# AFRICAN FUSION

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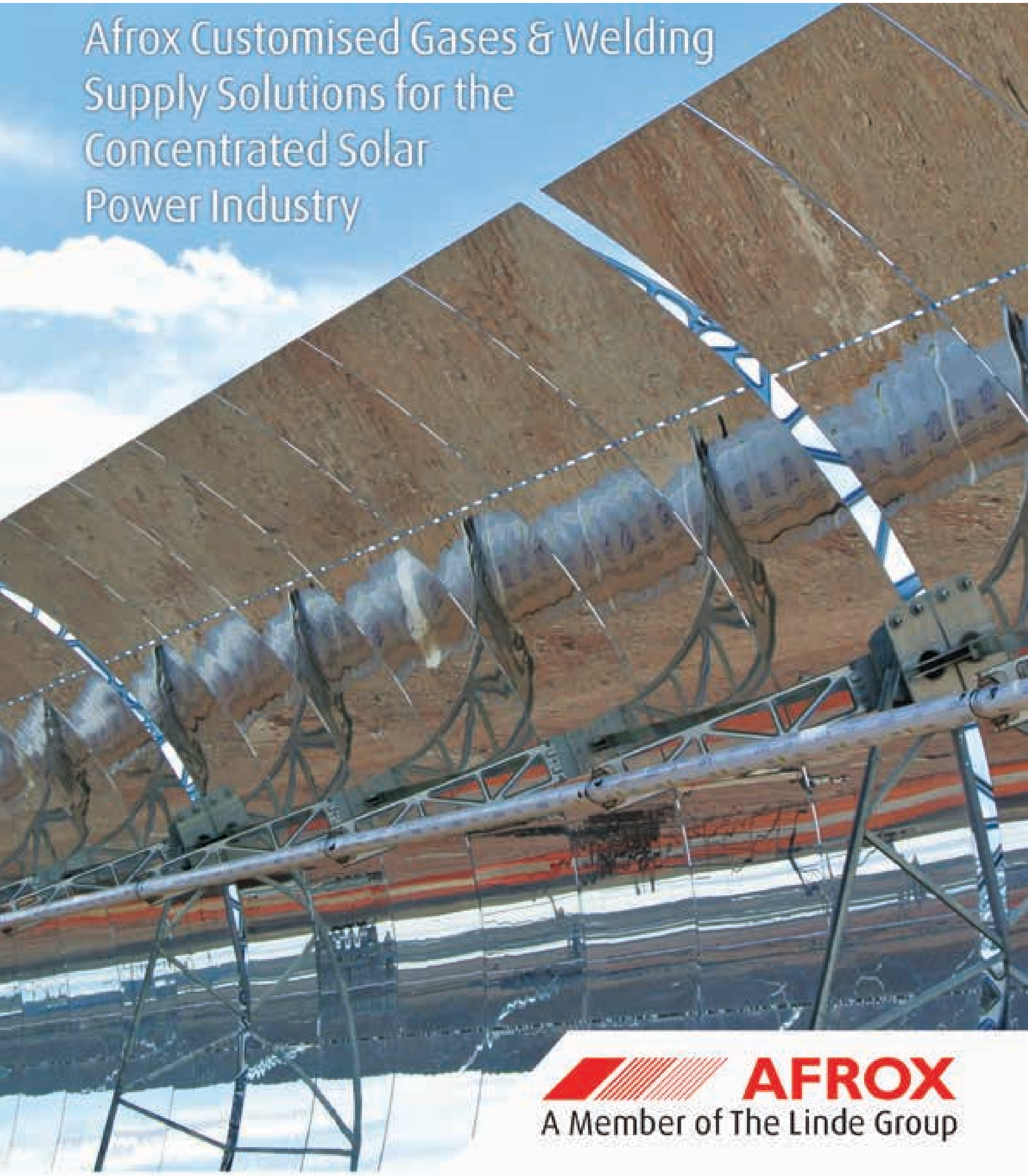

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In response to the specific requirements and needs of establishing and operating concentrated solar power (CSP) plants, Afrox, the country's largest industrial gases and welding products supplier, has developed a comprehensive product and energy solutions offering to specifically suit the industry. *African Fusion* talks to Johan Pieterse, Afrox's business manager for the manufacturing industries.

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# June 2015

## FEATURES

**4 Towards good quality NDT technicians**
SAIW NDT manager Harold Jansen 'pulls up a chair' to help outline his vision for a holistic NDT technician development programme that incorporates the best of ISO 9712 and the employer-based SNT-TC-1A NDT personnel certification schemes.

**8 SAIW member profile: Hi-Tech Pressure Engineering**
*African Fusion* speaks to Warren Hollingsworth of Hi-Tech Pressure Engineering.

**16 Deposition of crack-sensitive nickel-based alloy using LAAM**
In this paper layer by layer fabrication using laser aided additive manufacturing (LAAM), was successfully implemented on the nickel-based superalloy, IN100.

**22 Current progress in the science and technology of GMAW processes**
Yoshinori Hirata highlights key current developments in quality and productivity for the gas metal arc welding (GMAW) processes.

**26 DICONDE: Bridging NDT's digital divide**
At an evening meeting at the SAIW earlier this year, Michael Beaugrand from Larivière of the US presented on the latest technology for transitioning from film-based to digital radiography.

**29 Spray coatings: quality matters**
Thermal spray coatings need to adhere to strict quality standards due to the criticality of industrial components, argues Jan Lourens of Thermaspray.

**30 WASA's new tubular hardfacing electrodes**
Wiehan Zylstra technical manager of Welding Alloys South Africa (WASA) introduces the company's new tubular welding electrodes.

**32 Fume extraction: at source solutions**
*African Fusion* talks to Envirox's Schalk Hoon and Anton Herteberger about the company's fume extraction solutions.

**34 Trends, processes and consumables for pipeline construction**
During May, Böhler Uddeholm Africa, in partnership with Fronius and Gridweld, hosted a seminar and practical workshop on pipeline welding. *African Fusion* attends and summarises the keynote presentation.


8


30


32


34

## REGULARS

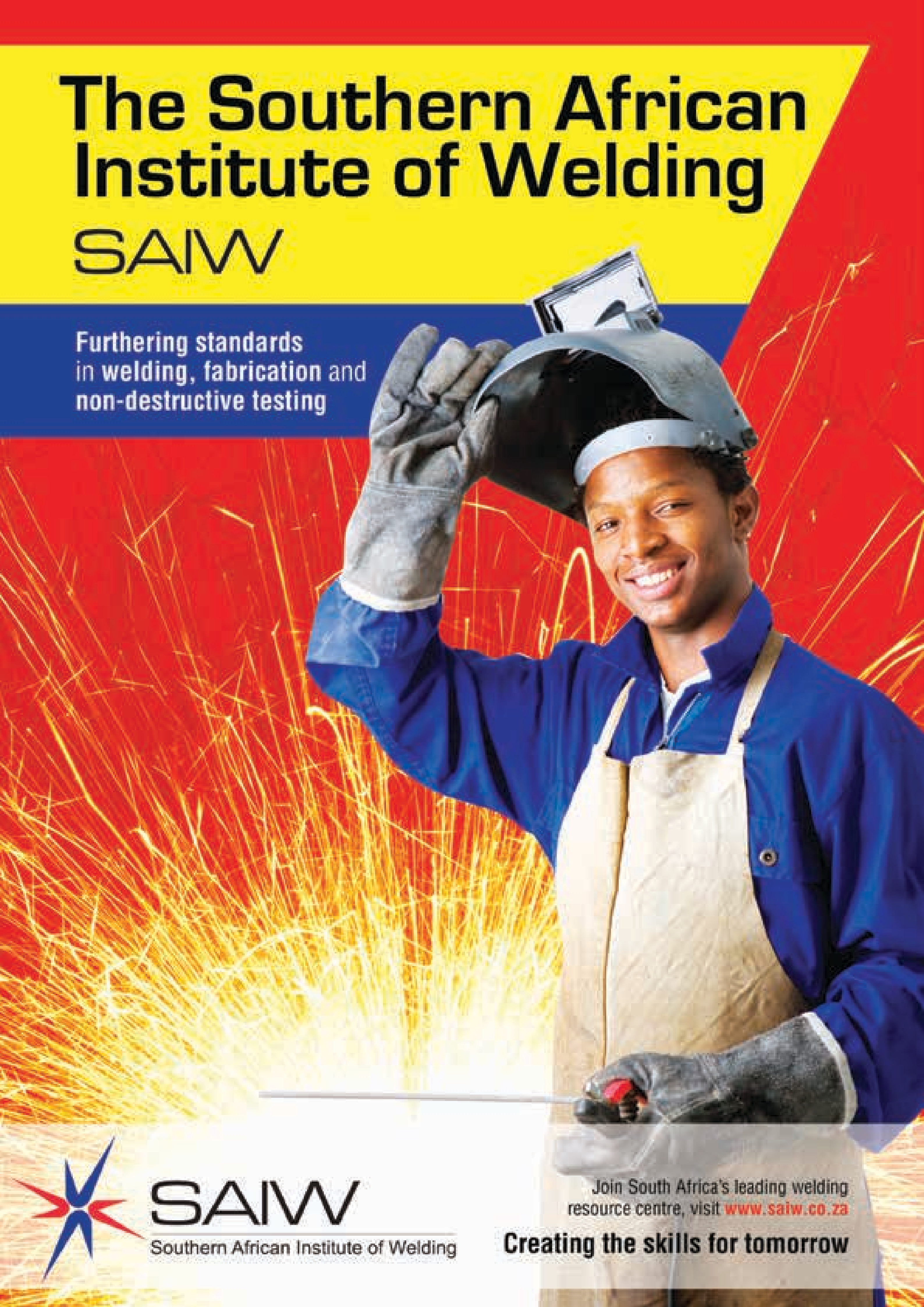
**3 Sean's comment**

**10 SAIW Bulletin board**

**14 Front cover story: Gas and welding solutions for the CSP industry**

**39 Welding and cutting forum**

**44 Today's technology: ABB's large industrial robot line**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As our president, Morris Maroga, reported at the AGM in May, the SAIW continues to be successful and financially sustainable, despite the challenges faced by South Africa. Most pleasing is that over 98% of our total income is now self-generated and we have again been able to make provision for further development.

Following a process that began last year, the Institute has now completed the conversion from an Unincorporated Association to an Incorporated Not for Profit Company registered under the Companies Act of 2008. We hope that the conversion will greatly assist the Institute in its business dealings with clients. The adoption of the Memorandum of Incorporation will also reduce the liability of the members of the Institute.

But we cannot rest on our laurels. While we have enjoyed very strong industry support over the years and our current board has a vast amount of experience, we need further involvement of industry members to guide and advise the Institute into the future. We are looking for passionate and motivated people from the welding industry, people with new ideas about how to bring modern technology developments into our daily industrial activities. There are a number of different ways people can contribute, through our training boards or on the various technical committees, or simply by engaging with us as individual or company members.

Another significant issue facing the SAIW this year is the changing of the B-BBEE scorecard rules. For the past two years we have been rated as a Level 4 contributor to B-BBEE, which is excellent for a small organisation such as ours. But given the new codes, achieving the score required for Level 4 is going to be difficult. We are going to need to be more innovative in terms of the Enterprise and Supplier Development (ESD) scores, which look at who we provide services to and where we do business.

In the past three months, we have been successfully audited by experts in three key areas. In March our training offering in support of AFRA and AFNDT was audited by an IAEA internal assessment team, which was extremely satisfied with the quality of our training programme and the controls in place for personnel certification. The successful audit ratifies our status as a Regional designated training centre for the African continent.

In April, we were audited by SANAS for the renewal of our accreditation as a Certification Body in South Africa for Inspectors of Pressurized Equipment and Competent Persons, as well as for NDT Level 1, 2 and 3 Inspection qualifications. And in May, the SAIW was audited by the IIW. We are an Authorised National Body of the IIW, which enables us to accredit training organisations and to issue IIW diplomas, which are recognised globally.

All the auditors were extremely satisfied with our systems and indicated that continuous improvement was evident. We value these audits, which involve international experts overseeing the quality of our SAIW activities. They ensure that our offerings comply with international standards.

But three audits in quick succession involves a lot of hard work from our quality department, so thanks very much to Herman Potgieter, Iliske Joubert and Harold Jansen for their efforts in this regard.

*Sean Blake*

# Towards good quality **NDT technicians**

**SAIW NDT manager Harold Jansen (right) 'pulls up a chair' to help outline his vision for a holistic NDT technician development programme that incorporates the best of ISO 9712 and the employer-based SNT-TC-1A NDT personnel certification schemes.**

NDT can be defined as *'an applied science, which, through mastered skills and processes, provides the end-user with accurate information that entitles them to make engineering decisions related to component availability, productivity, remnant life predictions and consequent maintenance/refurbishment strategies'*.

NDT not only provides a very important supportive role to engineering but it supplies the raw data to initiate and maintain comprehensive engineering practices. Should NDT not be able to fulfil this role, then its usefulness in the production and maintenance chain is questionable. While NDT equipment, procedures and the inspection environment play a significant role in the accuracy of results, the quality of NDT inspection is mostly dependent on human resources and the competency of the NDT Technician.

## Paths to NDT qualifications

Two paths to NDT technician qualification are applicable:

- Personnel Central Certification Schemes, also referred to as third party conformity assessment schemes, mandated through the international ISO 9712 standard.
- Employer Based Certification Schemes, also referred to as first or second party conformity assessment schemes, described in the recommended practice SNT-TC-1A and implemented via a written practice (referred to as a quality manual in ISO 9712)

These have long been regarded as mutually exclusive systems, with the one option superseding the other depending on the industry, historical background or code requirements.

Superficially both of these systems address the qualification and certification of NDT personnel and since the apparent outcome appears to be similar, companies tend to adopt either the one or the other, with some aspects of the 'eliminated' system being retained.

Careful and systematic analysis of these two systems however reveals that each system focus on a different outcome which is crucial when creating a quality NDT Technician.

## Personnel Central Certification Schemes

Since NDT is an *'applied science'*, a minimum personnel qualification and skills level are required. The international standard that describes the basic qualification and certification of NDT personnel is ISO 9712. While ISO 9712 mainly focuses on the Qualification and Certification of NDT personnel, it does refer to ISO technical reports, which relate to training bodies and course contents specified in ISO TR 25108 and ISO TR 25107.

Key advantages of this system include: the international platform it provides for the harmonisation of basic knowledge, codes and standards, specifications and the application of practical skills. The ISO 9712 system ensures the basic level of knowledge and skills is comparable worldwide. In addition, the independent nature of personnel assessment, reduces the risk of biased outcomes when qualifying NDT personnel.

A major disadvantage, compared to the SNT-TC-1A system, is that industrial experience and company related training or mentoring is not properly addressed.

The SAQCC-NDT (Southern African Qualification and Certification Committee) scheme is controlled by an independent ISO 17024 SANAS-accredited Personnel Certification Body or PCB: SAIW Certification in South Africa, which is supported by an Authorised Qualification Body or AQB: the SAQCC NDT Exam Panels.

Approved Training Bodies or ATBs are companies that have been audited by the PCB and approved as training providers for the relevant scheme. ISO TR 25108 and ISO 25107 form the foundation of this approval process with additional requirements stipulated by the SAQCC regarding resources and training procedures.

## Employer-Based Certification Schemes

Since NDT also relies on *'mastered skills and processes'* a mentoring environment is required in which technicians can apply their basic knowledge and skills learned within an industrial environment. Training and assessment based on company specific procedures and processes, as applied to industrial components, are critical towards quality NDT results. The employer generates income by supplying a service to the end-user. The company takes full responsibility for the product that is delivered and by authorising a technician to test on their behalf, indicates compliance with a Quality Manual and the Written Practice, based on an industrial mentoring and assessment programme loosely adopted from the recommended practice SNT-TC-1A.

Within this scheme, company authorisation and certification is managed by a responsible Level 3 Inspector.

The key advantages are that industrial experience and company related training and mentoring are embedded in SNT-TC-1A and mandated by the written practice. The system ensures technique specific skills are mastered based on company-specific quality management systems (QMSs) for that company's industrial components and environment. It ensures that the level of knowledge and skills of a technician is benchmarked within a specific com-

*Ultrasonic testing at DCD's Top Guns welding competition during 2014.*

*Jansen believes that the quality of NDT inspection is mostly dependent on human resources and the competency of the NDT Technician.*

pany and directly related to end-user expectations.

On the negative side, the lack of independence when assessing personnel competencies are problematic and the system is difficult to harmonise with respect to basic knowledge, codes and standards, specifications and the application of practical skills between different companies, since employers only focus on their own area of activity.

Based on the analysis of both systems it is clear that the limitations of the one system are addressed by the benefits the other. If the two systems were combined, therefore, a quality NDT technician with a balance of harmonised theoretical knowledge and industry relevant skills could be qualified for NDT work in South African industry.

To achieve this combination, a facilitator body is needed to ensure that each aspect of the qualification and certification for quality NDT personnel is achieved. The South African Institute for Non-Destructive Testing (SAINT) has undertaken to fulfil this role, by establishing the SAINT Professional Body for NDT, whose sole purpose would be to professionally designate qualified and certified NDT personnel.

## An approach to developing quality NDT technicians

A good quality, well rounded NDT technician can be compared to a sturdy chair, with the combined ISO 9712 and SNT-TC-1A systems as its seat. The seat is supported by four legs, with additional ongoing support in the form of a backrest being supplied by the professional designation system.

**Leg 1 – Abilities:** A sturdy chair requires four legs of equal strength. Representing the first supporting leg of the NDT technicians' chair are his or her abilities. The abilities of an individual refers to those qualities that they bring to the table prior to being trained or mentored and include physical and knowledge abilities and specific personal characteristics.

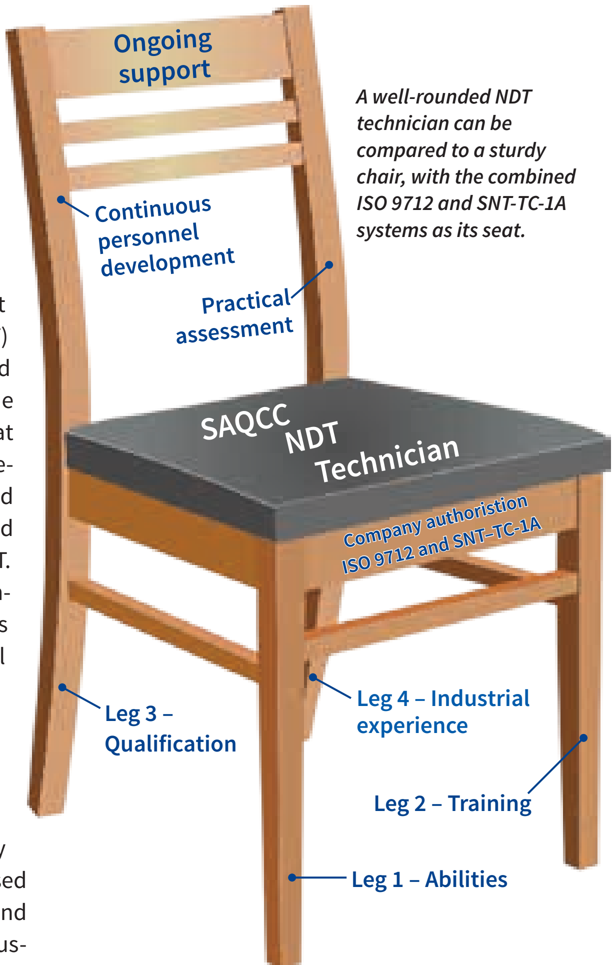
Any person wanting to become an NDT technician should at least be able to pass a visual acuity test and have the physical ability required, for lifting and carrying of equipment or climbing in or onto vessels, for example. Personality traits such as honesty, integrity and responsible, are also beneficial.

At the starting point, pre-knowledge pertaining to mathematics and science at a Grade 10 pass mark is needed to be eligible for the surface testing methods such as visual testing (VT), magnetic testing (MT) and penetrant testing (PT), while Grade 12 pass marks are more appropriate for eddy current testing (ECT), ultrasonic testing (UT) and radiographic testing (RT). Should the minimum requirements not be met, then a pass mark of greater that 70% in a proficiency test would be required. This test is specifically created to assess the basic mathematical and comprehensive skills required for NDT.

NDT students would then be encouraged to go through the various NDT Qualification levels, from Level 1 through to Level 3, which all have associated NDT roles and responsibilities in industry.

