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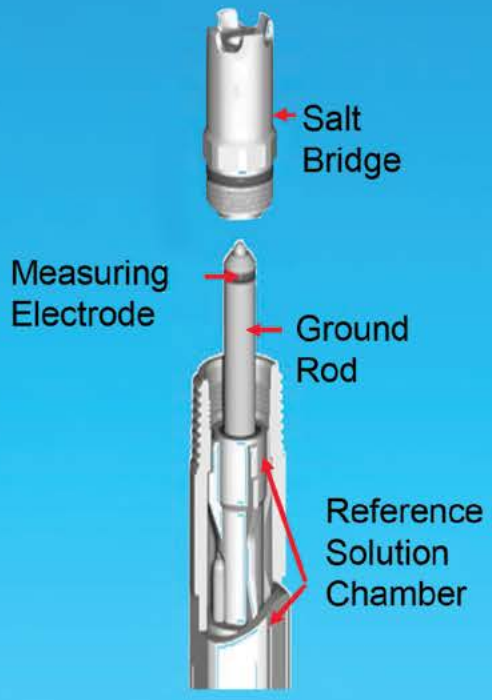

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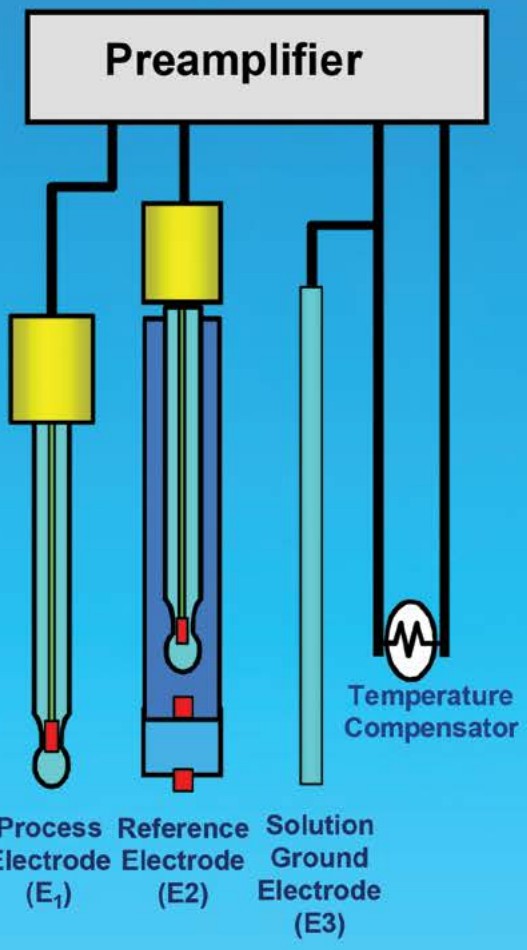

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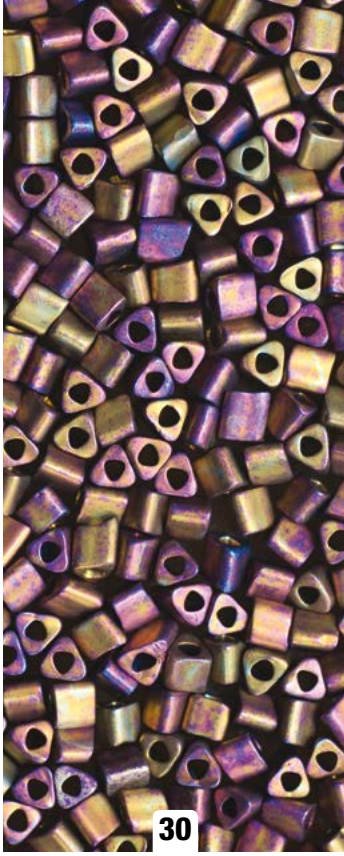

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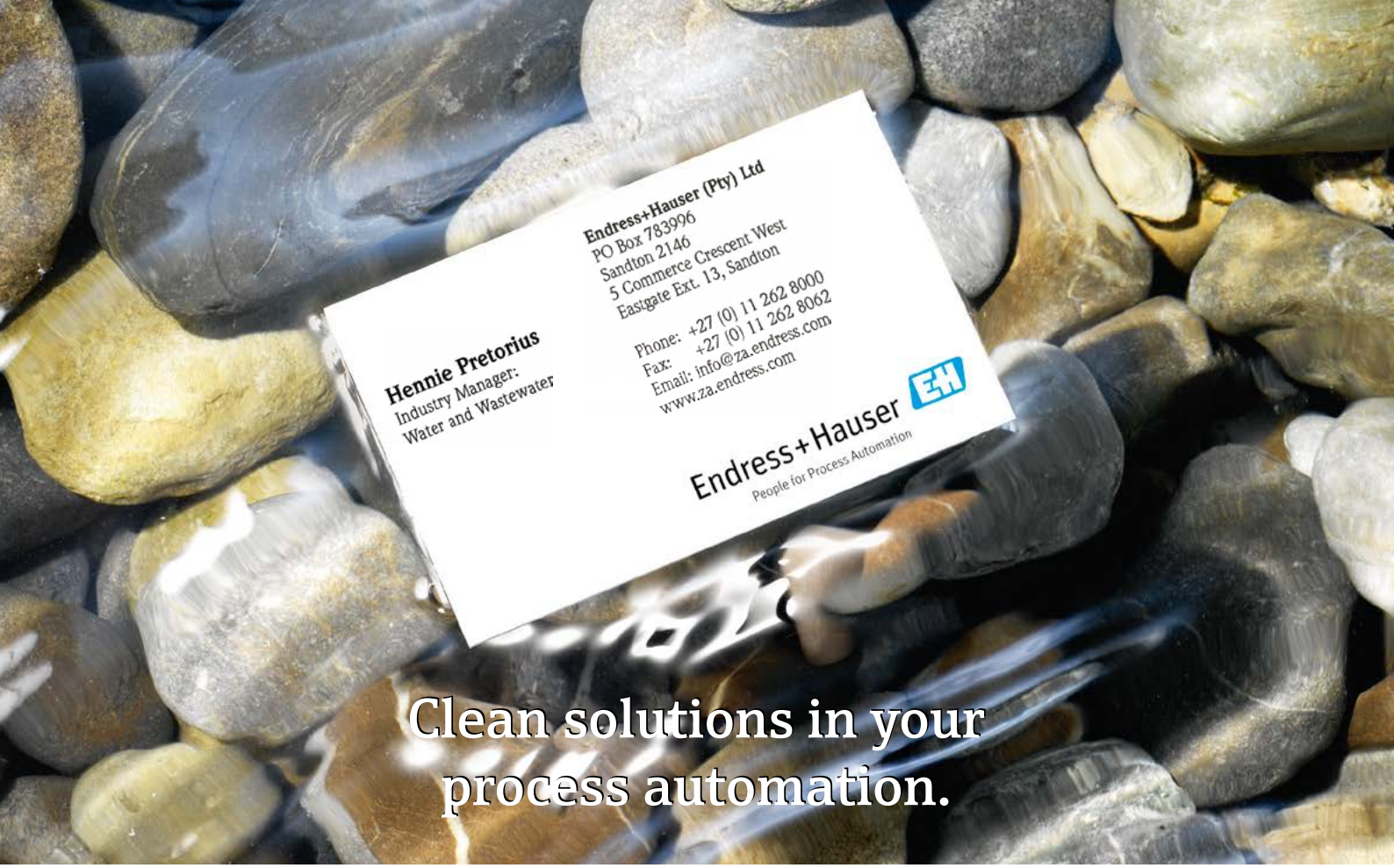

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Guidance on **environmental footprint of products**

The World Business Council for Sustainable Development (WBCSD) recently published a new guide designed to help chemical industry customers and stakeholders make more informed, sustainable choices. Entitled 'Life Cycle Metrics for Chemical Products', the guidance document is the result of a collaboration between leading chemical companies that are part of the WBCSD's 'Reaching Full Potential' project.

