Figure 1. *The use of higher strength and alloyed base materials for subsea installations and pipelines is resulting in more stringent welding specifications.*

CONSIDERING CONSUMABLES

Teresa Melfi, Lincoln Electric, USA, investigates some key considerations for consumable specification in deepwater welding applications.

With more than 50% of new offshore oil and gas reserves classified as deepwater and ultra-deepwater plays, increasing technical welding specifications for subsea installations and pipelines are anticipated.

Revamped and/or new specifications could include increasing the use of higher strength and alloyed base materials used for pipelines, including flow lines and risers, and subsea equipment such as blow-out preventers (BOP), Christmas trees and distribution manifolds where post-weld heat treatment (PWHT) cycles are needed. These cycles are used to improve the properties of a weldment, including increasing resistance to brittle fracture and relaxing residual stress, as well as minimising the potential for hydrogen-induced cracking.

As a result, owners and offshore contractors will have to increase their technical requirements for yield strength, hardness and toughness after PWHT to meet these new challenges. While many factors affect the final weld deposit before and after post-weld heat treatment, this article will attempt to identify some key principles and solutions to address end user and owner requirements. Lastly, it will cover process solutions that can optimise the outcome for achieving the best in class final weld deposit properties.

Increased scrutiny yields new technology

The proverbial ball is in motion. Already, high-strength steels used in critical subsea applications are undergoing more scrutiny in the welding and PWHT processes. No longer can contractors qualify a welding procedure and move it to production without significant validation of the production weld's properties. Consequently, end users often require sacrificial weld and base metal to be added to weldments. These are put through the same welding and PWHT processes with the weldment and then tested prior to accepting the weldment.

What is more, this increased attention to welding and PWHT means that the ability to monitor welding conditions is becoming increasingly important and can sometimes even reduce the level of testing required. With this in mind, fabricators are turning to new developments to improve their quality and consistency and to lower their costs.

New cloud-based monitoring tools, such as Checkpoint™ Production Monitoring, can enable a networked welding power source to transmit its own weld performance data. Cloud-based production monitoring from the field provides an advantage over the previous VPN-based monitoring platforms, especially for companies with multiple jobsites. It provides a simple way to accumulate data from these locations into a central database that can be easily accessed from anywhere, at any time.

These systems can track metrics and provide analysis down to the level of a single weld performed by a particular operator on a specific welding machine during a certain shift as to establish productivity benchmarks, support, troubleshooting capabilities and more. The latest solutions also offer traceability reporting, a key consideration for welders in the oilfield who must, in turn, hold records for customer review, and maintain records for quality initiatives and other similar activities.

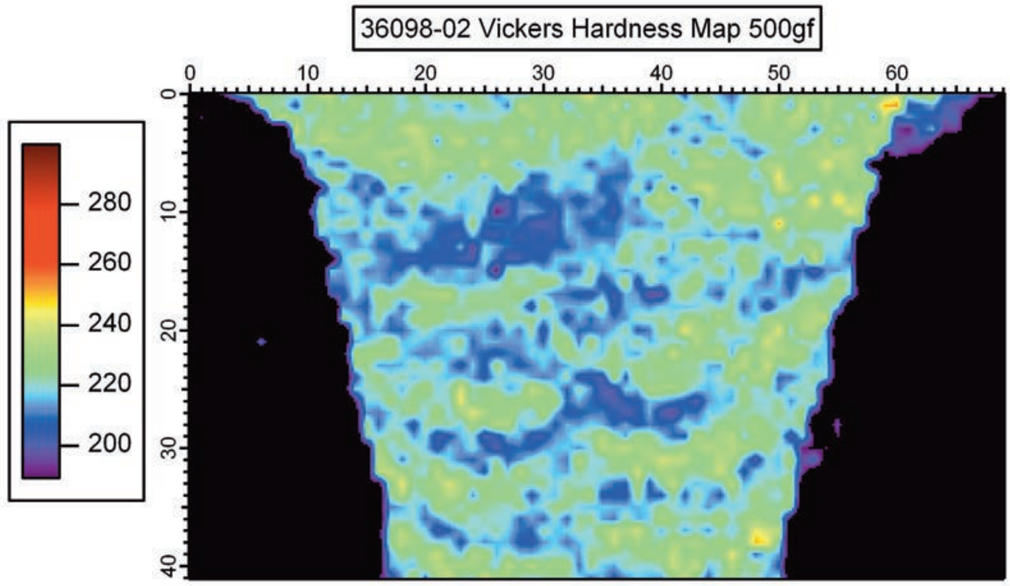

Figure 2. *Weld metal hardness is reduced by heat treatment (mapped with approximately 2000 indentations).*

In the Checkpoint system, for example, operators can track up to three fields: operator ID, part ID and consumable. In short, they can quickly determine who made the weld, on what part and with which welding wire for any weld on a job. All of this can be viewed easily on mobile devices in the field or downloaded back at the office for records retention.