**Leg 2 – Training:** This leg refers to formal classroom training provided by an approved training body (ATB) based on international codes, standards and procedures relating to relevant industrial or product sectors. The theoretical contents of training courses should comply with ISO TR 25107, IAEA Tecdoc 628 and ASNT CP 105.

Formative assessments to assess learning progress, and a summative assessment at the end of the training




*A well-rounded NDT technician can be compared to a sturdy chair, with the combined ISO 9712 and SNT-TC-1A systems as its seat.*

programme are required prior to issuing a proof of training record.

Dedicated practical training programmes can also be implemented to reduce the industrial experience requirements. ISO 9712 allows for 50% of the industrial experience to be gained by a dedicated practical course programme that can be weighted up to a factor of 5. This means that one week of dedicated practical training would equate to five weeks of industrial experience.

**Leg 3 – Qualification:** In ISO 9712, a qualification is the demonstration of physical attributes, knowledge, skill, training and experience required to properly perform NDT tasks, while SNT-TC-1A defines a qualification as the demonstrated skill, demonstrated knowledge, documented training, and documented experience required for personnel to properly perform the duties of a specific job. In essence, these two definitions are not incompatible and can be summarised as a student's ability to demonstrate his or her NDT capabilities.

Within the ISO 9712 system this is performed via an independent qualification examination consisting of a general, specific and practical examination. As mentioned previously, the SNT-TC-1A system is industrial-experience focused and this qualification aspect is, perhaps, better suited to Leg 4 of a combined system.

**Leg 4 – Industrial experience:** Industrial experience, if it is applied correctly, lies within the domain and strength of the SNT-TC-1A system. Since ISO 9712 focuses on the basic qualification of personnel, industrial experience requirements are deliberately vague. SNT-TC-1A, therefore could fill this gap, since industrial experience is related to a company specific environment and thus the company would be responsible for ensuring that the technicians have mastered their skills prior to authorising them to work on their behalf.

Without losing the benefits of industrial experience under SNT-TC-1A, it is relatively easy to stipulate industrial experience requirements to fit within ISO 9712 for Level 1, Level 2 and Level 3 NDT personnel. These can be summarised as suggested in Table 1.

Industrial experience is managed by an employed or subcontracted Company Level 3 Inspector in accordance with the company's Quality Manual and Written Practice. Thus the Level 3 is responsible for the mentoring programme as well as the company authorisation assessment.

To overcome discrepancies within the NDT qualification and certification with respect to Level 3 personnel involvement, the SAINT Professional Body shall monitor and designate suitable Level 3 NDT technologists for industrial experience mentoring and monitoring.

**The back support:** It is important to ensure that the information supplied by qualified and certified technicians remains accurate on an ongoing basis. This support to industry is achieved in two simple ways. First, a 'license to operate' assessment is performed by technicians on equipment similar to that found onsite.

This involves a simple practical test involving a relevant sample containing discontinuities comparable to the smallest rejectable indications found at the inspectors' workplace. Second, in order to keep up to date with latest developments and to ensure continuous personnel development, a system of CPD points at all levels of qualification is required.

These two process would be the domain of the SAINT Professional Body and would lead to the candidate being a designated NDT professional according to qualification levels: Level 1 – Operator; Level 2 – Technician; or Level 3 – Technologist.

In addition, the seat of the NDT technician's chair can only be 'occupied' for a period of five years. Thereafter, renewal or recertification would be applicable.

## Conclusions

While this process has the ability to address long-standing issues relating to the qualification and certification of NDT personnel, only full implementation would ensure success. The NDT fraternity would have to manage, maintain and take responsibility for all aspects described above, with regular interaction with the end-users. Only under these conditions can constant improvement in the NDT industry be achieved.

| | Level 1 | | | | Level 2 | | | | Level 3 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Written Practice & Written Instructions | Written Instructions & Recording Results | Technique Specific Mentoring (Receive) | OPTIONAL: Structured & Dedicated Prac Training @ ATB | Written Practice & Quality Procedures & Resource Maintenance | Procedures & Reporting | Technique Specific Mentoring (Receive & Provide) | OPTIONAL: Structured & Dedicated Prac Training @ ATB | Written Practice & Quality Procedures | Procedures & Reporting | Technique Specific Mentoring (Provide) & Level 3 work | OPTIONAL: Structured & Dedicated Prac Training @ ATB |
| PT, MT, VT | 5 | 5 | 17 | 5 | 10 | 10 | 46 | 15 | 20 | 20 | 480 | 50 |
| ECT, UT, RT | 10 | 10 | 46 | 15 | 20 | 20 | 158 | 20 | 20 | 20 | 480 | 50 |
| Company Authorization Examination | Mandatory – Performed by Company Level 3 in accordance with company QMS.<br>**ISO 9712 Qualification Examination is not applicable.** | | | | | | | | | | | |

*Table 1: A summary of possible industrial experience requirements that might fit within ISO 9712 and meet the essential requirements of SNT-TC-1A.*

# SA specialist in quality pressure equipment

**Hi-Tech Pressure Engineering (HTPE) is an SAIW member company certified under the SAIW Welding Fabricators Certifications Scheme to ISO 3834 Part 2, comprehensive quality requirements. *African Fusion* speaks to Warren Hollingsworth (right), the company's business development director.**

Hi-Tech Pressure Engineering is a well-established, medium sized engineering firm based in Durban, South Africa that designs and manufactures code compliant pressure equipment and related plant, storage and process vessels, as well as pressure piping systems. "Our company has evolved since 1995 into a specialist manufacturer, of pressure vessels, heat exchangers, pressure piping and other code compliant vessels. We offer high quality fabrications to meet the most rigorously specified design criteria," says Hollingsworth.

Hi-Tech has serviced the petrochemical, pulp and paper, mining, effluent and sugar industries since its inception in 1995. "Our clients include John Zink International, Lanxess Cisa, Areva (Nuclear), Illovo Group, Sappi Paper, Mondi Paper, Talbot & Talbot, Durban Metro Council, Sasol Technology, Durban Fibres, Macsteel Group, Transvaal Sugar Limited, Tongaat Hulett Group, Dunlop, S.A. Bioproducts, Cutler Management Board, Dulux, Plascon, Barker Flynn Associates, Chevron Texaco Angola, NCS Resins/Dow Sentrachem, Lonmin, Pressure System Capabilities and IBL Mauritius, and we are a Level 2 contributor in terms of the B-BBEE guidelines," he reveals.

"Our modern facilities include a design and drawing office and large fabrication workshops. The recently completed expansion of our purpose-designed facilities now enables us to separate carbon and stainless steel fabrication. A major investment in 2015 has been the installation of a complete inverter battery system for the offices and a generator capable of running the entire operation. This was considered critical for Hi-Tech to be unaffected by power supply issues. Our clients need their jobs completed and we cannot afford not to be producing."

Workshop space includes 5 000 $m^2$ under roof with a maximum lifting capability for 5.0 x 6.0 x 22 m fabrications weighing 20 t per part using two 10 t Demag overhead cranes. A further four Demag 5.0 t cranes are on hand for smaller work. Maximum head height of fabrications is 11,5 m, while ground based vessel rotators allow 7.5 x 8.0 x 22 m vessels weighing up to 65 t to be handled.

"On the forming side, as well as plate cutting facilities, we have four-roll plate rollers capable of rolling diameters of up to 3 100 mm in 20 mm plate; 3 000 mm in 70 mm at diameters of 2 000 mm or less," says Hollingsworth. "We have bending facilities for 3 000 mm plate at 10 mm thicknesses and, for piping, an automatic pipe cutting systems with bevelling equipment that allows complex shapes to be accurately prepared for welding," he adds.

To enhance the quality of welding fabrications, Hi-Tech has invested heavily in modern and automated welding equipment. For heat exchanger work, an Orbimatic orbital tube-to-sheet welding system is used to achieve best possible weld quality and productivity.

For thick section plate seams and circumferential welds, a Lincoln square wave 1000 ac/dc submerged arc welding system fitted to a 5 x 5 m column and boom and a rotator is used, fitted with automatic weld seam tracking systems to ensure seam quality. "But for long internal seams and butt joints on large plate, we use Lincoln Cruiser submerged arc tractors," Hollingsworth adds.

From a welding process point of view, all processes are applied: submerged arc, pulsed TIG, pulsed MIG, fully automatic orbital TIG, as well as SMAW and manual TIG. "We also detail, fabricate and supply specialised structural steel, pipe support structures and special supports, as well as structures for marine application, typically to the Norwegian DNV design standards.

"A climatically controlled welding consumable store is in place to help meet code and ISO 3834-2 standards and we have a water-cooled induction heat treatment system capable of a maximum temperature of 760 °C," he adds.

Materials of construction include carbon, low- and intermediate-alloy steels, while on the stainless side, Hi-Tech's experience includes 310, 321, 316L, 304L, 904L and the duplex steels, SAF2205 and LDX 2101 – and fabrications in all of the above can be accommodated in thicknesses from 3.0 to 70 mm.

As well as its ISO 3834 certification, Hi-Tech Pressure Engineering is also certified by TUV Rheinland to ISO 9001 and ISO 18001. The company is able to complete designs and design checks for all of the common codes of construction: ASME VIII, TEMA ASME B31.1, ASME B31.3, ASME PCC-2-2011, ASME PTC 19.3 TW 2010, PD5500 and BS2654. "Our drawing office has four CAD stations using AutoCAD Inventor – Routed Systems Suite 2014 – and our experienced drawing office staff is able to provide clients with detailed draw-

ings or initial concept design drawings for approval.

Vessel design checking is done using PV Elite, while piping designs are validated using Intergraph CAESAR II. "Hi-Tech offers full compliance with the Pressure Equipment Regulations (PER) and SANS 347:2012 Edition 2 and operates an audited quality control system that is certified to three international standards: ISO 9001-2008, ASME VIII Div 1: Appendix 10 and ISO 3834-2," Hollingsworth tells *African Fusion*.

Separate material traceability systems and record keeping for all materials are managed, as required, and external inspection authority approval for completed fabrications as well as certificates of construction are routinely provided for project work.

"Strategic supply partners include: Degerfors Formings AB, Sweden and Arabian Oasis Industries, Dubai for formed/dished ends; and Jacquet of France for cut-to-size plate in special materials," Hollingsworth reveals.

## Notable projects

Hi-Tech's core product experience lies in pressure vessels and heat exchangers: thick shelled pressure vessels (up to 70 mm); air receivers, de-aerators; chemical tanks with mixers; boiler components; high pressure steam separators; juice heaters; steam condensers; air heaters/coolers; along with tube, U-tube and coiled heat exchangers. "We have also successfully completed turnkey turbine alternator projects from 4.0 MW to 48 MW.

Citing a surge pressure vessel for Revertex Chemicals, Hollingsworth says that this project highlights Hi-Tech's ability to fabricate in complex modern materials, such as duplex stainless steel. "The client had requested the use of 304L material for this vessel, but we offered to use LDX2101, a duplex stainless steel with far higher strength than 304L," he explains.

The use of LDX material enabled the vessel to be manufactured from 5.0 mm plate, resulting in a weight saving and, ultimately, a cost saving for the project. "Due to the complex nature of the vessel, construction had to be done upside down. The bottom of the vessel was manufactured first and the legs fitted. While still upside down, the many nozzles were fitted using an electronic level to ensure the correct entry angle," Hollingsworth says.

Once completed, the vessel was inverted and the top section, which had been fabricated separately, was fitted. The vessel was pressure tested and successfully commissioned in January 2010. "As a direct result of this project, Hi-Tech secured another condensate vessel, along with the supply, fabrication and installation of all piping required for the surge tank."

The company also engineers, designs and constructs hyperbaric chambers and ASME PVHO (pressure vessel for human occupancy) vessels. "We installed the first oxygen treatment chamber in KwaZulu-Natal (South Africa). This chamber is certified by the Department of Labour and was donated to the Cerebral Palsy Association of SA," Hollingsworth adds. "We supply deck decompression chambers to the commercial diving industry and, in 2009, we manufactured the first 100 m saturation diving training system in South Africa.

On the heat exchanger side, Hollingsworth lifts out a set of juice heaters for Illovo Sugar, which were designed to client specifications and then manufactured and delivered to site. "The units were manufactured in pairs over a period of three months. The juice heaters featured hydraulic door opening systems, for which we supplied complete hydraulic power pack units and control panels. Prior to delivery, each vessel was pressure-tested with its doors to remove all risk of leaks on site," he says.

The contract also required Hi-Tech Pressure Engineering to supply all valves and pressure relief valves for each juice heater. These were crated specifically for each vessel and accompanied the vessel to site. "We also handled all logistics and transport and the heaters were delivered in record time, over the Christmas period," he adds.

Storage and process vessels designed and manufactured to BS 2654 and API 650 also feature in the company's skills set, including: jacketed vessels; helical coiled vessels; and boiler scrubbers. "And on the piping side, we have specific experience with steam piping systems of up to 125 bar. We undertake piping design, stress analysis, fabrication and installation of high-pressure steam systems; induction formed piping systems; stainless and alloy steel piping; along with all of the special supports, variable spring supports and compensators required onsite.

"Our investment in systems and technology over the last 20 years are paying dividends, and we will continue to invest to ensure that we are benchmarking against the best in the world. We also invest in our staff; continually improving their skills to enable them to perform in this dynamic environment.

"We believe that success in this industry is achieved by embracing technology and improving individual skills," Hollingsworth concludes.

*1. Heavy-walled 904L vessels awaiting delivery to the platinum industry.*

*2. Jet fuel filters for the Airports Company of South Africa manufactured by Hi-Tech in Durban.*

*3. Hi-Tech Pressure Engineering completed the design, manufacture and installation of this 250t/h de-aerator for Mondi.*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# Inspection, certification and remaining aligned

**At SAIW's first graduation dinner for 2015, over 130 students celebrated successfully completing SAIW courses, ranging from IIW Welding Specialist and Welding Technologist courses to Inspection Level 1 and/or Level 2 qualifications.**

*TZ Joubert, chairman of the SAIW Inspectors Committee and SAPREF inspection manager.*

*Welsh Philip Moller Wienand receiving Inspector Level 1 and Level 2 diplomas along with the IIW Standard Level Welding Inspector certificate from SAIW president Morris Maroga.*

Delivering the motivational address, TZ Joubert, chairman of the SAIW Inspectors Committee and SAPREF inspection manager talked about the functional responsibilities of inspection personnel and the need to "remain aligned".

"Unfortunately in industry, we frequently come across cases where our inspectors and QC personnel are not aligned with the Pressure Equipment Regulations (PER), health and safety standards (OHS Act) nor with the company's own quality system standards.

"Training from SAIW is a first step in making sure that we remain compliant within our inspection function, whether those are weld inspection functions; welding supervisor functions, welding engineering or welding technologist functions. All of you have now been trained to fulfil one or more of these functions within a company's quality system," Joubert points out.

"But we regularly come across inspectors who 'take the law into their own hands," he continues, "by allowing pressure tests that are not code compliant, for example, or by not attending seminars to keep abreast with the latest Pressure Equipment Regulations – part of the current SAIW requirements for ongoing registration.

"Because we represent the industry, the regulator, AIAs or manufacturers, we have responsibilities. We all have an obligation to maintain and to comply with health and safety standards and your license to practice depends on this compliance," he asserts.

Citing his experiences as a young inspector, Joubert urges the young graduates to respect the experience of their supervisors. "But alignment cannot only rely on supervision. Mostly, it depends on you being disciplined individuals. Make sure you have read the PER, the applicable welding or repair codes and the health and safety standards. Unless you have the code next to you, you are not following the aligned path. Lets uphold the legal requirements. We owe it to our clients and customers, who pay for our services. Let's remain aligned," Joubert urges.

Starting with the welding co-ordination programme, Sean Blake, the new SAIW executive director, began to award the certificates. "We are going to begin with our IIW welding coordination programme," begins Blake. SAIW offers IIW Welding Practitioner, Welding Specialist, Welding Technologist and IIW Welding Engineer qualifications. "Tonight we are awarding diplomas in two of these categories, Welding Specialist and Welding Technologist. "This the group of people will be responsible for managing welding processes within fabrication environments according to schemes such as ISO 3834. They require specialist knowledge of welding engineering and the control of welding processes, and when things go wrong, these specialists have the knowledge to rectify issues that are creating problems," Blake informs.

In total 12 Welding Specialists received diplomas, with a further four graduates receiving IIW Welding Technologist qualifications.

*At SAIW's first graduation dinner for 2015, over 130 students celebrated successfully completing SAIW courses.*

# The 67th SAIW president's report

## *African Fusion* summarises SAIW President Morris Maroga's report, delivered during SAIW's 67th annual general meeting on May 8, 2015.

*The 2015 Young Welder often Year, Jaco van Deventer (right) from Steinmüller, receives his stainless steel award from SASSDA's Mankabe More.*

"The past year has been one of change in South Africa, which has brought many challenges to SAIW and the welding industry," begins Maroga, before announcing the elected council members and welcoming its new member, SASSDA's John Tarbotan, who replaces retired SASSDA president Bill Scurr on the SAIW board. "I would like to thank all the Council members for the time and expertise which they contribute to the governance of the Institute," he says.

On the financial side, the Institute managed to generate a net surplus and "with self-generated income in excess of 98% of our total income" the Institute was again able to make good provisions for future expenditure. "So overall, 2014 was an excellent year for the Institute in terms of finances," Maroga reports.

Thanking the South African Iron and Steel Institute (SAISI), he says that, because of its continued sponsorship and support, "SAIW is able to offer practical welder training at our facility, which is a costly activity."

Addressing the status change of the Institute Maroga reports that last year, the Institute began converting from an Unincorporated Association to an Incorporated Not for Profit Company registered under the Companies Act of 2008. "I am pleased to report that this process is now complete and SAIW has been registered as a Not for Profit company," he announces.

### Membership and branches

In response to the challenge of growing its membership, a scheme has been introduced to encourage graduates from Institute courses to join as members on a trial basis. "Retaining and growing personal membership is a challenge we share with many other technical institutes. We need to continue exploring methods to promote membership of SAIW and I would like to recommend all our members to encourage their industry colleagues to join," he urges.

The Cape Town and KwaZulu-Natal branches have remained active throughout 2014, represented by Anne Meyer in Durban and Liz Berry in Cape Town, while "Kennedy Nyirenda continues as our representative in Zambia" though an informal association with the Engineering Institute of Zambia.

### Annual highlights

"The 2014 dinner, held in August, was once again a great success. Of particular note was the presentation of The SAIW Gold Medal to Robin Williamson for his outstanding contribution to SAIW and the welding industry, for over 30 years of selfless service.

Continued on page 13 ➡


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The biennial Young Welder of the Year competition was run in January of this year. "This year we had a record number of competitors from a variety of training institutions including: public TVET colleges; private training institutions; and company in-house training academies," Maroga says. The competition was extremely close with little more than one point separating the winner, Jaco van Deventer from Steinmüller, from the runner up, Romario Arendse from the West Coast College.

On the training side, good growth was experienced across the board, apart from a decline in practical welding. Training of in-service inspection personnel accelerated at a rapid rate owing to legislation requirements. "We are continuing to promote the IIW International Welder (IW) scheme, a programme that is achieving wider recognition as an optimum comprehensive skills programme for welders both locally and abroad.

SAIW is expanding its capability to meet the growing need of the rail, power generation, structural steel and petrochemical industries by strengthening the skills of its staff – in view of government's plans to spend hundreds of billions of Rands on infrastructure in the next few years.

## Qualification and certification

The ISO 3834 certification scheme continues to make progress and there are now more than 75 companies that have been certified for working in accordance with the ISO 3834 welding quality standard. The scheme is increasingly well supported by both fabricators and end users. "We have also seen an increase in interest for the International Welder training programme and have increased the number of Authorised Training Bodies to a total of five, with Eduardo Construction and Steinmüller having been authorised to undertake this training programme during the past year.

## International affairs

The next IIW Annual Assembly will be held from June 28 in Helsinki, Finland. SAIW will lead a delegation of South African participants in the meetings and conferences being held in the Assembly.

SAIW is also increasing its interest and influence in ICNDT. Both Harold Jansen and Jim Guild attended the ECNDT Conference in Prague in October last year, where ICNDT matters were also discussed. "We are pleased to report that Harold Jansen has been elected as vice chairperson of the ICNDT Certification Executive Committee, thus further entrenching our involvement in ICNDT," Maroga adds.

The IAEA/AFRA connection in NDT remains strong. "We are in the process of training students from both Sudan and Cameroon on triangular projects in partnership with IAEA. The triangular projects have been established in order to develop regional training and examination capacity in the respective countries. We are hoping to run a similar project with Kenya later in the year," he says.