Focused on life cycle assessment methods, a key objective of the new guide is to provide and communicate material information about the environmental footprint of products that customers and stakeholders can trust and compare.

A key role of the chemical industry is to enable improved sustainability across value chains, a principle fully embraced by the member companies of the Reaching Full Potential project. However, in order to get true market pull for more sustainable products and realize the WBCSD's Vision 2050 – 9 billion people living well within the limits of the planet – there is a clear need to communicate reliable information on a wide range of issues.

Reaching Full Potential companies will continue to advance developments in sustainability metrics for the chemical sector. The Project is currently developing a guide for companies to assess the impact and benefits of chemical products from a social perspective. This work was launched in early 2014 and is expected to be ready by late 2015.

Peter Bakker, President and CEO of the WBCSD, said: "Developing a common guide for the environmental assessment of products is an important step forward in the continued progress of the chemical sector activities at the WBCSD. This will allow chemical sector companies to communicate with a common language to companies downstream, and help scaling-up solutions to enable greater sustainability in value chains."

Feike Sijbesma, CEO of Royal DSM NV and Co-Chair of the WBCSD Reaching Full Potential Project, commented: "Our industry is committed to addressing our environmental footprint and to combating climate change in order to create a more sustainable world. With this clear guide, which we have developed collectively, we are taking the next step. At DSM we continuously pursue opportunities to further integrate and measure sustainability into everything we do. We use our bright science to innovate and create a brighter world."

Peter Nieuwenhuizen, Director of Innovation and Partnerships at AkzoNobel, one of the companies that compiled the guide, said: "This is an extremely valuable document that will enable us to provide credible information about how chemical value chains impact on and contribute to sustainability."

Member companies and partners of the chemical sector Reaching Full Potential project are: AkzoNobel; BASF; DSM; Cefic; Eastman Chemical; Evonik Industries; Henkel; SABIC; SCG Chemicals Company; Solvay; Mitsubishi Chemical Holdings Company, supported by PricewaterhouseCoopers.

For more information contact Irge Olga Aujouannet on tel: +41 22 839 3129 or email: aujouannet@wbcsd.org.

The ℮-mark and other marking **requirements for products**

by Janet Tomkow, BSc, LLB

Some readers may not be aware of the unbundling of the National Regulator for Compulsory Standards 9NRCS) from the South African Bureau of Standards (SABS) several years ago leaving two independent bodies with the NRCS focusing on the enforcement of the Compulsory Standards and the new Legal Metrology Act.

This is of particular importance to importers since the NRCS has been on a drive to ensure that imported products meet all the compulsory standard requirements on the marking of goods sold in South Africa, such as SANS 285 and SANS 458, which determine where and how the quantity in the package is to be indicated.

There are some requirements which make it very difficult for imported goods to comply without overlabelling, for example, the requirement that there be a gap of a character's width between the last digit of a content indication and the SI unit used to indicate the quantity. Of course the letter sizes are prescribed depending on the quantity in the packaging and the units used must be SI units.

The NRCS has ordered products to be removed from sale because the letter sizes were 5,5 mm instead of 6 mm, or because there was no gap between the last digit and the SI unit. This has huge cost implications for the importer as the product has to be uplifted from the shelves and the label corrected, and then the product can once again be placed on sale.

The "℮" mark

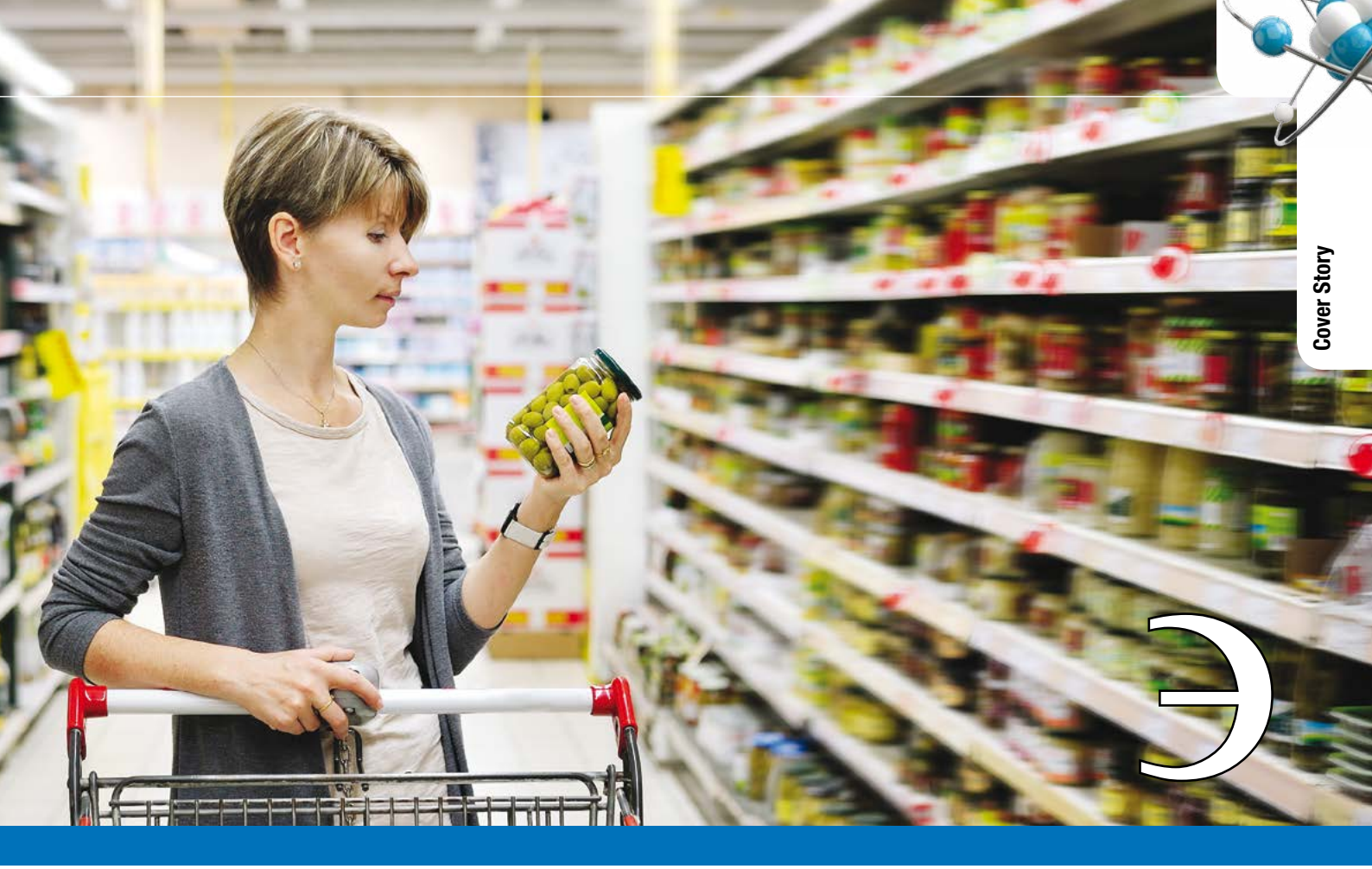
Another critical issue to the sale of products in South Africa is the accuracy of the content indication on the packaging of products. A consumer has the right to be sure that when a bag of compost is marked 30 dm^3 it in fact contains 30 dm^3 when packed, otherwise price comparison becomes impossible. Yet further there are some products, such as pasta, which may only be sold in predetermined pack size, eg, 250 g and 500 g and you may not import and sell a 400 g of pasta regardless whether it is clearly marked as such and the mass indicated thereon is accurate.

