Q&A COMPLETIONS

OILFIELD TECHNOLOGY INVITED EXPERTS FROM CARBO, FRANK'S INTERNATIONAL, CATERPILLAR, AND TENDEKA TO SHARE THEIR KNOWLEDGE ON A VARIETY OF COMPLETIONS TOPICS. READ ON FOR INSIGHTS FROM:

CARBO

TERRY PALISCH is global engineering director at CARBO Ceramics and leads a team advising clients on completion/fracture optimisation. He has authored over 40 SPE technical papers, is past chairman and board member of the SPE Dallas Section and is a member of the ATCE Program committee, including the 2017 Program Chair.

FRANK'S INTERNATIONAL

STEPHEN LEBLANC currently serves as Engineering Manager in the Technology Enhancement department. He has held various roles since joining Frank's International in 2008, including Design Engineer and Engineering Team Leader.

DR. BRENNAN DOMEC is the Director of Strategic Technology at Frank's International. Dr. Domec leads a team of multi-discipline engineers, scientists, and researchers tasked with the research and development of emerging and disruptive technologies, rig-of-the-future concepts, and think-tank ideation.

LOGAN SMITH has been with Frank's International for 12 years and is currently New Product Delivery Manager and oversees efficiently launching new products and services.

CATERPILLAR

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TENDEKA

ANNABEL GREEN joined Tendeka from Weatherford where she spent more than 14 years in numerous technical and R&D roles – both in the UK and overseas. She has broad experience in sand control, reservoir completions and general completion technology across global markets.

COMPLETION TOOLS

TENDEKA – ANNABEL GREEN

In conventional reservoirs there are two main reasons for running a completion across the reservoir: to control sand production and/or to optimise inflow.

Both are highly specialised subjects, and this is reflected in both the range of technologies and the ongoing focus on development in these areas. Inflow optimisation is fundamental to field economics; in the FEED phase, long before a final investment decision (FID) is made, evaluation and screening of potential reservoir or advanced completions executed.

Detailed planning of the optimal completion configuration occurs throughout the execution phase with final configurations often determined only once the logging while drilling (LWD) data becomes available and the completion is lying on the deck of the rig. This reservoir completion is then expected to provide the functionality required for the life of the well. Top-hole workovers are common practice but for reservoir completions this is where operations end, or at least it used to be.

As fields mature, the range of production and recovery challenges increase or become more apparent – unwanted fluids are produced, differential depletion occurs, and hydrocarbons are bypassed. On the flip side, new developments provide an increased range of solutions that can contribute to improved performance, and so a trend towards retrofitting advanced completions into existing wellbores can be seen. These are not only aimed at improving production but optimising secondary and tertiary recovery projects and reducing well intervention requirements.

There are some key technologies that are enabling this trend:

- Through-tubing autonomous and wireless technology that can be installed to manage inflow without linkage back to surface or mechanical manipulation.
- Advanced packer technologies that can compartmentalise the production zones.
- Chemical solutions that can access the existing wellbore annulus and high expansion swellable and mechanical options.

As with primary reservoir completions the range of technologies is increasing with the latest systems offering full intelligent completion functionality.

CATERPILLAR – SHAUN BOLLER & DANIELLE WILLS

Fluid end and power end maintenance are significant cost drivers for pressure pumping operators. Even with proper employee training and diligent pump maintenance, seemingly minor problems can cause catastrophic failure of components, leading to extended downtime or removal of the trailer from the well site.

Based on extensive research with customers, the PEMS® Pump Electronic Monitoring System was developed for new installation on or retrofit of triplex and quintuplex well stimulation pumps in the 2000 - 3000 hp range. The PEMS instrumentation covers both the fluid end and power end and can mitigate severe damage to all pump components as its J1939 diagnostic event codes are displayed to the operators. The J1939 output is agnostic to the trailer control system and is designed for simple installation and minimal commissioning.