## Future developments

"We are actively pursuing permanent premises in Durban and hope to have a functional facility in KwaZulu Natal before the end of this year, which will have facilities for both practical and theoretical teaching in welding technology as well as non-destructive testing," Maroga reveals. In addition, a satellite facility in Mpumalanga is being explored to take pressure off the Johannesburg building, which is working at capacity.

"The SAIW Board of Directors believes that Institute expansion into Africa is imperative for continued growth of the Institute," he says. "We will be using existing cooperative relationships and partnerships with organisations that are already working in these markets, most notably mining activities in central and western Africa as well as oil and gas projects in Angola, Nigeria and Mozambique," Maroga informs members.

# SAIW Gauteng and KZN golf days

The SAIW Golf day for Gauteng took place on the May 19, 2015 at the Royal Johannesburg Golf Club. A total of 84 players participated in a 'fourball alliance' with the best two scores counting on each hole. The winning team, from AFROX, consisted of Simon Poiyner, Dries Grobler, Alan Buchholtz and Leonard Sandham.

In KZN, the golf day is scheduled for July 23 at the Royal Durban Golf Club. Book early to avoid disappointment. Contact Kim Stevens.

*stevensk@saiw.co.za*

*Afrox winners of the Gauteng golf day, photographed with Sean Blake, SAIW executive director (second from left): Simon Poiyner, Dries Grobler, Alan Buchholtz and Leonard Sandham.*

# SAIW's new training services manager

Shelton Zichawo, following several years as the coordinator of the SAIW's ISO 3834 Welding Fabricator Certification Scheme, has been promoted to the training services manager position. "The ISO 3834 experience will be of great benefit to me in the training role, because it kept me in touch with industry," he tell *African Fusion*. "So I come to training with a very clear picture of where our students will end up. I know what company's expect of their staff in terms of skills and knowledge, and from ISO 3834 requirements, I have a clear idea of the roles and responsibilities of trained personnel," he says.

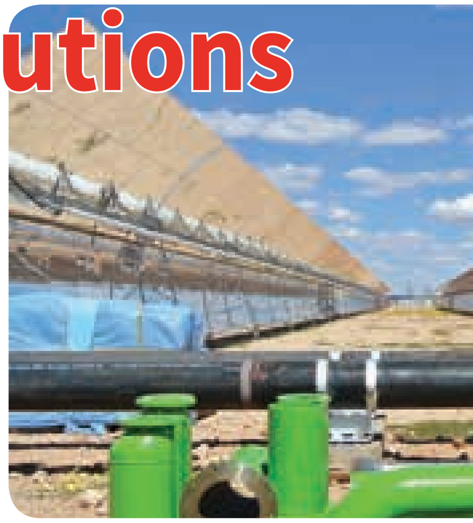
His priorities? "Initially, I think we need to look in-house to ensure that our own lecturers and training staff are able to perform at the necessary level. We will be sending some lecturers to the US for training in specialised areas such as the ASME Code courses and we hope to send more people on local and overseas training to improve SAIW expertise," he responds.

*Shelton Zichawo has been promoted to SAIW Training Services Manager.*

Zichawo will be responsible for all welding inspection and technology courses, along with the inspectors of pressurised equipment (IPE), competent persons (CP) and all of the IIW welding, welding coordination (IWC) and welding technologist (IWT) courses.

"I am committed to retaining SAIW's position as the preferred training body for welding-related training services," he assures.

# Gas and welding solutions for the CSP industry



**In response to the specific requirements and needs of establishing and operating concentrated solar power (CSP) plants, Afrox has developed a comprehensive product and energy solutions offering to specifically suit the industry. *African Fusion* talks to Johan Pieterse, Afrox's business manager for the manufacturing industries.**

On a 1 100 ha site near Pofadder in the Northern Cape, The 100 MW KaXu Solar One concentrated solar power (CSP) plant has now been commissioned. It is the first CSP plant in South Africa to use parabolic trough technology. Following close on its heels are Khi Solar One, a 50 MW power tower CSP plant outside Uppington, and the 50 MW Bokpoort solar parabolic trough CSP plant, which is nearing completion.

In addition, the 100 MW Eskom plant in Uppington has been approved for construction and three CSP plants were announced as preferred bidders by the Department of Energy in the third round of the government's Renewable Energy Independent Power Producer Procurement Programme (REIPPPP): Kathu Solar Park, Redstone Solar Thermal Power, and Xina Solar One, all of which will have 100 MW capacities and significant night time storage capability – Redstone is promising a full 12-hours of energy storage, a first in Africa.

The Northern Cape is clearly becoming South Africa's solar energy hub.

Afrox has developed customised solutions in response to the specific and unique requirements of the CSP industry and, in particular, the challenges associated with having operations in remote areas of the Northern Cape. "A simple visit to a CSP site takes a week, particularly if equipment has to be delivered," Pieterse points out.

## Welding and cutting solutions

At the starting point of Afrox's CSP offering are its welding and cutting products for the construction phase of projects and, later, for scheduled maintenance during shutdowns. "Our fabrication specialists work closely with construction contractors to ensure a full understanding of the on site needs. Once these have been established, welding consumables and gases, as well as welding equipment is sourced from the nearest Afrox sales outlet," Pieterse tells *African Fusion*.

"Parabolic trough plants such as Bokpoort require 20 000 km of pressure piping to be welded, along with the support structures for a solar field consisting of 588 600 m$^2$ of mirrors. The site is 3.0×1.5 km in area and consists or rows of piping running above the parabolic troughs, which are polished steel mirrors that track the suns moment across the sky to focus sunlight onto the pipes," he explains.

Inside the pipes an oil-based transfer fluid is steadily heated as it is pumped through the field towards the generation plant at its centre. "The fluid reaches temperatures of about 400 °C, which is just below the critical creep temperature for piping, so you don't need to use chrome-moly materials for the piping. This is a pressurised circuit, though, so high quality welding is essential for reliable operation," he continues.

Onsite pipe welding is done using the TIG process for root runs followed by fill and capping passes using low hydrogen MMA electrodes. "We were awarded the contract for the supply of TIG welding wires and the Argon gas for the Bokpoort CSP contract, along with the LH welding consumables," he adds.

## Molten salt storage solutions

A key feature of the Bokpoort CSP plant is the molten salt storage system, which will endeavour to provide more than nine hours of electrical generation capacity (1 300 000 kWh$_{thermal}$) after sunset or during cloudy weather.

The molten salt is contained in two huge storage vessels. These have also been constructed onsite with Afrox-supplied consumables, using a combination of MIG/MAG, flux-cored arc welding and submerged arc welding processes.

Pieterse explains: "During the day, the transfer fluid heated by the parabolic troughs is passed through heat exchangers, which heat the molten salt being stored in the tanks. At night, the hot salt is then pumped through another heat exchanger where it is used to create steam for the turbine after hours."

Because of the high temperatures and corrosive nature of the molten salt, stainless steel piping is used for these circuits, which is welded using Afrox's TIG range of wires and its Argon gas for the root passes and capped using Afrox's stainless steel range of electrodes.

A large part of Afrox's contribution to the Bokpoort CSP plant arose because of its industrial gas expertise. "The salt only melts at 200 °C, and it needs to be melted before it can be used as a heat-exchange fluid. We have developed an LPG storage and supply system to melt the salt on start up of the plant and following shut-downs," Pieterse reveals.

Afrox's modular and portable skid-based container system consists of a series of containerised bulk LPG storage tanks along with all of the evaporators necessary to supply the fuel for the initial salt melt. The whole system is transported to site and offloaded in a designated area. Once the salt is molten, the system is no longer needed on site, so to save space and investment costs it can be transported to and deployed at another site or returned to our stores until required again," he tells *African Fusion*.

In addition, the molten salt requires and inert atmosphere in order to 'blanket' the thermal storage medium, that is,

*Above: Afrox's CSP solutions have been supplied to the Bokpoort parabolic trough plant, which requires 20 000 km of pressure piping to be welded, along with the support structures for a solar field consisting of 588 600 m$^2$ of mirrors.*

*Above right: Afrox's modular and portable skid-based container system consists of a series of containerised bulk LPG storage tanks along with all of the evaporators necessary to supply the fuel for the initial salt melt.*

*Centre right: The Bokpoort CSP plant has a molten salt storage system to provide over nine hours of generation capacity after sunset or during cloudy weather.*

*Right: Onsite pipe welding is done using the TIG process for root runs followed by fill and capping passes using low hydrogen MMA electrodes.*

to prevent the hot salt from reacting with moisture and atmospheric gases. "Afrox has developed a custom-designed nitrogen storage and reticulation network to provide the inert atmosphere necessary for the salt storage tanks, the expansion tanks and the high temperature fluid boiler. The system comprises an on-site nitrogen production system, using pressure swing absorption technology (PSA), backed up by a high-pressure liquid nitrogen storage and supply system," says Pieterse.

Afrox's parent, the Linde Group Engineering division, is supplying the on-site nitrogen generating facility, while the cryogenic storage facility and custom designed nitrogen reticulation system has been installed by Afrox. A long-term nitrogen supply agreement between Afrox and Bokpoort CSP has been concluded to ensure an uninterrupted and reliable nitrogen supply to the project.

Bulk liquid supply is ideal for applications where flexibility is required or uneven demand patterns are prevalent. Once the demand at the CSP plant has been established, however, on-site nitrogen generation or a combination of bulk and on-site supply are options that can be considered.

Through the Bokpoort CSP project, Afrox has demonstrated its ability to design and deliver reliable systems and services for both the construction and operation phases of CSP projects. "Our supply network covers almost every region in South Africa, but it becomes increasingly less cost effective as the distance from a source increases. We have already opened a branch in Upington and are in the final stages of planning for a branch in Katu to support this growing industry," reveals Afrox's Pieterse. "When you consider that several of coal fired plants may be adding CSP systems to improve their efficiencies, we anticipate up to 22 CSP plants being built by 2030.

"And Afrox is well positioned to support this future potential. Based on an in-depth understanding of the requirements and challenges during the construction phase of CSP projects, along with our knowledge of the ongoing operating and maintenance needs, we have developed a comprehensive CSP solutions offering," Pieterse concludes.

*In order to 'blanket' the thermal storage medium, Afrox has developed a custom-designed nitrogen storage and reticulation network comprising a pressure swing absorption (PSA) nitrogen generation system backed up by a high-pressure liquid nitrogen storage and supply system.*

# Deposition of crack-sensitive nickel-based alloy using LAAM

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**In this paper, presented at the 67th IIW International Conference in Seoul, South Korea, in 2014, layer by layer fabrication using laser aided additive manufacturing (LAAM), a laser deposition/cladding technique using powders, was successfully implemented on the nickel-based superalloy IN100.**

It is known that IN100, a type of superalloy having high titanium and aluminium contents, has poor weldability due to weld liquation cracking in the heat-affected zone (HAZ). In this study, the LAAM process was optimised through a set of designed experiments to eliminate crack formation and reduce porosity. It was found that the heat affected zone can be controlled to less than 50 μm due to the low heat input of the LAAM process used.

Results also revealed that similar phases were retained in the heat-treated deposited IN100 material to those of cast IN100. Three distinct sizes of the γ′-phase were observed after the heat treatment process. The volume fractions of γ to γ′ ($Ni_3Al$-type) phases were found to be approximately 60% to 40%. Microstructures and chemical compositions were also analysed and results showed that γ′ phase ($Ni_3Al$-type) was embedded within the γ-Ni matrix. In addition, various carbides (MC, $M_{23}C_6$ and $M_6C$) were observed as precipitates at grain boundaries.

## Introduction

Laser aided additive manufacturing (LAAM) is a rapid manufacturing technique that uses a high power laser beam to repair or build 3-dimensional (3D) components layer by layer directly from powders. LAAM is similar to other 3D additive manufacturing techniques being developed at various laboratories in the world under different names, such as direct metal deposition (DMD) [1], laser engineered net shaping (LENS) [2, 3], laser rapid manufacturing (LRM) [4], laser metal deposition (LMD) [5], etc. All of these techniques have the capability to build 3D high performance components through multi-layer overlapped deposition in a predetermined pattern via CNC or robot programming.

In recent years additive manufacturing has emerged as an effective tool for fabrication or repair of low-volume and high-value parts in aerospace, medical and precision engineering industries due to its ability to shorten the manufacturing time and to reduce material waste and manufacturing costs. The laser process has the flexibility to produce components that are directionally solidified, have controlled porosity or chemical composition gradients. The rapid solidification nature of this technology also enables it to create finer microstructures that are difficult to achieve using other conventional methodologies.

| Element | Ni | Cr | Co | Mo | Al | Ti | V | C | B | Zr |
|---|---|---|---|---|---|---|---|---|---|---|
| wt% | 60 | 10 | 15 | 3 | 5.5 | 4.7 | 1 | 0.18 | 0.014 | 0.06 |

*TABLE 1: Chemical composition of the IN100 powders used for LAAM.*

Until now, a number of metals, including steels [6], titanium alloys [7], cobalt-chromium alloys [8], and a few nickel-base alloys [1, 4, 9-11] have been used for creating functional parts using laser deposition techniques. For example, Dinda et al [1] investigated the microstructural evolution and thermal stability of nickel-based alloy IN625, while Ganesh and Paul et al. [4, 10] focused on the mechanical properties of the same alloy. Other researchers studied the influence of laser processing [9] and heat treatment effects [11] on microstructures and mechanical properties of IN718. Nickel-based superalloys are commonly used in harsh environments requiring superior strength at high temperatures and therefore find extensive applications in hot sections of gas turbine engines, rocket propulsion systems, and nuclear reactors.

Among nickel-based superalloys, IN100 is used mainly for jet engine parts such as turbine blades and wheels operating in the intermediate temperature regime [12, 13]. Due to the high Ti/Al content (>11%), the two major phases present in IN100 are the γ′ ($Ni_3Al$-type) phase embedded in a face-centred cubic (fcc) solid solution γ-Ni matrix. Carbides and borides appear as minor phases.

Material properties of IN100 depend on a number of interrelated microstructural parameters including the volume fraction of γ′ to γ, grain size, elemental distribution, and the precipitation of carbides and borides. When γ′ volume fractions are higher than 40 to 45%, the gap between the solvus and incipient melting temperature is very narrow and makes hot working of cast ingots most difficult among the Ni-based alloys [13]. Thus, IN100 is typically produced in cast or powder metallurgy (P/M) forms whereas LAAM or similar techniques have never been attempted on IN100 because rapid cooling during laser processing is likely to induce solidification stress cracking in the heat-affected zone.

In this study, we explored the feasibility in creating multi-layer structures from IN100 powder materials using LAAM. LAAM process was optimised with low heat input to minimise stress cracking as well as to retain structural integrity. Also presented in the paper includes microstructures and crystalline phases the laser-processed IN100 as well as those of the cast material, which was used as the substrate. Characterisation results of the laser-processed samples showed desirable microstructures.

## Experimental procedure

The experiments were carried out using a laser aided additive manufacturing system which was developed at Singapore Institute of Manufacturing Technology. The cladding head with coaxial powder feeding was mounted on a CNC system which was enclosed in a metallic chamber to prevent operators from accidental injury by laser radiation. A 500 W fibre laser system (IPG Photonics), operated in CW mode at a wavelength of 1 070 nm, was used in this study. Argon gas was used as the powder carrier gas as well as the shielding gas to prevent the melt from undergoing rapid oxidation at elevated temperatures.

Powder was delivered to the cladding head by a powder feeder (Twin 10-C, Sulzer Metco). Process parameters included CW laser power of 150-250 W, scanning speed of 5-10 mm/s, and overlapping of 50%. Commercially available, gas atomised IN100 powder (IN100) was used in this study. The gas atomised powders had an average size of 20-45 $\mu$m in diameter and were used as received. Table 1 shows the chemical composition of the IN100 powders and substrates and Figure 1 shows the morphology and microstructure of the IN100 powders.

For the deposited IN100 samples, it was necessary to perform heat treatment in order to relieve the residual stresses as well as enable the precipitation of strengthening phases. Heat treatment consisted of a solution treatment at 1 080 °C, followed by a two-step age hardening sequence wherein the parts were held at 845 °C and then 760 °C to fully develop the strengthening phases.

As part of the sample preparation procedure, both the as-deposited and heat-treated samples were sectioned and polished down to 0.05 $\mu$m finish. Samples were then etched in two ways: First was chemical etching (1 part 30% $H_2O_2$, 2 parts HCl, 2 parts distilled water) for grain structure observation; and second, electrolytic etching (LectroPol-5, Struers) by Struers' A-2 etchant (78 ml perchloric acid, 120 ml distilled water, 700 ml ethanol, and 100 ml butylcellosolve) at room temperature using 9-10 V and etching times of between two and 4 four seconds. Electrolytic etching reveals the $\gamma'$ phase while the $\gamma$ matrix is dissolved.

Microstructures were examined by optical microscopy (OM) (MX51, Olympus) and scanning electron microscopy (SEM) (EVO-50 & ULTRA plus, Carl Zeiss) with simultaneous elemental analysis using energy dispersive X-ray spectroscopy (EDS) (X-Max, Oxford Instruments) and texture analysis by electron backscatter diffraction (EBSD) (HKL Channel 5, Oxford Instruments).

Crystalline phases were analysed using X-ray diffraction (XRD) (D8 Discover, Bruker) with a radiation source of Cu K$\alpha$ ($\lambda$=1.54060 Å). The volume fraction of $\gamma'$ to $\gamma$ and the average grain size of the $\gamma'$ phase was determined using image analysis software (analySIS pro, OLYMPUS).

## Results and discussion

### Microstructures of as-deposited and post heat-treated components

As shown in Figure 2, microstructures of as-deposited samples revealed the pattern of layer-by-layer deposition and the overlapping of the scan tracks produced by laser processing. The layer thickness was found to be approximately 300 $\mu$m and the heat-affected zone (HAZ) was seen as a white trace using optical microscopy as shown in Figure 2a.

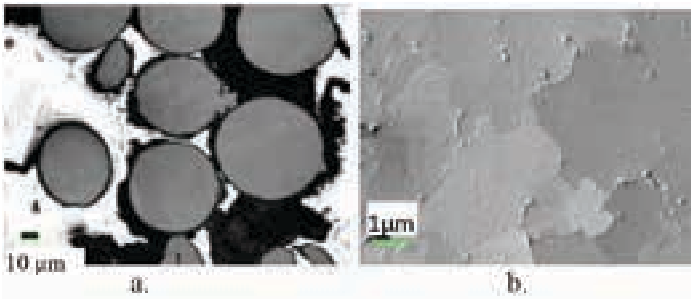


*Figure 1: SEM images of the pre-alloyed IN100 powder: (a): low magnification showing the powder size and morphology; (b). higher magnification showing carbide precipitates at grain boundaries.*

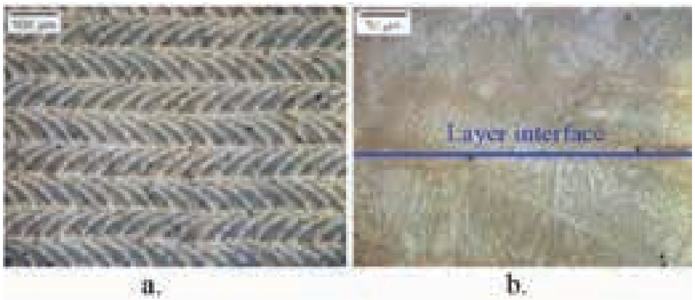


*Figure 2: Microstructures of as-deposited IN100: (a): multiple layer development on the cross-section normal to the scanning direction; (b): magnified view of the microstructure showing columnar grain structure.*

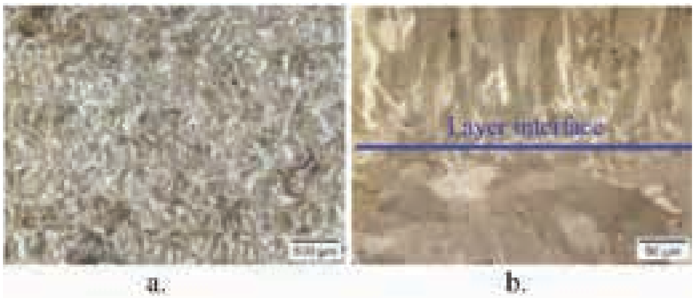


*Figure 3: Microstructures of post heat-treated IN100: (a): multiple layer development on the cross-section normal to the scanning direction; (b): magnified view of the microstructure showing various sizes of equiaxed and columnar grains.*

Two types of dendritic structures were observed (Figure 2b): a columnar dendritic region and fine equiaxed dendrites. The columnar dendrites grew epitaxially from the partially remelted grains of the previously deposited layers, which acted as the nuclei for directional growth of the crystal [1]. Dendrites typically grew along the build direction [001] because the cooling of the melt pool was primarily via the substrate or previously deposited layers and partially via the adjacent solidified deposited layer. A similar observation has been reported as the directional growth of the dendrite was opposite to the heat flux direction, which was perpendicular to the substrate of the laser deposited samples [14, 15].