Many importers and consumers may have noticed an "℮" placed after the weight indication of a product, but what does it really mean and why is it there? An "℮" mark indicates to the consumer that the weight indicated on the package of a product is in fact what the consumer is getting, ie, a bag of sugar really is 250 g as indicated on the label and not 230 g or even 200 g.

The "℮" mark applies to any item that indicates a measurement, or quantity of a product such as drinks, food, appliances, anything indicating a weight or measurement. For packaged goods the symbol "℮" is used, whereas container bottles will bear the "Ɜ" mark. It indicates to the consumer that the average weight or measurement of the product is not less than the quantity declared on the label. There are specific specifications that must be complied with in South Africa such as the Standard SANS 1841 in order for a product to bear the "℮" mark.

It is a form of providing international confidence in trade measurements as well as confidence in consumers and reduces overfill in products resulting in savings for the importer. The ℮-mark provides the consumer with an assurance that the consumer is not being misled and is purchasing the quantity declared on the packaged product. It is a guarantee that provides a consumer with peace of mind when it comes to the quantity of a product.

The Legal Metrology Division of the National Regulator for Compulsory Specifications (NRCS) is responsible for ensuring fair trade and traceability of measurements in trade. They are equipped with all the tools to investigate packaged products that bear the "℮" mark but do not comply with



the quantity declared on the package the product comes in. Although "e"marking is not compulsory in South Africa the Trade Metrology division is taking "e"marking very seriously and have begun to discuss details regarding "e" mark registration with retailers, suppliers as well as importers. Workshops will be held in respect of "e"marking to inform consumers and retailers of the meaning of the "e" mark and the implications of packaged products bearing the "e" mark.

This drive by the NRCS is derived from a goal to align itself with international standards to ensure uniformity and standardization in business. A new system recently implemented by the Legal Metrology Division now places companies wishing to place an "e" mark on their packaged products into three categories:

A: Once off importation

B: Importers who continue to import goods into South Africa and are registered with a Legal Metrology Authority in their country.

C: Importers who continue to import goods into South Africa but are not registered with a Legal Metrology Authority in their own country but instead claim compliance.

Each of the above categories has specific steps that must be followed in order to register with the NRCS. Once a supplier of imported products or importer has applied to register with the NRCS the inspectors of the Legal Metrology Division will begin the process of inspecting the suppliers of imported products or importer's labels and documents as well as a sample of the products will be tested. Audits will be carried out and once satisfied that the supplier of imported products or importer comply with all the requirements as well as specifications set out in SANS 1841, a certificate is issued by the NRCS to the supplier or importer who may then confidently place the "e" mark on its products.

It may already be necessary for an importer to bear the "e" mark on its packaged products in the country of origin they are importing from. Even though "e" marking is not yet compulsory in South Africa, the NRCS will get involved should one of their inspectors find a product bearing the "e" mark but the supplier of the imported product and/or the importer is not registered with the NRCS and/or it is discovered the quantity declared on the package of the product is not what is inside the package.

What happens if a supplier of imported products or an importer bears the "e" mark on its product but is not registered with the NRCS and/or it does not comply with the quantity requirements?

Inspectors from the Legal Metrology Division at the NRCS may conduct random checks at any retailers, whether as part of a routine investigation or by way of a tip-off. If it is found that a supplier who imports products bearing the "e" mark or an importer are not registered with the NRCS and/or the quantity as declared on the package is not the quantity of the product, the NRCS has the power and the authority to issue a Prohibition of Sale Notice on the supplier or importer, whereby the product must then be removed from the stores and either destroyed or returned back to its country of origin. A fine will be imposed on the supplier or importer and/or the products may even be blacklisted.

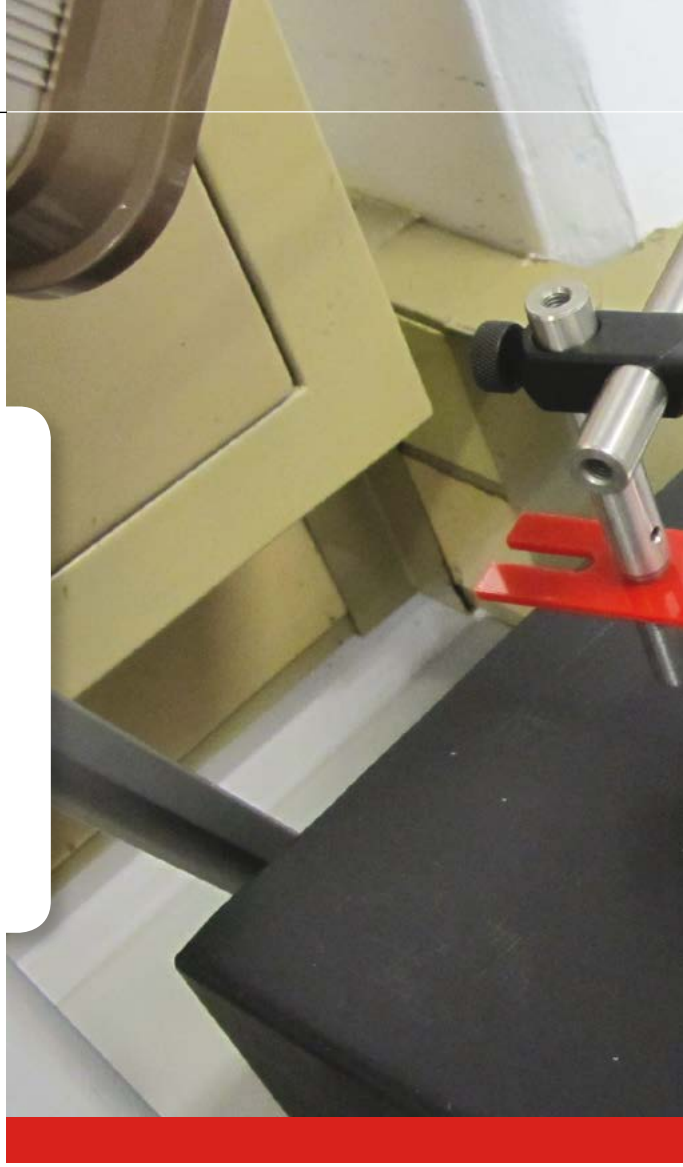
Local suppliers that wish to bear the "e"mark must also register with the NRCS and comply with all the requirements set out in the SANS 1841.

Labelling specialists such as Hahn & Hahn Attorneys can assist suppliers of imported products or importers in compliance with labeling regulations and "e" mark registration with the NRCS.

For more information contact the author at janet@hahn.co.za ▮

A centrifugal microfluidic platform for **point-of-care diagnostic applications**

by Suzanne Hugo and Kevin Land of the Council for Scientific and Industrial Research, Pretoria, (Materials Science and Manufacturing), South Africa, and Marc Madou and Horacio Kido of the Department of Mechanical and Aerospace Engineering, University of California, Irvine, California, USA



The lab-on-a-disc centrifugal microfluidic platform has the potential to provide new diagnostic solutions in health and industry-related areas.

