offering at Gurgaon, with two wheel loaders and a motor grader on display and opportunities for customers to engage with technical staff and see machines at close quarters. So is there any prospect of SDLG broadening its Indian range by beginning to ship in backhoe loaders or excavators from its manufacturing base in China?

ABOVE: **SDLG will be present at Bauma ConExpo India, which is taking place in Gurgaon in December 2018**

BELOW: **SDLG saw over 50% growth in wheel loader sales in India from 2013 to 2017**

"In the short term, we do not wish to enter the backhoe loader space in India," says Mehta. "Globally, India is the biggest backhoe loader market and JCB enjoys a 70% share of that segment. But, as the economy grows and markets mature, we are observing a gradual shift away from backhoe loaders into mini- and midi-excavators and 3 to 4 metric ton wheel loaders, where we are already present in the country. At this stage we do not wish to bring in excavators, but to consolidate our position and improve our market presence with wheel loaders and graders."

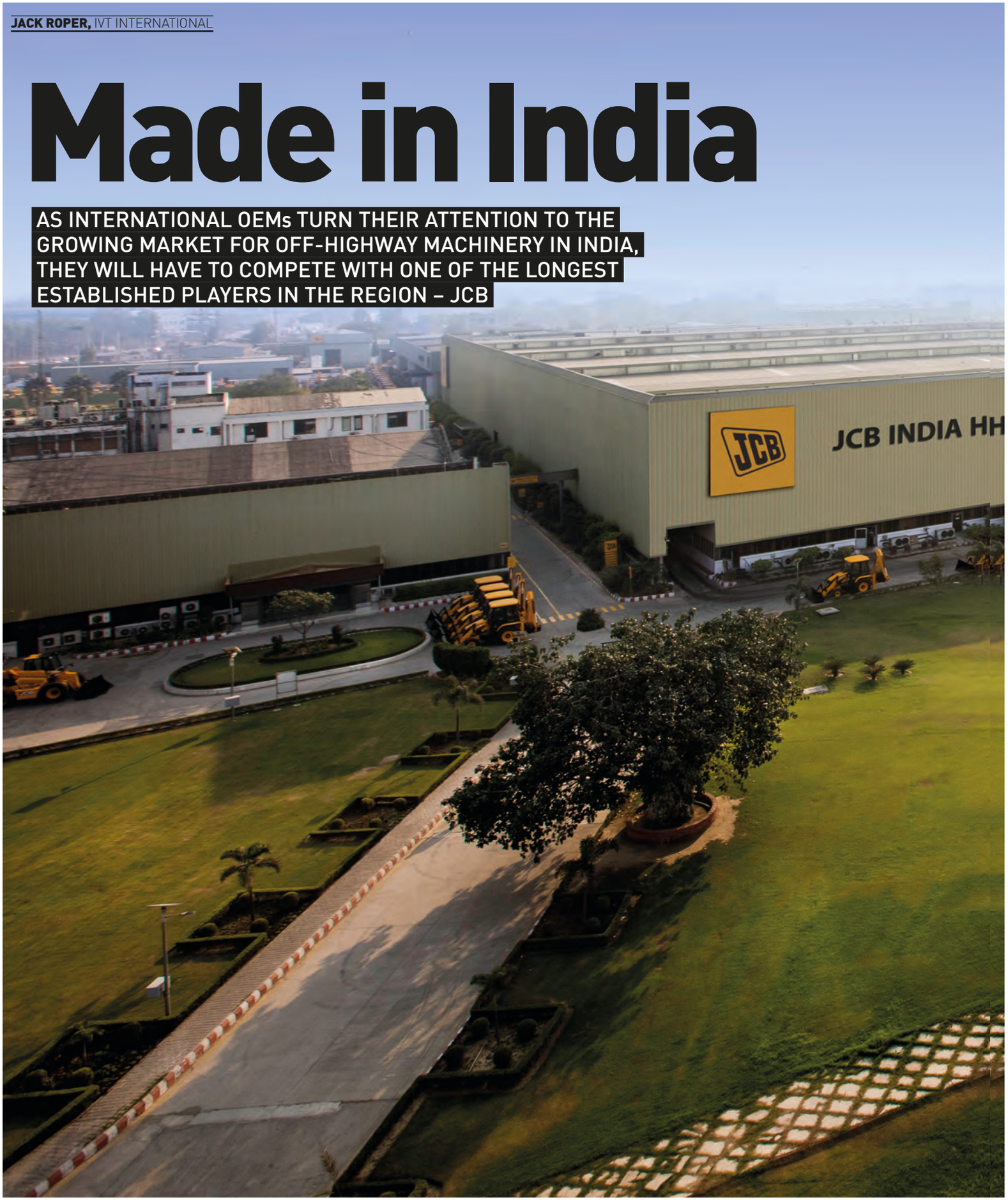
It is a mark of Surat Mehta's professionalism and dedication that he has made time to speak to me during the festival of Gandhi Jayanti, which commemorates the birth of Mahatma Gandhi, Father of the Nation. This seems somehow apposite, since the pride Mehta takes in his work stems from an intimate knowledge of the country and a customer base which he sees as uniquely demanding.

"I keep myself up-to-date with the macroeconomics that drives demand and we plan to ensure we have a sustainable, profitable business for SDLG in India. Personally, the quality we are delivering to the customers at a value acceptable to them gives me a sense of satisfaction. We are able to crack the code and meet their requirements. But we wish to be ready for the future and I enjoy keeping in touch with customers and understanding their future needs, because their requirements are also evolving." **iVT**

JACK ROPER, IVT INTERNATIONAL

Made in India

AS INTERNATIONAL OEMs TURN THEIR ATTENTION TO THE GROWING MARKET FOR OFF-HIGHWAY MACHINERY IN INDIA, THEY WILL HAVE TO COMPETE WITH ONE OF THE LONGEST ESTABLISHED PLAYERS IN THE REGION – JCB



JCB's Indian headquarters at Ballabgarh is now the world's largest backhoe loader factory

In November 2014, JCB Group chairman Lord Bamford was joined by Vasundhara Raje Scindia, Rajasthan's chief minister, at the inauguration of two brand-new factories 19 miles (30km) southwest of Jaipur in northwest India. Providing 1,000,000ft² (93,000m²) of manufacturing space and designed to employ more than 1,000 people, Jaipur represented a US$80m investment and the largest single construction project in the JCB Group's 69-year history. India overtook the UK as JCB's largest single market in 2007 and now accounts for over 40% of the group's global sales, with 300,000 JCB machines sold in India since 1979. As the 40th anniversary of JCB's first entry into India approaches, a boom in government-sponsored infrastructure projects promises a bright future of increasing growth. But in 2014, the picture looked a little less certain.

"Since 1979, JCB has made continual investments in India and created a world-class manufacturing ecosystem," explains JCB India's managing director and CEO, Vipin Sondhi. "After building two factories in Pune in 2006 and 2007, then expanding its existing New Delhi facility, JCB decided to invest again in Jaipur. This was a bold move, as the plant was commissioned during the economic downturn in India, with the construction equipment industry in a sustained downcycle which lasted from 2012 to 2015."

Four years on, dramatic market growth is being driven by a government focused on building new highways, ports, reservoirs and rural infrastructure at an unprecedented rate. One such initiative, the Bharatmala Pariyojana

40%
Proportion of global JCB sales in India, making it the OEM's largest market

2006
The year that JCB opened the first of its two factories in Pune, 93 miles (150km) east of Mumbai

road project, aims to improve conwnectivity in key corridors, far-flung areas and border regions, stimulating quicker cargo movement and boosting exports, with 52,000 miles (83,680km) of new roads set to be built at an overall cost of US$75bn. JCB India sold a record number of machines in 2017 and is seeing a further surge in demand during 2018. The company is well-positioned to capitalize, thanks in part to JCB Jaipur, underlining the prescience of factory building during the lean years earlier in the decade.

"The Indian market is at its highest-ever level and Jaipur is buzzing with activity," says Sondhi. "One objective of building a new plant was to create extra capacity. Experience proves the increase in demand after a downcycle is steep and JCB India had to be ready to service that demand when it came. Critically, increasing demand for JCB products could not have been fully met had Jaipur not been producing machines today – as anticipated in 2014."

It was not only the timing of JCB's investment that proved judicious – the choice of Jaipur as a location was also a strategic success. "The State of Rajasthan has a pro-business approach and extended its full support to promote manufacturing," continues Sondhi. "Other important factors were the availability of young talent and proximity to the New Delhi facility, enabling us to leverage the existing supplier base. Jaipur is also on the Delhi-Mumbai corridor, allowing transfer of finished goods to other parts of the country, or for export." Within India, JCB has more than 650 outlets, providing a product-support lifeline, even in remoter tracts of country. Meanwhile, 'Made in Rajasthan, Jaipur' products are exported to more than 50 countries, while JCB India exports to more than 95 countries from its three Indian manufacturing locations.

ABOVE: **Workers busy on one of the production lines in Pune**

BELOW: **JCB India prides itself on the age range and gender diversity of its workforce, with female engineers excelling in welding tasks** (BOTTOM)

Working together

JCB prides itself on the youth and gender diversity of its Jaipur workforce. The average age of shop floor employees is just 24, and 30% are women, most recruited locally in Rajasthan. According to JCB, female engineers are excelling in roles such as welding and assembly, traditionally considered a male-only preserve in India, with some progressing to leadership roles. As well as component manufacturing, the Jaipur facility houses production of skid steers and mini excavators, and provides extra capacity for manufacturing the vehicle which has been JCB's calling card in

The JCB 3DX Xtra backhoe loader in action

India since the beginning: the backhoe loader.

"JCB understood the need of customers in India to do many things with one machine," says Sondhi. "It introduced a multipurpose product, the backhoe loader, soon after entering India in 1979." The backhoe remains the best-selling machine in the country and JCB has maintained its market leadership through technology upgrades, introducing a wide range of variants and maintaining its focus on product quality. In the early days, other factors were also important. JCB had to invest in skills – not only manufacturing skills but also in building a competent supplier base. "It was equally essential to have operators who could use the machines safely and productively, since no ready-made base of trained operators was available," Sondhi explains. "JCB India today has 15 operator training centers and has trained 25,000 operators to date."

75%
The share of the backhoe loader market JCB enjoys in India

The legendary backhoe

JCB's made-in-India backhoes may be a truly global product adhering to JCB's 'One Global Quality' ethic, yet they must also endure the particular rigors of Indian use.

"One key differentiating factor is the usage pattern of backhoes in India, which average close to 3,000 hours of operation per year, compared with 1,000 hours in Europe," says Sondhi. "Terrain and temperatures vary immensely across India, a country with deserts, mountains, plains and coastlines, so JCB backhoes must perform even in harsh terrain or climatic conditions. Moreover, machines in India are

"THE INDIAN MARKET IS AT ITS HIGHEST-EVER LEVEL AND JAIPUR IS BUZZING WITH ACTIVITY"

Vipin Sondhi, CEO and managing director, JCB India

PASSAGE TO **INDIA**

Upon entering India in 1979, JCB opened its first factory at Ballabgarh near New Delhi, a 57-acre (23ha) plant which remains JCB India's HQ and is now the world's largest backhoe loader factory, with the capacity to produce over 100 backhoes daily. JCB now has a total of five factories in India. The company also has 12 factories in the UK and others in Brazil, China and the USA. JCB offers a full range of construction equipment in India and has a market share of over 75% of backhoe loader sales in the country.

In 2017 JCB India enjoyed record sales despite significant challenges, including the introduction of a Goods and Services Tax which saw construction equipment placed in the high 28% bracket. This adversely affected sales, but it was subsequently reduced to 18%, creating a surge in demand in 2018. Growth across the sector is being driven by a program of investment in infrastructure, with government focus on large projects stimulating the excavator market to grow by 22% in 2017 and 32% in 2018. In line with this, JCB has introduced newer and larger excavators to India, ranging up to the 38 metric ton 380LC.