The effect of post-deposition heat treatment on microstructure is shown in Figure 3. The formation of a new grain structure by the diffusion process during heat treatment was observed as the microstructure had lost its dendritic characteristic. The grain size distribution was not uniform because each layer was composed of three different regions. As seen in Figure 3b, relatively finer grains of average diameter less than 30 $\mu$m were concentrated at the lower part of each layer, i.e. at the bottom of the melt pool. These small equiaxed grains

were randomly orientated and formed at the very beginning of solidification. As solidification proceeded, coarser and columnar grains of average diameter greater than 50 μm were formed at the middle part of the layer. The columnar grains generally grew along the build direction [001], which would be in the opposite direction to the heat flow direction or adjacent to the previously deposited layer. At the upper part of the layer, more equiaxed and large grains of average diameter of ~50 μm were observed. This phenomenon is called the columnar-to-equiaxed transition (CET) [14-16] and the size and volume fractions of various equiaxed grains depend on the thermal gradient and the solidification velocity.

Figure 4 illustrates the detailed microstructure of the as-deposited IN100, where fine secondary dendrites (Figure 4a) were produced within a grain with an average dendrite arm spacing of around 2-3 μm. White particles of globular and irregular shapes were seen as precipitates along the interdendritic regions as shown in Figure 4a and 4b. They are likely to be MC carbides (M=Ti, Mo or Zr) that were segregated during the laser processing. Carbides often contribute to the strengthening effect on mechanical properties in superalloys. In general, carbon plays an important role in liquid-phase processing, where carbon acts as a deoxidiser. The residual carbon in the melt may immediately combine with refractory elements to form primary MC carbides or segregate to the interdendritic regions during solidification and form additional primary carbides. Some carbon is retained in the solid γ matrix solution and can be subsequently precipitated as secondary carbides upon heat treatment [17].

Dendritic structures at the dilution zone shown in Figure 4b and 4c were more subdued as the dilution zone possessed characteristics of a mixture of the laser-processed layer and the base material. Likewise, the heat-affected zone in Figure 4c revealed a transition into cube-shaped secondary γ′ phase as a more subdued microstructure of γ′ was observed when compared to the microstructures shown in Figure 5c, which was a material produced by casting. In comparison, the base material was composed of primary γ′, secondary γ′ and carbides as indicated in Figure 5a.

At higher magnification as shown in Figure 5b, secondary γ′ phases surrounded by the γ matrix was clearly seen. Figure 5c illustrates a deep etched sample with the cube-shaped secondary γ′ phase in relief as the γ matrix has mostly being dissolved.

Figure 6 reveals the detailed microstructure of an IN100 sample having undergone solution and ageing heat treatment. A fine γ′ phase of average size around 200 nm and a few carbides were observed in both the cladding and the dilution zone. Comparing Figure 6 and Figure 5, one notices that the γ′ phase was finer in the dilution zone than that in the base material, which had an average size of the γ′ phase around 500 nm.

To further illustrate grain structures and carbide precipitates, post heat-treated samples were chemically etched and then examined by SEM as shown in Figure 7. In contrast to the electrolytic etching, chemical etching employed here attacked γ′ phase, whereas carbides and the γ phase were in relief. Since γ′ phase was dissolved, carbides of blocky and elongated shapes were observed at grain boundaries and globular shaped ones in the grains are easily identified.

It is known that carbides were present in the raw powder and would not melt during laser processing as the temperature of the melt pool was only around 1 800 °C. In addition to pre-existing carbides in the powders, additional MC carbides might have precipitated during laser processing. Upon melting of the IN100 powder and partial remelting of the specimen, unmelted carbide particles could start their turbulent motion before the beginning of crystal formation and they have time to move towards to the grain boundaries. During their movement the unmelted carbide particles might collide and coalesce.

The globular-shaped carbide, which nucleated and grew in the interdendritic regions appeared to be caught up by the advancing solid and therefore entrapped in the grain boundaries rather than pushed ahead [18]. During heat treatment these unmelted and primary MC carbides began to transform

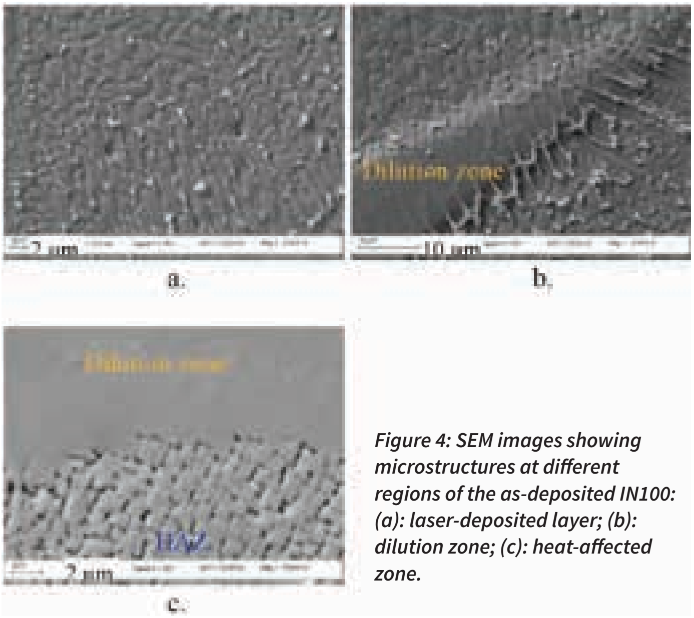


*Figure 4: SEM images showing microstructures at different regions of the as-deposited IN100: (a): laser-deposited layer; (b): dilution zone; (c): heat-affected zone.*

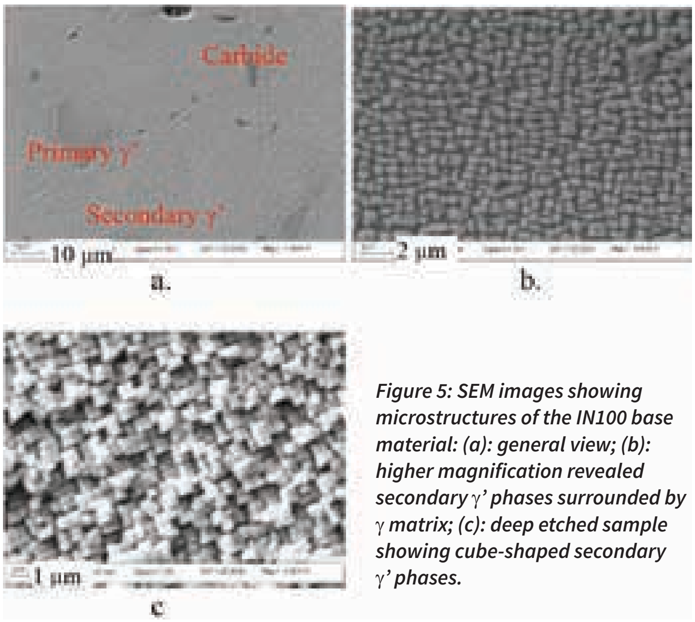


*Figure 5: SEM images showing microstructures of the IN100 base material: (a): general view; (b): higher magnification revealed secondary γ' phases surrounded by γ matrix; (c): deep etched sample showing cube-shaped secondary γ' phases.*

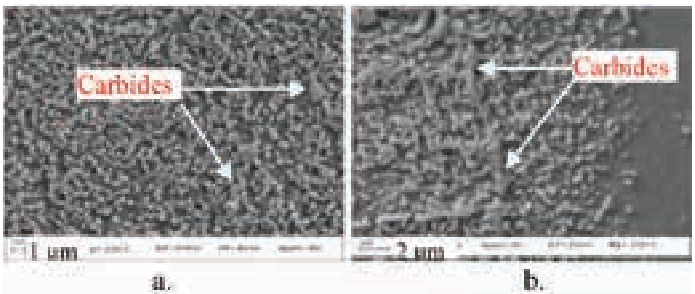


*Figure 6: SEM images showing microstructures of post heat-treated IN100 prepared by electrolytic etching: (a): laser deposited region; (b): dilution zone.*

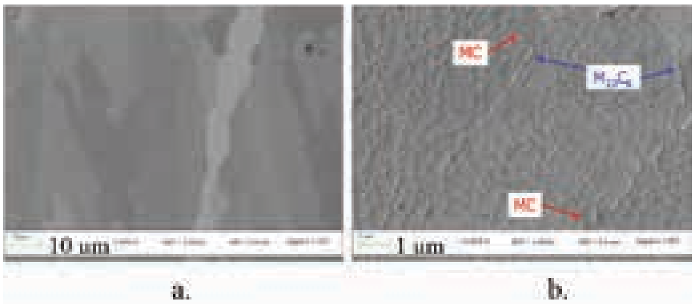


*Figure7: Secondary electron SEM images showing morphologies of IN100 after chemical etching; (a): low magnification showing elongated grain structures; (b): high magnification showing precipitates at grain boundaries (blocky and elongated shapes) and in the grains (globular shape).*

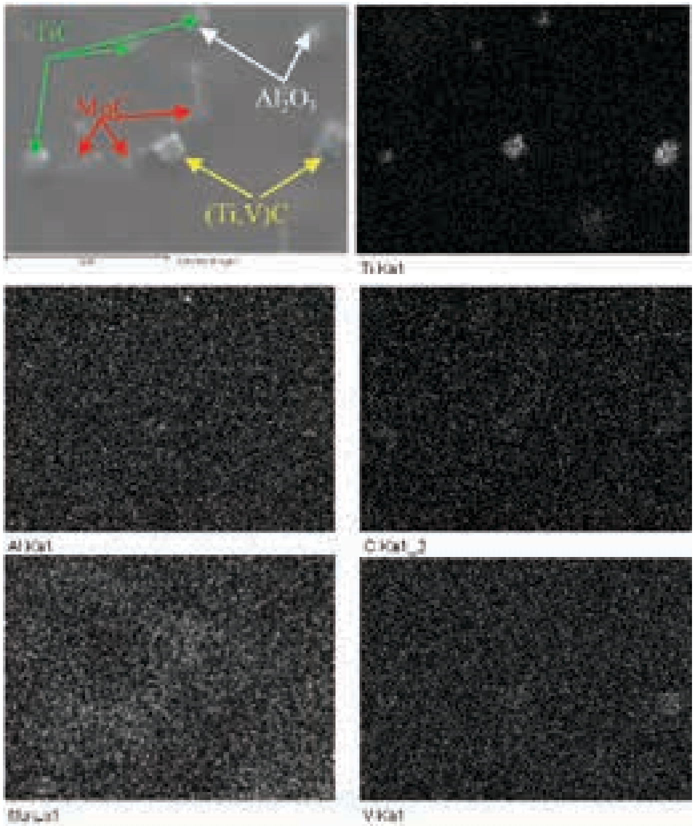


*Figure 8: EDS results showing different carbides in the as-deposited IN100. The globular particles are MC-type whereas the blocky and elongated ones are M23C6-type. Some of the carbides contain an alumina core.*

into secondary carbides such as M23C6 and M6C, which tend to populate the grain boundaries [17].

### Crystalline phases and chemical composition

Figure 8 illustrates EDS results of elemental distribution and shapes and sizes of different types of carbides in the as-deposited IN100. Similarly, EDS results of post heat-treated IN100 samples are shown in Figure 9 and Figure 10 by different etching methods. Although both carbides and borides were expected to be present as minor phases, borides were not identified in this work due to low boron concentration and inherent difficulty in detecting boron by the EDS. Commonly observed carbides were typically found to contain elements like molybdenum, chromium, vanadium and titanium. For instance, refractory elements such as molybdenum are capable of forming MC carbides, but the bonding with carbon is weak and hence, MoC can degrade to the more stable forms of $M_{23}C_6$ and $M_6C$ after heat treatment or service [17]. MC-type carbides were seen as globular particles whereas the blocky

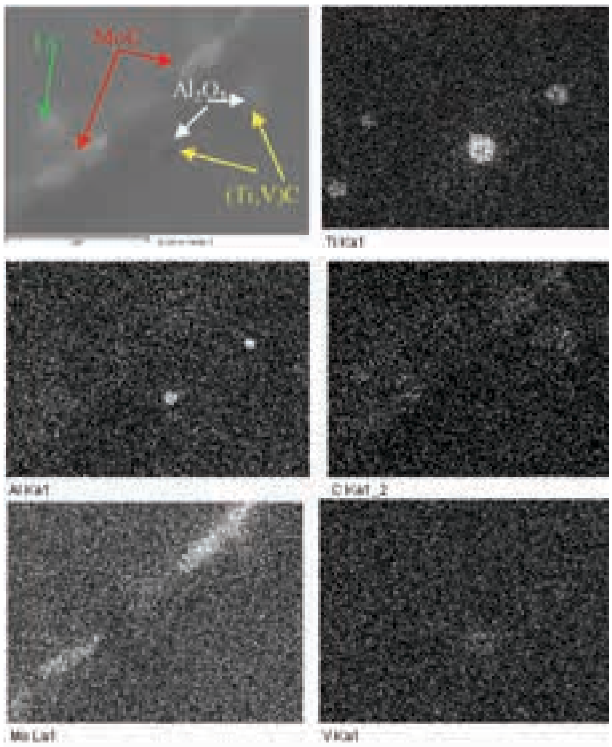


*Figure 9: EDS results showing different carbides in the post heat-treated IN100 after electrolytic etching. The globular particles are of the MC-type whereas the blocky and elongated ones are M23C6-type. Some of the carbides contain alumina cores.*

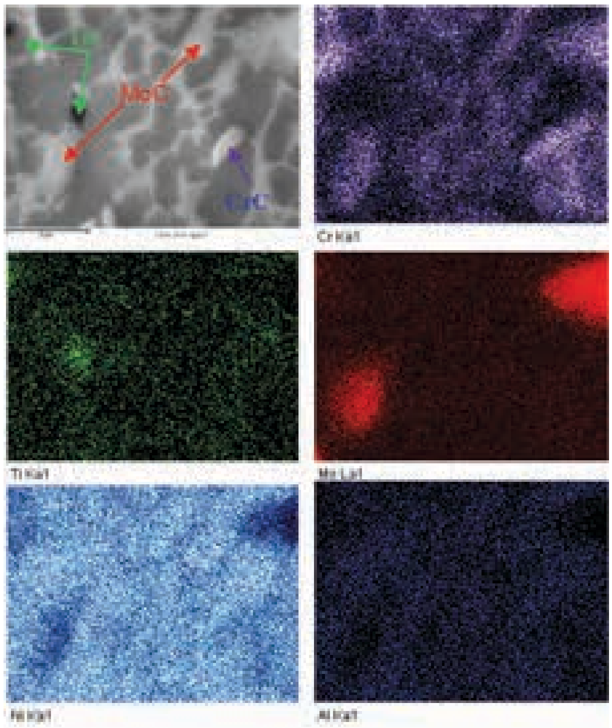


*Figure 10: EDS results showing different carbides in the post heat-treated IN100 after chemical etching. TiC was observed as black dots and often found in the grains, while MoC and CrC were seen at grain boundaries.*

and elongated ones were M23C6-type. Some of the carbides contain alumina core that has also been observed by other researchers [18]. Oxygen may be introduced in the alloy by interactions with the atmosphere during laser processing. Trace amounts of oxygen (above 50 ppm) and the subsequent formation of oxides should be avoided because they cause grain boundary embrittlement and can significantly reduce the stress-rupture life of the alloys [20].

### $\gamma$ and $\gamma'$ phases

Figure 11 shows the detailed microstructure of the post heat-treated and as-deposited IN100 that went through electrolytic etching using Struers' A2 etchant. As can be seen in both Figure 11a and 11b, the non-uniformity of elemental distribution resulting from the laser deposition process was preserved even after solution heat treatment. It is likely that lighter elements were pushed aside in the dendrites (darker region shown in Figure 11a) during solidification while heavier elements remained in the dendritic centre (grey) region shown in Figure 11a. Fine secondary dendrites within a grain were observed with an average dendrite arm spacing around 2-3 µm in both cases. As shown in Figure 12b, the three-step heat treatment cycle produced a final microstructure with distributions of the $\gamma'$ phases at three distinct sizes: primary (average diameter about 500 nm); secondary (average diameter about 100 nm); and tertiary (average diameter about 10 nm), which were embedded within the solid $\gamma$ solution matrix. The relative volume fractions of $\gamma'$ to $\gamma$ was estimated to be approximately 60 to 40%, which are in agreement with the results of Wusatowska-Sarnek et al. [12, 21]. These authors stated that the size and distribution of primary $\gamma'$ is set at the solution treatment temperature; secondary $\gamma'$ formed during cooling from annealing temperature; and tertiary $\gamma'$ formed during ageing. Temperatures of a solution treatment and a two-step ageing sequence used in their study were 1 143°, 982° and 732 C, respectively.

Figure 13 shows the microstructure generated by chemical etching that revealed $\gamma'$ precipitates in the $\gamma$ phase as well as carbide particles. As mentioned previously, $\gamma'$ phase was dissolved by this etching method. Three distinct sizes of $\gamma'$ phase were also observed although the size distributions were somewhat different from the electrolytically etched ones (Figure 11b and Figure 12).

This is understandable as the sample hadn't reached equilibrium, even after heat treatment, so the localised size fluctuation of precipitates can be expected. It is noted that the size of the tertiary $\gamma'$ phase (10-50 nm) was much larger than the one shown in Figure 13(b). This may be due to the clustering effect of many tiny tertiary $\gamma'$ precipitates (average diameter about 10 nm) that resulted in larger than usual tertiary $\gamma'$ phase being observed.

## Conclusions

IN100 samples with low porosity and free of micro-cracks have been successfully fabricated using the LAAM process. The microstructure of as-deposited samples typically consisted of columnar dendrites, which grew epitaxially from the partially remelted grains of the previously deposited layers.

A three-step heat treatment was conducted on the deposited sample in order to form the strengthening $\gamma'$ ($Ni_3Al$-type) phase within the $\gamma$ solid solution matrix. It was found that the $\gamma'$ phase had three distinct sizes with diameters of 0.5-1 µm, 0.1-0.3 µm and 10 nm for primary, secondary and tertiary $\gamma'$, respectively, although the size distribution varied with different specimen locations and with different etching methods.

Elongated and blocky shaped carbides were observed at the grain boundaries while globular shaped carbides were mostly seen in the grains. The present results suggest that IN100 components can be fabricated or repaired by LAAM when appropriate processing is utilised, especially the low heat input control for the deposition of successive layers.

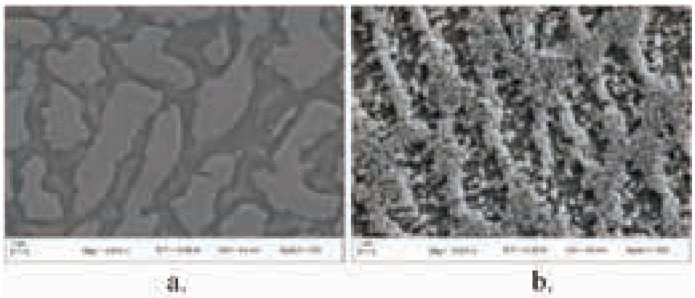

*Figure 11: Secondary electron SEM images showing morphologies of IN100 after electrolytic etching: (a): as-deposited sample; (b): post heat-treated sample.*

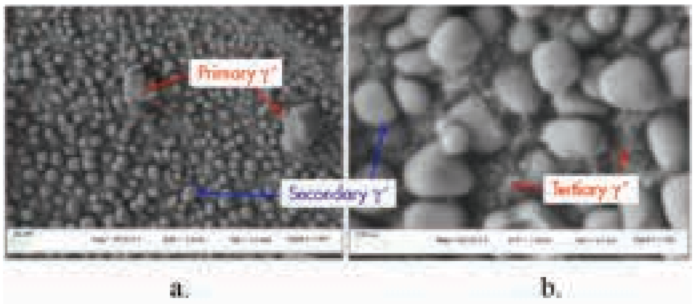


*Figure12: Secondary electron SEM images showing three sizes of the $\gamma'$ phase on electrolytically etched, post heat-treated IN100: (a): primary and secondary $\gamma'$ particles; (b): secondary and tertiary $\gamma'$ particles.*

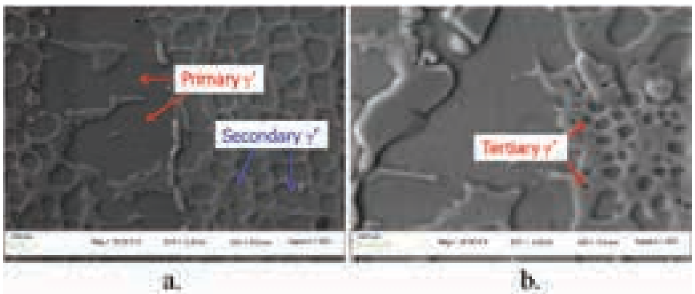


*Figure13: Secondary electron SEM images showing three sizes of the $\gamma'$ phase on chemically etched IN100: (a): primary and secondary $\gamma'$ phase; (b). tertiary $\gamma'$ phase.*


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# Current progress in the science and technology of **GMAW processes**

*Yoshinori Hirata*

**This paper by Yoshinori Hirata of the Graduate School of Engineering at Osaka University, Japan, was presented at a plenary season of the IIW's 67$^{th}$ International Assembly and Conference in Seoul South Korea and highlights key current developments in quality and productivity for the gas metal arc welding (GMAW) processes.**

Research and development of high productivity and/or high quality welding processes have been conducted for several years. The gas metal arc welding (GMAW) process is widely used in various production fields because it provides high deposition rate and/or it is suitable for automatic/robotic welding. In the GMAW process, the electrode wire melts due to arc heating and forms a molten metal droplet at the wire tip. Then it detaches and transfers from the wire tip to the weld pool. The series of wire melting and subsequent molten drop transfer processes results in deposition of the metal required to complete butt welds and/or fillet welds.