The technology of microfluidics entails the precise and automated control of very small volumes of fluids, usually on a nanolitre scale. A number of comprehensive reviews detail the advances that have been made in microfluidic technologies over the last 30 years [1, 2]. Microfluidic systems are often referred to as lab-on-a-chip systems or micro-Total-Analysis-Systems (microTAS), and are well-suited to the development of point-of-care diagnostics [3-5] as these systems utilise a small sample to provide a compact and low-cost solution.

Centrifugal microfluidic systems, (or lab-on-a-disc/lab-on-a-CD solutions), provide a particularly attractive solution for the implementation of microfluidic point-of-care diagnostic systems, specifically for biomedical applications [6].

Centrifugal microfluidic technology makes use of a disc, similar in size and shape to a CD or DVD, to house microfluidic channels and features. A motor is used to rotate the microfluidic disc, transporting fluid radially outwards through the microfluidic device, and manipulating fluid by means of various microfluidic functions and features on the disc. Functions such as valving, mixing, pumping and separation of fluids can be readily achieved in centrifugal microfluidic systems by exploiting the forces responsible for fluidic control. Fluidic control in lab-on-a-disc microfluidics depends on centrifugal forces, Coriolis forces and capillary action.

Centrifugal microfluidic systems are well suited to integrated point-of-care diagnostic systems – and have a number of advantages over existing microfluidic and other point-of-care diagnostic methods [7-9]. The lab-on-a-disc platform eliminates the need for active elements such as pumps, actuators and active valves which present complex and costly challenges in many microfluidic systems [7-9]. In these systems, pumps, valves and other fluidic functions are achieved primarily using centrifugal forces, with only a small motor required to power the system. A high degree of parallelisation is also offered by centrifugal microfluidics, as numerous devices can be implemented on one disc as a result of radial symmetry. Examples of centrifugal microfluidic applications for biomedical diagnostics have been described including blood plasma separation [10] and a variety of biological assay implementations [11-13].

The simple, low-cost and multiplex nature of the lab-on-a-disc platform is further strengthened by the low-cost and rapid fabrication techniques that can be used to make the disc devices. Simple layered designs manufactured from plastics and adhesives can be used to fabricate microfluidic discs quickly and effectively. Centrifugal microfluidic systems enable a variety of components from sample preparation through to detection to be implemented efficiently into an integrated microfluidic solution for point-of-care diagnostic applications [14].

In addition to the low-cost factors, centrifugal microfluidics have the added benefit of an accelerated route to market, as they can be viewed as microfluidic applications compatible with various existing and commercially available technologies [15]. Existing equipment such as CD players, DVD drives and laboratory centrifuges can be used to drive the microfluidic discs and analyse the results, eliminating

Testing a drop of fluid using the microfluidic disc

the need for extensive development on the reader/actuator component of the point-of-care device. The compatibility of lab-on-a-disc devices with commercially available readers is of particular benefit for developing countries, as this compatibility enables a readily accessible solution where it is needed most.

Centrifugal microfluidic platform

The lab-on-a-disc platform consists of three main components: a microfluidic disc device, a system for controlling fluid flow on the device and a system to record the results obtained. These components have been successfully implemented into an integrated system including programmable spin cycles and both macro imaging and microscopy. The integrated components provide a complete centrifugal microfluidic platform on which to develop new and novel applications in fields such as point-of-care health diagnostics, environmental diagnostics and chemical and biological production.

Microfluidic disc design, manufacture and assembly

Centrifugal microfluidic disc devices can be designed using a computer aided design (CAD) program such as Solidworks or DesignCAD and manufactured in-house. The microfluidic discs were made from polycarbonate sheeting and pressure-sensitive adhesive, assembled in layers. The various features of the microfluidic disc, including channels and chambers, were machined using different materials and methods. The polycarbonate layers were machined using a milling machine, while the pressure-sensitive adhesive layers were cut out using a vinyl cutter plotter. Individual pieces were then assembled and pressed together using a cold roll laminator to produce the finished microfluidic disc device. Figure 1 on page 8 shows the microfluidic disc manufacture process and the relevant equipment and materials required.

Fluid control and analysis of disc

After assembly of the device, the disc was tested using a system that consists of a motor to rotate the disc, as well as an image-capturing unit that allows for a picture of an area of interest to be captured for each revolution of the disc. Different rotational speeds and timing cycles were used to implement various fluidic functions (including valving, mixing, sedimentation, separation and compression) by exploiting centrifugal forces.

Figure 2 shows the disc testing set-up that was assembled to enable fluid control on the microfluidic disc and imaging of the device as it rotates to enable results of the fluidic functions on the disc to be recorded.

A motor and controller were used to control the rotation of the microfluidic disc. An imaging set-up, consisting of an optical sensor, fibre optic cable, a CMOS camera and lens, as well as a strobe light, was constructed.

The optical sensor and fibre optic cable served as a trigger to the camera and the strobe light to allow for a clear still image to be captured each time the disc completed a revolution. A small piece of reflective tape was attached to

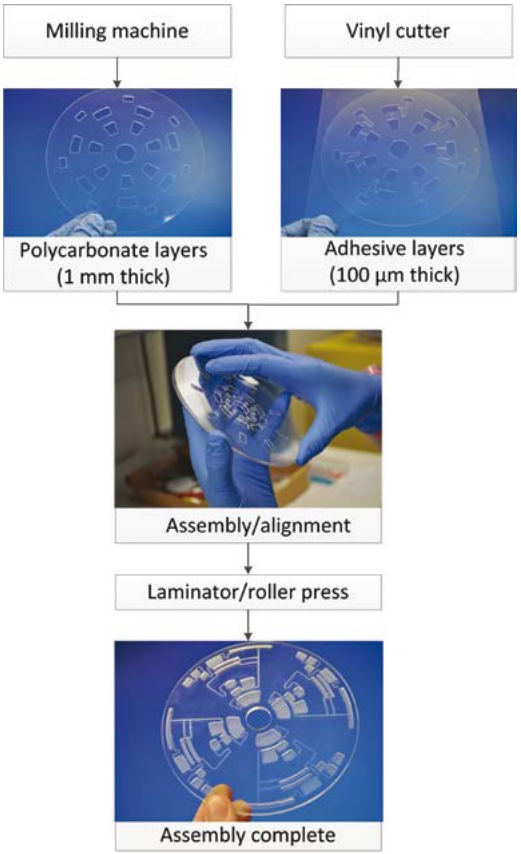


Figure 1: Illustration of microfluidic disc manufacture and assembly process

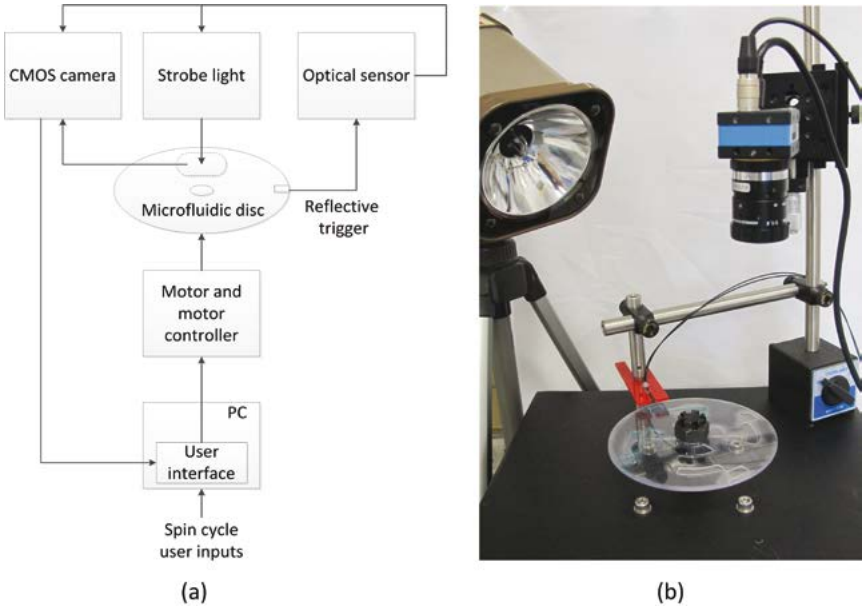


Figure 2: (a) Schematic of the components required for fluidic control and imaging of the disc device and (b) the integrated testing system set-up

the microfluidic disc to be tested to allow the transmitted light from the optical sensor to be reflected into the receiver of the optical sensor, in turn triggering the camera to capture an image, and triggering the strobe light to illuminate the region of interest on the microfluidic disc, ensuring that a clear still image was captured.