JCB took the lead in the material-handling category by introducing its telehandlers, skid steers and super loaders to India in 2015. Telehandlers in particular are reportedly becoming more popular as palletization gains ground on the subcontinent. JCB has sold over 300,000 machines in India and calculates that, since each machine engages an operator and helper, it has created around 600,000 jobs.


Jaipur


Jaipur Backhoe Line


Pune Design Centre

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LEFT: **JCB India's Livelink Command Center**

BELOW: **The JCB 3DX Xtra backhoe loader**

85,000
The number of JCB LiveLink telematics-enabled machines in India

prone to stress due to contaminated fuel. Ecomax engine features like optimized air fuel, advanced filtration, water separators and FIE (fuel injection equipment) systems help to protect and extend an engine's life."

Historically, Indian customers may have been inclined to shun sophisticated technologies in favor of basic vehicles offering durability and ease of use, but Sondhi believes that expectations and tastes are evolving. "Acceptance of digital technologies is on the rise. With high mobile phone penetration, technologies such as JCB's telematics system, LiveLink, which has 85,000 enabled machines across the country, are becoming extremely popular. The industry is changing, and customers are now demanding feature-rich, intelligent, productive and safe machines."

To stay ahead of the game, in December 2017 JCB launched its new 'Eco-excellence' backhoe with a host of innovative features. It has an automated manual transmission system, akin to those found in cars, eliminating the need for gearchanges, which provides tremendous ease-of-use while reducing operator fatigue and optimizing productivity. The choice of two modes – economy and power – enables the operator to either maximize engine power or conserve fuel, according to the task.

"MACHINES IN INDIA ARE PRONE TO STRESS DUE TO CONTAMINATED FUEL. ECOMAX ENGINE FEATURES HELP TO PROTECT AND EXTEND AN ENGINE'S LIFE"

Vipin Sondhi, CEO and managing director, JCB India

Other new technologies make Eco-excellence backhoes well-equipped for work in more remote locations in rural India, where much new infrastructure is planned. An SOS switch, for example, can send out SMS alerts to registered contacts in an emergency, when the operator is unable to use their mobile phone due to low battery. JCB's Guide Me Home feature means that, for a period after a machine is turned off, its working lights remain on, enabling the operator to see their way through worksites, which, at night, may be engulfed in darkness. Smart app machine diagnostics also reduce the time taken to identify faults, according to JCB: through a Bluetooth dongle paired with a mobile device, service engineers can quickly zero-in on a technical problem.

"JCB's journey in India is based on vision, hard work and a sense of urgency," concludes Sondhi. "Apart from the usual earthmoving and construction jobs, the much-loved JCB backhoe has carried newlyweds home from their wedding venue and rescued stranded schoolchildren in flooded areas. It has moved from being a product to a way of life." The timely investment at Jaipur means this way of life, like India itself, will surely continue to flourish. **iVT**

On the Web

Watch a short film telling the story of JCB India at **www.iVTinternational.com/jcbindia**

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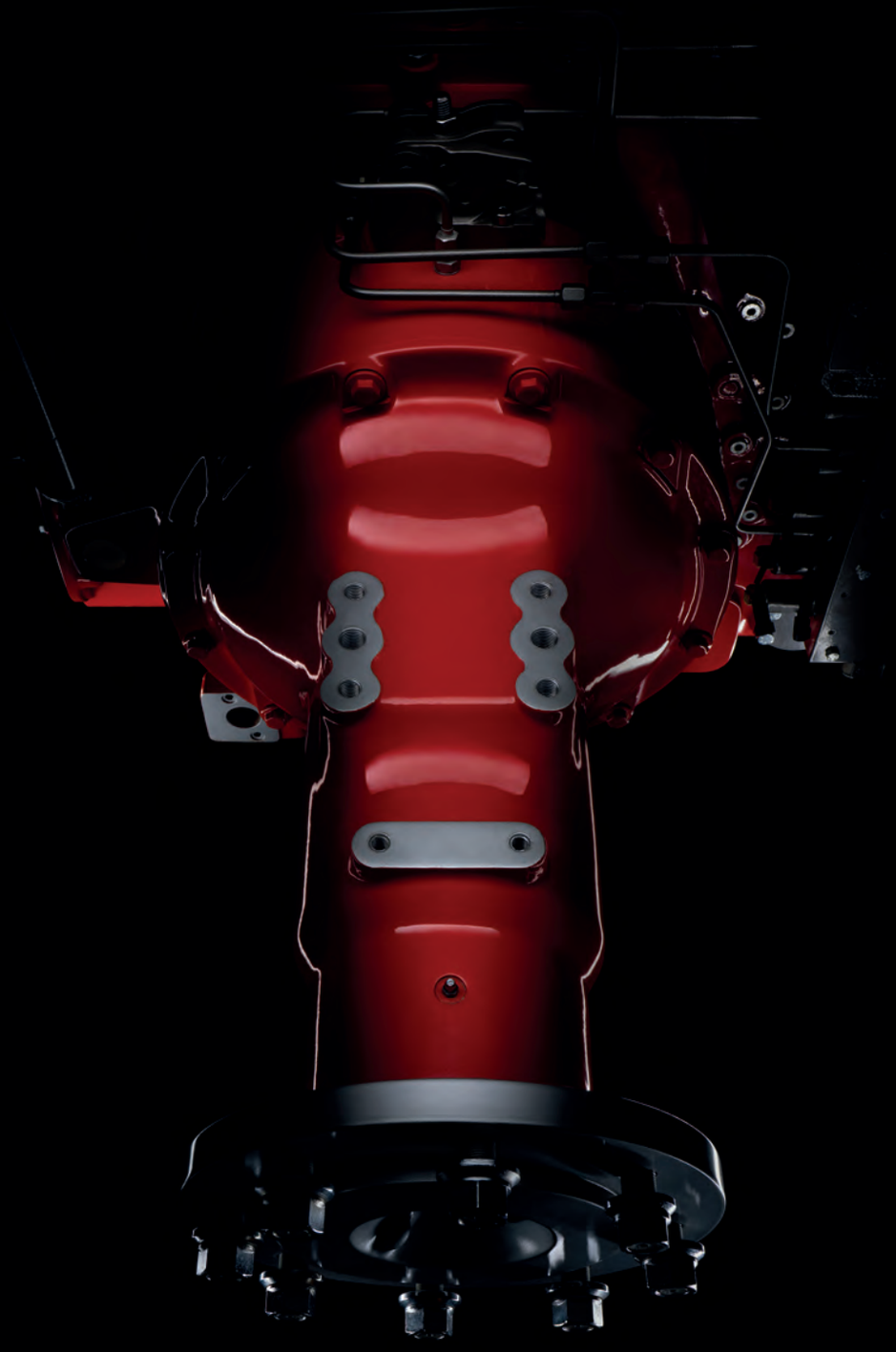

CARRARO

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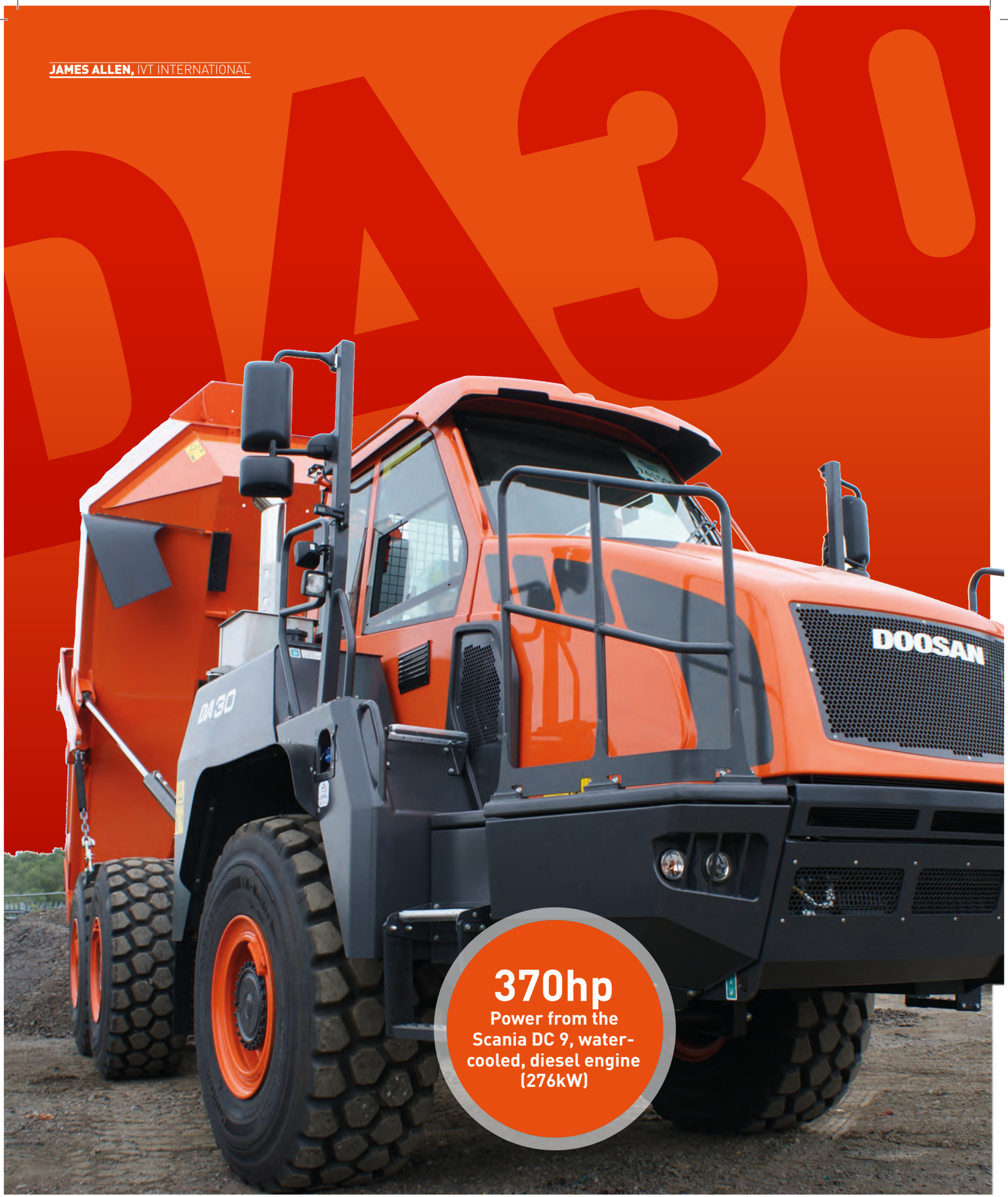
JAMES ALLEN, IVT INTERNATIONAL

DA30



370hp
Power from the Scania DC 9, water-cooled, diesel engine (276kW)

MANY IMPORTANT UPGRADES HAVE BEEN MADE DURING DOOSAN'S REFRESH OF ITS DA30 ARTICULATED HAULER, BUT IT'S STILL UNDENIABLY ONE OF THE TOUGHEST CONTENDERS IN ITS CLASS

ABOVE AND BEYOND

Having developed its first articulated hauler in 1972, Doosan can rely on more than four decades of experience when designing vehicles for this segment of the market. As a result, the OEM is one of the most innovative in the sector. The updated DA30 illustrates this point perfectly.

A new beginning

The articulated hauler was originally launched in 2017, but the updated version was unveiled to the world earlier this year, with a degree of fanfare unusual for a machine that was initially intended to be a simple refresh with some modest cosmetic changes.

"In the beginning, we were just calling it a face-lift as we wanted to introduce some changes in order to meet customer expectations, and balance the costs a bit better," explains Doosan product manager Adrian Winnicki. "In the end, the number of changes were on a level that made us realize it was more like introducing a completely new model."

"THE NUMBER OF CHANGES WERE ON A LEVEL THAT MADE US REALIZE IT WAS MORE LIKE INTRODUCING A COMPLETELY NEW MODEL"

Adrian Winnicki, product manager, Doosan

A new color scheme is a very visible sign of change; the completely orange skin of the original vehicle is now peppered with splashes of grey.