The heart of the system performance is a diagnostics decision engine which analyses the pump components with sampling rates corresponding to the speed of each potential failure phenomena – be it fluid end leak or cavitation, or issues with the power end lube circuit. The system also maintains summaries of pump utilisation to help correlate maintenance schedules with duty in service.

FRANK'S INTERNATIONAL – STEPHEN LEBLANC

Mechanical damage to the surface of corrosion resistant alloy (CRA) tubulars, which the dies of conventional power tongs often impart during the installation process, has the potential to lead to premature failure of the tubular in the wellbore. Considering the high cost of CRA tubular goods, in addition to the cost, time, and danger associated with pipe failure, it is critical to minimise all surface damage during assembly and disassembly of threaded connections.

An improved means for gripping tubular goods, one that does not cause surface damage or structural deformation, is the Fluid Grip® Tong, wherein an inflatable bladder-like structure pressurises the tubular so that friction can transfer the torque to make the connection. In contrast to conventional gripping devices with CAM-activated jaws and dies, the Fluid Grip Tong requires the introduction of hydraulic fluid flow and pressure to pressurise elastomeric bladders, which effectively establish a high friction engagement between a rigid outer housing that encases the elastomeric bladders and a tubular member. The generated hydrostatic pressure is evenly distributed about the circumference of the tubular member, resulting in a significant reduction in contact stress and the reduction or elimination of connection distortion and zero permanent defects on the surface of the tubular.

The latest iteration of the Fluid Grip technology, the Remote Fluid Grip Tong, has been used successfully on several jobs, including a deepwater project for an independent operator in the Gulf of Mexico. Frank's International landed out the first completion for this project using the Frank's remotely-controlled Fluid Grip Tong (patent pending). The Remote Fluid Grip Tong was deployed first to build stands on the auxiliary side rotary. After which, the Remote Fluid Grip Tong was used to run 19 502 ft of 5.5 in. 23 and 26 lb/ft tubing and 4000 ft of 7 in. vacuum insulated tubing (VIT), for a total buoyed weight of 659 304 lb. The minimal tubular surface damage and the increased safety of a remotely-controlled system made this an effective choice for the customer.

Using new non-marking technologies such as the Remote Fluid Grip Tong will result in less pipe body failures due to accelerated corrosion with the added safety benefits of operating the system using remote control panels away from the rig's rotary.

MULTISTAGE COMPLETIONS

CARBO – TERRY PALISCH

In multi-stage hydraulic fracturing programmes, there are many variables that can alter the effectiveness of the frac design. These factors include well volume, proppant selection, fracture spacing and treatment rate. Effective frac designs can enhance production and improve

operating economics by preventing design, operational and production issues that typically arise during the fracturing process. STRATAGEN, a CARBO business, provides fracture consulting services, specifically fracture design and evaluation, onsite fracture supervision and advisory services and well performance analysis to identify the optimal balance of contact and conductivity for the reservoir and to safeguard fracture execution.

STRATAGEN has developed BASINWORX™ to provide operators with a multi-well evaluation for frac and completion optimisation. BASINWORX employs artificial neural network (ANN) modelling and other artificial intelligence techniques as well as machine learning techniques to develop data-driven models to identify factors that optimise production in fractured completions. The key indicators of reservoir performance are used for the optimisation of frac and completion designs.

Models are built from completion and geology data types to predict new well production. The BASINWORX modelling process includes the following steps:

- Build a predictive model by incorporating multidisciplinary data and artificial intelligence modelling technique.
- Perform sensitivities on the model to quantify the impact of each predictor and rank significance.
- Evaluate well performance using alternative completion and frac designs.
- Discover hidden correlations within the data using advanced multivariate statistical data evaluation.

BASINWORX evaluations provide an index of the critical reservoir, drilling, fracturing and completion factors that drive productivity in the field. When working with unconventional reservoirs, success is largely contingent upon identifying the optimal frac and completion design for each particular well. The detailed multi-well evaluation produced by STRATAGEN's BASINWORX can assist in developing more effective frac designs both economically and for enhanced production.