The user controls the rotation of the microfluidic disc or spin cycle via a user interface on a PC. The user can program the speed, acceleration, deceleration and timing cycles of the disc to automate fluidic functions on the microfluidic disc.

Platform and scale-up costs

Excluding the equipment, which was already available in-house, the costs to produce a complete centrifugal microfluidic system amounted to R25 000. The cost of materials for the disc devices amounted to R500/m^2 and R10 per prototype disc device.

A comparison of system integration criteria for various microfluidic technologies [16] shows that centrifugal microfluidic systems rank highly as viable, low-cost solutions for integrated lab-on-a-disc systems [16]. Although the lab-on-a-disc system is in the early stages of development, scale-up of the system is an ongoing consideration. Scale-up will continue to be considered and developed based on the desired end application of the system.

To ensure the successful development of the lab-on-a-disc system into a viable medical diagnostic product, medical device regulatory requirements will be an important consideration. Role players in the regulatory environment are currently being engaged to determine the requirements for the South African market.

Results

Initial applications of the complete centrifugal microfluidic platform were implemented to illustrate the process carried out from design to analysis of a lab-on-a-disc system. The first example demonstrates basic fluidic functions on the disc such as introduction, valving and combining of fluids, and illustrates potential diagnostic applications for manipulation of biological samples such as blood. The second example demonstrates microfluidic droplet generation using the centrifugal microfluidic platform.

Basic fluidic functions

To demonstrate basic fluidic functions, a simple microfluidic disc design was formulated to allow for a sample and a sample reagent to be introduced separately, added together at different times, and combined, with an overflow chamber for excess solution. For the purposes of illustration, a yeast solution was used to simulate blood, while the reagent was a staining solution commonly used to stain blood cells for visualisation and performing manual blood cell counting. The use of a yeast solution as a proxy also allowed the sedimentation or separation of particles in fluids to be illustrated by the centrifugal microfluidic system.

Figure 3 on page 10 shows the microfluidic features of the disc design used to achieve the desired fluidic functions. Four identical microfluidic systems were designed and manufactured on one disc. The microfluidic channels are 1 mm wide and 100 µm deep, while the chambers have a depth of 1,2 mm and vary in width and length. The vent holes have a diameter of 1 mm.

The blood simulant solution was made from 10 mg dry baker's yeast in 100 mℓ deionised water to yield a similar concentration of cells to that of white blood cells found in a human blood sample. The staining reagent was a 2 % acetic acid solution with 1 mg crystal violet in 100 mℓ deionised water – a standard white blood cell reagent commonly used to lyse red blood cells and stain the nuclei of white blood cells for manual white blood cell counting.

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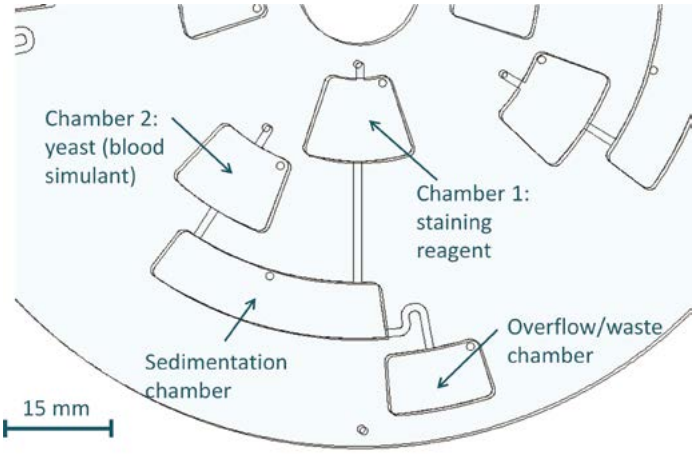

Figure 3: Microfluidic disc design to illustrate the introduction, combination and sedimentation of samples and reagents, with applications for blood testing

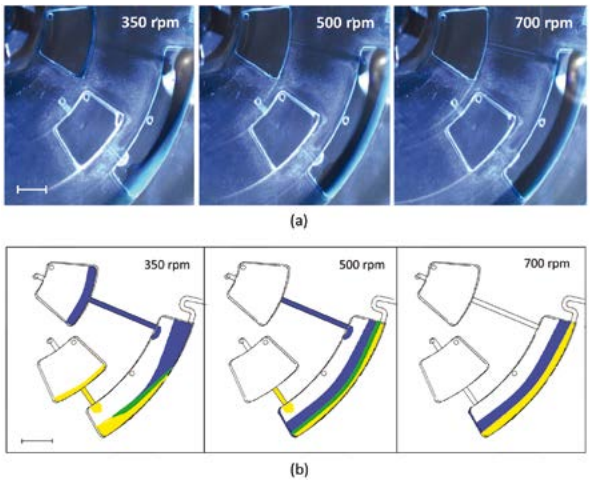

Figure 4: The microfluidic disc at various spin speeds to illustrate sedimentation of fluids: (a) images of the disc device captured using the experimental set-up and (b) corresponding sketches to illustrate the fluid interactions for each of the images in (a).

Approximately 70 μℓ of both the staining solution and the yeast solution were pipetted into chambers 1 and 2, respectively, via the inlet holes on top of the chamber openings (Figure 3). The microfluidic disc was then placed on the motor spindle of the centrifugal microfluidic platform set-up for testing of the fluid functions.

The motor was controlled through the SmartMotor Interface software issued with the motor hardware. The motor was set to operate at a constant velocity to enable continuous rotation of the disc on the motor spindle. For each change in the speed of the rotating disc, an acceleration of 350 rpm^2 was used.

The motor was initially set to rotate at a speed of 100 rpm. At this speed, no fluid movement occurs and both the yeast solution and the staining reagent stay in the inlet chambers into which they were introduced. At 200 rpm, the fluid in both the inlet chambers starts to compress and is pushed to the bottom of the chambers. At a slight increase in rotational speed up to 280 rpm, the staining solution from chamber 1 is released via a channel into the sedimentation chamber. The fluid is released as a result of the centrifugal force exceeding the capillary force – commonly referred to as the burst frequency. Increasing the speed further to 320 rpm causes the yeast solution from chamber 2 to prime the connecting channel to the sedimentation chamber. At a slightly higher speed of 350 rpm, the yeast solution from chamber 2 is released fully into the sedimentation chamber, combining with the staining reagent. At 500 rpm, the inlet chambers have been completely emptied and the fluid is combined in the sedimentation chamber.

Figure 4 illustrates the sedimentation of fluids in the microfluidic disc, again by making use of the yeast solution as it contains cells or particulate matter. Fluids were introduced into the same disc design in the same manner as previously. In this example, the yeast solution used was a higher concentration (approximately 10 g dry baker's yeast in 100 mℓ deionised water) for ease of visualisation of the sedimentation process. This concentration is also similar to the concentration of both red and white blood cells found in a sample of human blood. The staining reagent used was again a 2 % acetic acid solution with 1 mg crystal violet in 100 mℓ deionised water.