Weld quality and productivity not only can be tracked from the production site; it also can be improved from there, from the initial passes during the SAW process. Today's innovative submerged arc systems couple advanced power sources with mobile, hard automation or robotic feeding equipment to achieve new levels of welding performance and

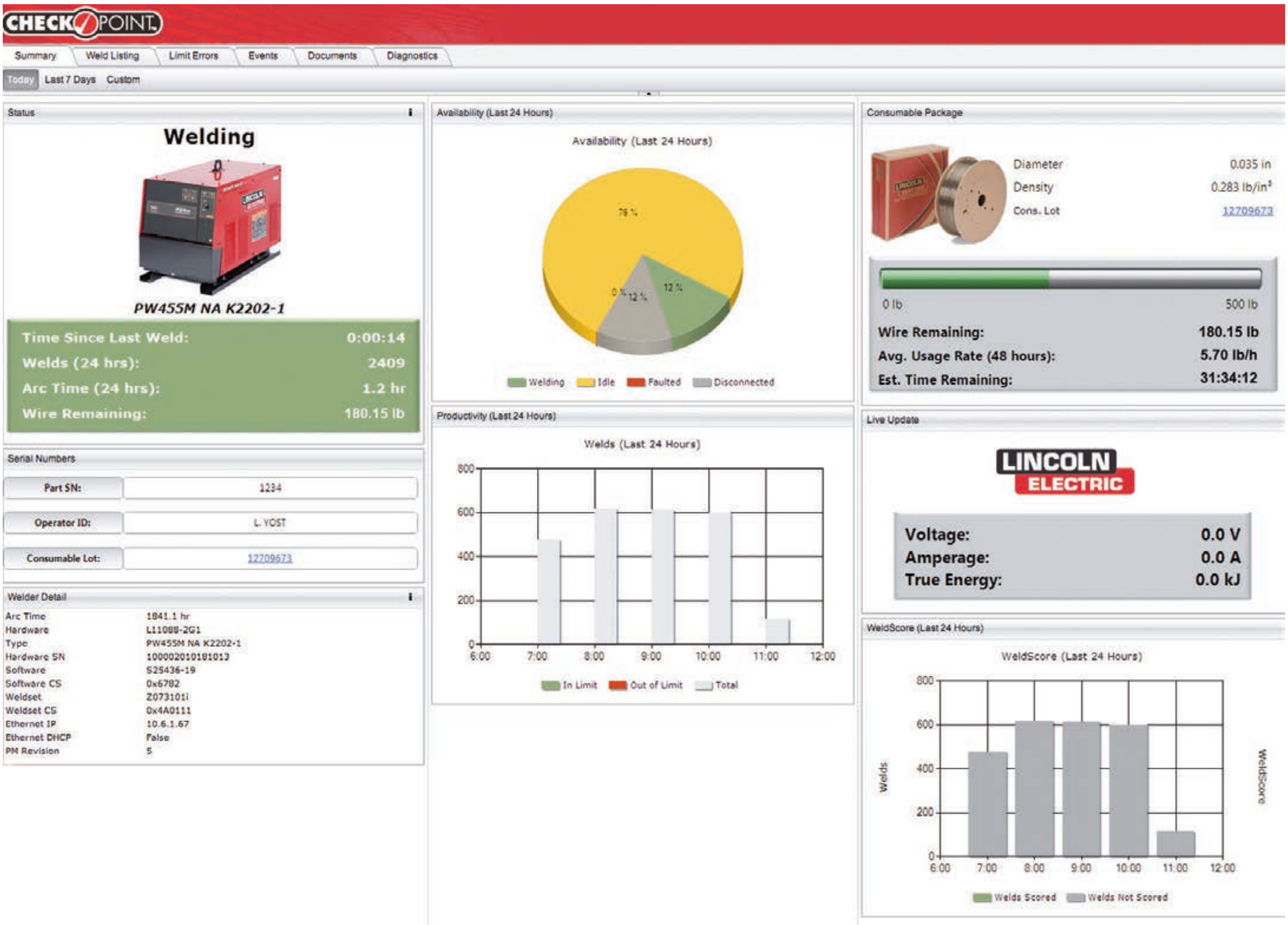

Figure 3. *Cloud-based weld monitoring tools, such as Checkpoint™ Production Monitoring, simplify data collection, tracking and reporting.*

operational efficiency, all of which is tracked and reported through production monitoring.

Today's SAW systems, such as the inverter-based Power Wave® AC/DC 1000® SD submerged arc welder, combined with the operator's choice of integrated feeding equipment, can provide constant current or constant voltage operation and set variable frequency and amplitude with the turn of a knob. Software-driven AC, DC positive and DC negative output allows users to have greater control over bead shape, deposition rates, penetration and heat input. Modified AC technology gives operators the ability to tailor parameters to a specific application, every time.

The result is improved weld quality, reduced welding and operational costs and increased weld team productivity in single or multi-arc environments. With input current requirements reduced by up to 50% for some of the newest inverter-based SAW systems, users consistently report significant energy savings over traditional submerged arc welding equipment.