WIRELESS SYSTEMS

CATERPILLAR – MARTIN BAEHR & DANIELLE WILLS

Cat® Connect is changing the way equipment is monitored through a collection of services, which provide a remote monitoring system to help remove guesswork from asset management. The system allows operators to work efficiently and smarter by receiving accurate, timely and useful information about location, utilisation, and the condition of equipment. This type of information can make a huge difference in the efficiency and costs of the entire operation.

One service within the system is the Product Link™ Web, which has an intuitive web interface that transforms data from a customer's entire fleet of equipment into the essential information required to boost productivity, reduce costs, and manage risks. With Product Link hardware and Product Link Web services, customers know where their equipment is, what it is doing, and how it is performing.

One of Caterpillar's newest features for this hardware is the Product Link Configuration Tool. The company has developed an online and offline version of the tool to allow users access to more features. The tool provides a common user experience between the online and offline tools. Both the online Product Link Web Configuration Tool and offline Product Link Local PC Configuration Tool have similar features such as, creating and editing a configuration, using templates to add parameters and features, and deploying the configuration to the PLE601 Network Manager. In addition, the local PC offline tool has extra features to help make importing, editing, and redeploying files an easier process for the user.

TENDEKA – ANNABEL GREEN

To combat the limitations associated with the use of conventional control lines, the development and deployment of wireless completions equipment is now becoming more prevalent.

From drill stem testing to multi-node intelligent completions, the shift from downhole equipment with no communication and/or actuation mechanisms to wireless technology represents potentially huge efficiency and performance savings, as well as improved safety. However, these solutions tend to be targeted towards new field developments where there are currently limited options for replacement of failed equipment, or applications for existing wells, other than to conduct a complete workover.

For instance, there are a variety of digital oilfield solutions on the market today for topside applications, which can be integrated into existing fields to manage data and automate processes. Unfortunately, the same cannot be said for downhole solutions. The limited scope of intelligent equipment available does not address the needs of existing assets and can therefore demonstrate limited value. Without these retrofittable, intelligent downhole systems, the full benefit of the digital oilfield is beyond the reach economically for many mature fields.

Tendeka has developed a pressure pulse telemetry system, which can be applied to downhole devices for communication in a flowing well. The system provides a versatile wireless alternative to existing data transfer and actuation methods within both production and injection wells.

The telemetry was first applied to a retrofit downhole pressure and temperature monitoring system, creating the PulseEight Wireless Gauge, which expanded upon the limited functionality of the traditional industry memory gauge. This provided a means of adding real time downhole data from an existing well into reservoir models, rather than waiting for the memory gauge to be retrieved to surface for download before analysis could begin.

The system's additional ability to function autonomously in reaction to specific wellbore events, without the need of surface instruction, opens a new chapter in the digital oilfield delivery. It now brings aspects of data analysis downhole to illicit responses in a timeframe unachievable by traditional human analysis and action alone.

Intelligent, wireless technology, as a minimum, could simplify and confidently advance digital oilfield operations by removing the need for traditional hydraulic or electric control lines. The removal of these items can positively impact overall system costs whilst delivering an improved design from a safety aspect. Moreover, the truly intelligent capability of modern tooling sees the absolute need of surface data analysis for key trigger points in the well lifecycle to be mitigated, leaving engineering time to focus on more complex aspects of the reservoir's production potential.

The future for this and other technologies should be to extend the operating envelope for intelligent completions

and address its various applications. With advances in surface data analysis, autonomous completion tools which can link both inter-tool, but also inter-well, should be considered as the next step for production optimisation over multiple wells and have demonstrable value to both existing and new field developments.