A sequence of images from the rotating disc device is shown in Figure 4a, with corresponding sketches of the fluidic operations for each of these images illustrated in Figure 4b. At 350 rpm, both the yeast solution and the staining reagent are in the process of being released into the sedimentation chamber. However, Figure 4 clearly illustrates, as a result of the higher concentration of yeast, how the fluids combine in the sedimentation chamber. Although the yeast solution is released after the staining reagent, the yeast solution starts to move to the bottom of the sedimentation chamber as a result of the centrifugal forces. At an increased speed of 500 rpm, sedimentation of the yeast solution from the staining reagent is clearly visible, and at 700 rpm the inlet chambers have been completely emptied into the sedimentation chamber and compressed sedimentation of the yeast solution is visible. Again, the acceleration used for the adjustment of each rotational speed was 350 rpm^2.

Microfluidic droplet generation

Microfluidic droplet generation using the centrifugal microfluidic platform was also investigated.

A large poly(methyl methacrylate) (PMMA) disc was designed and manufactured to house existing droplet generation devices (Figure 5 on page 11). The droplet generation devices, which produce monodisperse droplets, are currently being used for the production of self-immobilised enzymes, which would find application in chemical, food, textile and other industries.

The existing droplet generation devices are made out of polydimethylsiloxane (PDMS) using soft lithography techniques to manufacture micro-channel features. The PDMS layer that houses the micro-channels is bonded to a glass slide to create a complete microfluidic device for testing. Typically these devices are tested using syringe pumps to introduce fluid to the devices. Desired flow rates can be programmed into the syringe pumps. For testing the PDMS droplet generation devices using the centrifugal microfluidic platform, the microfluidic devices were manufactured with relatively large reservoirs (8-mm diameters), allowing for a

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Figure 5: Close-up of the disc used to house the polydimethylsiloxane droplet-generation devices.

larger volume of fluid to be stored on the microfluidic disc and used during a droplet generation experiment.

A microscope set-up was implemented using various attachments connected to the CMOS camera of the centrifugal microfluidic platform. The microscope set-up consisted of –(in the order in which they were connected to the CMOS camera): a SM1 to C mount adaptor, a tube lens, two lens tubes, an RMS adaptor, and a microscope objective.

This set-up enabled images of the droplet generation on the rotating microfluidic disc to be captured (Figure 5). The large PMMA disc allowed for PDMS devices to be mounted on the centrifugal microfluidic platform. The reservoirs on the PDMS devices were filled with mineral oil as the continuous phase and blue dye in deionised water as the droplet phase.

The PDMS devices were mounted to the PMMA disc with the reservoirs filled with mineral oil (with surfactant 3% by weight of Span 80) and deionised water with blue dye and observed at varying rotational speeds. At approximately 550 rpm, monodisperse water droplets in an oil phase were produced with high stability.

Discussion

The centrifugal microfluidic platform was successfully assembled. The design, manufacture and assembly processes were then successfully implemented and tested. The microfluidic disc control and analysis set-up was also successfully established, with hardware and software interfaces designed and implemented. A complete design-to-analysis example was developed, which illustrated the success of the integration of the various components of the centrifugal microfluidic platform. The ability of the centrifugal microfluidic platform to implement diverse microfluidic functions was illustrated by generating monodisperse water droplets in oil.

The results of the microfluidic disc example illustrate microfluidic functions as would be required for diagnostic applications, with particular relevance to blood tests. The microfluidic disc example illustrates that a biological sample can be added to an inlet chamber, with an appropriate sample preparation reagent – such as a lysing and/or staining reagent – contained in a separate chamber on the disc. The sample and reagent can then be added together in a controlled manner and contained for a required period of time.

Sedimentation of particles in fluids can also readily be achieved using the centrifugal microfluidic platform and could be useful in various diagnostic applications where cells need to be separated out of a sample. Sedimentation using the centrifugal microfluidic platform could be of use in blood tests in which plasma and blood cells are required to be separated, for example, for the packed cell volume or haematocrit tests which form part of a full blood count, as well as for various other assays which make use of plasma as a sample.

The results of the droplet generation experiments illustrate that monodisperse droplets can be generated on the centrifugal microfluidic platform with high stability. This example also illustrates the ease with which existing PDMS microfluidic devices with fine microfluidic features can be integrated with the centrifugal microfluidic platform. A low-cost and simple microscope system was established for the centrifugal microfluidic platform, creating a basis on which to test and observe a variety of microfluidic devices at a high level of detail.

Microfluidic functions can be implemented on the centrifugal microfluidic platform with relative ease. In addition, the microfluidic disc manufacture process is simple, rapid and lowcost, making it an ideal disposable component for point-of-care applications as well as allowing for rapid development of devices as a result of efficient prototyping. In addition, the radial symmetry of the microfluidic discs lends itself to multiplexed applications, where an array of tests can be carried out simultaneously on one disc. Similarly, a number of identical tests for different samples can be carried out on the same disc at the same time, increasing the throughput for the desired diagnostic application.

Fluid actuation of the lab-on-a-disc system is also simple and robust, using only a motor rotating at various speeds to achieve a vast array of functionality. The centrifugal microfluidic platform thus also has the potential to be developed into a compact, robust and simple system, ideally suited to point-of-care applications.

References

A list of references for this article is available from the editor at chemtech@crown.co.za. ▮

Acknowledgements

This work was made possible by the BioMEMS group at the University of California, Irvine (UCI) in the USA, who shared their expertise in the field of centrifugal microfluidics. The Council for Scientific and Industrial Research provided funding and support for this research.

VEGA introduces the latest in radar sensors for bulk solids

January saw the launch of VEGA's latest offering in radar sensors to the market. At a packed presentation at the Roodepoort Country Club customers were introduced to the VEGAPULS 69 by Clemens Hengstler, Product Manager Radar from VEGA Grieshaber KG, Germany. Hengstler took guests through the latest innovations of the new technology, stopping to give live demonstrations to prove some of the points he was making. Taking its customers' needsinto account, the Shiltach-based company has researched and developed the VEGAPULS 69, a sensor that takes a big step closer to the ideal of an all-round radar level measuring instrument for bulk solids.

Clemens Hengstler, (left), Product Manager Germany and John Groom, MD VEGA Instruments SA.

The level transmitter operates at a frequency of 79 GHz, which allows a considerably better focusing of the transmitted signal. This is a distinct improvement on the previous model which operated at 26 GHz. In containers and silos with many internal obstructions, this enhanced focusing helps to reduce the influence of background 'noise'. This means that reliable measurement is also possible even with complex internal structures.

New microwave components allow the sensor to detect even the smallest reflected signals. Products such as plastic powders or wood chips, which until recently were very difficult to measure because of their poor reflective properties, can now be measured with very high reliability. This considerably extends the application range for radar technology in the bulk solids industry and opens up new application areas as well.

With a measuring range of up to 120 m and an accuracy of ± 5mm, the sensor has sufficient performance capability even for out of the ordinary tasks such as level gauging in mine shafts or distance measurement on conveyor systems. Despite its large measuring range, the sensor is also an ideal solution for small hoppers or containers; the different antenna designs enable the optimum solution to meet the application needs.

Completely unaffected by dirt and build-up, the innovative lens antenna guarantees maintenance-free operation even in harsh environments.

To make setup and commissioning easier, an intelligent App for smartphones has been developed. It allows quick and easy alignment of the sensor on a swivel holder. By entering the vessel height and the distance from the discharge opening, the App automatically calculates the optimum tilt angle.