Careful consumable specification

The resulting productivity increases from the use of high-tech welding power sources with AC waveform control are often associated with higher deposition rates, accompanied by thicker individual weld passes (more grams of weld per centimetre). This requires the proper selection of welding consumables to provide a microstructure that delivers adequate mechanical properties and resistance to a common failure: delayed hydrogen cracking in the thicker weld beads that result from higher deposition rates.

Many alloy systems develop toughness when as-deposited weld metal is refined by subsequent passes. Thicker weld beads can affect mechanical properties by leaving larger quantities of as-deposited and unrefined weld metal, which can be associated with coarser grain structure and lower toughness in some alloy systems. Long PWHT cycles also can have an effect on weld quality if the wrong consumable is used in a SAW application.

Thus, with such considerations in mind, both electrodes and flux for AC SAW applications in a deepwater oilfield environment must be selected with care. Low-alloy solid electrodes, such as the nickel bearing with 0.5% molybdenum Lincolnweld® LA-84, combined with a carbon-neutral flux like Lincolnweld® 812-SRC™, can be used for higher-strength weldments. This combination can produce excellent yield and tensile strength after extended stress relief required for the base and weld metal to meet the NACE hardness requirement of less than 250 Hv10 after post-weld heat-treating.

The use of high-strength steels also brings with it the risk of hydrogen cracking, a significant issue for consideration in many deepwater and ultra-deepwater welding applications. Cracking in the welds of any subsea pipeline or component is a potentially severe defect, with risk of failure increased due to the difficulty associated with detecting hydrogen cracks. These cracks may occur immediately or even days after welding. Research shows that weld metal hydrogen has been measured to be most concentrated (i.e. hydrogen per 100 grams weld deposit) in the first weld passes of a multiple pass joint. This means cracks could be located deep within a weld joint.

Increasing time between weld passes, particularly at interpass temperature, is effective for reducing diffusible hydrogen content. While increasing preheat and interpass temperatures can mitigate the risk of hydrogen cracking, such practices also reduce strength and increase the cost of welding.

All fluxes have a unique correlation between moisture content and diffusible hydrogen, and thus, the potential for cracking. This relationship limits the minimum achievable hydrogen content for a given flux, even at low moisture levels, regardless of pre-baking or pre-drying flux. Combining this with the resistance to moisture pickup in a flux determines whether a flux can be used with no preconditioning to further reduce cost and complexity.

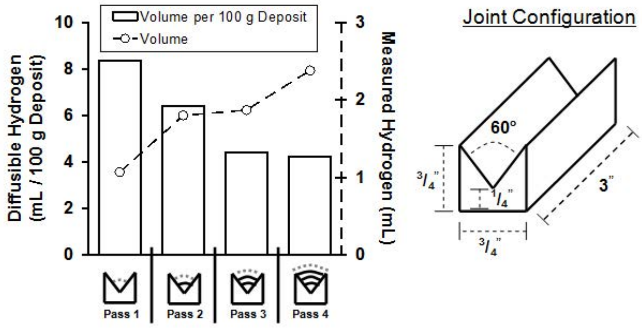

Figure 4. *Diffusible hydrogen in various layers of multiple-pass welds.*

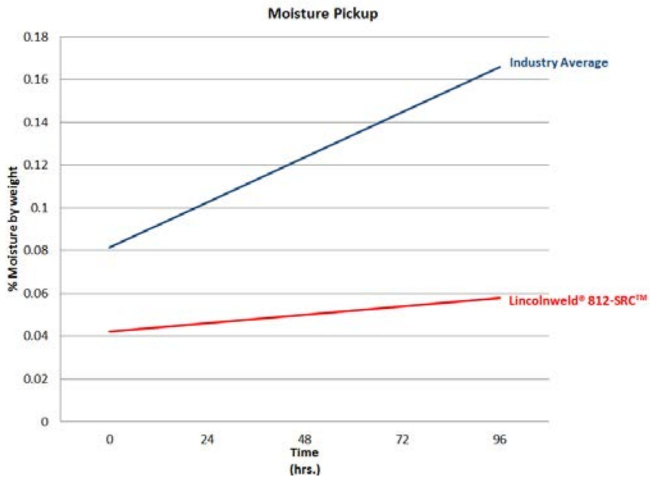

Figure 5. *Low initial moisture and low moisture pick up provide low risk of delayed cracking.*

As a result, a flux with minimum diffusible hydrogen level that has low moisture pickup tendency is ideal for deepwater applications. One such flux, Lincolnweld 812-SRC, has an H4 diffusible hydrogen level of less than 4 ml/100 g of weld deposit in both DC and AC polarities. Its design resists moisture pickup, helping reduce the likelihood of hydrogen cracking.

Delivering quality results

Specifying consumables for deepwater and ultra-deepwater SAW applications requires forethought and diligence in order to produce robust welds that not only stand up to harsh environments and the PWHT process but also meet increasingly stringent industry quality and testing standards.

Welding with AC waveform control on the latest inverter AC/DC power sources while using a low-alloy electrode and a carbon-neutral, low hydrogen flux, can achieve this goal. This combination can deliver high productivity, including increased weld speeds, robust mechanical properties and consistently higher quality welds and improved efficiencies in subsea construction settings. OT