Materials challenges in oil & gas
National Oilwell Varco (NOV) is a vast organisation covering almost every aspect of oil and gas drilling and production activities onshore and offshore for both surface and subsea activities. With more than 60,000 employees in 67 countries, NOV has a wealth of knowledge and experience in the field of specifying and using stainless steel and other corrosion resistant alloys (CRA). Stainless Steel World spoke to two members of the NOV Completion & Production Solutions team to learn about the impact of low oil prices on business and some of the challenges that must be overcome through material selection in this demanding application.

By Joanne McIntyre
In 2014, NOV was organized into three Segments. NOV Rig Systems is responsible for building onshore rigs and equipment for offshore drilling rigs. NOV Wellbore Technologies is responsible for drill bits and drill pipes for downhole tools and all aspects of drilling wells and exploiting the oil and gas. The third Segment is NOV Completion & Production Solutions, which deals with equipment and services related to post drilling and pre-production including well service, stimulation and well testing. We spoke with Neil Kennedy, NOV’s Technical Solutions Director and Nigel Garrod, Technical Quality and Materials Manager from the Pressure Performance Systems (PPS) group within CPS. Both are currently based in Gateshead, UK and are responsible for the smooth operations and satisfaction of their customers.

Substantial expertise
The sheer size of the NOV group means it supplies an enormous scope of equipment, from subsea well control equipment to complete mobile land drilling and workover rigs. “We supply either part of or the complete suite of equipment required to operate a rig whether it’s a land rig, a drilling vessel or FPSO,” explains Neil. “Essentially we’re an organization of original equipment manufacturers, with numerous core manufacturing facilities involved in everything from material selection and capital equipment design, to design of individual valves and seals, actuator design, the BOP design, to entire land rig design. At heart we are both designers and manufacturers and we’ve grown to cover the supply chain to such an extent that our customers can place a single purchase order for a rig, a vessel, or a surface well test spread, making the customer’s job that little bit easier. The NOV centralised corporate design and development team is based in Houston, Texas and Norway, with each division having its own internal product development team. The Gateshead facility in the Northeast of England has around 480 employees and a core design engineering team that continuously work on product development.

“Change doesn’t happen quickly in this industry for two main reasons. First, it takes a long time to get acceptance for new technologies. Second, we are a customer driven industry so when drilling activity is at a peak, inevitably product development suffers due to increased sales order activity. It tends to be during slower times when the current market activities for the product development team accelerates.

Effect of low oil price
“Within the oil and gas industry at the moment there are two key effects,” states Neil. “The first is the low oil price which is affecting all of our customers. Whilst we in PPS are primarily focused on well service, a lot of our activities overlap into drilling and production, with both well

About Neil Kennedy and Nigel Garrod

Neil is a mechanical engineer who has been involved in engineering design and management on high pressure well control and well service equipment for 18 years.

“As Technical Solutions Director, I work with well service customers to provide solutions to technically challenging problems for our global operations, dealing directly with customers on product development programs and helping design solutions for well service companies,” explains Neil.

Nigel has Master’s degrees in Quality Management and Metallurgy and works with materials issues specifically to do with the technical side, processing, heat treatment, welding and surface treatment.

“I also carry out internal and external audits on specific critical processes and work with various departments on engineering design, product realisation, after sales repairs, production engineering and purchasing specifications to ensure that we meet all of our customers’ requirements,” explains Nigel.

Much of the equipment NOV produces at its Gateshead (UK) site is surface related, such as well control equipment for land rigs.
service and drilling activities suffering as a result of the low oil price in the last few months. Fortunately we’ve got a lot of flexibility and expect the oil price to turn around which is encouraging. However it’s not encouraging enough to bolster confidence back to where it was 12 to 15 months ago.”