For more on the VEGAPULS 69 contact Chantal Groom on +27 11 795 3249 or email chantal.groom@vega.com.

Smart Wireless Navigator helps users manage their expanding wireless infrastructure

Emerson Process Management has introduced the Smart Wireless Navigator, a new software platform that enables users with large wireless deployments to maximise the power of their wireless networks. The Navigator brings together Smart Wireless tools for planning, managing, and maintaining networks. Valuable wireless network and device diagnostics and data are organized in an intuitive interface, along with the wireless tools, to streamline the Smart Wireless experience.

"Wireless technology is as scalable as it is powerful," commented Bob Karschnia, Vice President of Wireless at Emerson. "As users' facilities grow, they are expanding to installations of multiple wireless networks managed by different groups."

The Smart Wireless Navigator helps users effortlessly manage their expanding wireless infrastructure and get the most value from their wireless networks. A single software platform design makes it easier for users with large deployments of wireless to manage their networks across functional groups, delivering actionable information to the people who need it.

"To maximise value, facilities also needed a central platform to plan and deploy new networks and to organise the influx of new data and diagnostics," continued Karschnia. "In answer, we developed a single window interface that brings together several Smart Wireless tools on a specially designed appliance to maximize visibility, efficiency and value."

An intuitive design organises large amounts of wireless diagnostic information and data, and existing infrastructure is illustrated and easily understood.

"The Smart Wireless Navigator is a comprehensive tool that helps users realise the value of wireless across the range of reliability, safety, environmental accountability and process performance," summarized Karschnia, "It delivers value throughout the cycle of engineering, installation, operation and maintenance."

For more information contact Michael Eksteen, Emerson Process Management, on tel: +27 11 451 3700 or email Michael.Eksteen@Emerson.com.

Instrumentation sunshade lowers cost of field protection

Intertec has launched a large cube-shaped sunshade for process instrumentation. It provides plant engineers with a highly cost-effective means of shielding equipment such as electronic monitoring systems, explosion-proof junction boxes or analyser installations from solar radiation. Dubbed CubeShade, the protective cover measures 600 x 550 x 500 mm (HxWxD). This provides a massive 165 litre capacity shaded environment that makes it easy to accommodate and protect large or multiple instruments, as well as simplifying maintenance access.

The new sunshade design is manufactured using an automated moulding process and offers a particularly economic solution for this common application. If Intertec needs to provide solar protection for larger installations – such as two or three process transmitters – sunshades are usually created to suit the specific application by building up multiple layers of glass reinforced polyester (GRP) in a custom mould to achieve the necessary thickness.

Intertec's new CubeShade is constructed entirely from glass fibre reinforced sheet moulding compound (SMC). This combines chopped glass fibres, fillers, polyester resin and a catalyst in the form of a ready-to-mould composite that is ideal for low cost, high volume manufacturing. The material has similar advantages to GRP for this type of application, including a high resistance to UV and corrosion from salt and common petrochemicals, and a low thermal conductivity, which helps to prevent heat generated by solar radiation being transferred to the shaded area. It also combines excellent rigidity and mechanical strength – for protection against impact – with a very low weight.

CubeShade's single-part design and SMC-based construction facilitates production using automated moulding techniques. As standard, the body of the sunshade is 5 mm thick but incorporates 8 mm thick reinforcing ribs around the rim and down the back of the unit. These ribs also help to channel rain and melt-water run-off.

Intertec's design incorporates structural side walls that also shade low-angle sun, as well as providing partial protection against rain, snow, wind-chill, blown dust or sand and accidental impact. The design is also suitable for use with equipment such as explosion-proof junction boxes or distribution units and is likely to prove especially popular for new-build processing plant projects.

For more information contact Intertec Instrumentation on tel: 0800 756 1102, email sales@intertec-inst.co.uk or go to www.intertec.info.

Actuators aid pump station

pressure surge solution

by David Buchwald, president of Pipestone Equipment and Steffen Koehler, SIPOS Aktorik, part of the AUMA Group, represented in South Africa by AUMA ZA

With their variable speed functionality directly integrated into the firmware, SIPOS's Variable Speed Actuators (VSAs) have been identified by Pipestone Equipment as the optimum solution for minimising, or avoiding, water hammer using intelligent control of pump or pressure compensation valves.

A Pipestone Equipment pump station installation featuring SIPOS Aktorik's Variable Speed Actuators.

Ever since they were invented, control valves have been on the move. As an integral and essential element of pumping applications, the issue of managing the performance of these valves has been the driving force behind the development of new generation actuators and actuation solutions. Pipestone Equipment, which has adopted SIPOS's Variable Speed Actuator (VSA) technology in a number of pump station installations has provided technical data and illustrations to support the following report. A supplier of municipal and industrial water products providing comprehensive support including system design, Pipestone's services include hydraulic analyses as well as the engineering element of the plant incorporating directly linked control valves, other shut-off valves and air valves or surge tanks.

David Buchwald is a member of the American Waterworks Association (AWWA) and Colorado Renewable Energy Society (CRES); www.pipestoneeq.com

Steffen Koehler is an International Sales Manager for SIPOS Aktorik, he has extensive experience of global business and electric actuation projects.

Variable speed actuators

With a hundred year history — originally as part of the Siemens organization — SIPOS supplies both standard and Variable Speed Actuators. The company, which has been established as SIPOS Aktorik for over a decade, launched the SIPOS 5 VSA in 1998. Introducing an integrated frequency converter to valve actuation, and pairing with intelligent controls, gave SIPOS the ability to facilitate the smooth control of valves in both an open and closed loop. Additionally, functional reliability was provided, which could be monitored in the interests of efficient process operation. The product development initiative also meant that the actuator's output speed could be changed at any time, depending on valve/process requirements.

The automation experts at Pipestone Equipment confirm that, for modern pumps, which are combined with valves to ensure controlled and reliable flow rates, minimising the risk of pressure surges is essential, and this can be achieved by using Variable Speed Actuators. Avoiding water hammer is of particular interest, as this is a very real potential danger for plants and pipeline systems.

With their variable speed functionality directly integrated into the firmware, SIPOS's VSAs have been identified by Pipestone as the optimum solution for minimising, or avoiding, water hammer using intelligent control of pump or pressure compensation valves.

Pressure point

A key area that the VSAs have addressed is the highly

damaging impact of water hammer. High pressure build up culminates in shock waves and, in the worst case scenarios, pipelines can break. Vacuum can also be created that causes pipes to collapse or implode. The topic of pressure surge reduction is, therefore, a key consideration for pump station projects and an issue that requires considerable engineering work to facilitate solutions.

SIPOS invested heavily in R&D to address the issue of 'soft starting' or 'caressing'. The reason that the valve needs 'caressing' can be explained by drawing a parallel with the motion of a lift. To avoid impact on both the lift, and the people using it, a soft start (and stop) is required. The lift should ease gently into its movement, gradually gather momentum and slow to a stop at its selected end point.

The same principle applies to water — flow needs to be 'caressed' to avoid the build-up and pressure peaks associated with water hammer, which have been known to rupture pipes. SIPOS's integrated VSA frequency converter ensures that motor speed is reduced automatically in the end positions. Therefore, there are no magnification torques if the valve is blocked between the end positions. The voltage for each of the many available speed/cut-off torque combinations is pre-selected so that the cut-off torque setting corresponds to the stalling torque of the motor.

In other words, if a VSA is used, the massive current peaks experienced when the motor starts are eliminated and, even an unscheduled stop, does not result in torque damage.