SAND CONTROL

CARBO – TERRY PALISCH

During 'Cased Hole Frac & Pack' (CHFP) stimulation, proppant fills the wings of the fracture, then the annulus between the casing and the screen with the annular pack providing a secondary barrier for sand control. Over time, conventional proppant washes out of the annulus, creating voids and allowing the ingress of formation fines. Eventually, the connection to the fracture can be lost and the pressure needed to inject at the required rates becomes so high as to make injection economically unviable. CARBO developed a new type of immobile proppant system that would bond the highly conductive proppant pack in the formation and the annulus without closure stress so that operators can inject at ultra-high rates for many years and at pressures exceeding the parting pressure of the soft sand formations.

A resin coating is applied to a lightweight ceramic substrate, a chemical activator that could be run in the proppant slurry and an internal tracer placed inside the proppant during manufacturing. The solution became known as FUSION technology due to the combination of these four technologies.

The specially formulated chemical activator was developed to enable the resin coating to bond in non-compressive and low-temperature environments (in the annulus as well as in the fracture), creating a high integrity pack that withstands stress cycling while sustaining long-term pack integrity. As the FUSION coating also bonds with closure stress, it works to maintain the integrity of the proppant pack in the fracture. The bonded proppant in the fracture minimises embedment in the formation face, prevents prop pack rearrangement and lowers the delta P across the pack. It also allows for a single resin-coated proppant and liquid additive to be used simultaneously in a continuous frac and pack operation. As the unique bonding process is chemically and temperature activated, any excess proppant in the workstring can be reversed out prior to the bonding of the proppant pack.

An inert, non-radioactive tracer, CARBONRT, is added to the ceramic proppant mix and incorporated into the ore used to make each pellet. It is detected downhole by wireline tools and interpreted at surface, helping operators to identify where voids are present in the pack. For the entire life of the well, operators can re-log the well and determine annular pack integrity, near wellbore connectivity and propped fracture pack height.

SAFETY SYSTEMS

FRANKS INTERNATIONAL – DR. BRENNAN DOMEC

There are many instances in the oil and gas industry where serious bodily injury or death has been caused by a person being struck by or being caught between equipment. Often, the cause of these incidents is human error, either on the part of the tool operator or the person who finds themselves in an unsafe position. Current anti-collision or zone management systems do not track personnel, cannot stop a machine from colliding with a person, are rig specific, and are difficult to integrate with third party equipment.

Current technology on the market can help prevent these incidents using a control system capable of knowing the location of personnel and tools in the area. GPS systems do not function when line of sight or the satellites are lost and only has an accuracy of 3 m. Other technology such as radio frequency identification (RFID) can only reliably tell when a person or object possessing a tag has passed through a gate. There are also real time location systems (RTLS) that use existing WiFi networks and Bluetooth beacons to track a person's position and movement, but the accuracy varies between 1 - 3 m. New technology using ultra-wide band (UWB) has brought the ability to track position to an accuracy up to 10 cm in a work environment.

Frank's International is using UWB technology to provide a proprietary portable local positioning system (PLPS) that monitors and tracks the real time position of personnel and machines on a rig floor and prevents the machines from operating when a human could potentially be injured. The Frank's Vigilance™ system is designed to be portable and easily and quickly installed and configured onto any rig floor and work with any equipment. By having knowledge of the real time location of all personnel and all mobile and stationary equipment on the rig floor, this system automatically locks tools in place and prevents them from moving whenever a person is in an unsafe position relative to the tools on the rig floor. The system could help provide insights into lessons learned, incident investigations, operations efficiency, and process automation. This new technology could also provide insights into operations optimisation and enable the development of smarter systems that are currently not feasible.

In the short term, this new technology provides an engineered control solution for hazards associated with people working around automatically-controlled or remotely-operated machines on a drilling rig floor environment. It also allows for easier rig integration or even the ability to provide a stand-alone alternative to the rig's anti-collision systems. In the long term, the Vigilance™ system is an enabling technology that would provide a foundation network for enhancements in many areas including process control, intelligent system automation, machine learning through patterns of movement, and efficiency gains through path anticipation/optimisation.

FRANKS INTERNATIONAL – LOGAN SMITH, P.E.