Softer lines to the DA30 now give a more curved shape to the vehicle. However, a number of other changes have also been made to the 30 metric ton machine – the large majority of which were geared around improving the operator's experience.

The most significant development is in the DA30's suspension. This has been upgraded to a hydro-gas, self-leveling system that provides superior shock absorption compared with the previous system. Offering better comfort, the new suspension is most notable when the truck is being driven with an empty load.

51.4T
Total weight when fully loaded

"MOST ADTs HAVE TWO RIGID AXLES IN THE BACK WITH TWO DIFFERENTIALS ON THEM, BUT OUR SOLUTION HAS ONE CENTRAL DIFFERENTIAL THAT SPINS ALL FOUR WHEELS. NOBODY ELSE OFFERS IT IN THIS CLASS, SO IT'S UNIQUE TO DOOSAN"

Adrian Winnicki, product manager, Doosan

Complementing the suspension is the inclusion of plush seating from Grammer. Boasting its own independent, low-frequency pneumatic suspension, the Actimo XXL seat is now available in the cab as standard.

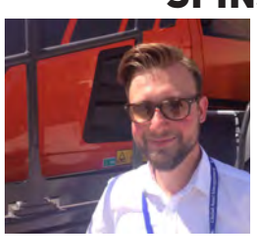
The operator can call on a 7in, high-resolution (800x480 pixel) color display to automatically show footage from the rearview camera when reversing, but also allow for calibration of the clutch without needing additional computers.

Continental provides the vehicle's tires and was one of the few suppliers operating on a CAN system. This detail was important to be able to integrate with the DA30's onboard tire pressure monitoring system that can also be brought up on the display screen.

Hidden benefits

Another major change might not actually be noticed by customers at all – and the more it flies under the radar, the more successful its inclusion in the vehicle will be considered. It is the decision to bring production of a number of vehicle components in-house.

Winnicki explains, "With this upgrade, we also wanted to get some parts produced in our factory. Years ago, we decided to outsource many of our components, but now we have decided to bring a number of those parts in-house once more."



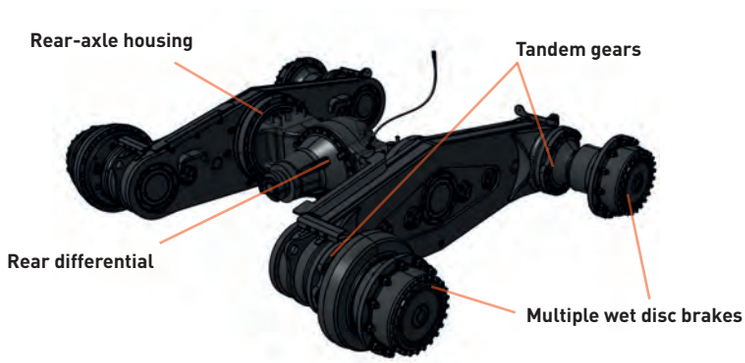
TOP: **The DA30 has been upgraded to enhance the operator experience, with automatic tire pressure monitoring now fully integrated with the CANbus**

ABOVE: **Adrian Winnicki chats to *iVT* about the new machine**

The vehicle's tandem bogie was most affected by this decision. Until recently, this was supplied externally, but Doosan has brought it in-house, increasing its control of the design and production process.

The tandem bogie sets Doosan haulers apart from the competition in this weight class. "Articulation is common for these types of machines, but most articulated dump trucks have two rigid axles in the back with two differentials on them," explains Winnicki. "Our solution has one central differential that spins all four wheels. Nobody else is offering it in this class, so it's unique to Doosan."

With the necessary welding robots on-site at its production facilities, Doosan now has the



LEFT: **Doosan's tandem bogie helps to create even distribution of weight when the vehicle is turning, as well as creating extra space for material in the box, enabling it to be sloped down toward the front. Since there is only one rear differential the driveline delivers more power with fewer parts**

ABOVE: **A new cab tilting system enables quick and easy maintenance under the cab**

12 secs
Total tipping time (up). Down takes 9 secs

capacity to cope with surges in demand, while also reducing costs.

Weight distribution

Further design innovation can be found in front of the tandem bogie, where the articulation hinge is positioned behind the turning ring to ensure equal weight distribution on the front wheels while loaded and turning. This also enhances maneuverability of the front wheels, ensuring they do not lock up.

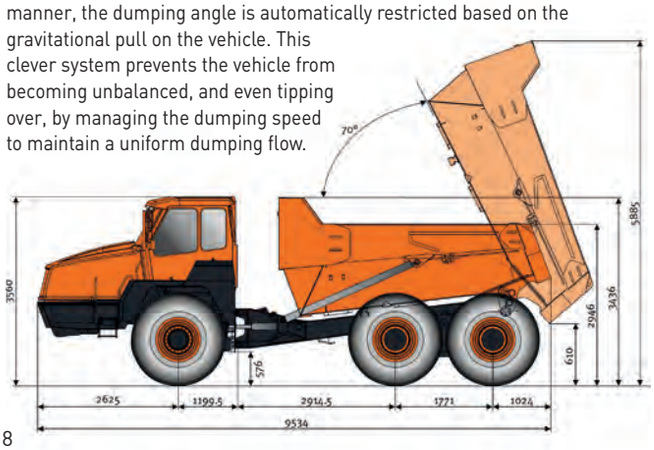
"We have the touring ring on the front frame and the hinge on the rear frame, while most have it done the opposite way," confirms Winnicki. "With the opposite articulation, you get most of the load on the outside wheel, so load distribution is not possible; it is easy to lose traction and get stuck. Our way gives equal load to the left and right wheel and therefore you can travel across more challenging areas."

The position of the turning ring on rival systems, along with 100% differential lock, can cause steering difficulties, but changing the position of the turning ring enables use of the differential with only 45% locking value – providing greater vehicle control as a result.

Bringing production of mechanical parts in-house may seem a natural extension of what it is capable of, but Doosan is also increasing its direct involvement in the development of other areas of the vehicle that it is traditionally less familiar with. "We don't produce electronic components, but we do design them ourselves as we have very good electronics designers," says Winnicki.

GRAVITATIONAL PULL

The inward sloping angle of the DA30's dump box bed limits material from falling out and enables the vehicle to have a payload of 28 metric tons. To ensure the DA30's dump box is emptied entirely of its contents in a safe manner, the dumping angle is automatically restricted based on the gravitational pull on the vehicle. This clever system prevents the vehicle from becoming unbalanced, and even tipping over, by managing the dumping speed to maintain a uniform dumping flow.



Engine developments

Doosan has a long history in engine development and yet it is the one part of this hauler that has consistently been produced externally, but there is a reason for this. "We have very big in-house engine facilities – for example, we made the biggest engine in the world for a ship," says Winnicki. "We also make plenty of smaller engines and use a number of them in our machines, but Scania is our main supplier for machines that can't use Doosan engines.

"We do actually have an in-house engine that fits the DA30, but we wanted the same supplier for both the DA30 and DA40 and currently we don't have an engine that is appropriate for the DA40, so we decided to stick with Scania."

The relationship with the Swedish engine manufacturer dates as far back as Doosan's first articulated hauler in 1972.

For the DA30, it is a Scania DC9 diesel unit that offers 370hp (276kW) of power. Use of both selective catalytic reduction and exhaust gas recirculation systems help the engine comply with Stage IV/Tier 4 Final emissions regulations. Another long-lasting supplier, ZF, provides the vehicle's transmission technology.

Altogether, the DA30 makes for a strong package, and Winnicki is keenly aware of what sets it apart from its rivals. "The key points are traction and stability," he says. "Thanks to the tandem bogie, this is the best machine for difficult terrain, but we also offer a high level of operator comfort, with a big cab that is very quiet, and we have low running costs."

Doosan has substantially added to what was already a serious contender in the articulated hauler market, and while the company has more than 40 years of history in this segment, the new DA30 underlines that it is not resting on its laurels. **iVT**

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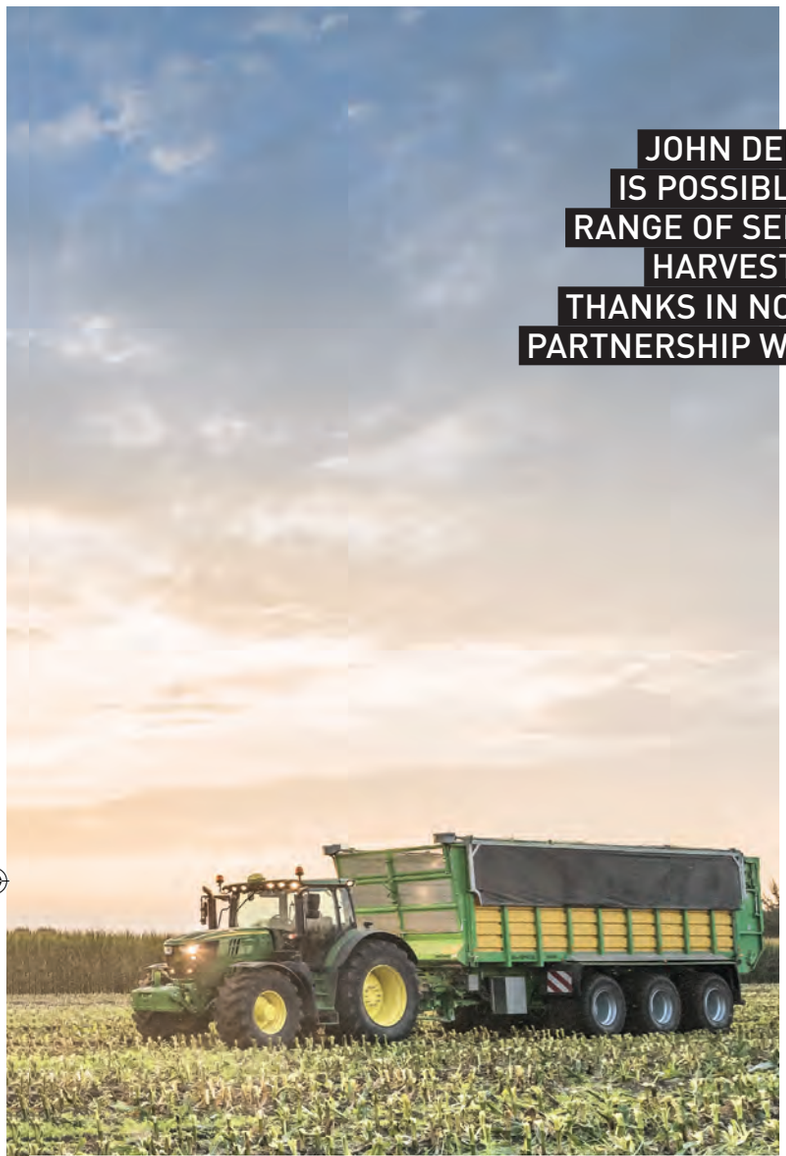
Powering ahead

970hp
The maximum power of the 24.2-liter Liebherr engine in the new John Deere 9900 (724kW)



JOHN DEERE'S NEW 9000 SERIES IS POSSIBLY THE MOST POWERFUL RANGE OF SELF-PROPELLED FORAGE HARVESTERS EVER PRODUCED – THANKS IN NO SMALL PART TO A NEW PARTNERSHIP WITH LIEBHERR ENGINES

In a bold break from tradition, John Deere has opted to switch engine suppliers for its new self-propelled forage harvesters. Three of the four models in the new 9000 Series range of forage harvesters are now powered by Liebherr engines instead of the Cummins engines used in the previous 8000 Series. Manufactured in John Deere's factory in Zweibrücken, Germany, the new series kicks off with the smaller 9600 at 625hp (474kW); 9700 at 770hp (574kW); 9800 at 870hp (649kW); and the 9900 at a massive 970hp (724kW).