So the stability of the gas metal arc and the associated metal transfer dominates weld quality and productivity. This technical issue has been prompting welding machine makers, consumable makers and gases suppliers to improve and develop high performance welding processes. In this paper, current progress in the science and technology related to GMAW processes is discussed based on the author's personal research history.

## Introduction

In the Materials and Manufacturing Science division of the Graduate School of Engineering at Osaka University, we have been investigating welding phenomena associated with MIG/MAG and TIG welding with both steady current and pulsed current using analogue transistor controlled power sources constructed by ourselves since around 1977[1][2]. Analogue transistor power sources enable us to explore various current waveforms. Then, in order to clarify the role of pulsed current parameters such as pulse peak current, pulse width, pulse frequency for rectangular pulse waveforms, metal transfer and/or weld pool oscillation phenomena were analysed with aid of high speed photography. In particular, we showed that the detachment time of metal droplets from the wire tip is significantly dependent on the magnitude of pulse peak current, which is important for the 'one droplet transfer per pulse' control transfer mode widely used in various sectors of industry at the present [3]. At the same time, our domestic welding machine makers have confirmed that 'one pulse-one droplet' transfer is very effective for spatter reduction [4][5]. Following this development, welding machines under transistor and/or inverter control promptly spread, together with applications that take best advantage of pulsed current welding processes.

Over the past few decades, current control using devices such as power transistors, MOSFETs and IGBT have advanced significantly. In addition, inverter circuits with high-speed digital control have been significantly improved. Separately from getting high performance from power supplies, the mechanical control of wire feeding has been progressing. Accordingly, very fast and precise control of current, voltage and wire feeding are now available.

In recent years, commercial digitally controlled arc welding machines have been spreading for the practical applications in various sectors of industries in all over the world.

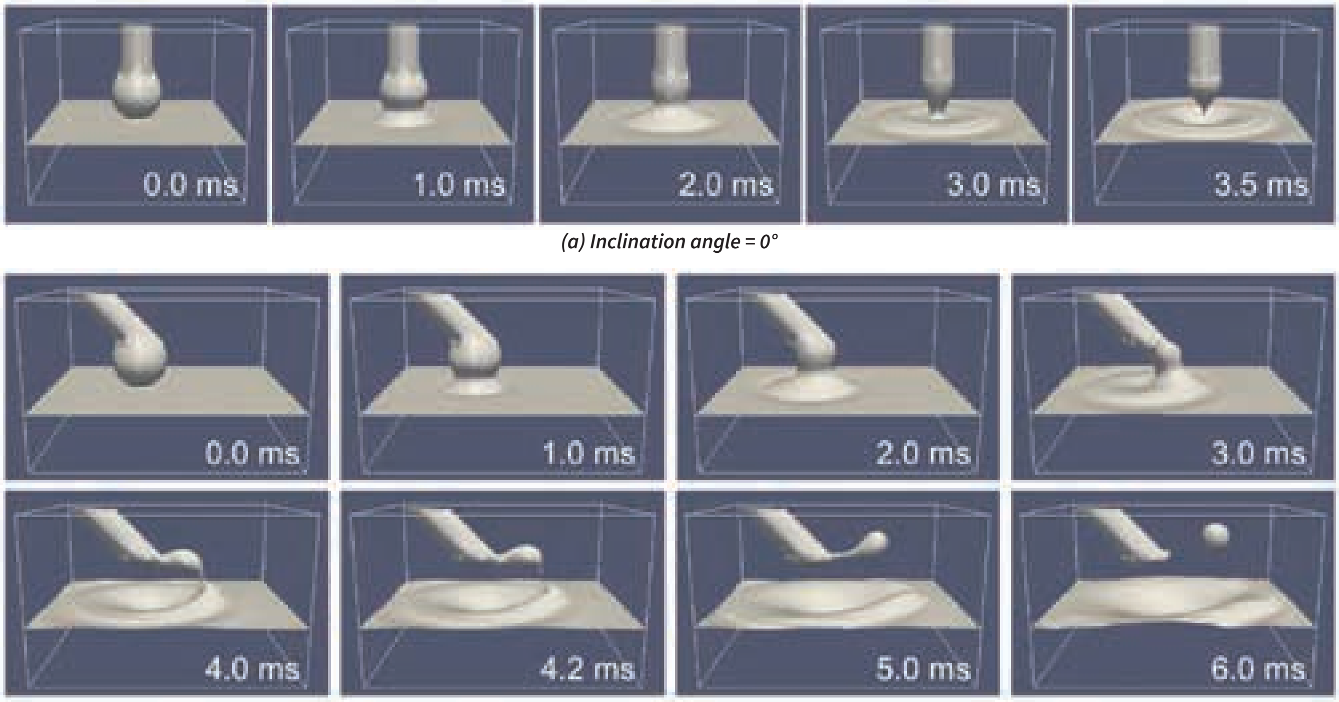
On the other hand, recent progress in visualisation and simulation of welding processes has been making it possible to observe, measure and analyse welding phenomena at high resolution in terms of both of time and space. The change from qualitative understanding to quantitative is sure to result in an evolution of welding processes towards better reliability and higher productivity. Today, high performance digital cameras have been spreading into production sites and applied to practical fabrication: detection of electrode position and groove shape, monitoring the arc/weld pool during welding operation, etc. The implementation of these systems and the resolution of the challenges posed will be more actively pursued as the availability of more explicit knowledge becomes available.

In this article, the science and technology of the GMAW process are described in the light of current progress in relevant and allied technologies.

## Present state of GMAW

In the GMAW process, the filler wire is the electrode. The electrode wire is melted by the arc heat and a molten metal droplet forms at the wire tip. Then it detaches and transfers from the wire tip to the weld pool, so the arc length and/or the arc root location are varied intermittently with each metal transfer. This means that, in comparison with the TIG arc, the gas shielded metal arc is less stable as a heat source in both time and space.

Also, the stability of metal transfer dominates weld quality and productivity. These problems have been driving welding machine makers, welding consumable makers, gas suppliers, universities and institutes towards research and development of welding processes for improved quality and productivity. Various GMAW processes have been delivered to the market corresponding to the needs of welding related products. In order to highlight specific advantages of processes, these have been tagged with various catch phrases, such as *'high stability metal transfer and welding arc', 'improved stiffness (directivity) of welding arc', 'high deposition', 'deep penetration'* and *'sound welds'*, but the understanding of the specific or quantitative effects of the newly developed processes is not always obvious, nor are the reasons for the improvement of weld quality and/or productivity in practical use on fabrication sites. This



(b) Inclination angle = 45°.

*Figure.1: The change in bridge profiles after contact between a pendent droplet and a weld pool; (a): At an inclination angle of 0°. (b): At an inclination angle of 45°.*

is, essentially, a result of a lack of deep understanding of welding phenomena.

## Modelling and high performance control of GMAW processes

The digitally controlled welding machine, as well as delivering very fast and precise current and voltage control, now also offers digitally controlled wire feeding, which has been considered a weak point in GMAW processes for many years, limiting the use of the process for high performance applications. It is now possible, however, for GMAW processes to become a high quality welding process with an extremely stable arc – equivalent to TIG welding arc – and simultaneously, a higher productivity welding process because of its high deposition rate. But in order to ensure the stability of the gas metal arc is equivalent to that of the TIG arc, software is required to continuously control welding phenomena and to provide the optimum combination of current, voltage and wire feeding. This means that information about the dynamic behaviour of the arc, the electrode wire and the weld pool must be linked to the control variables of the digital welding machine.

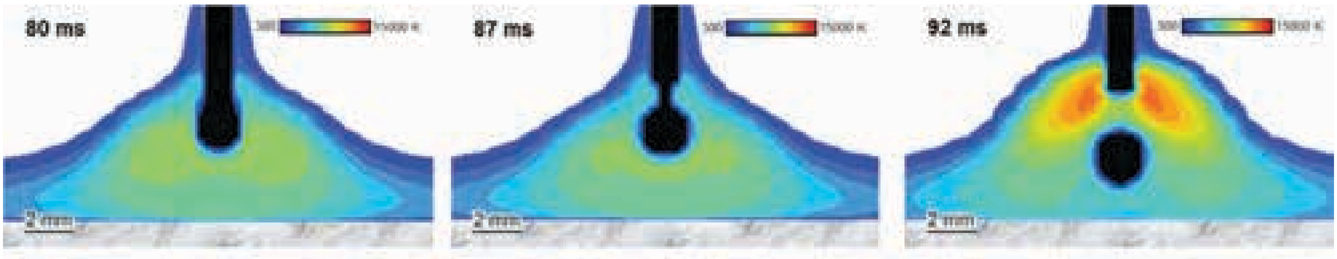
The computer technologies of today have made rapid and significant progress. They can now be used to carry out modelling and simulation of very complicated welding phenomena with high temperature and high luminescence. Some prediction about welding control phenomena are described here based on knowledge obtained through numerical simulations.

Figure 1 shows the change of a molten drop's shape with time calculated using a 3D numerical model just after contacting the pool surface in the short-circuiting transfer process [6]. In the case of a torch inclination angle of zero degrees, the liquid metal at the wire tip flows into the pool due to the forces of capillary pressure and electro-magnetic forces, as shown in Figure 1 (a). When high current flows in the liquid bridge during short-circuiting, the depression in the pool occurs at the breakup of the liquid bridge and, subsequently, it induces pool oscillation. The time required for breakup of the liquid bridge dominates short-circuiting frequency and dictates the welding current necessary for practical welding. In principle, therefore, only current modulation is available for use to achieve stable and smooth metal transfer. When the wire is inclined to the pool, because electro-magnetic forces do not act axial-symmetrically, the bridge is deformed like a bow. And after the breakup of the bridge, the drop at the wire tip is detached from the solid wire tip and is propelled away as a spatter, as shown in Figure 1 (b).

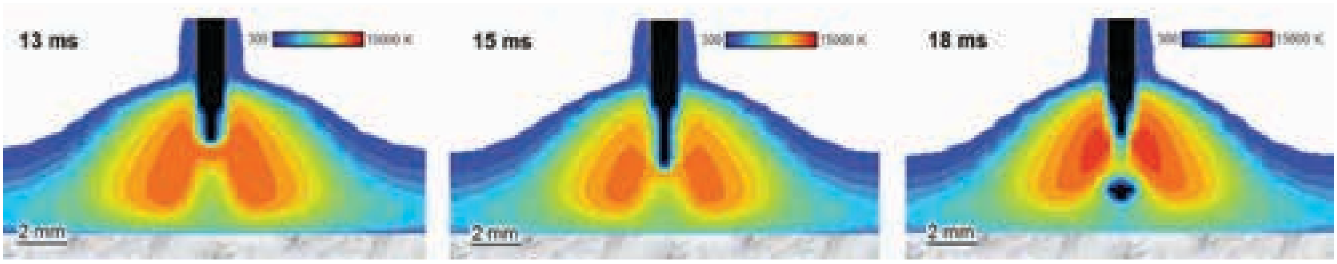
For several decades in Japan and Western countries, research and development in the short-circuit welding process has been focused on realising stable welding that is spatter free by means of actively controlling welding current alone. But in practical applications, this has never been completely satisfactory, because a multitude of welding variation, such as current, shielding gas and consumable material, which restrict the levels of control possible.

The presentation and publication of the CSC process for aluminium MIG welding by G. Huismann [7] notes that control of wire feeding speed and direction was very effective for stabilising the short-circuiting process and reducing spatter. Simultaneous control of current and wire feeding was then established, which expanded the available range of applications possible for the process. By using digitally controlled welding machines, the breakup of the liquid bridge could be achieved mechanically, via a precise movement of the wire tip under the control of the feeder. In addition, current modulation could be used to widen the available range of welding conditions. For example, the combination of short-circuit transfer with pulsed transfer was developed for the GMAW process and used in practice[8].

To realise a new welding process, however, we need to start from the concept stage, for which advanced numerical simulation is an effective tool. Figure 2 shows the numerical simulation results for metal transfer in an argon gas shielded




*(a) 170 A.*




*(b) 250 A.*

***Figure 2:** Changes of the arc-plasma temperature field and drop shape for the open arc, argon-shielded GMAW process. (a): Welding current of 170 A. (b): Welding current of 250 A.*

arc [9]. In the low-current case (170 A), globular transfer occurs. As can be seen in Figure 2, the temperature distribution of the MIG arc changes with the detachment of a metal droplet from the wire tip. In contrast at the higher current (250 A), spray transfer occurs. The liquid metal at the wire tip is elongated toward the pool like sharpened pencil. The arc plasma shape appears not to change, and its temperature field is less varied by molten drop behaviour. Fluidity, surface tension and viscosity of the liquid metal govern the shape and/or size of metal drop at the wire tip. As is well known, the electromagnetic force depends significantly on the current path flowing in the liquid metal. This means that the shape of the arc plasma touched with liquid metal plays an important role on dynamic behaviour of metal transfer.

In other words, the metal transfer mode is varied by physical properties such as thermal conductivity and electrical conductivity of the arc plasma. Accordingly, the composition of the shielding gas is one of the important variables for controlling metal transfer. With this established, the change in a gas shielded metal arc across a metal transfer cycle can be predicted with aid of numerical simulation.

## Concluding remarks

The essential components of the gas shielded arc welding process include the welding machine, electrode wire and shielding gas. In addition to universities and national institutes, welding machine makers, consumable makers and gas suppliers have been putting effort into the research and development of devices, consumables and new GMAW processes in collaboration with various fabricators. Some of these developments have been carried out based on visual observation with recent high performance digital cameras, along with knowledge derived from numerical results of theoretical model.

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# DICONDE: Bridging NDT's digital divide

**At an evening meeting at the SAIW earlier this year, Michael Beaugrand (right) from Larivière of the US presented on the latest technology for transitioning from film-based to digital radiography. *African Fusion* reports**

Now available in South Africa through GammaTec, VIDAR Systems Corporation, a 3D digital radiography systems company, is introducing a cost-effective industrial scanner to digitise radiographic film, which are then accessed and stored using ASNT's DICONDE (digital image and communication for non destructive evaluation) imaging standard for portability and compatibility with all digital NDT analysis software.

"20 years ago, we saw the transition in photography from 35 mm film to digital cameras. We have since seen a similar transition in the medical market," says Beaugrand, adding that the medical radiography transition is already 100% complete in Scandinavian countries and over 80% in most of the developed world. The NDT fraternity is now going though that same transition, albeit 15 years later, so Beaugrand expects the full transition to digital NDT to be nearing completion 10 to 15 years from now.


*The VIDAR NDTPRO industrial film digitiser uses the DICONDE standard for converting radiographic film into a transportable and accessible format for industrial users.*

Highlighting the advantages of digital radiography, he says that, in principle, the sources, shielding and collection techniques are the same as those use for film-based methods. But a detector is used to capture the image instead of film – and there are two detector technologies currently in use, computed radiography (CR) and direct radiography (DR) detectors.

"The post exposure image formation, however, is different from film. Instead of a light box, a computer and monitor are required to view digital radiographs, and instead of the grey exposure shades fixed on photographic film, exposure values are digitally stored as an array of pixels. Each pixel has a value proportional to its radiation exposure, which are converted into analogue grey values of varying brightness on the display monitor," he explains.

Key advantages of digital systems are: the brightness and contrast can be very easily adjusted to suit different areas of the image; magnification is easy; the image can be enhanced and processed; measurements can be applied and used in calculations and statistics; and annotations and stamps (metadata) can easily be incorporated directly into the image file. "I have seen an experienced Level 3 NDT Inspector being amazed by how much more information can be revealed on a digital image simply by zooming into an area of interest and adjusting the contrast," Beaugrand reveals.

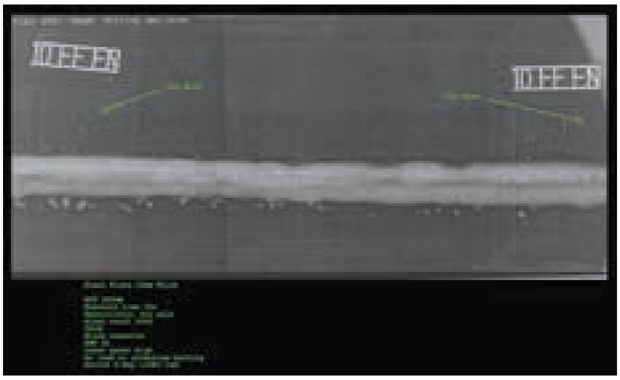
"The biggest problem with using digital systems, whether they are CR- or DR-based, is that companies all over the world have millions of film-based radiographs, in vaults and filing cabinets, and these also need to be easy to access and use in one common system," he explains. To monitor changes over time, it is often necessary to compare a radiograph from the past with a current image, and it is very difficult to compare a film on a light box with an image on a computer screen, because the visual quality of the two technologies is far too inconsistent, he points out.

"What was needed, therefore, was a platform that would enable archived radiographs to be digitised so that they could be accessed and used on the same platform and to the same standards as newly collected digital images," he adds.

In transforming the medical radiography market, after an initial period with multiple file formats, the industry decided on a standard file format to streamline procedures and workflow, where all manufacturers adopted the same format. The idea was to enable any image to be transferred between doctors using equipment from different manufacturers without any compatibility problems. This led to the development of the DICOM (digital imaging and communications in medicine) compatibility protocol for the medical imaging profession. "But for the first five years, the focus was on the choice between CR or DR technology and the bridge to film was seen as less important. Today all of the major medical digital imaging providers also provide scanners to convert existing X-rays into the equivalent DICOM digital format,"

DICOM was the forefather of the file format chosen for industrial NDT systems, DICONDE (Digital Imaging and Communications for Non-Destructive Evaluation) a standard established by the ASTM (American Society for Testing and Materials).

Describing how DICONDE is used, Beaugrand says that Larivière is currently digitising all of the historic film for one of its large pipeline construction clients. Using a service vehicle fitted with its VIDAR NDTPRO industrial film digitiser, inspection personnel go into the field and systematically digitise the film archives. "This solution fixes all compatibility problems between the technologies and enables compatible workflows to be employed for film-, CR- or DR-based images," he assures. "It enables images produced from film and digital devices to be treated identically and compared side by side, which is an integral step in enabling digital technology to be fully adopted," he says, before adding, "Can you imagine how many rows of boxes and filing cabinets can be emptied by digitising all the films being stored?"



*Once digitised, all of the key advantages of digital systems apply: the brightness and contrast can be very easily adjusted to suit different areas of the image; magnification is easy; the image can be enhanced and processed; measurements can be applied and used in calculations and statistics; and annotations and stamps (metadata) can easily be incorporated directly into the image file.*

As well as digitising the film image, the DICONDE standard is also able to capture the metadata associated with an image. Reports, measurements and all of the advantages of digital systems can also, therefore, be applied. "DICONDE and associated film digitisation solutions ensure compatibility between the existing NDT world and all future digital systems. In compatibility tests between seven leading equipment manufacturers, images were found to be 100% compatible with all brands of digital imaging systems and software," he assures.