Offshore drilling wells have been reaching increasingly greater depths, some over 30 000 ft. At such depths, the sediment level, which can extend hundreds of feet below the seafloor, is typically composed of a loose matrix of materials, thereby imparting negligible cohesive strength. In fact, rather than a rotary drill bit or drilling mud, the combined weight of the conductor casing and drill string may be sufficient to create the first hole. Nonetheless, a jetting procedure is incorporated into the operation to ensure proper placement of the conductor casing. As the foundation for the rest of the well, should this initial string collapse due to the critical structural loads experienced at these depths, every deepwater component

above and below the conductor casing would be jeopardised. As a precaution, operators have trended from 30 in. to 36 in. structural casing and higher grades of steel. The problem is that the traditional method of jetting large-diameter pipe can prove problematic because it requires padeyes or other lifting profiles, which can impair safety.

The removal of padeyes can be troublesome. Casing's high-grade materials are not designed to withstand heating outside of a controlled environment, so the torches and grinders used to remove these padeyes can damage and/or weaken the structural capacity of this string. Like padeyes, other lifting profiles have drawbacks, too. The installation and removal of lift subs and clamps prove cumbersome and time-consuming. Furthermore, the height at which these implements must be manipulated necessitates personnel working at these heights.

However, recent tools such as the Frank's Jet String™ Elevator (JSE) reduce these safety hazards. The JSE is designed to lift flush OD 30 in. to 42 in. casing from the horizontal to vertical position, helping eliminate the need for welded or bolted-on padeyes and thereby improving the overall safety of operations. In addition, its completely hydraulic design allows tool operation to be hands-free, eliminating the need for dangerous manual manipulation and removing the rig crew from the Red Zone.

Overall, the JSE and other modern tools are a marked improvement over traditional tools and improve safety on jobs that were previously run with crews handling heavy equipment and using cutting and welding machines on the rig floor.

CATERPILLAR - CASEY OTTEN & DEREK KAMP

Caterpillar is committed to making well service jobs safer and more efficient. It was with safety in mind that the Dynamic Transmission Output Control (DTOC) technology was developed for the company's well service transmission product line. DTOC is an integrated set of control features designed with knowledge of the pump engine and transmission operating characteristics. The automated stall test mode (ASTM) improves site safety by automating the manual processes currently used to pressure-test jobsite iron. Automated speed control (ASC) and economy mode allow automated rate control for a single pump rig, or the entire fleet, and can help reduce fuel burn at the same time.

In addition, DTOC can easily be integrated into nearly any third-party control system, it is intuitive and easy to manage for any experienced well service operator.

ASTM simplifies the pressure-test process for the operator by allowing them to simply enter the desired pressure into their control screen, and activating the feature. Once ASTM is activated, the transmission controller takes over and controls transmission gear and engine speed to achieve the desired pressure. Previously, an operator had to manually control the transmission gear and engine speed. With the ASTM feature, operators can now perform jobs more safely and efficiently.

Low-flow applications like cementing present unique challenges. ASC was created to meet today's work demands of high levels of speed, reliability, and the ability of the engine and transmission to achieve precise flow control even at the lowest rates.

This feature was designed to automate pump rate control. With ASC, operators can input the rates they want allowing for a more streamlined process compared to the manual process used in the past. One of the primary benefits of the technology is the ability to achieve consistent low flow during critical cementing applications.

On today's well service pumping equipment, pump flows are controlled by controlling engine speed and selecting the gear that provides the flow-rate nearest to the target flow rate. Each transmission gear shift increases pump flow and potentially pressure. With ASC, the rate control feature simplifies the pump control by allowing the operator to simply type in the desired flow rate. The technology then takes control and commands engine speed while selecting the appropriate gear to achieve and maintain the desired flow. While in ASC mode, the transmission will automatically shift gears as necessary and will control the gear shift and engine speed to maintain the desired flow rate before and after the shift, thus ensuring there are no flow spikes during the gear shifts. With economy mode activated, the transmission will achieve and maintain desired flow while operating at the most fuel efficient operating point, helping minimise fuel burn.