At the heart of the three biggest models – the 9700, 9800 and 9900 – is a powerful 24.2-liter V12 Liebherr engine, while the smaller 9600 is powered by a John Deere six-cylinder PSX 13.5-liter engine. John Deere first struck up a deal with Liebherr in February 2017 to supply engines for construction vehicles, but this has now been extended to the company's self-propelled forage harvesters for the agricultural market.

Signing the agreement in 2017, Mike Weinert, John Deere Power Systems' vice president responsible for engine engineering and manufacturing, said, "John Deere Power Systems and Liebherr are both world-class engine designers and manufacturers who have a long history of successful interactions with each other.

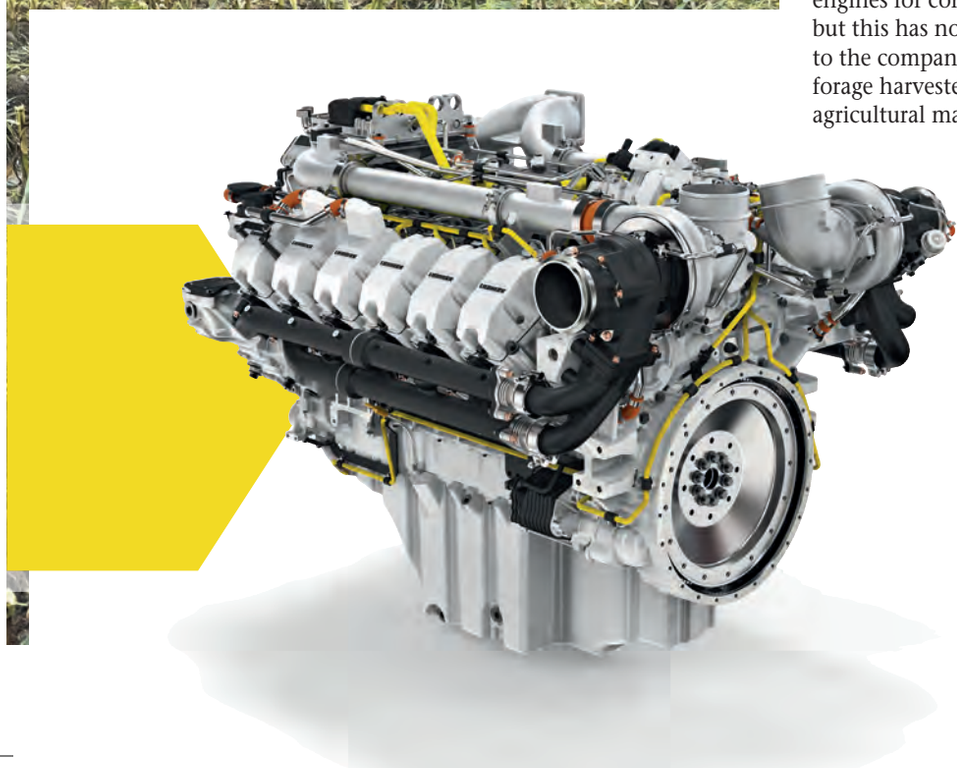
"Because of the capabilities each brings, and the long-standing, positive working relationship, it makes sense for our two companies to join technical efforts in areas of engine technology and architectures, component sourcing strategies, and best practices related to engine development and manufacture."

The new Liebherr V12 engines are already set for Stage V emissions regulations to be introduced in the EU in 2019. The launch of the 9000 Series range followed intensive DLG (German Agricultural Society) testing in Italy and in Germany. During these tests, the new John Deere 9800 self-propelled forage harvester demonstrated significant increases in performance and efficiency and has received official DLG certification.

John Deere has confirmed that the new 9000 Series is destined for markets in the EU, Canada, the USA, Australia, New Zealand and Japan.

New features

The key features of the 9000 Series include the new V12 Liebherr



MAIN IMAGE: **The new 9000 Series of self-propelled forage harvesters has been DLG tested in high-yielding maize fields in Northern Italy and Germany**

LEFT: **The John Deere 9700, 9800 and 9900 models are powered by Liebherr's 24.2-liter V12 engine**

engine, new kernel processor and headers, and the latest precision farming technology, which includes the new HarvestLab 3000 constituent sensing system, with the focus very much on forage quality.

The latest forage harvesting technology is said to increase productivity by 10%, while at the same time consuming 10% less fuel than the previous range.

In fact, when measuring fuel economy, usage rates of just 0.46 liters of diesel per metric ton of maize harvested were accomplished during the tests. However, John Deere stresses that this depends on conditions such as crop yield, soil and the climate.

In addition, when it comes to maize silage processing, the 9000 Series models consistently delivered 10% higher kernel processing scores. These performance figures have been verified through numerous field tests by both John Deere and renowned independent research institutes. The large crop channel width of 850mm (34in) is tailored to handle the tremendous throughput of these machines, to ensure the best possible forage quality and chopping efficiency.

The high-performance Liebherr power unit has been designed to operate efficiently at lower engine speeds. Beneath 1,400rpm it still provides outstanding torque capacity, as well as coping easily with peak loads.

Due to the higher engine horsepower, these new foragers feature a reinforced drivetrain and improved mainframe. The proven DuraDrum cutterhead is also designed for handling massive crop flows independent of the selected length of cut.

RowSense feeler guidance enables the forager to automatically follow maize rows

10%

The increase in productivity in John Deere's new forage harvesters (with a 10% reduction in fuel usage)

Extended range

John Deere has extended its range of kernel processors by introducing the XStream KP model. This high-performance processor has been developed together with the US-based company Scherer, an experienced leader in kernel processor technology.

LEFT AND BELOW:
The foragers have undergone a fresh, new design with striking elements including twin exhausts

ADDITIONAL **UPGRADE**

John Deere has also introduced another model to its 8000 Series of self-propelled forage harvesters (SPFH) in time for the 2019 season.

The decision to add on the 8600 model was prompted by increasing demand for a harvester with greater power, efficiency and productivity, but still with a transport width under 3m (10ft).

The 8000 Series models are popular with farmers or contractors who do not require the larger outputs of the 9000 Series, or who do not want to pay the higher prices for the new series.

Originally launched in 2014 as the entry-level, wide-body SPFH model in the series, the 8600 will now top the current range of standard crop channel models from the 8100 to 8500.

Even with 2.15m (7ft) 710/75R42 front tires, the 8000 Series models are within the critical road transport width of 3m (10ft).

Powering up the new 8600 SPFH is John Deere's PSS 13.5-liter 625hp (466kW) engine, which is the same model as that fitted to the new entry-level, wide-body 9600 model.

The new John Deere 8600 model has a 3-speed PBST electric shift standard transmission, or is available with a fully automatic ProDrive as an option.

The John Deere 8600 will also be available with the new XStream KP kernel processor and AMS systems found on the new 9000 series.

It is perfectly matched to the high-performance engine, providing a large roll diameter of 250mm (10in) and 50% roll-speed differential, thus increasing processing intensity by 10% at all cutting lengths.

Kernel processor rolls are available with a standard sawtooth design on the Premium KP unit, and either the sawtooth or a new XCut design on the XStream KP, which features a spiral cut groove across the roll surface.

Both types of roll design are also available with the proven Dura Line heavy-duty coating for increased durability.

Another highlight of the new XStream KP is the built-in temperature monitoring system, which keeps the operator informed about the KP bearing temperature in order to prevent unnecessary machine downtime. The kernel processor can be removed in just five minutes for quick changes between maize and grass.

Operator assistance

The new 9000 Series models are available with John Deere's complete range of AMS precision farming systems, for improved operator comfort and cutting quality.

These include the new HarvestLab 3000 NIR (near infrared) sensor, which enables viewing and documentation of real-time crop yield, moisture, and other constituents such as protein, starch, fiber, etc, as totals or in convenient site-specific maps. It also enables AutoLOC automatic length-of-cut settings and silage additive dosing on the move, based on dry matter content. The same sensor system can be used in stationary mode for analyzing clamp silage to manage feed rations more accurately, and for analyzing the chemical constituents in manure. **iVT**

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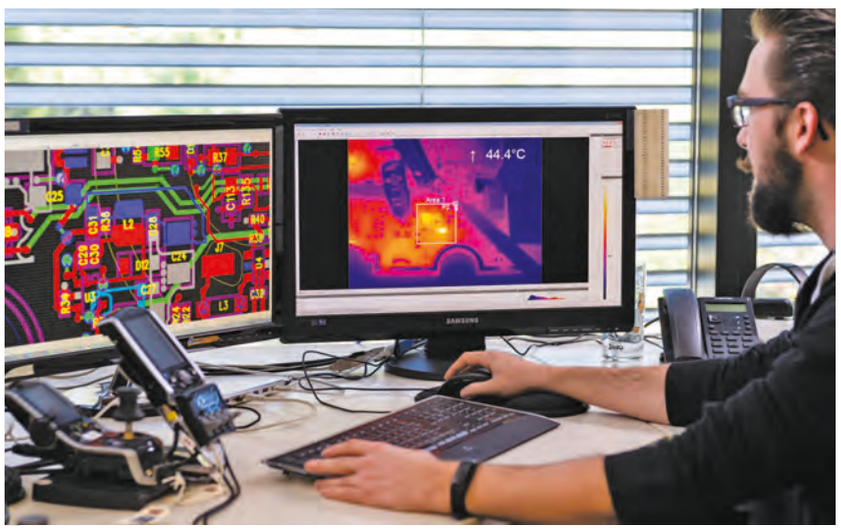

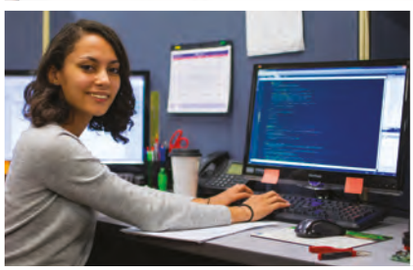

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MATS KJELLBERG

Display size: less is more

LARGE IN-CAB DISPLAYS ARE USEFUL AS MAIN TERMINALS, BUT WHERE SECONDARY FUNCTIONS NEED TO BE DISPLAYED OR SPACE IS LIMITED, A SMALLER BUT STILL FUNCTIONALLY DIVERSE DISPLAY IS NEEDED

As machines get more advanced, there are more controls and subsystems competing for space in the operator environment, from engine instrumentation, tire pressure monitoring and work process control to video monitoring, tool implementation control and GPS guidance.

CrossControl has launched its next-generation 3.5in color display – the CCpilot VI. With an i.MX6 ARM CPU, Linux operating system as well as the open and modular LinX software application platform, it enables a premium user experience within a compact space, making it suitable for use in a range of industrial vehicles.

The CrossControl large multifunctional displays – in sizes 7-12in – are typically deployed as main terminals, hosting functionality in an integrated human-machine interface (HMI) system. The main terminal is often mounted to the A-pillar and typically runs the visualization that supports the direct work task, allowing the operator to easily switch his attention between an external view and support from the screen.

These small eye and head movements make operation more efficient and they are ergonomically advantageous. However, functions that do not require frequent operator interaction are often best served through a smaller, secondary display located in the dashboard or armrest.

Versatile configurations

The new CCpilot 3.5in display uses the same software application platform as larger CrossControl displays. The complete integrated HMI system can be developed into one tool, spinning off certain pieces of a larger display application to run separately on the small display instead. This is especially useful for OEMs who want to support a range of machines with a common, modular HMI platform where different machine configurations may require alternative HMI setups.

The CCpilot VI is not only a secondary display; in compact machinery it can be used as the main terminal in the cab, hosting multiple HMI functions within the footprint of a traditional gauge instrument. The software platform is based on Linux/Qt, which offers advanced graphical features such as glow, animations, transitions and transparency.

ABOVE: **The CCpilot VI display supports advanced graphical features**

This platform, with hardware acceleration, makes it possible to create a graphical user interface (GUI) that efficiently handles much more information than other 3.5in displays on the market. Through smart user interface design and use of the features available within the LinX software suite, the CCpilot VI 3.5in display can replace a much bigger display, saving valuable space in the cab environment.