“The second impact is that the low oil price is almost synchronised with a slow-down in the building of new offshore drilling rigs. We have orders in place for equipment until around the middle of next year, but beyond that the new rig build drilling cycle drops off to almost nothing. This is not a direct result of the oil price, but due to the cyclical nature of the industry. However the effect of this anticipated cyclical decline has been accelerated by the low oil price to the extent that some planned projects have been postponed or cancelled. Customers want to wait in the hope the oil price rises before progressing any further with their newbuild projects”.

Dealing with corrosion

“We are confronted with a wide range of general corrosion issues in the oil and gas industry,” says Nigel. “The majority of corrosion resistant alloys (CRA) are used for overlay and inlay on carbon steel and low alloy steels. Pitting is common due to chlorides and seawater in the offshore environment. We have had to deal with galvanic type corrosion, which has led us to advise against using dissimilar materials at the design stage. Crevice corrosion appears in places such as bends and joints. We also encounter specific cases involving hydrogen induced cracking related to corrosion, sulphide stress cracking and stress corrosion cracking so there is a wide range of corrosive processes that we see with the components that we manufacture here. My job is to help solve the problems in areas such as surface coatings, weld procedures for overlays and inlays and researching new materials.”

Material specifications

“Many of our components are manufactured to comply with NACE standard MR 0175, so we tend to use the materials that are already proven and approved by NACE,” explains Neil. “CRAs tend to be specified either for components impacted by the external environmental factors, such as seawater or sulphurous rain or in components used in pressure control equipment exposed to H2S. These may be used to shut off or control pressure in the well. Most of the equipment we have here in Gateshead produce is surface related, such as well control equipment on offshore or land rigs. This equipment is challenged with acidic environments ranging from hydrochloric acid from well service operations and production environments with up to 25% hydrogen sulphide and 15% wet CO₂, so there’s a strong focus on correct material selection.”

The materials commonly specified are alloy 625, other nickel alloys and 316 stainless. These are followed by 17-4 precipitation hardened (PH) stainless, then the 410 grades and other martensitic grades and we will occasionally apply duplex or super duplex. These materials may be used for overlay, weld inlay, while some of it is cast material and forged materials. While the materials chosen are usually defined by NACE standards and the environmental limits of the application, customer preference also plays a role. “Customers may prohibit the use of certain alloys: 17-4 PH stainless in particular is not favoured by some offshore operators,” explains Neil. “For the designer, it’s a fantastic alloy because in the form that we use it in accordance with NACE MR 0175, it has extremely high strength and excellent base level corrosion resistance,” says Neil. However in 2003, the NACE MR 0175 standard severely restricted the use of 17-4 PH stainless which meant the only viable option was the 700 series.
of nickel alloys which have severe cost implications for our industry. There is no limit in terms of the partial pressure of hydrogen sulphide that alloy 718 can be exposed to, up to 250 degrees Fahrenheit. By comparison, 17-4 PH stainless, is limited to 0.5 PSI of partial pressure H₂S, which is generally unworkable for a designer or our customer in our segment of the industry.

**Challenges with CRAs**

Nigel gave examples of some challenges his team has recently dealt with. A major challenge recently was producing a weld procedure for F6NM type martensitic stainless steels. In order to satisfy the NACE requirement, the procedure needed to deliver a maximum hardness of 23 Rockwell. It’s difficult to get down to those levels with martensitic stainless, mainly because a double post-welding treatment followed by a subsequent sub-ambient finish temperature is required to ensure the martensitic reaction is finished and any retained austenite is converted to tempered martensite. An added problem is that the NACE standard was changed to restrict the post-welding treatment temperature from 650°C to a minimum of 670°C and yet, technically, 670°C makes it more difficult to produce a hardness under the specified maximum.