The simplified operation of DTOC and both the ASTM and ASC features provide for a safer and more efficient well service job.

CHEMICAL TECHNOLOGY

TENDEKA - ANNABEL GREEN

To maximise return on investment, reducing the time and cost to complete wells in unconventional shale plays is crucial, particularly given the increasing trend to pump more proppant per 1000 ft as well as the associated increase in volumes of fracturing fluids.

One such way to achieve this decrease in time and cost is during perforating in the acid stage during plug and perf completions. This new process and technology eliminates the procedure of placing acid 'after' the guns are removed from the well. A spearhead acid stage is typically pumped prior to the main fracturing stage to clean cement debris and generally assist in reducing initial injection/fracture pressures. Taking a four well pad as an example, with 50 stages per well, with an average displacement volume of 250 bbls and acid displacement time of 20 to 60 minutes per stage (based on pump-down method and rate), this would amount to over 50 000 bbls of fluid and up to 200 hrs of equipment time that could potentially be minimised.

The application of perforating in acid is not a new concept, but to date, its use has been limited in unconventional shale plays because of the corrosive properties of the hydrochloric acid (HCl) or urea-hydrochloride and the temperature limitations of urea-based products.

A new thermally stable Modified Acid™ system is now available and is already in use by various North American operators. It shows improved performance properties compared to hydrochloric or urea-based acids, without the hazardous/negative exposure, transport, effluent, and corrosive properties associated with HCl. This system is a replacement for hydrochloric acid blends and can be utilised and exposed to perforating tools and wireline at high temperatures over long periods with minimal effect. This system allows operators to pump acid with the perforating guns and plug, reducing time per stage and saving considerable water per stage (a hole-volume per stage) where applicable.

In addition to the advantages of this system, it also achieves ultra-long-term corrosion protection on corrosion resistant casing

widely utilised in industry, such as P110. Casing integrity issues have been observed by multiple operators due to spearhead acid placement (hydrogen embrittlement). This system will provide corrosion protection well below the industry standard of 0.05 lb/ft^2 for up to 96 hrs versus the usual 6 hrs provided by HCl based systems, virtually eliminating the risks of casing integrity.

CARBO – TERRY PALISCH

Operators of wells situated in some remote onshore or offshore locations are days or months away from being able to remediate their wells' operational issues once they become apparent. Scale deposition downhole is, in particular, a common oilfield production problem with the potential to cause major blockages in tubulars and proppant packs. This can dramatically limit the efficiency and effectiveness of downhole pumping equipment. Oil flow can become restricted with production needing to be halted. Scale remediation can spell costly workovers and pump repairs, which lead to further production downtime and lost revenues. With the cost of scale inhibitor delivery solutions, such as chemical injection systems and remedial chemical squeezes proving to be prohibitive in most cases, the CARBO SCALEGUARD proppant-delivered scale-inhibiting technology was developed as a one-time scale inhibitor that is designed to be used with the completion, blocking scale at its point of origin, and can be engineered to last for the effective life of the well, giving operators an added degree of confidence in their wells' integrity.

SCALEGUARD is comprised of a porous, ceramic proppant engineered with a controlled release technology and infused with scale-inhibiting chemicals. The water-activated technology is designed to be placed throughout the entire fracture as part of the standard fracturing process, with a single treatment capable of safeguarding the entire production system, from the fracture through the wellbore, to the surface processing equipment for the life of the well. Serving as both a scale inhibitor and proppant, the technology has no impact on fracture conductivity or integrity, nor does it create excessive fines that restrict or block hydrocarbon flow spaces. Controlled release technology lengthens treatment life and reduces initial inhibitor washout, ensuring that scale-generating water is constrained at a controlled rate so that levels remain above the minimum inhibitor concentration (MIC) determined for each application. By placing the production assurance chemicals directly in the fracture where they are required and avoiding chemical washout, the technology provides effective, long-term protection while reducing chemical consumption and treatment costs. It has been deployed across the US, in every major basin including the Gulf of Mexico and Alaska, as well as Canada.