Application use

For large programs, the CCpilot VI offers the option of built-in Bluetooth support, which can be used in a range of applications, such as cloud connectivity via a custom-developed smartphone app, remote control and viewing of machine parameters as well as software updates and remote logging. When applied in such a way, the CCpilot VI can provide customers with an inexpensive solution for telematics and remote access.

Many tool-carrying vehicles – such as utility tractors and excavators – do not offer tool suppliers a good level of integration for the control of their specific tools.

Tool and implement manufacturers may themselves want to leverage technology and equip their products with smart controls and user-friendly operator interaction to enhance their products. This is where the CCpilot VI can step in – its powerful computing core and open-software application platform make it suitable for use in these kinds of value-adding tool control systems.

In addition to providing the operator with feedback on the tool work process, the CCpilot VI can be used for datalogging, electronic manuals and other functions. Furthermore, the CCpilot VI's small size, light weight and compatibility with the same fasteners and holders as smartphones enables easy installation into the cab of any type of off-highway or industrial vehicle. **iVT**

Mats Kjellberg is head of global marketing at CrossControl

PAUL BAIER

A module family

THE CAPABILITIES AND EASE-OF-USE OF HUMAN MACHINE INTERFACE SYSTEMS ARE BEING ENHANCED BY THE INTRODUCTION OF A RANGE OF NEW, INTELLIGENT CANBUS MODULES

To increase the versatility and scope of CANbus data systems, Ametek VIS (Vehicular Instrumentation Systems) has developed a family of individual modules that expand the capability and sophistication of CANbus-based instrumentation systems. All can be seamlessly integrated into a wide variety of instrumentation and control schemes.

Versatile and economical

Ametek VIS's CAN keypad is able to satisfy J1939 CAN multiplexed switching requirements for all vehicle platforms. Easily customized with minimal cost and time, the keypads can be provided with laser-etched buttons or custom decals, along with multiple LED indicators to show button status.

All communications to and from the vehicle flow through the standard J1939 CANbus, as do the command messages that control the LED status indicators and LED brightness settings.

To make mounting as versatile as possible, the eight-button keypad can be top-panel mounted with clips, oriented either vertically or horizontally. All keypad buttons provide tactile feedback and are laser-etched to provide an inherently high wear life and durability. The decal version has domed buttons for increased tactile feedback and the custom icons are printed on the second layer for maximum wear life and durability.

Sealed to IP67 specifications both front and rear, the keypads are designed to withstand the harsh conditions typical of off-road environments and meet all SAE J1455 and J1113 requirements for vehicular instrumentation.

Connecting mechanics to electronics

Ametek VIS's CAN I/O Expander (CAN I/O X) module can be used to enhance complete vehicle instrumentation systems. The CAN I/O X units provide a means to connect manual transmissions and engines with electronic instrumentation by converting pulsed inputs to digital information.

The modules also provide switched and analog inputs that can be converted to digital data. The converted data is broadcast out on the J1939 CANbus at regular intervals.

CAN I/O X modules are sealed to IP67 specifications and can be mounted on a vehicle chassis.

The Ametek VIS CAN I/O Expander (ABOVE LEFT)**, Smart Dual Pressure Transducer Module** (BELOW LEFT) **and CAN keypad** (LEFT) **can be integrated into a wide range of vehicle platforms**

Designed to withstand the harsh conditions typical of commercial on-road, off-road and manufacturing/warehousing environments, the modules meet all SAE J1455 and J1113 requirements for vehicular instrumentation.

Ametek's robust keypads and I/O X modules are specifically designed for use on: heavy trucks; buses, coaches and recreational vehicles; military vehicles; forklifts, wheel loaders and skid steers; cranes, road-building and construction equipment; earthmoving and mining vehicles; utility and emergency vehicles; farm and agricultural equipment; and stationary engine instrumentation.

Converting pressure into data

The Smart Dual-Pressure Transducer (SDPT) from Ametek VIS converts air pressure and/or vacuum inputs from two separate sources into data and broadcasts this over the vehicle's J1939 CANbus.

Designed to withstand the harsh conditions encountered in the heavy vehicle and construction industries, the SDPT combines two independent pressure sensors; signal conditioning electronics; CANbus interface electronics; and a six-pin, self-locking, sealed Packard Metri-Pack connector in a compact, environmentally sealed, polymer package.

Powered by the vehicle's ignition power, the SDPT eliminates the need for pressurized air lines and hoses behind the dash for instrumentation purposes.

The SDPT uses the vehicle CANbus to provide both pressure information and a low/high pressure indication that is suitable for driving a warning light.

The SDPT meets all SAE J1455 and J1113 requirements for vehicular instrumentation. Designed for vehicular braking and other applications in which reliability and durability are of prime importance, the SDPT can be incorporated into a variety of pressure- and/or vacuum-monitoring systems, making it the ideal solution for pressure monitoring applications.

Uses include monitoring brake line pressure, pedal application pressure, auxiliary air pressure, turbo boost pressure, suspension pressure, engine manifold vacuum, air or fuel filter restriction vacuum, and central tire inflation. **iVT**

Paul Baier is the business development manager at Ametek VIS

JAMES REED

Rethinking engine design

OEMs ARE DEMANDING THAT NEW ENGINES BE VALIDATED NOT SIMPLY IN ISOLATION, BUT AS PART OF COMPLETE POWER SYSTEMS, THEREFORE THE BEST CHOICES ARE ONES THAT HAVE UNDERGONE A RIGOROUS, DIVERSE ASSESSMENT

As machine systems have grown more complex – with engines, transmissions and control systems more integrated – the lines between what is engine and what is machine validation have become blurred. Consequently, OEMs are looking to engine manufacturers for products validated as part of a complete power system, in a real, working machine, so they can focus on the design and validation of their new machine features.

There are many ways to measure customer satisfaction but, for Perkins, integrating effectively with 800 customers who manufacture over 3,000 different machines is anything but easy. To make the challenge even more interesting, the traditional needs of power and durability expand into a complex and interacting range of requirements, which differ depending on the customer and the machine type.

Consider packaging, for example, which includes not just overall size, but also options such as flexibility for details such as turbocharger position. The packaging needs of an excavator are very different from those of a telehandler, where the height of the engine and aftertreatment layout have a big impact on sightlines and safety.

Fluid consumption is another area where priorities differ. Minimizing it may be more important for a 30-ton excavator than it is for a compact machine, where operator comfort and engine NVH could well be more critical requirements.

But even with the growing complexity of conflicting requirements, customer satisfaction is still underpinned by three essential musts. The engine must fit, it must be simple to engineer into the machine, and it must deliver maximum functional performance and uptime.

LEFT: **Perkins engineers at work**

BELOW LEFT: **The Perkins Syncro 3.6-liter engine**

Important requirements

Perkins' new Syncro range is a good example of how manufacturers are delivering these essential musts. It is a clean-sheet design project that has given the engineers the opportunity to take a fundamental look at engine architecture and technology strategy to produce a common platform for current Tier 4 standards, upcoming Stage V standards and future China 4 territories. Designing a solution for each of those markets without compromising any of them was a major challenge, but one which has brought considerable customer benefits in terms of development, logistics and product support.

While a one-size-fits-all approach to technology across a wide power band is not unheard of in the off-highway market, the Syncro design team approached it in a fresh way. They used engineering data from elsewhere in the Perkins range to select the most appropriate technology solution for the 45-100kW Syncro engines (60-134hp). That enabled the systems team to assess the design trade-offs early in the process and to avoid compromises later on, thus optimizing the engine architecture.

Once those decisions were made, the team used telemetry data to assess the real duty cycles of machines in operation. In this case, they examined around 100,000 machines with over 300 million hours of Tier 4 experience to get a real-world view of the fuel-burn rates, ambient conditions and load cycles that impact technology choices.

Finally, the Syncro engines were tested on a fleet of over 20 Perkins-owned machines, generating about 25,000 hours of data from real-world operating environments. That gave the engineers insight into things like installation compatibility, aftertreatment transparency and transient response. It also enabled them to sign-off on the engine in that particular machine type, which further allowed customers to save a considerable amount of work in terms of their own sign-off process.

Long-term outlook

Running this machine fleet is a serious logistical and engineering challenge, but the result is confidence in the design of the engine hardware and functional performance in the real world. It confirms the accuracy of the control system and diagnostics. Most importantly, it gives customers objective data about putting a brand-new engine in their type of machine, as well as the ability to see and test it for themselves. **iVT**

James Reed is an engineering manager at Perkins

CHRISTIAN HOWE

Innovative control systems

SMART DESIGN CAN ENABLE COMPLEX MACHINE FUNCTIONS TO BE CONTROLLED WITH SIMPLE, ERGONOMIC SWITCHES, THUMBWHEELS, PADDLES AND LEVERS, FOR ADVANCED OVERALL FUNCTIONALITY

Curtiss-Wright's Industrial Group is a recognized leader in the research, design and manufacture of electronic throttle and joystick controls, HMI consoles, sensors, transmission shifters, hydraulic levers and power management electronics for off-highway vehicles. The company's portfolio of products is designed to work within the most challenging of environments, while maintaining an operating feel that is, at the same time, both ergonomic and effortless.

Developing trends

The globalization of supply chains, rising labor costs, and continuous improvements in operator health and safety have driven the material handling industry to deliver highly efficient, flexible and safety-critical self-propelled vehicles. The industry has developed a vast array of trucks, machinery and equipment to increase productivity in the transporting, loading, unloading, positioning and picking of materials, goods and products.

In new vehicle designs multiple hydraulic levers and discrete components are now being replaced with electronic human-machine interfaces (HMI) that integrate fully into armrest assemblies and provide operators with a wide range of new capabilities. And for many material handling applications, Curtiss-Wright is developing vehicle controls that incorporate multiple functions that can be operated with the use of just one hand, or via finger or thumb activation. These controls typically comprise push-button switches, rotary thumbwheels and joystick paddles and levers, which variously offer switched and proportional control of a vehicle's numerous features.

There have also been a number of trends and customer requirements that have affected Curtiss-Wright's approach to design and manufacturing. Rapid design techniques have played an important role in reducing the cost of design, with much less time – and therefore money – devoted to prototyping. With respect to manufacturing, thanks to improved technology and CANbus wiring systems, component counts – and the materials subsequently used – have reduced, all of which has contributed to a cost-effective design and has had a positive impact on overall reliability.

ABOVE: **Curtiss-Wright's JC040 joystick controller**

RIGHT: **The JC050 thumbwheel roller from Curtiss-Wright**

Latest innovations

Curtiss-Wright's single-axis JC040 proportional rocker joystick controller is ideal for arduous applications and builds on the successes of legacy potentiometric versions. Using non-contacting, Hall-effect sensing technology for long-life integrity of the output signal, the IP67-rated JC040 provides safety functionality via dual outputs – which can be set to positive, or a combination of positive and negative ramps – and benefits from independent supply voltages for each of the outputs.

The JC040 has been designed for in-cab use with a 'pass through' design for any contamination. Electronic robustness is assured with IP67-rated sealing of the internal PCB. An optional, mechanical over-press feel – that operates at ±20° of travel from the center position – is integrated within the JC040 design to provide additional operator feedback. The electrical output of this mechanical feature can be used in a system to indicate a new mode of operation, such as a rapid traverse.

Another innovation is the Hall-effect JC050 thumbwheel roller, which is suitable for integration within joystick hand-grips and other in-cab HMIs, and features a low under-panel depth of 23mm (0.9in) and return-to-center functionality over a range of ±37° roller travel.

The JC050 is rated for three million operating cycles and, like the JC040, benefits from a 'pass through' design and an IP67 rating for the internal electronics. To ensure safety is enhanced, the JC050's dual-redundant electronic architecture is constructed using two power supplies and two sensing circuits, the outputs of which can be set to positive ramps, a combination of positive and negative ramps, or full voltage range over half travel from each sensor with constant output in the other half travel. **iVT**

Christian Howe is marketing manager at Curtiss-Wright Group

ALEXANDER USSELMANN

Safety without compromise

WITH THE INEXORABLE RISE OF ELECTRIC POWERTRAINS, LITHIUM-ION BATTERIES THAT MAINTAIN HIGH PERFORMANCE BUT DON'T OVERHEAT ARE BECOMING INCREASINGLY ATTRACTIVE

Lithium-ion batteries play an essential role in the vision of electromobility. They offer impressive benefits such as emission-free drives, high efficiency and low self-discharge. But their design also requires special fire-protection features.