Describing the specific advantages of the VIDARNDT PRO, he says that this system offers the NDT industry "a product that not only carries a smaller price tag, but is lighter and has a smaller footprint." The digitiser can handle film as narrow as 2.36″ wide and up to 51″ long. It also features VIDAR's high-definition CCD (HD-CCD™) solid-state technology, as well as its ADC (automatic digitiser calibration) mechanism, which virtually eliminates variation in image quality and ensures excellent greyscale reproduction.

# **Spray coatings:** quality matters

**"It is imperative that thermal spray coatings, which are used to address an ever-increasing variety of surfacing needs, adhere to strict quality standards due to the criticality of industrial components," argues Jan Lourens, managing director of thermal spray and plasma coating specialist, Thermaspray.**

"While good quality coatings extend component life, reduce costs and improve productivity, on the other hand bad quality coatings can cause components to delaminate, crack, or spall during operation," explains Thermaspray's Jan Lourens. "With implications of costly unplanned downtime, maintenance costs and reduced production, the importance of high quality thermal spray coatings cannot be overemphasised."

The microstructure of a thermally sprayed coating is characterised by the existence of various pores, micro-cracks, splat boundaries, oxides, grit entrapment, and unmelted particles. These attributes greatly affect the mechanical properties of a thermally sprayed coating. In general, an inhomogeneous microstructure reduces the overall stiffness, coating strength, and integrity. Coating characteristics such as porosity, cohesion, and oxide content all play a role in the quality of a coating.

Thermaspray remains at the forefront of the thermal spray coating industry in South Africa and boasts the only metallurgical laboratory in Southern Africa dedicated to the evaluation of thermal sprayed coatings. In partnership with Oerlikon Metco (formerly Sulzer Metco) and UK-based TWI (The Welding Institute), Thermaspray has developed techniques specifically tailored to evaluate the quality of thermally sprayed coatings.

A coating is produced by a process in which molten or softened particles are propelled towards a substrate to bond on impact. A common feature of all thermal spray coatings is their lenticular or lamellar grain structure resulting from the rapid solidification of small globules, flattened from striking a cold surface at high velocities.

Several key processing steps are required to produce optimal thermal sprayed coatings. To ensure adequate bonding of a coating material, the substrate must be properly prepared through cleaning, followed by roughening usually through grit blasting. Masking and heating are commonly applied to the substrate prior to thermal spraying. Coating quality also depends on spray process variables such as part temperature control, gun and substrate motion, spray pattern, deposition efficiency and deposition rate. Post-coating operations – which include finishing treatments such as grinding, polishing, testing and inspection, along with densification treatments such as layer fusion – further enhance the quality of the coatings.

Typical examples of poor coating quality include:

- A coating with lack of adhesion and cohesion leads to flaking and peeling during in-service operations.
- A coating with foreign particles entrapped in the coating also leads to poor cohesion, flaking and peeling.
- A coating with excessive grit entrapment leads to poor adhesion to the substrate causing undue stress in the material leading to cracks or weak points in the coating that will serve as points of attack in corrosive and abrasive environments.
- Coatings with oxide inclusions lead to the added hardness of the coating, which in turn leads to brittle coatings as oxides fracture easily. If these strings are too concentrated it will lead to a decrease in cohesive strength of the coating.

One of the most common causes of porosity, another important factor that influences coating properties, is the presence of unmelted particles. These solid particles, some of which are reflected from the coating surface, may adhere to or become trapped in the rough finish of the coating. These particles are not well bonded nor are they in intimate contact with the underlying splat, which creates voids and porosity. Excessive porosity creates poor cohesion and allows for higher wear and corrosion rates. Poor cohesion can lead to cracking, delamination, and spalling.

With a highly skilled, qualified staff, state-of-the-art equipment and a dedicated metallurgical laboratory, Thermaspray is able to ensure that coatings are of the highest standards and quality by adhering to strict standards in its coating process and quality evaluation.


**References**

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*The microstructure of this thermal spray coating shows no defects – cracks, unmelted particles or oxides – and minimal porosity.*

*A good coating quality with low porosity and the absence of flaws and no grit entrapment, ensuring maximum adhesion to the substrate.*

# **WASA's** new tubular hardfacing

**At an SAIW evening meeting held in May, Wiehan Zylstra (lef), technical manager of Welding Alloys South Africa (WASA) introduced the company's new tubular welding electrodes for manual surface repairs and hardfacing of thin or small parts.**

Welding Alloys' core business in South Africa is hardfacing, cladding and build-up repairs. "The difference between hardfacing and cladding is simply that hardfacing is about depositing wear and abrasion resistant materials, while the term cladding is more commonly used to describe a deposit that protects against corrosion," Zylstra begins.

Locally, WASA produces tubular consumables and flux-cored welding wires and is the only tubular wire consumable producer in Africa. "We manufacture 60 to 70 t of product per month, of which 50% is used by one of our own Group companies, Apex Benoni, where we refurbish crushing components and produce CrC overlay plates for wear applications on southern African mines," he adds.

Briefly summarising the history of tubular electrode development, Zylstra says that the first patent for an arc welding process using a metal electrode was awarded in 1892 to CL Coffin of Detroit. A few years later, in the 1900s, Oscar Kjellberg of Sweden invented the covered or coated electrode by dipping bare iron wire into a thick mixture of carbonate and silicate deoxidants. This paved the way for modern covered electrode development.

The evolution of tubular electrodes began some 60 years later with the emergence of flux-cored and Innershield welding wires. Welding Alloys was founded near Cambridge in the UK in 1966 and began manufacturing cored hardfacing wires a few years later. "Then, in 2010, as part of Welding Alloys' Green Electrode project, the company acquired tubular hardfacing electrode manufacturing technology from a Malaysian company and, in 2014, began manufacturing a successful range of formulations of its own," Zylstra reveals.

WA tubular hardfacing electrodes (TEs), while designed to be used in the same way and with the same power sources as coated shielded metal arc electrodes, are constructed like a cored wire electrode. The alloying constituents, which are mostly metal powders rather than flux, are contained inside the hollow electrode by an outer metal sheath.

Why? The main advantage of using a cored electrode is the smaller cross sectional area of the conducting path. "If you think of a cored wire, it has a thin metal sheath that needs to be melted by the welding current, instead of the relatively thick solid wire," Zylstra explains. "To melt the thinner section, a lower total current is required to achieve the necessary current density. The cored construction, therefore, offers lower heat input and higher deposition rates compared to solid wire electrodes with flux coatings on the outside," he says.

WA's tubular hardfacing electrodes, which range in diameter from 6.0 mm in diameter to 12 mm, offer extra-low heat input; low dilution and base metal penetration; and smaller heat-affected zones than any solid electrode equivalents. "Low dilution is very important when it comes to hardfacing. The more the dilution, the more the alloying elements such as chromium, niobium or vanadium become diluted by the base metal, reducing the wear properties of the hardfacing layer. We usually advise depositing three full hardfacing layers to guarantee the chemistry and properties of the deposit are fully achieved, but high alloy content in the first layer can allow acceptable properties to be achieved using only two layers," Zylstra advises.

A further advantage of the low heat input associated with the tubular electrode construction is reduced


*A key differentiating feature is the green outer coating, which is designed to offer exceptional moisture resistance.*

*WA's tubular electrodes can be welded at low operating currents, which allow thin sections such as the flights of screw conveyors to be hardfaced successfully without destroying the basic geometry. Also, because of the spiral shape of conveyor screws, these products are not so easy to hardface using more automated processes.*

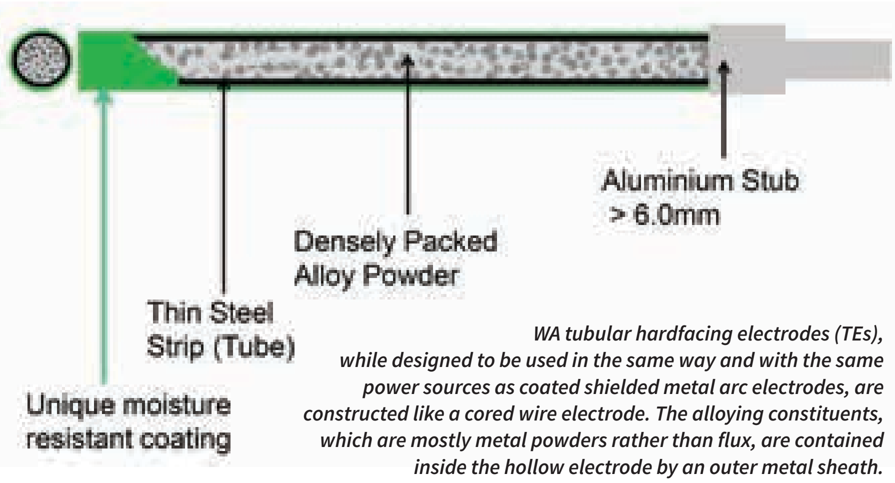
# electrodes

distortion and a lowering of the risk of burn-through. "These tubular electrodes can be welded at low operating currents, which allows less expensive power sources to be used and, most importantly, it allows thin sections such as the flights of screw conveyors to be hardfaced successfully without destroying the basic geometry," he suggests, adding that because of the spiral shape of conveyor screws, these products are not so easy to hardface using more automated processes.

While WA's 6.0 mm tubular electrodes have a steel stub, the larger diameters use an aluminium stub, which enables the stub diameter to be retained at 6.0 mm, regardless of the electrode size. This makes the entire range compatible with typical MMA electrode holders.

The electrodes are highly alloyed and densely packed, with a thin steel sheath, which requires low amperage to melt and sustain an arc. "A key differentiating feature for us is the green outer coating, which is designed to offer exceptional moisture resistance," Zylstra believes. "This means that baking is no longer required as the core ingredients are not susceptible to moisture pickup at all. This saves energy, processing time and, therefore, money. It also makes the electrodes ideal for use in humid, outdoor environments," he adds.

Describing the feel while welding, Zylstra says tubular electrodes are "feather-light", which takes some getting used to, but the "weldability is excellent". Spatter is almost non-existent and, because the core is mostly made up of metal powders rather than flux, slag levels in the deposit are low, requiring no slag removal or grinding between layers.




*WA tubular hardfacing electrodes (TEs), while designed to be used in the same way and with the same power sources as coated shielded metal arc electrodes, are constructed like a cored wire electrode. The alloying constituents, which are mostly metal powders rather than flux, are contained inside the hollow electrode by an outer metal sheath.*

Offering a 50% higher deposition rate than coated SMAW hardfacing electrodes, Zylstra points out that a further niche advantage is the positional capability of tubular electrodes. "Because the electrodes can be welded at currents as low as 80 A (6.0 mm), our tubular consumables can be used to hardface in the vertical-up position (3G/3F)," he assures. "This makes the range very versatile, with down hand welding being possible at 120-130 A for the 6.0 mm electrode and as low as 150-160 amps and 200-220 A for the 8.0 and 12 mm electrodes, respectively.

## The product range

At the starting point of Welding Alloy's tubular electrode (TE) hardfacing range are the primary chromium carbide coatings (HC-TE and HC40-TE). These electrodes produce a microstructure of chromium carbides in an austenitic matrix. "These are high chromium cast irons and will produce stress relief cracks. This is normal," Zylstra suggests. "If no cracks are produced, then something is wrong with the hardfacing composition," he points out.

Typical uses include palm oil extruders, screw conveyors, gyratory crusher cones and mantles, dredge pump bodies, mining and earth moving equipment, agricultural equipment, wear plates, sugar mill crusher hammers, drag line components, quarry and sand handling equipment, and brick manufacturing equipment.

One step up in terms of metallurgical sophistication are the CN-TE and the CNV-TE electrodes that are used to deposit complex chromium carbide layers that offer better wear resistance at higher temperatures. The CNV-TE alloy, for example, maintains its abrasion resistance at up to 600°C and is suitable for use in boilers, sinter plant or for blast furnace components.

A third alloy group, STEELCARBW25-TE and STEELCARBW45-TE produce layers of tungsten carbide (WC) and Fe-Cr-W carbides in an austenitic matrix. "Many will have seen tungsten carbide particles being dropped into a melted pool to produce layers such as these," Zylstra recalls. "But the powders used in these tubular electrodes are so fine that they can't be seen."

Both these grades have very high abrasive resistance, with the W25 grade having slightly better impact resistance than the harder W45 grade. Typical application include materials handling components in contact with medium to fine ores, coal crusher blades, conveyor screens, concrete mixer components, wood chipping or crushing machine components, and brick and clay mill augers.

Concluding, Zylstra says that tubular hardfacing electrodes are ideal for use on irregular shapes where out of position welding is sometimes required, for low volume applications or for applying surface coatings on many small parts. "They are typically suited to repairs of worn coatings and for use whenever the advantages of continuous welding with cored wires cannot be achieved," he suggests.

| Performance | Tubular | Coated |
|---|---|---|
| Weldability | Excellent | Average/Poor |
| Heat Input | Extra Low | High |
| Spatter | Insignificant | High |
| Slag | Negligible | High |
| Slag Removal | Not required | Essential |
| Deposition Efficiency | High | Average/Low |
| Dilution | Low | High |
| Baking | Not required | Necessary |

*A comparison of the welding performance of tubular and coated hardfacing electrodes.*

# Fume extraction:

*African Fusion* visits the Elandsfontein facilities of Envirox, the South African distributor of Nederman's range of fume extraction systems, hoods and extraction arms and talks to Schalk Hoon (left), the company's general manager and Anton Herteberger (right), business development manager.

"Where most people will put large hoods above a welding bay, we prefer to extract welding fume at source, where the welding is happening, so that no fume goes anywhere near the welders face," begins Hoon. To do this, Nederman offers the most comprehensive range of fume extraction arms to ensure that the extraction point is always less than 500 mm from the point of welding. "All possibilities are covered. We offer mobile fume extraction systems and fully centralised extraction and filtration solutions, along with on-torch fume extractors that can be supplied with a dedicated torch or as a retrofit that can be fitted to any torch. Nederman produces the full range of hi-vac and low vac systems coupled with a number of dust filtration and collection systems," he says.

Centralised high-vac systems, according to Herteberger, are typically mounted onto the welding torch and involve suction pressures of -20 kPa at high airflow speeds and relatively low volumetric flow. "High-vac would typically be used with 38 mm pipe on the extraction arms," he explains, adding that these systems extract less of the surrounding air but they need to be very close to the source, "typically 50 mm away", hence their suitability for on-torch use.

"These solutions are quite universal and can even be attached to grinders, for example," adds Hoon. "On-torch extraction is an excellent at-source solution that has been proven to have no effect on gas shielding, but people remain sceptical," he reveals. "Low-vac systems, on the other hand, are designed for higher volume flows at lower suction pressures, in the order of 1.5 kPa."

Welding fume is particularly harmful because of the metal vapour and particles in the fume. "Stainless welding, for example, produces chromium-6 or hexavalent chromium, which exists in fume as particle in the 0.01-0.1 µm size range. This means they are easily inhaled deep into the lungs and can penetrate facemasks. Chromium-6 is a known carcinogen and investigations have proved that exposure has a very dangerous effect on a person's health," Hoon warns.

Back in 2006, the Occupational Safety and Health Administration (OSHA) in the USA significantly lowered the permissible exposure limit (PEL) of chrome-6 from 50 to 5.0 $\mu g/m^3$ as an eight-hour time-weighted average (TWA). Fume from manual metal arc (MMA) welding and flux-cored arc welding (FCAW) contain a high proportion of components coming from the electrode coating or the flux-core, while little comes from the filler metal. Fume from metal inert gas (MIG) and metal active gas (MAG) processes, on the other hand, while they may look less 'smoky', contain high concentrations of the metals being deposited, which can make these processes even more dangerous.

"Any particle size less than 0.5 µm in welding fume can reach the lungs, causing health risk including: cancers; asthma; nasal and skin ulcers (chrome holes); allergic and irritant contact dermatitis; lung disease (siderosis); fertility complications; and infarctions (tissue death). Company's can also reduce the number of sick-days taken by welders, simply by removing their exposure to fume," Hoon suggests. "And while respirators are also an option, welders don't like to work an eighth-hour shift breathing through a mask," he adds.

Collected dust, continues Herteberger, can also pose a fire or explosion risk: "We supply FX-rated (explosion proof) hoods and air filtration systems for applications such as aluminium grinding, because aluminium dust poses an explosion risk if ignited. Any dust can, in fact, be dangerous, so it needs to be properly handled and disposed of in a


*Nederman's Filterbox can be used with more that one extraction arm. These systems have a self-cleaning filter that operates via reverse pulse compressed air, along with a scraper.*

# at source solutions

safe and environmentally responsible way," he advises.

## Small and mobile fume extraction

While Envirox offers solutions for general industry – including plasma cutting extraction systems, oil-mist filtration on the CNC side, and complete workshop systems that can extract dust off the floor to keep it clean – "our niche focus in South Africa is welding fume. We offer everything from small (0.7 to 2.2 kW) mobile systems for occasional welding, to very large systems extracting 20 000 m$^3$/h or more," says Hoon.

Nederman portable fans are simple and powerful extractor units. They are compact and easy-to-use with multiple inlet and outlet connection options. The smallest is the Fume Eliminator, which is a small, lightweight, portable unit designed to be carried to the working area. These units provide an airflow of 150 m$^3$/h, use disposable cartridge-type filters and are ideal for on-torch extraction. FilterCart is another mobile extraction and filter unit for light welding applications. These come with an arm length of 2.0 or 3.0 m and are suitable for up to 1 050 m$^3$/h over a filter area of 35 m$^2$.

Where a mobile solution for continuous welding and dust extraction is required – for large fabrications on an open shop floor, for example – Nederman has developed the Filterbox, which can be used with more that one extraction arm. "These systems have a self cleaning filter that operates via reverse pulse compressed air, along with a scraper. As with large-scale dust collectors, the dust is dropped into a collector below the unit for safe disposal after use," Hoon tells *African Fusion*, adding that these Nederman systems are "among the most cost effective small system available" and the range can be "customised to suit almost any workshop application".

Twelve Nederman mobile filtration systems have recently been supplied to Kumba Iron Ore for its welding activities, to overcome the limitation of a 3.0 m radius arm.

## Centralised extraction and filtration systems

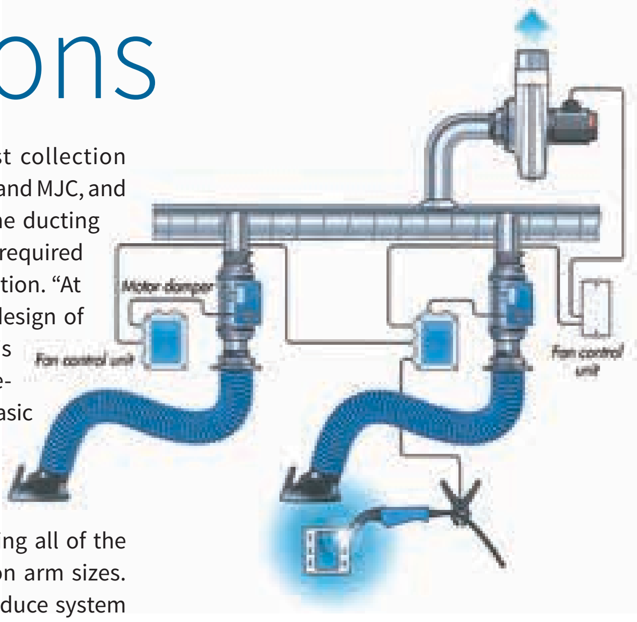
Nederman centralised systems are available with three dust collection variations, Filtermax, FMC and MJC, and are installed with all of the ducting extraction arms and fans required for each particular application. "At the starting point of the design of a fume extraction system is Nederman's NetQuote design software. Based on a basic specification, this 'app' can produce a 3D drawing of a fume extraction system within 10 minutes, including all of the fan, ducting and extraction arm sizes. The software will also produce system performance curves that show the relationship between pressure, flow and power for different operating points," Hoon says.

Highlighting Envirox's capability, according to Herteberger is the centralised extraction installation at Murray and Robert's Medupi welder training centre in Lephalale. "This is our biggest installation to-date. It consists of two independent 18.5 kW systems, with 30 telescopic arms connected to each system.

"To cater for the variation in the number of welders being trained at any one time, Murray and Roberts chose to use variable speed drives (VSDs) on the fans of both systems. When a welder begins to weld, the damper in the telescopic extraction arm automatically opens to allow the fume to be extracted. On opening, a signal is sent to the VSD to increase the fan speed and accommodate the additional flow. So the fan speed adjusts to the total extraction requirement, speeding up when more welders are busy and slowing down as each welder stops welding. This ensures that the energy use of the system matches the extraction demand and that the fan is never running at an unnecessary speed," Herteberger explains.