“Another challenge we had is with overlay with 316 stainless. This is predominantly overlayed onto carbon steels, resulting in a huge difference in thermal contraction between the two materials. Often the 316 stainless tries to pull away from the carbon steel, which we combat by adding a layer of 309 stainless. As a result we are moving away from 316 in favour of materials such as alloy 625. There is a cost implication but it’s not prohibitive,” says Nigel. Many of the CRA’s are surface treated. A nitriding treatment is applied to increase wear resistance for dynamic parts and we’ve experienced some problems with the process. The nitrogen from the nitriding process uses much of the surface chromium to create chromium nitride to increase surface hardness. This usually results in a depletion of the chromium required for an effective corrosion resistance. This has led to the problem of nitrided stainless steel corroding quite quickly. The solution was to trial several processes that incorporate an oxidizing treatment after the nitriding to impart more corrosion resistance. Other coating technologies PPS employs are HVOF, tungsten carbide and nitrocarburizing.

**Procurement issues**

Nigel is involved with procurement for both CRAs and general materials. “From a corrosion perspective it’s important to know about things like pitting resistance numbers, so we have input into creating the specifications and ensuring that the delivered goods meet these. We ensure factors such as heat treatment consistency and occasionally carry out corrosion tests on materials, requiring us to work closely with the commercial department,” says Nigel. A common problem that Nigel usually comes across is representative testing definitions; for example for a project requiring 6 in. thick sections, the material delivered is qualified using a test coupon only 4 in. thick. Nigel also discovers problems where heat treatment hasn’t been effective. There have also been odd pieces of duplex, for instance, where sigma phase is present so it’s corroded quite quickly. “Auditing the supplier is sometimes necessary to make sure that their processes are in line. We carry out process audits focusing on the technicalities of the process. From a heat treatment perspective, this may include

“A NOV Surface Safety Products pneumatically actuated gate valve installed in a production facility..
A wish list for suppliers…

• “I would like suppliers to define representative testing so they actually test materials based on the properties representative of the sections we are looking at, rather than simply producing mechanical properties from a test piece that has accompanied the production batch through its processing,” says Neil.

• “Better control of steps such as heat treatment to ensure phases detrimental to the material properties from occurring would also be a great improvement. For example certain state oil companies have an approval process for the manufacture of duplex and super duplex, and an extension of that type of specification to other materials would be beneficial. API has introduced their own specification for alloy 718 to avoid delta phase in the microstructure so the onus is on manufacturers to take a reactive approach.”

• “I feel the metals industry in general doesn’t put enough emphasis on training and education,” adds Nigel. “A lot of the metallurgical courses, degrees and qualifications that were available a few years ago have disappeared. Much of the metallurgy content of training now tends to be just a one or two week module alongside an engineering degree. I’d like to see a return to more metallurgical training specific to the different aspects of metallurgy, of which CRAs would form one.”

Trends in the use of CRAs

There have been some clear trends in the use of CRAs in recent years. “In the past five years, we’ve seen an increase in working pressures from 15,000 psi - which was perceived as quite high – up to 20,000 psi today. I have even heard that customers will be looking at 30,000 psi soon,” says Nigel.

Where the CRAs are actually part of the design, strength will be an important factor so we will use more 718 and 725 type alloys in the future, which will also have cost implications. Alloy 718 was released under licence over 10 years ago, but alloy 725 hasn’t reached the same level of availability and remains difficult to source in the relatively small quantities we need. We struggle to meet our customers’ requirements although we have been able to source it through Special Alloys in Sheffield. Hopefully, the availability in the future will be improved.”

As oil and gas wells become deeper and pressure correspondingly increases, processes such as nitriding to improve wear resistance will become more common, continues Nigel. “Companies today are more budget conscious and want their equipment to last longer. There is a lifetime issue now where we’re not only looking at the available materials but how to coat them to improve wear resistance and get the maximum value out of them.”

Unfortunately, some customers still focus on the initial cost of the equipment rather than the total cost of ownership, or that the equipment is made to last 25 to 30 years. Nigels says his team tries to educate their customers that the cost of ownership is more important than the cost of the first purchase order.