Lithium-ion batteries are chemical energy storage systems that release the stored charge through a chemical reaction. When a certain operating temperature is reached, there is a thermal runaway in the battery, which means that it heats up on its own to the point of destruction. This is because lithium-ion batteries, unlike their lead or nickel counterparts, rely on flammable components.

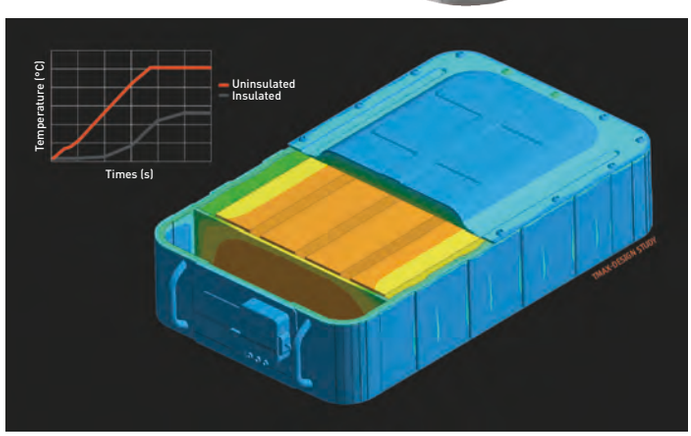
An electronic malfunction or mechanical damage can cause the lithium ions to withdraw the oxygen stored in the cathode, which may result in oxidation of the electrolyte. This creates gases and vapors, while the pressure and temperature increase as a consequence. At temperatures of 120-300°C (248-572°F), the separator melts and the electrolyte starts to burn. This causes a short circuit and thermal decomposition of the cathode. The oxygen released in this process, combined with the thermal energy, ignites the other battery components and can produce temperatures of over 1,000°C (1,832°F).

As a result, lithium-ion batteries are classified as dangerous goods in transport or storage. They respond to their environment with great sensitivity and should never be directly or permanently exposed to higher temperatures.

The development of alternative drives for mining and construction equipment is pushing lithium-ion batteries to center stage, helped by a new safety-focused solution from Thermamax.

Thanks to its long experience with high-temperature insulations, the company can contribute to the operational safety of battery systems. The Tmax-Battery Housing protects the environment against the effects of thermal runaway and safeguards the battery against the risks of high ambient temperatures.

To protect lithium-ion batteries against fire, it is not enough to just develop high-temperature insulation. Instead the temperature must be monitored permanently. This is why the Tmax-Battery Housing has thermal management with high-performance cooling, helping to keep the temperature under control and to ensure safety.



ABOVE: **Thermal management is built in to the Tmax-Battery Housing**

LEFT: **Battery heat map and graph showing differences in temperature gain between insulated and uninsulated lithium-ion batteries**

BELOW: **Tmax-Battery Housing is modular and scalable**

The insulated housing protects the battery from external influences such as water, extreme temperatures, dust or vibrations. If there is a strong increase in pressure, the burst valve opens and thus prevents an explosion. Crucially, the valve automatically closes when the pressure drops.

To sum up, with a modular and scalable design, the Tmax-Battery Housing is easy to maintain and assemble. The system is resistant to high temperatures, pressure balanced and offers protection against water spray, dust and the impact of stone. Having optimal onboard temperature controls, the battery range is maximized with longer lifecycles as well. **iVT**

Alexander Usselmann is a battery systems engineer at Thermamax

FABIO LEPORE

Stage V competitor

CATALYST TECHNOLOGIES APPEARING ON THE MARKET ARE ENSURING INDUSTRIAL VEHICLES MEET TOUGHER EMISSIONS LEGISLATION WHILE ALSO OFFERING HIGH LEVELS OF PERFORMANCE

FPT Industrial exhibited its Stage V engines – dedicated to agriculture applications – at EIMA, in Bologna, Italy, in November 2018. These solutions combine emission compliance and features that make each engine the perfect solution for any need. The Italian company has focused its R&D activities on becoming a leader in innovation in agriculture powertrains and a go-to provider of the most advanced solutions with a low environmental footprint. Compliance with emission standards comes with minimal impact on vehicle architecture. HI-eSCR is a breakthrough technology bringing enormous performance and efficiency benefits. This FPT Industrial patent makes the most of a 25-year, million-unit experience. To comply with future Stage V standards, the second-generation HI-eSCR2 is building competitive advantage, including best-in-class performance and low running costs.

Stage IV FPT Industrial's patented HI-eSCR system can reduce NO_x levels by more than 95%, offering best-in-class conversion efficiency; moreover, thanks to its lack of diesel particulate filter (DPF), the FPT solution is maintenance-free and requires no regeneration, improving productivity by avoiding mid-operation downtime for filter cleaning or replacement. To maintain the advantages of the unique HI-eSCR technology, FPT Industrial will integrate a maintenance-free filtering device on its selective catalytic reduction (SCR) catalyst, thus enabling compliance with tightened limits on particulate matter (PM) emissions within a compact package.

The second-generation HI-eSCR2, applicable for engines above 56kW (75hp) and below 560kW (750hp), where different emission limits apply, will maintain the same aftertreatment dimension of the current Stage IV applications, requiring neither machine redesign nor layout changes for easier upgrade to the next emission level. Thanks to optimized combustion, it boasts excellent performance and fuel efficiency. Maintenance-free aftertreatment and zero requirement for parked regeneration also ensure low running costs by helping prevent unplanned downtime.

FPT Industrial's offer starts at 55kW (73hp), with the F34 engine: without needing an SCR, it has a diesel oxidization catalyst (DOC) and a DPF mounted on the flywheel. It delivers a maximum torque of 424Nm at 1,200rpm and has a 600-hour oil change interval.

FPT Industrial's HI-eSCR2 technology maintains the same aftertreatment dimensions used in current Stage IV applications

Maximum power is reached with the V20: it can deliver 678kW (910hp) while remaining best-in-class for compactness and power-to-weight ratio. Between these, there is the Cursor 9 Stage V engine, a high performer with up to 7% more power density than its competitors. Plus, being exhaust gas recirculation free (EGR) and adopting a maintenance-free HI-eSCR2 technology, it brings reliability, low fuel consumption and high efficiency.

At EIMA, FPT Industrial also exhibited its PowerPack, a new solution that encloses all key aftertreatment components in a single package, enabling an easy upgrade to meet Stage V requirements. This pre-packed HI-eSCR2 solution was shown within the F36 and the N67 engines, characterized by greater power than previous versions, delivering 106kW (143hp) and 264kW (354hp), respectively. **iVT**

Fabio Lepore is a press officer at FPT Industrial

LEONHARD BAZLEN

Combating the cold

THE LATEST HEATING TECHNOLOGY PROVIDES A QUIET, EFFICIENT AND RELIABLE WAY TO KEEP VEHICLE CABS COMFORTABLE IN EXTREME CONDITIONS, WHILE WATER HEATERS CAN HELP PREHEAT MOTORS AND CLEAR ICE FROM WINDOWS

In order to maintain pleasant temperatures in an off-highway vehicle cab when it's cold and windy outside, powerful preheaters are needed. Heating and air-conditioning expert Eberspächer manufactures just such hardware.

Its Airtronic 2, for example, is a fuel-operated air heater that efficiently warms vehicle cabins to help maintain operator performance in cold conditions. It is available as a compact Airtronic S2 Commercial version, which can even be integrated into tight installation spaces in small construction vehicles. It benefits from an optimized heating mode with stepless heating performance control for efficient and quiet heating. Its integrated altitude sensor permits automatic adaptation for optimized combustion, making it suitable for use in mountainous regions. Heaters from the second Airtronic generation are therefore particularly durable and reliable companions, not least thanks to their brushless motors.

ABOVE: **The Airtronic S2 Commercial is a compact, quiet heater for use in industrial vehicle cabs**

RIGHT: **The EasyStart Pro enables one or two heaters to be controlled from a central point**

BELOW: **The Hydronic S3 Commercial water heater is compatible with most vehicle control units**

Ice-free windows, preheated motor

If the motor needs to be preheated or the windows defrosted, then Eberspächer's Hydronic water heater comes into play. The third-generation of this piece of hardware provides efficient heating performance in a compact design. With their wide range of outputs from 1.3-5kW, the Hydronic S3 Economy and the Hydronic S3 Commercial featuring the 5.6kW power variant are suitable for many different machines, from special purpose vehicles to heavy-duty trucks.

With their robust design and brushless motor, Hydronic water heaters are built to last. The Hydronic S3 Commercial (24V) power variant is a new development, producing a 5.6kW heat output and featuring automatic adjustment at altitudes for trucks and construction site vehicles.

Simple operation with EasyStart Pro

Control units from the EasyStart family are available for convenient preheater operation. The new, permanently installed EasyStart Pro control unit can be surface-mounted or flush-mounted to fit the available space. Operation is intuitive for the driver.

The required start time and heating period are preset using the timer function. The integrated temperature sensor ensures optimal temperature control. The display and an LED color ring surrounding the operating knob clearly indicate whether heating mode is active. Another advantage, particularly for vehicles with several heaters, is central control of up to two heaters at the same time. In addition to the Airtronic, a Hydronic water heater can be operated to preheat the engine, for example. Eberspächer preheaters can also be controlled remotely using the EasyStart Web app.

Additionally, fleet operators benefit from the advantage of being able to operate up to five heaters per user account.

Eberspächer will exhibit products including the latest generation of the Airtronic and Hydronic family and the associated EasyStart Pro operating element in Hall A4, Stand 249, at the 2019 Bauma trade fair in Munich.

About the company

With approximately 10,000 employees at 80 locations worldwide, the Eberspächer Group is headquartered in Esslingen am Neckar, Germany. It specializes in innovative solutions in exhaust technology, automotive electronics and thermal management for a broad range of vehicle types. Eberspächer components and systems provide more comfort, greater safety and a cleaner environment, on or off the road. In 2017, the group generated revenue of around €4.5bn (US$5.15bn). **iVT**

Leonhard Bazlen is senior marketing segment manager for Eberspächer Climate Control Systems

JEANINE BOUDREAU

Operator-assist extras

A SHORTAGE OF SKILLED LABOR IN THE CONSTRUCTION INDUSTRY IS A CHRONIC PROBLEM, BUT DESIGN ENGINEERS CAN BUILD IN TECHNOLOGIES THAT CAN OVERCOME THE ISSUE

Many industries are suffering from a skilled labor shortage. According to the Bureau of Labor Statistics, 200,000 construction positions are unfilled across the USA – that's an increase of 81% in two years.[1] Additionally, 80% of contractors are currently struggling to find skilled workers able to operate their equipment.[2]

Although design engineers can't solve the skilled labor shortage, they can leverage technology to give more capabilities to the equipment used by unskilled laborers. Often this means incorporating advanced sensors and switches into vehicles. Inertial measurement units (IMU) are a type of technology that give operators important information about a vehicle's position, or the position of its parts relative to the ground. Having this information can help prevent rollovers, which are the leading cause of death for operators of heavy equipment.[3]

Withstanding tough conditions

Of course, not all IMUs are suitable for vehicle applications because of the rugged and harsh environments they need to withstand. Honeywell, a trusted name in industrial equipment manufacturing, has developed the Tars-IMU, which gives design engineers the freedom to bring operator-assist features to more vehicles. It was designed to increase efficiency with the automation of repetitive movement and it can filter out noise that interferes with accurate positioning data. The Tars-IMU also has a fusion algorithm that can be customized for specific vehicle applications through onboard firmware.