"These systems are necessary for welding operations to comply with health and safety regulations – and almost every workshop has a welder on its premises," says Hoon. "The OHS Act specifies that you must create a safe environment for your employees, while ISO 14000 specifies the exact allowable values. All European companies are now tending to adopt these globally accepted standards and even our mines are mindful of the air their workers are breathing.

"We are proud promoters of at-source solutions. Not only is this safer, but it also saves energy, because less airflow is needed. Nederman's at-source solutions range from the most cost effective portable and mobile solutions available through to very large, modern and highly efficient centralised designs," he concludes.




*Centralised systems such as Murray and Roberts' installation at the Medupi Welder Training Centre use variable speed drives (VSDs) on the fans. When a welder begins to weld, the damper in the telescopic extraction arm automatically opens to allow the fume to be extracted. On opening, a signal is sent to the VSD to increase the fan speed and accommodate the additional flow.*

*Nederman's FilterMax DF solution is a modular, efficient and compact centralised solution for dust and fume problems with capacity to handle up to 13 000 m$^3$/h from a single unit.*

# Trends, processes and consumables for pipeline construction

**On May 19, 2015 at the SAIW's City West premises in Johannesburg, Böhler Uddeholm Africa, in partnership with Fronius and Gridweld, hosted a seminar and practical workshop on pipeline welding. *African Fusion* attends and summarises the keynote presentation by Voestalpine Böhler Welding's Manfred Höfer (left), the company's global pipeline segment manager.**

Böhler has been present in South Africa for over 35 years, its global welding credentials go back 90 years and, prior to developing a welding offering, the company had already accumulated many years of history in steelmaking.

According to Höfer, the company was originally founded by Albert Böhler in 1870 and began to manufacture welding consumables in 1926. "Through a series of mergers and acquisitions, Böhler accumulated some of the world's best-in-class welding brands, including Thyssen, Böhler, UTP, Avesta Welding, Soudokay, Fontargen and Fileur. Today we have 41 branch offices in 28 countries worldwide and a global network of 12 production plants. In addition, we support over 1 000 selected distribution partners in 65 countries and have customers in 120 countries," he says, adding that the company has been a Voestalpine Group company since 2007.

On the pipeline side, its first bare welding rods were produced in 1926. "These were used in a very primitive joining process associated with large amounts of spatter and porosity," he relates. "In order to improve the process at that time, however, a prototype flux-cored wire was produced, called Seelendraht. This development was not taken to market for a further 30 years, however," he says.

Böhler produced its first cellulosic electrode in the 1950s; its first solid gas metal arc welding (GMAW) wire in the 1960s; and began to manufacture flux-cored wire and its BVD range of low hydrogen vertical down pipeline electrodes in the 1970s. "Low hydrogen technology is now over 40 years old and it remains a sensitive topic for pipeline welding," Höfer relates.

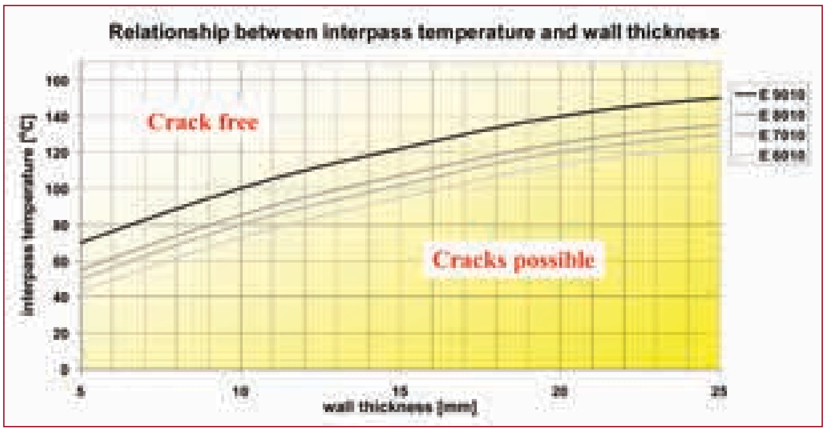
## Global pipeline welding trends

Key to the ongoing improvements in pipeline construction is the introduction of new welding equipment and pipe materials, which offer better productivity, quality and reduced construction costs. Summarising the key trends, Höfer says that mechanised welding, and in particular, narrow gap welding with solid GMAW wire, offers significantly better productivity. "The use of solid, gas-shielded and self-shielded flux-cored wires and metal-cored wires continue to grow, while the use of cellulosic electrodes is expected to reduce in developed markets in favour of processes that offer higher productivity," he predicts.

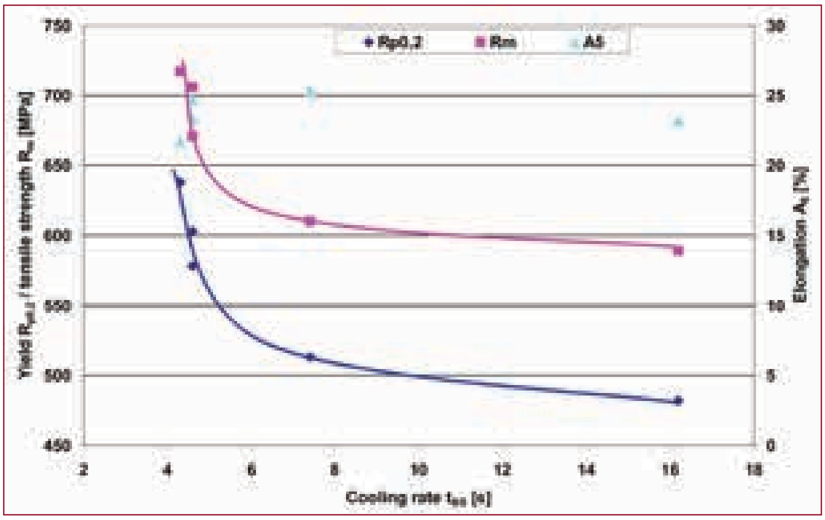
The higher yield and tensile strengths associated with new pipe materials such X70 and X80 enable reduced wall thickness and/or increased pipeline pressures, compared to the X60 and X65 grades. "Also, in the offshore industry, we are seeing increased demand for corrosion resistant alloy (CRA) pipe materials of types 625 and 825, for example, to combat the aggressive corrosive environment offshore.

Displaying a bar chart showing the deposition rate comparisons for different pipe welding options, Höfer says that if a productivity index of one is allocated to downhand pipe welding using cellulose (6010) electrodes, then low hydrogen vertical down electrodes offer 30%

*Dominick Doyle of Gridweld in the UK demonstrates the use of Böhler cellulosic electrodes using a battery operated Fronius AccuPocket welding machine. Doyle, a founder and partner of Gridweld, a welding buggy supplier, has over 40 years of experience in the pipeline welding industry and has worked on a vast range of projects for major contractors.*




*"If preheating and interpass temperatures are correctly controlled, hydrogen cracking need never be a problem," Höfer asserts.*




*A graph showing how yield and tensile stress falls off with increasing $t_{8/5}$ cooling times. The achieved weld strengths for narrow gap GMAW welding is significantly higher than the published all weld metal consumable strengths because of the rapid the cooling rate – in the 4.0 to 5.0 second range.*

*Gridweld's GMAW buggy being used to weld the fill and capping passes at the practical pipewelding seminar.*

better productivity and have an index of 1.3. "When using self-shielded flux-cored wire we go to an index of 1.6, ie, a further 30% improvement, with gas-shielded cored wires offering productivity of a few percentage points better.

"But if adopting mechanised solutions with flux-cored wires, this productivity index increases to 2.5 and, by fully adopting automatic GMAW welding, then factors of 4.4 and 7.5 are achievable using single torch and dual torch options respectively. Imagine how much faster a project can be finished, and how much money can be saved by adopting an automated welding process that offers 7.5 times better productivity than traditional cellulose electrode welding," he says.

## Developments in pipe steel grades

The original steel pipe grades in the sixties were produced in the normalised condition while today most of the grades are produced with micro-alloying concepts and rely on thermo-mechanical treatment processes for their strength. These grades are much less sensitive to work hardening than normalised pipe. "But there are very long lead times to using these new materials. For example, the first X80 project was completed in Germany in the nineties.

"Globally, we are only now moving towards the use of X80, with X100 and X120 still a long way off. From a consumable point of view though, basic coated electrodes for shielded metal arc welding (SMAW); solid wires for gas metal arc welding (GMAW); and rods for gas tungsten arc welding (GTAW) are ready. Submerged arc (SAW) wire and flux is also available; and, for flux-cored welding (FCAW), gas shielded metal-cored wire is available for grades up to X120," Höfer informs.

## Processes and consumables in pipeline girth welding

Although there are differences between the countries of the world, the use of cellulosic stick electrodes (SMAW) in the vertical down mode is still the Number 1 process used in the pipeline industry. Basic electrodes welded in either the vertical down or vertical up positions are also widely used. "The SMAW process is cheap, reliable and people are used to it. But its dominance is falling," he reports.

Cellulosic electrodes such as those in the BÖHLER FOX CEL range include consumables from E6010 to E9010 in a number of different alloy options. "Cellulosics are associated with high hydrogen content, though, so precautions such as proper pre-heating and inter pass temperature control, according to wall thickness and the type of electrodes being used, have to be applied," Höfer points out. The SMAW process is suitable for use in ambient temperatures from -40 to +50 °C and the process speed is relatively high for root pass welding with cellulosic electrodes.

Low hydrogen basic electrodes are found in the BÖHLER FOX BVD and FOX EV classifications. "In terms of mechanical properties, maximum tensile strength for cellulosics goes up to 650 MPa. Basic electrodes can usually accommodate higher tensile strengths, up to 850 and 900 MPa, and these low hydrogen electrodes also achieve higher Charpy impact values.

*While automated pipewelding systems offer significantly better productivity, they also offer more consistent weld quality.*

Basic systems give less than 5.0 mg of hydrogen per 100 g of weld metal, but for cellulosic electrodes, hydrogen levels have to be much higher. There is, therefore, a risk of hydrogen cracking occurring in the heat-affected zone and/or in the weld metal. "But if preheating and interpass temperatures are correctly controlled, hydrogen cracking need never be a problem," Höfer asserts, displaying a slide relating wall thickness to interpass temperature for the E6010 to E9010 range of BÖHLER FOX CEL electrodes. Giving an example of a wall thickness of 8.0 mm, he says: "cracks will be avoided if the interpass temperature is at a minimum of 80 °C, for example, when using E8010 electrode. And if the thickness increases, to say 15 mm, the interpass temperature should be raised to a minimum of 110 °C. So as long as you apply proper preheating and inter pass

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"It's our business to know your business" temperatures for the electrode being used, hydrogen induced cracking will not be a problem," he says.

In terms of speed, while cellulosics offer higher welding speeds for root passes, basic electrodes are faster for fill and cap passes. It is therefore common to mix cellulosic with basic electrodes on pipeline projects, with cellulosic electrodes being used for the root and hot pass, and basic vertical down electrodes for increasing the deposition rates of the fill and capping passes. "Globally, this principle has been successfully applied for over 20 years," Höfer says, showing a number of completed pipeline references that have used BÖHLER SMAW electrodes.

"At the other extreme in terms of productivity, we have the mechanised GMAW solid wire process used in narrow gap joint preparation," he continues.

In general, apart from submerged arc welding, the GMAW process offers the highest productivity and can result in clean, high quality welds with low hydrogen content. On the down side, gas shielding is required, along with protective tents against wind, and the equipment investments costs have to be seen as rather high.

"A disadvantage: if the fit-up, positioning accuracy and welding process parameters are not well controlled, lack of fusion may result, which will be costly to repair," Höfer points out.

GMAW root welding can be performed from inside or outside and, depending on pipe diameters, "up to eight torches can be used for internal root welding, which makes this critical pipewelding operation very economical".

On the selection of the welding wire, Höfer says that the mechanical properties published by consumables' manufacturers are usually based on all weld-metal tests. "For an ER70-S6 wire, we will typically get yield strengths of between 460 and 530 MPa and tensile strength from 530 to 680 MPA during as standard all weld metal test.

"But the values achieved for a pipe weld joints are dependent on cooling rates. Yield strengths of 650 to 700 MPa are typical, depending on the actual cooling rate," he says pointing to a graph showing how yield and tensile stress falls off with increasing $t_{8/5}$ cooling time. "What does this mean?" he asks: "For an X70 pipe, minimum yield strength of 482 MPa is required. To achieve this value in a weld joint, though, GMAW wire with a lower all weld metal yield strength can be used, because the cooling effect of a narrow gap weld preparation gives rapid $t_{8/5}$ times. The achieved weld strengths are, therefore, significantly higher than the published all weld metal consumable strengths," he explains." For a stick electrode or a flux-cored wire, typical $t_{8/5}$ times are above 10 seconds, but with mechanised narrow gap welding, the cooling rate is in the 4.0 to 5.0 second range, and you can see how much the yield and tensile strengths increase as a result," he adds.

Also widely used for pipe welding are flux-cored wires, and "here we need to differentiate between gas-shielded flux-cored wires and self-shielded wires". Self-shielded wires are applied semi-automatically in the vertical down position and are very widely used in China," Höfer continues, adding that mechanised systems can also be used with gas shielded flux-cored wires.

The use of gas-shielded wires such as BÖHLER Ti 70 Pipe T-FD, offers low hydrogen content; low investment costs compared to solid wires; and good weldability in spray mode at currents as low as 180 A. "Flux-cored wires are not usually used for root welding but are ideal for fill and cap passes – and the slag is usually self-releasing.

A key issue with flux-cored welding is the influence of the layer sequence, governed by the heat input of individual passes. Describing two tests done with BÖHLER Ti 70 Pipe T-FD on a 910 mm API 5L X70 pipe with a 14 mm wall thickness, Höfer says that typical all weld metal yield strength is 620 MPa, with Charpy impact values of 90 J at -40 °C. Both tests were done using a GMAW root using Fronius' CMT process, followed by fill and cap passes using Ti 70 Pipe T-FD. A constant interpass temperature of 140 °C was maintained.

"The first test was done by weaving, while the second was completed using two beads for the upper layers instead of weaving, to reduce the heat input." Showing a comparison of the yield and tensile results taken from the 12:00, 3:00, and 6:00 o'clock positions, he points out that the yield strength varied from 520 MPa for Test 1 (higher heat input) at the 6:00 position, to 590 MPa for Test 2 (lower heat input) at the 6:00 position. "Higher heat input associated with weaving also reduces the impact properties. In the 3:00 position at -40 °C, for example, from nearly 60 J for Test 2 to 40 J for Test 1," he points out. "In summary, it is important two remember that when using shielded flux-cored wires, the mechanical properties are influenced by heat input; preheat and interpass temperatures; cooling rates; and layer sequence."

*The Gridweld buggy going past the overhead position.*

Self shielded flux cored wires, such at Böhler Pipeshield are "very interesting for the African market", as a direct replacement for coated SMAW electrodes. Available for pipe grades up to X80, these wires do not require gas shielding or curtaining. They are easy to handle and give excellent impact properties. "Self-shielded flux-cored wire (SSFCW) are used in the vertical down position for manual (semi automatic) pipe welding for fill and cap layers. They are usually basic, low-alloy type wires with some nickel and depend on a micro-alloyed microstructure. The mechanical properties of these modern consumables are excellent, with Charpy toughness values as high at 150 at -27 °C," says Höfer.

The equipment required is also much cheaper than GMAW equivalents and the process is almost as easy to handle as SMAW welding.

## Conclusion

Voestalpine Böhler Welding has a long history in pipeline welding and can offer solutions involving any combination of consumables and processes. "We offer full support for any chosen application and our global engineering division is on hand to give expert advice with respect to the correct consumables and welding process options," Höfer concludes.

# Protect Components and Extend Service Life with World-Class Surface Coating and Specialised Welding Solutions

Thermaspray and Surcotec, under a new joint venture, add value to OEM customers and end-users through the delivery of world-class surface coating technologies, engineering capabilities and allied service solutions.

Our wide range of surfacing techniques protect components against severe environments (corrosion, erosion, abrasion, sliding, wear, chemicals, high temperatures, oxidation, etc.) to extend equipment life cycles, maximise uptime and productivity for lowest total cost of ownership.

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**Thermal Spray Laboratory:**
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# CryoEase: an innovation for efficiency and peace of mind

Air Products South Africa, leaders in the industrial gas and chemicals market, prides itself on finding innovative modes of supply that match customers' demands and usage. Focusing on ways to enhance security of supply, and therefore customer service levels, the company introduced CryoEase, an effective and convenient alternative to cylinders.

This mode of supply, exclusive to Air Products, has particular relevance for the local welding industry, which relies on a continuous and reliable supply of gases for uninterrupted operations. CryoEase is a solution where gas is supplied on-site through the use of specially designed cryogenic storage tanks, and is ideal for customers using ten cylinders or more on a monthly basis.

Gary Lombard, CryoEase business manager at Air Products South Africa, explains: "CryoEase is a method of liquid gas delivery that suits a manufacturing, fabrication or welding facility where gas requirements have outstripped cylinder volume capability, and where the premises are large enough to house a reasonably large storage tank. One of the compelling advantages of CryoEase is that Air Products manages the process end-to-end. This means that we monitor levels and replenish supplies without the customer having to be involved in the ordering process."

Air Products' telemetry system alerts the company well before customer levels run critically low, therefore eliminating the risk of unplanned downtime due to an interruption in supply, which could be potentially disastrous in the middle of a critical welding process.

CyroEase is also a cost-effective alternative for customers who require gases in liquid form for its cryogenic properties, where the product can be drawn directly from the tank. For applications where product is required as gas, it may automatically be converted from liquid into gas on demand.

"For our welding customers whose needs vary, month by month, or whose demand has suddenly changed or grown, CryoEase presents a flexible solution for effectively matching demand. And, because it eliminates the need for the company to manage its cylinder turnover, do cylinder stock reconciliations and deal with product loss, CryoEase optimises operating efficiencies," says Lombard, adding that "there are other spin-offs, such as improved worksite safety and a guarantee of gas quality and purity."

The cost-savings offered by CryoEase also relate to the need for fewer deliveries, a reduction in cylinder loss or residual product loss, and a decrease in time-consuming cylinder management processes and related labour costs.

"Air Products' specially designed fleet of trucks come to our customers' premises and replenish stocks on-site, quickly and efficiently. There is a choice of flexible tank storage options, which depend on volumes required and, because the trucks are smaller than our standard road tankers, they allow for easier access to our customers' sites," says Lombard.

CryoEase forms part of Air Products' philosophy of offering a 'total gas management' solution which is designed with its customers' individual requirements in mind.

"When it comes to long-term customer relationships, one way in which we are able to offer optimum levels of service is to ensure individually tailored security of supply through our CryoEase solution. It means our customers need never worry about gas availability, or even having to lift the phone. This frees them up to concentrate on their own core business."

"Continuous flow means continuous productivity, and ultimately peace of mind for the user through this innovative solution," Lombard concludes.

*www.airproductsafrica.co.za*

*Gary Lombard, CryoEase business manager at Air Products South Africa.*


*Air Products' CryoEase is a solution where gas is supplied on-site through the use of specially designed cryogenic storage tanks.*

## Air Products South Africa

Air Products South Africa (Pty) Limited manufactures, supplies and distributes a diverse portfolio of atmospheric gases, specialty gases, performance materials, equipment and services to the Southern African region.

The company serves customers across a wide range of industries: food and beverage, mining and petrochemicals, primary metal and steel manufacturers; and services welding, cutting and laboratory applications across all sectors.

Founded in 1969, Air Products South Africa has built a reputation for its innovative culture, operational excellence and commitment to safety, quality and the environment. The company aims to continue its growth and market leadership position in the Southern African region.

# Dedicated on-site support to the petrochemical industry

Renttech South Africa, a leading provider of on-site rental and supply solutions, assures petrochemical refineries of high levels of service during shutdown projects, providing on-site technical support, with the aim of minimising downtime.

The company specialises in the rental and sales of welding and construction-related equipment, as well as industrial tools, machinery and refinery-approved consumables to a wide range of industries. Renttech SA is very active in the petrochemicals industry, having a presence on all of the refineries in South Africa, as well as a number of high-profile projects, ensuring minimal disruption, technical support and easy accessibility of critical equipment and consumables.

The company owes its successful track record in this industry to the provision of total on-site rental and support solution; as well as having experienced, dedicated personnel stationed on-site for the duration of a project.