HPHT APPLICATIONS

FRANKS INTERNATIONAL – DR. BRENNAN DOMEC

As oil and gas wells are being drilled in more aggressive environments, the use of corrosion resistant alloy (CRA) tubulars for well completions is increasing. One such alloy that has seen and will continue to see considerable use globally is 13Cr. This alloy is hardened by quenching and tempering, which often results in a hard oxide layer developing on its outer surface. The hardness of the oxide layer may exceed 1000 HV (70 HRC), making it much harder than the base material. Research has shown a general trend of increasing oxide layer hardness of tubulars delivered from the mill, with average values trending from 510 HV - 600 HV (50 HRC - 55 HRC) more than a decade ago to 1000 HV (70 HRC) today. The impact of this finding upon handling and running of 13Cr tubulars, and those of similar quenched and tempered alloys, is apparent when considering the equipment commonly employed for such operations.

Conventional handling and running technologies use case hardened (carburised) inserts and dies. The carburising process applied to the steel substrate imparts a surface hardness generally ranging between 600 HV - 750 HV (55 HRC - 62 HRC) that decreases with depth until the core hardness, typically 300 HV - 380 HV (30 HRC - 39 HRC), is reached. These properties enable dies and inserts to penetrate and grip tubulars with oxide layers at the low end of the scale, but not so for tubulars with oxide layers at the high end. In the latter instance, die and insert teeth have been shown to fracture and wear prematurely, ultimately resulting in slippage or dropping of the tubular string.

New technologies exist that overcome this issue. For example, Frank's Fine Point™ technology has been shown to effectively and reliably penetrate even the hardest oxide layer without fracture or wear. This was made possible through geometric optimisation to generate optimal contact pressure and the development of a proprietary metallurgical treatment that promotes hardness while maintaining necessary toughness. Other technologies rely upon friction or mechanical interference between the gripping component and the tubular (e.g., Frank's Fluid Grip® and Collar Load Support (CLS™) systems, respectively). These technologies also offer the additional benefit of being completely non-marking, eliminating mechanical damage that can lead to premature tubular corrosion and failure.

CARBO – TERRY PALISCH

CARBO's expertise within materials science and manufacturing enabled it to develop the most conductive and durable proppant technology in the market that significantly improves overall fracture conductivity, resulting in less erosion, more production, increased recoverable reserves and greater returns for the operator. Utilised by all super major E&Ps operating in the Gulf of Mexico, KRYPTOSPHERE HD technology is an ultra-conductive, high-density ceramic proppant, specifically engineered for high closure stress and risk environments, including ultra-deepwater regions such as the Gulf of Mexico. Precision-engineered, strong, durable, round, single-mesh-sized and smooth proppant grains avoid the creation of fines to ensure high conductivity across the entire range of low to high stress well conditions. It exceeds the conductivity of existing bauxite-based high-strength proppant and reduces costly wear-and-tear on pressure pumping equipment, ultimately providing higher production and EUR.

The ceramic technology creates a frac with more space for hydrocarbon flow, maximising the operator's return on investment. Whereas KRYPTOSPHERE HD technology is specifically engineered for offshore applications and very deep well applications, KRYPTOSPHERE LD has been developed for onshore applications and moderate to deep wells. The LD technology is engineered to have the same characteristics as the HD technology but in addition, the LD technology provides higher conductivity, improved proppant transport and increased propped fracture volume compared to intermediate-density and bauxite ceramics.

In order to build the most optimal solution for a variety of different well challenges, KRYPTOSPHERE has been designed to serve as the base ceramic technology, or to be otherwise integrated, with a range of additional technologies to enhance proppant functionality, such as flowback/fines control, pack integrity and frac fluid clean-up. The ceramic works in conjunction with resin coating technology, proppant pack consolidation and relative permeability modification technologies.