An example both of potential customization and of extending the capability of a common vehicle, is using the Tars-IMU to bring ground-leveling capabilities to skid-steer loaders. Skid-steers are small, engine-powered machines that are extremely maneuverable and valuable in situations that require compact, agile loading capability. However, nimble as they are, these small loaders have far less ability to perform grading and ground-leveling. Larger, harder-to-operate machines are equipped with technologies that enable operators to precisely grade and level the jobsite.

To address the skid-steer's deficiency in grading and ground-leveling, a Tars-IMU was programmed to meet its parameters. By integrating the IMU with the machine's equipment control unit, feedback can be sent to the operator about where the machine is sitting in relation to gradient. Such indicators enable the operator to make real-time adjustments to the grade as the loader is in motion. In fact, in this case, operators can use the Tars-IMU-equipped loader to achieve a level of 0.6° – equivalent to a 1% grade for proper water run-off. **iVT**

ABOVE: **The Tars-IMU can be customized for specific vehicle applications**

LEFT: **Ground-leveling capabilities in skid-steer loaders have been enhanced by the Tars-IMU**

Jeanine Boudreau is an account manager at RocketLawnchair

1) National Association of Home Builders, ProBuilder.com
2) 2018 Industry-wide survey by Autodesk and the Associated General Contractors of America.
3) 2013 data from the bureau of Labor Statistics

LINDA VAN DIJK

Smart warehouse technology

GOOD VISIBILITY AROUND MACHINERY AND VEHICLES IMPROVES SAFETY AND EFFICIENCY IN WAREHOUSES AND DISTRIBUTION CENTERS

Cameras are an indispensable feature in warehouse vehicles, trucks, agricultural vehicles, cranes and construction machinery. The fast, shock-resistant EMOS Ethernet camera from Orlaco takes camera technology to the next level.

An increasing number of industrial vehicles worldwide are being equipped with Ethernet networks. This means that they can be used in new, intelligent ways to improve safety, efficiency and ergonomics. With the EMOS, Orlaco offers a versatile Ethernet camera for use in smart warehouses (Industry 4.0). There are two variants of the EMOS camera: Fast Ethernet (100BASE-TX) and BroadR-Reach (100BASE-T1).

The Orlaco EMOS is a low-latency Ethernet camera compatible with onboard computer systems used in industrial vehicles

Harsh conditions

The EMOS is designed to perform in the harshest of conditions. The camera is shock resistant (50*g*), vibration resistant, and is resistant to temperatures between -40°C and +85°C (-40°F and +185°F). It has an aluminum housing with two-component potting and is completely waterproof (IP68/IP69k). The camera is therefore suitable for industrial environments, including cold storage units.

Real-time images

The camera stands out thanks to its compact 55 x 60 x 24mm size (2.1 x 2.3 x 0.9in), its light 150g weight (15.2oz) and low <2W power consumption. The digital camera is ideal for integration into onboard computer systems, with a startup time of less than two seconds, a delay of only 48ms (system latency ~90ms), and HD display quality.

Intelligent applications

The high-definition (HD) display, combined with extremely low delay, makes it possible for intelligent technologies to be used on the camera images obtained by mobile industrial vehicles. The EMOS Ethernet camera has options for real-time remote view, image recognition, and 360° view. It is suitable for use on forklifts, trucks, cranes, construction machinery, and more.

The EMOS camera can be mounted on the fork carriage of a warehouse vehicle or can be used as a rear-view solution, increasing safety and efficiency in warehouses and distribution centers. Improved visibility also reduces direct costs, for example with fewer damage calculations, less machine downtime and fewer broken goods. Additional advantages are improved staff comfort and working conditions.

The EMOS can be easily integrated into rugged mobile computers, which are frequently used in warehouse vehicles. The camera can be connected to an existing screen, meaning that there is no need for an extra screen in the warehouse vehicle's cab. This is particularly important in small-sized vehicles, as additional screens can limit the operator's freedom of movement and block direct view.

Event highlights

Orlaco will present the EMOS for use in warehouses and distribution centers at one of the world's largest supply chain and logistics trade fairs – Promat, which is taking place in Chicago, USA, from April 8-11, 2019.

The EMOS will also be in the spotlight at the leading construction Bauma trade fair in Munich, Germany, from April 8-14, 2019.

Orlaco is aiming to use these trade fairs as an opportunity to open up conversation about the integration of EMOS on various platforms with OEMs, mobile computer manufacturers, software developers and users.

An important theme within logistics is the smart warehouse, and there is a particular focus on improving cooperation between people, smart machines and technology. The EMOS has the potential to play an important role in this arena. With IP technology, the camera can be added to existing IP networks.

Highest standard of quality

Orlaco is a leading global camera monitor specialist for industrial mobile vehicles. Each year, the company produces more than 200,000 cameras, vision systems and monitors. Approximately 70% of these are delivered directly to the world's largest OEMs. Orlaco's camera monitor systems are all designed, engineered, produced and tested in the Netherlands according to the highest international standards of quality. **iVT**

Linda van Dijk is communications project manager at Orlaco

STEPHAN GRITSCH

Compact Stage V power

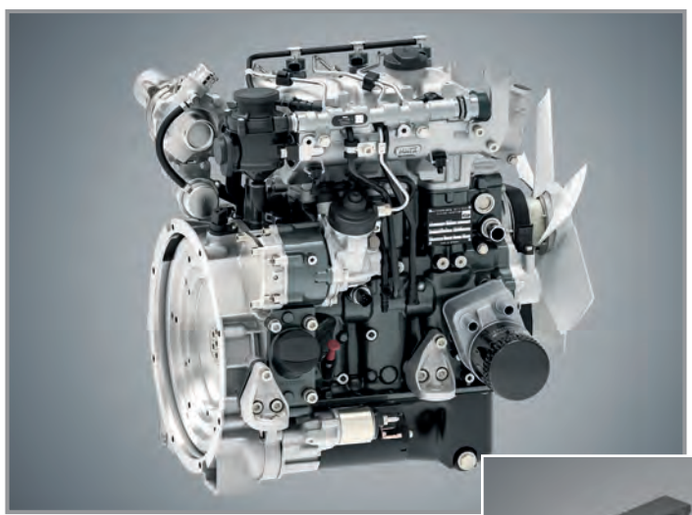
UPGRADING SMALL MACHINES TO STAGE V CAN BE A CHALLENGE, WHICH IS WHY OEMs ARE LOOKING TO COMPACT SOLUTIONS THAT WON'T REQUIRE EXTENSTIVE VEHICLE REDESIGNS

Motorenfabrik Hatz presents the newest member of its H-series: the Stage V-compliant 3H50T industrial diesel engine. The compact, liquid-cooled, three-cylinder diesel engine is available as a fan-to-flywheel version and as an open power unit (OPU). The 3H50T, which has a performance class under 19kW (26hp), has a displacement of only 1.5 liters (0.4 gallons) and a maximum output of 130Nm – making it one of the highest torque models in its class on the market today. The engine achieves its output without an intercooler.

Thanks to its small dimensions, light weight and absence of a diesel particulate filter (DPF), the 3H50T is suitable for use in compact machines – thereby giving manufacturers the option to build their machines with small engine compartments. In addition, it allows machines to be upgraded to EU Stage V compliance, at the same time safeguarding previous investments input into the design and development of the machine.

Saving on space

The Hatz 3H50T engine emits an extremely low particle mass that also achieves only a tenth of the limit value (for EU Stage V this is 0.4g/kWh) without further exhaust emission aftertreatment, such as a diesel oxidation catalyst or exhaust gas recirculation.



LEFT: **The fly-to-flywheel Hatz 3H50T**

BELOW: **The 3H50T OPU (open power unit) is a plug-and-play solution**

During development of the 3H50T, Hatz consistently followed the H-series engine strategy of incorporating state-of-the-art materials and technologies such as turbochargers and a Bosch common-rail system (for the off-highway version). The resulting series consists of compact, robust and reliable engines that all feature high torque at low speed.

Engine type	**Hatz 3H50T**	**Hatz 3H50T OPU**
Type	Water-cooled 4-stroke diesel engine	
Cylinders	3	
Injection system	Bosch common-rail system OHW	
Injection pressure [bar]	1,800	
Turbocharging system	Turbocharged engine without charge air cooling	
Exhaust emission after-treatment	–	
Max. power [kW]	18.4 @ 1,350-2,600rpm	
Max. torque [Nm]	130 @ 1,300rpm	
Emission stages	Stage V, EPA Tier 4 final	
Maintenance	500 hours standard interval	
Model	Fan-to-Flywheel	OPU (only tank, display and battery required)
Installation dimensions L x W x H [mm]	577 x 650 x 604	577 x 650 x 662*
Weight [kg]	132	147*

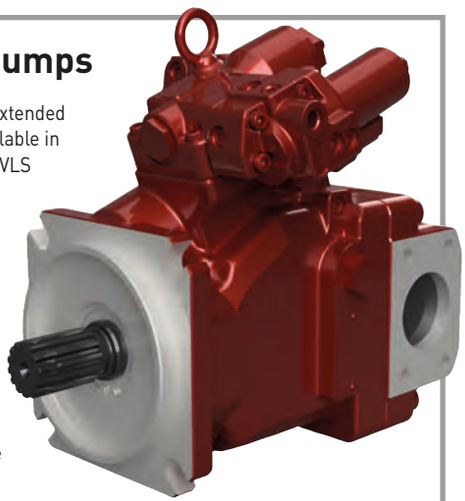
* Preliminary values

The Hatz 3H50T OPU is a plug-and-play solution that is ideal for use in compact machines where engines need to be ready-to-use when installed. Examples of applications include lifting platforms, hydraulic systems, drilling machines and stationary applications such as pumps and alternators. With the integrated and optimal design of its radiator, hoses, cabling and electronics, the Hatz OPU concept greatly simplifies design and installation. **iVT**

Stephan Gritsch is marketing team leader at Motorenfabrik Hatz

BULLETIN BOARD

Power shift pumps



Kawasaki has extended the options available in its K3VL and K3VLS series of medium-high pressure piston pumps to include torque limit control with remotely adjustable settings.

Utilizing the expertise gained as a leading manufacturer of hydraulic pumps for excavators, Kawasaki has been able to introduce this feature for use on many different types of construction machinery.

The control is referred to as 'power shift' because it enables the machine operator to change or shift the pump torque limiter setting from a high power setting to a lower one. The shift is activated by means of a hydraulic or electric signal. When a machine's engine is operating at low idle, available torque is low and can be stalled. Using the power shift control, input torque to the pump can be restricted, to prevent the engine overloading and stalling at varying engine speeds and output power. Optimizing the power input demands of the pump in this way can result in significant savings in fuel consumption and emissions.

Power shift is available on the 320 bar-rated K3VL series in frame sizes 80cc to 200cc and on the 280 bar-rated K3VLS series pumps in frame sizes 50cc to 150cc. Contact Kawasaki for more information.

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Quote Ref: **511**

Tailor-made solutions

The P09 is a compact electronic pedal that delivers high-precision operation and enhanced ergonomics. Sometimes, however, even the best quality product fails to meet the consumer's needs at first. Additional effort is required to create a bespoke product.

Finnish company Vilakone has a multifunctional machine called Wille that is popular for environmental and property maintenance tasks, especially in the Nordic countries.

Vilakone was seeking to replace its current pedal with a more robust and long-lasting version. At the time, **Caldaro**'s P09 pedal was only available as a 30° version.

"The people from Caldaro quickly responded to us with a 45° version of the pedal that was a perfect fit for our use", says Antti Lindström, industrial designer at Vilakone.

The signals, connector and wiring of the pedal were also customized by Caldaro to meet the specifications provided by Vilakone.

"The development process with Caldaro was quick and pleasant, and included a functional 3D-printed prototype for verifying the design. Now the pedal is ready for production, and soon it will be used in all Wille models," says Lindström.

"We always try to meet customers' needs," says Erik Kauppi, sales engineer at Caldaro. "I smile now whenever I see a Wille machine clearing snow here in Stockholm, Sweden."