"The key to any successful rental operation is providing a comprehensive solutions package, which includes maintenance. Petrochemical companies are advised to appoint an experienced and knowledgeable company, with the required capacity and proficiency, to assume complete responsibility for both the technical and safety issues of equipment rental," says Gerrit van Zyl, managing director of Renttech South Africa.

"Renttech typically appoints a senior project manager to oversee the entire operation from the planning stage through to finalisation of a project. By having a single point of contact for the entire project, petrochemical companies are assured of a complete audit trail. In addition, the maintenance process is considerably more streamlined because of dovetailing of the responsibilities between each sub-contractor," Van Zyl adds.

Renttech is a full equipment infrastructure solutions provider, and represents a number of leading international welding, rigging, lifting and construction-related principals and brands.

"As a complete-resource company, Renttech South Africa provides customers with the on-site management of the consumables and products stockholding facility from renowned global suppliers such as Lincoln, Metrode, Harris, Miller Weldcraft and Kelmeg. In addition, we are able to provide customers with a vast range of personal protective equipment (PPE) to ensure the strictest adherence to the stringent on-site occupational health and safety (OHS) requirements of the petrochemical industry," van Zyl notes.

The company has been closely involved in some of the largest petrochemical shutdown projects in South Africa in recent years. These include several multiple-phase shutdowns and expansion projects, such as the SAPREF refinery shutdown, which was the largest in Renttech's history and the largest single shutdown in the history of the country.

The success of the latter project can be attributed to the fact that "Renttech provided 24 hour technical support to contractors, had multiple stores and offices on-site and created an entire infrastructure within the shutdown site", to ensure the "highest standards" of service to the customer, according to van Zyl.

*Renttech has recently launched an extra heavy-duty 'rental spec' diesel-driven generator, that can be double-stacked, are painted to marine container specifications and come with a standard five year rust proof warranty.*

When another large multi-national petrochemicals customer decommissioned a portion of its operations last year, Renttech was once again at the ready. During the shutdown, the company supplied and sold equipment to assist in overhauling the site, which included welding, mechanical, electrical and instrumentation activities. Again, Renttech provided the technical expertise, support and equipment to successfully complete the shutdown.

"The challenges we face on large projects of this nature include the varying requirements in terms of project specifications. Quality and safety remain overriding factors and we address these challenges through the deployment of employees who are able to leverage their vast experience in both the rental and petrochemical industries," says van Zyl.

He adds that the company's employees receive extensive training and skills transfer from a number of sources, both externally and internally, in order to guarantee that all work is undertaken according to the customer's requirements.

Van Zyl notes that clients benefit from being able to access the "latest available" technology. "Renttech South Africa continually renews its fully-certified fleet to ensure best practice in terms of maintenance equipment. We deal directly with the original equipment manufacturers (OEMs) when it comes to our welding equipment, welding consumables and generators, and we also maintain high levels of stock to ensure continuity."

While maintaining a permanent presence on-site during shutdowns has become non-negotiable, van Zyl also emphasises the need for proactive maintenance during normal operation.

"A number of petrochemical refineries are fairly old and, therefore, on-going maintenance becomes critical. One of the positive effects of a well-maintained refinery is an increased ability to comply with environmental regulations. Renttech has accumulated a vast database of specification requirements over the past 21 years in the industry, which allows us to customise suitable procedures and plans for each individual petrochemical facility maintenance contract," Van Zyl concludes.

***www.renttechsa.co.za***

# Battery-powered TIG welding

Fronius has expanded its range of battery-operated welding solutions to include a variant for TIG welding. Weighing 10.9 kg, the AccuPocket 150/400 TIG is as handy as the device already available for MMA welding, which has already impressed with TIG functions such as the touchdown ignition and TIG Comfort Stop (TCS). However, the AccuPocket TIG also offers additional, powerful TIG functions such as two and four-step switchover, which enables the welding of thin sheet, in particular.

*The new portable AccuPocket 150/400 TIG battery-powered welding system enables TIG welding to be performed at full power for up to 17 minutes without a mains connection.*

The TIG pulse function of the new AccuPocket is of central importance to TIG welders, as this ensures reduced heat input, improved gap-bridging ability and a better weld seam appearance. This can also be used to achieve a weave pattern in the weld seam typical of TIG welding, in which the two components are joined autogenously (without filler wire). With the TAC function, the customer can quickly and safely join the base material at the start of welding as well as during ramp up, slope out and tacking.

In addition, the AccuPocket TIG has an integrated gas solenoid valve, which guarantees optimum gas shielding during the start and stop phases. Particular attention has also been paid to the newly developed welding torch for this mobile TIG welding innovation. It has a TIG multi-connector and a built-in UpDown switch that reduces the main current during the welding process. This regulates the heat input and considerably reduces the risk of burn-through.

*www.fronius.com*

# Electrically powered torch cleaning

In automated arc welding, torch cleaning affects both the cost and productivity of the whole process. To positively influence both factors, the eReam innovative torch cleaning system from SKS Welding Systems offers striking benefits. Its all-electric drives save considerable amounts of energy compared to pneumatic drives, are easier to control, comply with the applicable safety regulations and offer good monitoring capabilities. Based on the experiences and results gained from tests performed with pilot customers, SKS has further optimised eReam and currently manufactures the system in two standard versions.

The fact that the milling unit, the spraying unit, and the optional wire cutter are electrically driven also means that there are measurable and controllable electrical values. This allows for electrical monitoring of safety-relevant functions, rendering the safety mechanism required for compressed air in a welding cell redundant.

As the functions of eReam are digitally controlled without any additional components or software, they are easy to integrate into common welding robot controllers and PLCs of automation systems, while the costs and complexity of supplying compressed air are obviated.

The cleaning process is under programmed control. Following welding, the robot moves the torch to the eReam unit, where central clamping avoids damage to the gas nozzle while material is removed by a milling system. The use of torque feedback as a control variable is used to avoid damage to the contact tip or nozzle. Following milling, an electronically controlled pump ensures that the correct amount of anti-spatter is sprayed onto the torch. An optional electrically driven wire cutter is also available.

*www.yaskawa.za.com*

*The eReam torch cleaning system offers substantial savings in energy consumption, higher productivity, lower costs, and easy compliance with safety regulations.*

# Plasma metal cutting seminars in SA

Hypertherm, a manufacturer of plasma, laser and waterjet cutting systems, is pleased to announce that, in cooperation with its local Channel Partners, several seminars about plasma metal cutting will take place in South Africa during July 2015.

The plasma metal cutting industry is rapidly changing. Every day, new advancements and new technologies are introduced. As customers are always interested in finding out more about the latest developments in plasma metal cutting, Hypertherm and its partners are organising seminar sessions to inform end users on modern plasma cutting technology.

In total, eight seminars are planned in July. The first sessions will take place at our OEM partners from July 13 until July 16. Focus during these seminars will be on the latest enhanced capabilities of Hypertherm's HyPerformance® HPRXD® product line, giving end users more options and flexibility for multiple cutting applications. Advanced technologies, including True Bevel™, Rapid Part™ and True Hole™, which are part of Hypertherm's Built for Business™ integrated cutting solutions platform, will be explained in depth.

A second round of seminars will take place at the premises of local distributors from July 20 until July 23. Focus will be around Hypertherm's handheld and automated air plasma systems. The complete family of Powermax® metal cutting systems, including the three newest members of the product family: the Powermax30® AIR with built-in compressor, the Powermax30 XP and the Powermax125, the most powerful system in the line-up, will be demonstrated

In addition, the MAXPRO200®, a 200 A LongLife® air and oxygen plasma system engineered for heavy-duty, high capacity mechanised and handheld cutting and gouging will be on show. The events will be focused on specific industries such as emergency services, mining, agriculture and plant hire.

"This is the first time that Hypertherm has organised educational events in South Africa," says Jurgen Boelaars, Hypertherm's EMEA marketing manager. "South Africa is a key market for us and we feel it is extremely important to educate end users on what our technologies are capable of, so they can make well-informed decisions when they need to invest in new machines or when upgrading or retrofitting their existing cutting machine to the latest standards."

Customers interested attending a seminar can e-mail to marketing.emea@hypertherm.com and will receive more information about the event of interest.

*www.hypertherm.com.*

# Hard contact surface, straight beam phased array probes

The MB.FPA16 and B.FPA16 ultrasonic probes from GE Measurement & Control are the world's first straight beam phased array probes to feature hard face, direct contact surfaces instead of non-abrasive protective membranes. As a result, they offer longer working life and higher sensitivity, without the need for delay lines, while providing the timesaving, comprehensive coverage of phased array technology. Typical applications include fast, accurate and comprehensive inspection of billets, welds and forgings in a wide range of industrial sectors.

As Weiwei Zhang, senior product manager at GE explains, "By developing new manufacturing technology, we have been able to match a low impedance composite transducer material with a high impedance hard face protection. Consequently, there is no need for surface protection or delay lines, which can cause recurring interface echoes. This reduces the inspection range and improves the probability of detection of small defects. In addition, the phased array operation of the probe eliminates the need for wedges, which further increases the probes' sensitivity – especially for near-surface defects – and significantly reduces inspection times."

The new probes are each available at frequencies of 2.0 MHz and 4.0 MHz. B.FPA16 probes have a longitudinal steering wave range of ±35°, while MB.FPA16 probes offer a steering range of ±45°, providing comprehensive sector scan coverage without the need for wedges. The high energy of the longitudinal wave enables the inspection of workpieces up to 100 mm thick and a high bandwidth signal ensures high resolution of defects and near-surface defect detection.

With their ergonomic and robust housing, the probes offer ease of inspection in the harshest of applications and their low-profile, fingertip design, with a height of only 14 mm, offers accessibility in areas of limited access and their small footprint permits inspection of curved surfaces.

*The MB.FPA16 and B.FPA16 ultrasonic probes from GE Measurement & Control feature hard faced, direct contact surfaces that replace non-abrasive protective membranes.*

The new probes are suitable for use with a wide range of commercially available phased array flaw detectors, including GE's Phasor, and they can also be used as conventional straight beam probes for thickness measurement, dynamic focusing and DAC sizing.

*www.ge.com*

# Weld plates for Wits material tests

Tony Paterson, professor for welding and fabrication science in the school of Chemical and Metallurgical Engineering at Wits University, is seeking assistance in securing practical engineering material for research purposes – material that would otherwise be regarded as scrap. "In particular, we are looking for 150 mm wide carbon steel plate offcuts (300WA, 350WA/C) that include welds that are over 11 mm thick. And for a second set of unrelated tests, we need 250 mm lengths of 316L stainless steel tube with a 1,5 mm wall thickness," he asks. The material will be used to undertake research that is representative of reality. While it is easy to buy plate and tube, "these do not show the variability introduced by real welding".

Paterson's research involves two distinct areas. The first is to characterise the cast structure of welds for joining wrought materials so that the cast structure can be correctly represented in finite element (FEA) analysis programmes. The primary research tool to do this is the Gleeble, a thermo-mechanical simulator. "What the Gleeble does is to predictably repeat the heating, holding and cooling cycles (or any variations) represented by welding processes. Amongst its output is a stress-strain diagram for the HAZ. From a structural engineering point of view, a weakness of FEA models has always been the tacit assumption that material with welds is homogenous. FEA is thus unable to represent welded joints in terms of their own cast characteristics," Paterson explains.

Hence the need for structural steel offcuts from practical projects. Start stop tabs for butt welds that include sufficient material to cut the 11×11×70 mm test samples required by the Gleeble for HAZ simulation testing would be ideal. Samples need to have a cross section of roughly 150×100-150 mm with a central weld through the 150 mm width.

The second research area involves stainless steel process plants. Paterson explains that hygienic fabrication is becoming more important as health issues become dominated by water sourcing and scarcity. For the research, the stainless steel pipe samples will be exposed to E. coli to ascertain the degree to which pipe alignment, profiles and ovality contribute to bacterial growth.

"We are looking for pipe profiles that meet specifications with joint alignment mismatch of up to 0,1 mm (6% wt)," he says.

*tony.paterson@wits.ac.za*

## Clean mobile extraction, filtration and dust disposal

While offering mobility and protection against large volumes of welding fume, the MaxiFil Clean from KEMPER has also added a system with a cleanable filter to its portfolio of mobile extraction and filter units. The unit ensures effective collection of pollutants at their point of origin. With MaxiFil Clean, KEMPER is the first manufacturer to take the entire pollutant cycle into account beyond extraction and filtering. The company has applied for a patent for its unique contamination-free dust disposal system in cartridges. Initial use of the extraction and filter unit in plants has already been met with a positive reaction.

"With MaxiFil Clean, plants that work with metals can ensure high standards of work safety for their employees," emphasises Björn Kemper, managing director of KEMPER-GmbH. "Apart from the extraction and filtering of large volumes of pollutants, our new system guarantees their safe and reliable disposal from the filter unit."

*www.kemper.eu*

# Hire inverter welders for African conditions

Attention to industry needs is the driving force behind each item of equipment within the Lambson's Hire fleet. Addressing the need for an inverter welder that is suitable for operation in harsh African environments led to the introduction of the 220 V, 200 A inverter welders, which feature leading insulated gate bipolar transistor (IGBT) technology.

"Rapid technological developments in the welding equipment industry dictate the need to stay current on our own product offering. Hence we defined and reacted to a demand for a dc inverter arc welder that is very small, light and portable, yet capable of undertaking demanding tasks," says Devin van Zyl, CEO of Lambson's Hire.

Introduced less than four years ago to selected branches in high-density areas, the units have become so popular that they are now available from all of Lambson's Hire's 18 branches throughout South Africa. Van Zyl explains that it is common practice at Lambson's Hire to conduct pilot studies at branches where a specific need has been identified. "This allows us to assess whether the product is suitable for the applications at hand and whether we need to expand our fleet across more branches."

He says that the range adopts advanced, leading arc control technology that provides higher arc stability and better welding performance. This not only leads to a higher quality weld finish but also enhances safety for the welder and other employees in the immediate vicinity.

Quality is heightened by the operation of the welders, which offer easy striking, low spatter and smooth dc output.

"While quality is the predominant factor in all welding, clients are also conscious of budgetary constraints, so a balance between price and performance is required. The end result is deep steel penetration at an affordable price," van Zyl says.

These dc inverters are also appropriate for use with compressed air for arc air gouging of curvilinear shapes in different thicknesses of sheet metal. The compact and lightweight 8.0 kg design of the inverters and their low power consumption make them ideal for use in production and maintenance applications where portability and cost containment are factors.

The inverter welder range is also CE and EMC compliant and each welder that goes out to a client is supplied with an earth clamp and electrode holder. "Feedback from clients demonstrates that these products are very efficient with good duty cycles, allowing operators to weld for longer on higher settings. Lambson's Hire will continue to research suitable solutions to industry issues and upgrade its fleet to meet client needs," Van Zyl concludes.

***www.lambsonshire.co.za***


*Designed to suite African conditions, Lambson's Hire's 220 V, 200 A inverter welders feature IGBT technology and arc control technology to provide higher arc stability and better welding performance.*

# ABB's large industrial robot line

ABB's IRB 6700 family of robots is a natural evolution of its large robot heritage. Featuring a multitude of next generation improvements, these robots strive to achieve the lowest total cost of ownership available today.

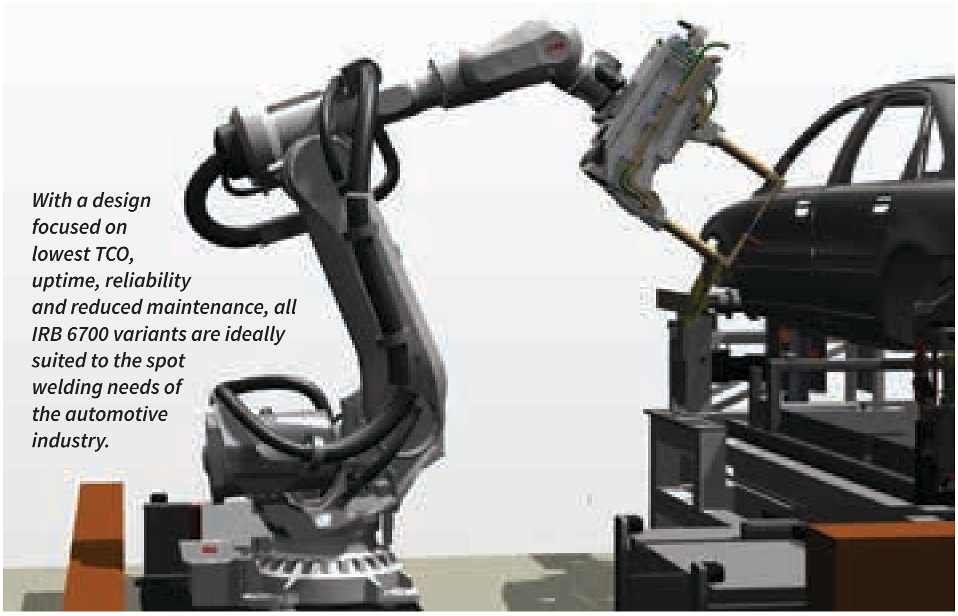
For 40 years ABB has evolved its line-up of large industrial robots to meet modern manufacturing needs. This depth of experience has led to a comprehensive knowledge of the needs of our customers, along with the technical capability to produce the most robust and cost effective machines available.

ABB unveiled the first four members of the IRB 6700 family in November 2013; followed by two additional members during 2014. The company has again raised the bar with the recent introduction of the IRB 6700-300/2.70 and the IRB 6700-245/3.00, the last two variants in its 7$^{th}$ generation large robot family.

Not only have accuracy, payload and speed been increased, but power consumption has also been lowered by 15% and servicing has been simplified. In determining what improvements to include, ABB studied the detailed field reports from the IRB 6700's predecessor and engaged closely with customers during a yearlong study.

"Historically, when designing our robots we have always focused on performance. This time we emphasised reliability and lowering total cost of ownership," says Ola Svanström, ABB product manager for Large Robots. "The IRB 6700 focuses on MTBF (mean time between failures), MTTR (mean time to repair), and the essential elements required to lengthen these mean times."

Every robot in the 6700 family is designed to accommodate LeanID – a new Integrated Dressing (ID) solution meant to achieve a balance between cost and durability by integrating the most exposed parts of the dress pack into the robot. Equipping an IRB 6700 with LeanID makes it easier to program and operate with predictable cable movements; creates a more compact footprint; and lengthens service intervals due to lessened wear and tear. Any of the IRB 6700 eight family members also can be ordered with ABB's Foundry Plus for additional protection. This optional protection system guards ABB's robots in the harshest foundry environments, which can be extremely hard on standard robots and equipment.



*With a design focused on lowest TCO, uptime, reliability and reduced maintenance, all IRB 6700 variants are ideally suited to the spot welding needs of the automotive industry.*

"Our automotive customers have told us it is not unusual to change a spot welding dress pack on 60% of their robots every year," adds Svanström. "Thanks to the IRB 6700 family, we can deliver a dress pack with a full warranty – just like the rest of the robot – which is a giant step forward when it comes to uptime."

In designing the new robot, easier serviceability was identified as a critical aspect for improving its total cost of ownership. Service routines for the machine have been shortened and intervals between them have been increased.

A summary of the key features:

- Two new variants join the family, the Power Line 245 kg and 300 kg with payloads of 245 and 300 kg and reaches from 3.00 to 2.70 m, respectively.
- ABB's Foundry Plus additional sealant protection option is available for each of the robots' axes.
- Built around the LeanID principle, the IRB 6700 range offers reduced wear and smaller footprints.
- Cost-effective Integrated Dressing encloses the most exposed parts of the dress pack into the robot, protecting conduits and enabling less restrictive path programming.
- Simplified maintenance is achieved through longer service intervals, highly accessible components and optimised service routines.
- Key improvements combined with better energy efficiency add up to 20% lower total costs of ownership (TCO)

ABB Robotics also provides robot software, peripheral equipment, modular manufacturing cells and service for tasks such as welding, handling, assembly, painting and finishing, picking, packing, palletizing and machine tending and all robotic products are fully supported by the ABB Robotics' global sales and service organisation.

*new.abb.com/southern-africa*

## INDEX TO ADVERTISERS


Afrox ............ OFC
Air Liquide ............ IFC
Air Products ............ 24
BED Holdings Fronius ............ 36
Böhler Uddeholm Africa ............ 6
Crown Publications ............ IBC
Envirox ............ 43
Hydra Arc ............ 27
Lincoln Electric ............ OBC
Probraze Metals ............ 25
Thermaspray ............ 38
SAIW ............ 2, 11
Welding Alloys South Africa ............ 18
Yaskawa Southern Africa ............ 28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