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Quote Ref: **512**

Power for steering independence

Mobil Elektronik showcased the new version of its Hydraulic Power Pack at IAA 2018 commercial vehicle show in Hannover, Germany, in September.

Manufacturers of trucks and buses, as well as chassis modification companies, appreciate the high performance of this unit. Powered by a 2.7kW asynchronous motor, the Hydraulic Power Pack is able to steer the rear axle of a fully-loaded vehicle at the same speed as the driver moving the front axle. This is a very important feature for trucks on construction sites or during complicated maneuvers.

The increasing popularity of electric buses has been reflected in the growing demand for the Hydraulic Power Pack. These vehicles do not have any power take-off (PTO) engine-driven hydraulic supply, so there is a need for an independent hydraulic supply. A further benefit of the Hydraulic Power Pack is that it is a low-noise device.

The Hydraulic Power Pack demonstrates Mobil Elektronik's flexibility. It can be applied to different vehicle geometries according to parameter setting.

The pack communicates with the safety steering computer via CANbus to monitor the rotational direction of the engine, its speed and its status.

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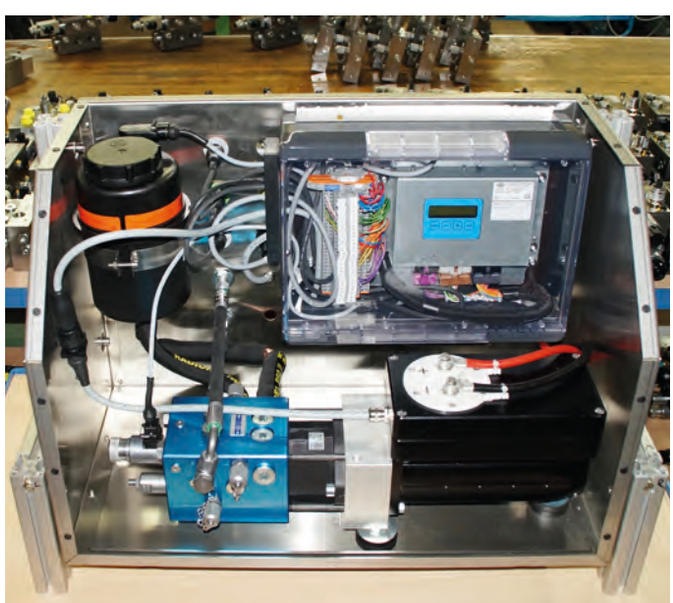

A robust, affordable display

Specializing in the development and production of technology for off-highway vehicles, German company **Bauser** offers flexible and affordable displays that can be customized to suit user requirements.

Type 819.TFT is a color TFT LC display that is capable of holding several LED warning lamps. Two optional buttons can be added for setting the time and date or scrolling through the menu screens.

The design of the human-machine interface (HMI) is simple, clear and customizable. The operator can use bar graphs, digits, symbols or text outputs. Graphic 320x240 dots can be used for a variety of visualization

purposes, including error codes or warnings from the machine's electronic control unit (ECU), speed indication in miles or kilometers per hour, temperature values, and machine operation and service hours.

Type 819.TFT comprises 26 connector pins (optionally super-sealed). It can be used for digital inputs, analog sensors, digital outputs and communicating via CANbus.

The CANbus communication is capable of working with standardized protocols such as CANopen and/or SAE J1939.

Type 819.TFT's optional extras include a custom front fascia, custom colored HMI, integrated audible alarm (approximately 85dB) and a real-time clock. It is operational in rough environments at temperatures of -30°C to +85°C (-22°F to 185°F).

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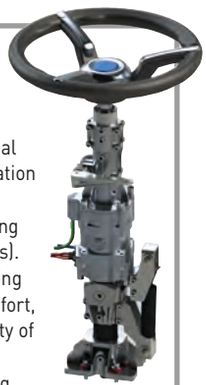
Quote Ref: **514**

Enhanced steering experience



The 2018 EIMA International Award for Technical Innovation was awarded to **Ognibene Power**, a supplier of hydraulic steering systems (actuators and steering units).

The innovative digital power steering (DPS) system improves steering comfort, safety and productivity, and the quality of work for industrial vehicles.

Placed over the traditional steering system of off-highway vehicles to improve maneuverability, the DPS makes use of a global positioning system (GPS) and joystick without an additional external steering system.

Key benefits of the DPS include: direct integration with GPS guidance; steering wheel re-centering in forward and reverse gears; speed-dependent steering assistance; programmable driving (synthetic boost curve); and haptic feedback on the steering wheel.

Ognibene Group has production sites in Italy, Brazil, India and China, as well as a logistics site in the USA and a commercial office in Japan.

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To learn more about this advertiser, visit ukimediaevents.com/info/ivm
Quote Ref: **515**

For use in challenging environments

ASM Sensors has updated its proven posiwire cable-extension sensor: the WS12. Now with magnetic absolute encoder technology, the sensor's non-contact magnetic multi-Hall technology is wear- and tear-resistant, therefore more robust than optical encoders.

The WS12 sensor measures up to 3,000mm (9.8ft) and is enclosed in aluminum that is resistant to shock, vibration and dirt damage. The IP protection class is up to IP67 with a mating connector and the sensor operates precisely over a temperature range of -20°C to +85°C (-4°F to 185°F).

Due to the robust encoder technology, the sensor can reliably detect measuring data ,even if the housing is filled with water or oil. This means the WS12 is well suited for use in outdoor applications.

Analog outputs are available as 0.5-10V and 0.5-4.5V, or 4-20mA, while digital outputs are CAN, CANopen and SSI (synchronous serial interface).

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Advanced air-conditioning ergonomics

Kalori's butterfly valve improves air-conditioning ergonomics by enhancing the system's distribution of air.

The throttle flap is activated by an actuator, which is controlled either by a dedicated button or by the new PCK3 panel from the Kalori TrimLine range. This enables the operator to open or close the air distribution in any area of the cabin.

The butterfly valve is installed on an air duct, or on the air distribution plenum of heating, ventilation and air-conditioning (HVAC) units. A single actuator can control up to five throttle valves, as it is possible for these to be connected.

The operator can set up an air distribution arbitration to a single area of the machine's cab.

The butterfly valve adds sophistication to a cab's interior and it can be adapted to any HVAC system in the Kalori range without the operator needing to invest in a specific HVAC system.

An economical, cable-controlled version of the butterfly valve is also available.

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THE BIRTH OF THE SKID-STEER

Bobcat celebrates the 60th anniversary of the machine that single-handedly kick-started the compact equipment industry

The M200 was among the first loaders manufactured after the Keller brothers joined Melroe in 1958

60 YEARS 1958 TO 2018 Bobcat®

Just over 60 years ago, the Keller brothers, Louis and Cyril, invented a compact front-end loader, but little did they know how significant it would be – both for the vehicle industry and for their tiny business.

The three-wheeled loader, built in Rothsay, Minnesota, for a turkey farmer whose barns needed cleaning, had a rear caster wheel and two drive wheels with a clutch drive mechanism that, at the time, really made competitors sit up and take notice.

Melroe Manufacturing was one such company and the Keller brothers were recruited by the North Dakota-based firm in 1958. With greater resources behind it, the loader went through several generations. The M60 and M200 were two further three-wheeled versions of the vehicle, which eventually evolved into the world's first true skid-steer loader, the M400. With a rear axle added, what made the four-wheel-drive machine unique was its two independent transmissions that enabled it to turn in its tracks.

The vehicle was initially somewhat under-appreciated, and in 1962, Melroe was close to exiting the loader business, but had enough confidence in the uniqueness of its M400 to have one final attempt at helping the US public see the vehicle's quality. A 15.5hp (11.5kW), two-cylinder Kohler engine was fitted, and the drive system was redesigned, enclosing it in side tanks so that the operator entered the vehicle from the front.

A rebrand of the vehicle was also carried out. The resulting M440 Melroe Bobcat with the now familiar white and red color scheme, which is still closely associated with Bobcat products, was an instant hit and sales soon topped US$6m.

The success of the skid-steer can arguably claim to have single-handedly created the compact equipment industry that we have today. Six decades later, and with the might of Doosan – which bought the brand in 2007 – behind it, one in every two skid-steer loaders sold is a Bobcat vehicle. **iVT**

Read our case study on Doosan's new articulated hauler, the DA30, on **page 64**; and watch a video showing the evolution of the Bobcat skid-steer loader at **ivtinternational.com/skid-steer**

The M400 was the first four-wheeled skid-steer loader

The Bobcat brand was born with the M440

The slightly larger M444 was the first to be sold in Europe

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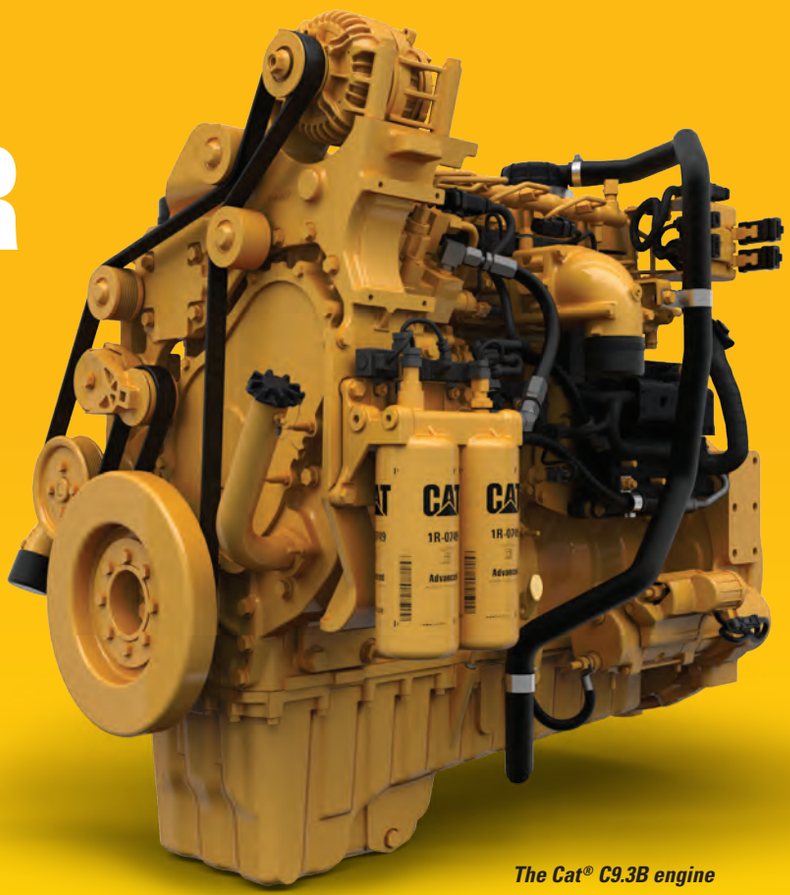

The Cat® C9.3B engine

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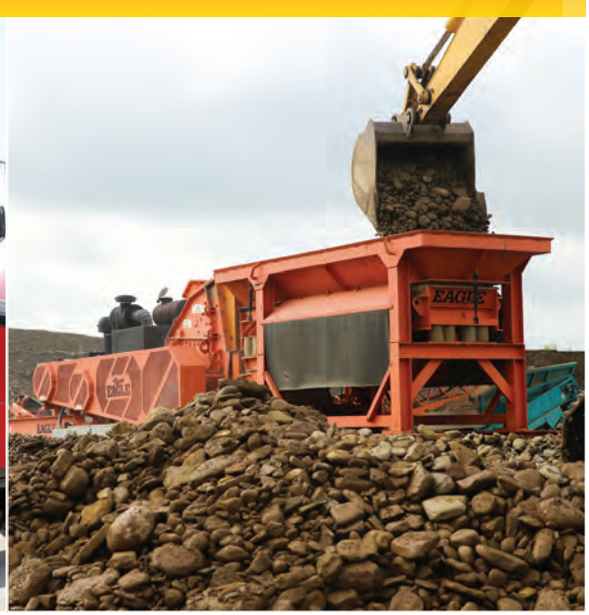

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