The alternative to VSAs is to fit an external frequency converter: this is not an aesthetically pleasing option and, more importantly, workers on site are required to program and maintain highly complex converter software.

Flow capacity

Free selection of output speed is the basis of SIPOS technology. This is achieved using an integrated frequency converter for control. Intelligent software within the actuator not only controls the motor but also provides a special travel-positioning time function.

Actuators are historically selected to open or close within a specified time, which defines the output speed. Typical water industry pump control ball valves have very high flow capacities (Cv) and, when combined within a waterline, have non-linear flow capacity curves whereby relatively small

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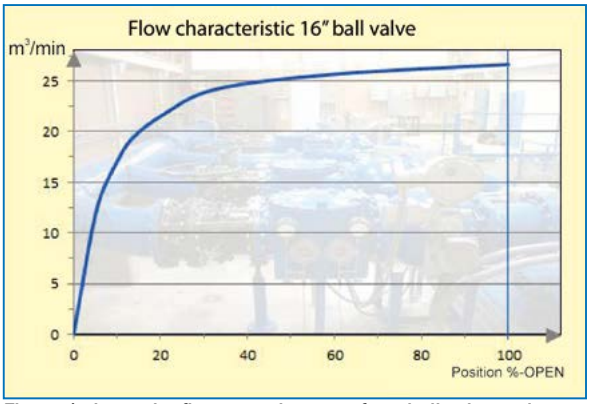

Figure 1 shows the flow capacity curve for a ball valve and waterline used in a pump station application managed by Pipestone Equipment. The graph illustrates the throughput curve of a typical ball valve and waterline. Note that, when just 6 percent open, the throughput rate is already 50 percent.

opening percentages (ie, 10 %) result in capacities of greater than 50 % and full flow rates can be achieved at openings in the one third range. As such, constant speed actuation only provides flow rate control over roughly the first third of the operating time. Additionally, the control provided is non-linear and is determined by the valve characteristics, not the actuator.

Ball valves have a rugged, simple design and a high volume throughput which minimises headloss during pumping operation and saves energy cost. When the high capacity ball valve is combined with a waterline and pump station, the flow capacity of the waterline quickly becomes a limiting factor. Effective valve control is therefore essential for maximizing the benefits of ball control valves, while minimizing transients within the system.

Ideal pump station start-up and shut-down sequences would accelerate and decelerate water within the pipeline at a constant rate or linearly. Due to the complex interrelationship between pump curve, ball valve Cv curve and pipeline configuration, achieving linear flow rate changes has been difficult to achieve over the years. However, if the rotational speed of the valve shaft during the opening and closing sequences could be varied, linearisation becomes possible. With this ability, computations could be made to determine valve shaft rotational speed at various points during operation and a valve could be programmed to essentially be a linear control valve for that specific installation site. This theory applies to any type of valve or gate, any water source and any type of fluid control system.

Bridging the gap between theory and reality are SIPOS actuators. By defining up to ten value pairs (position; positioning time); the required parameters may be set directly within the actuator according to the system characteristics. Once programmed, the SIPOS actuator will operate the valve as required to achieve optimised and linearised flow rate changes. For first-time input based on manufacturer curves, use of COM-SIPOS actuator parameterisation software is highly recommended. Separate operation curves for opening or closing the valve can be specified. COM-SIPOS presents the entered values on a chart enabling quick verification of figures (see Figures 2a and 2b). For the operator, the result is a practical linear relation of run time and throughput (see Figure 2b).

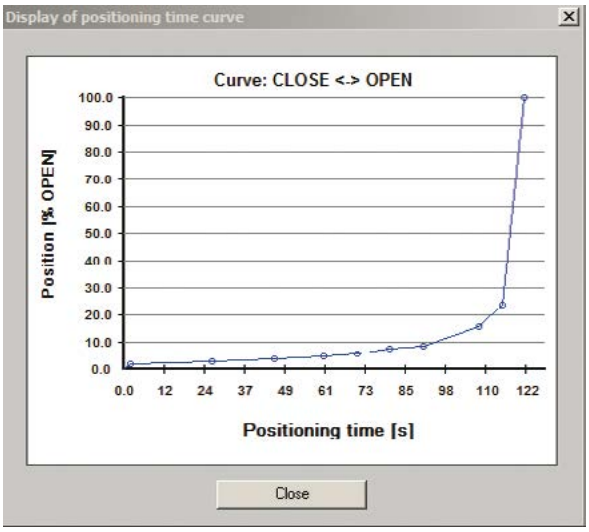

Figure 2a: Example of a travel-positioning time function for the SIPOS actuator. The parameterised curve compensates for the curve of a ball valve and pipeline. Rapid operation within the OPEN range, from approximately half the closing time is indicated with considerably reduced output speed.

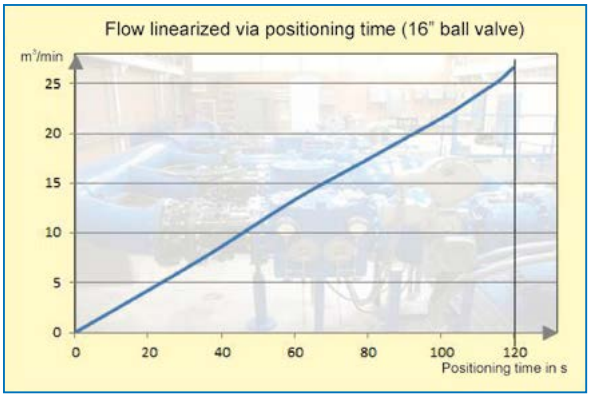

Figure 2b shows the resulting linearized curve of the ball valve and pipeline from Figure 1.

Surge solution

SIPOS actuators address water hammer.

Pressure surges are often caused by valves opening quickly with excessive pressure variation in front of and after the valve. Pressure peaks, due to simultaneous closing of several valves within closed systems, are also known. The flowing medium suddenly halts and kinetic energy is turned into pressure.

Another reason may be the quick start of a powerful pump. The overpressures and low pressures, also called water hammer, can be reduced by combining a pump with additional start-up control and a ball valve with a Variable Speed Actuator. Pressure relief valves and/or bladder surge vessels can also be used to aid pressure surge reduction and system attenuation.

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David Buchwald, Pipestone Equipment President and article co-author.

Pump failure, eg, in case of power failure, has major impact. Pipeline breaks may also generate pressure surges and cause further damage to the entire system.

Every day, companies like Pipestone Equipment address the challenges of pressure surges and water hammer. Central competences include detailed examination of the behaviour of systems which comprise pumps, shut-off valves and pipelines with water. The starting point for all considerations is often measurements and simulations, such as the pressure curve shown in red on Figure 3.

The amplitude at measuring point 2 after the pump ball valve shows significant pressure surges. As an alternative, or in addition to reduced mechanical and hydraulic measures, pressure waves can also be remedied by means of intelligent control of the pump valve. The blue curve clearly shows softer pressure variations when using SIPOS travel-positioning time function.

Conclusion

In conclusion, SIPOS stresses the importance of controlling water hammer in pump stations and, although actuation devices look quite innocuous to most people, anyone working in the 'front line' dealing with the aftermath of pipe ruptures will reinforce the importance of valve control technology. The experts at Pipestone Equipment can confirm that the control of pressure surges are all important and advancements such as VSAs play a significant role in enhancing automation processes. ▮

A new electric actuator range has been added to SIPOS' portfolio; visit www.siposseven.com for more information. Orders for the new SIPOS SEVEN can be made with delivery from July 2015. The SIPOS 5 actuator will continue to be available, along with spare parts.

For more information go to: www.sipos.de/www.auma.com.

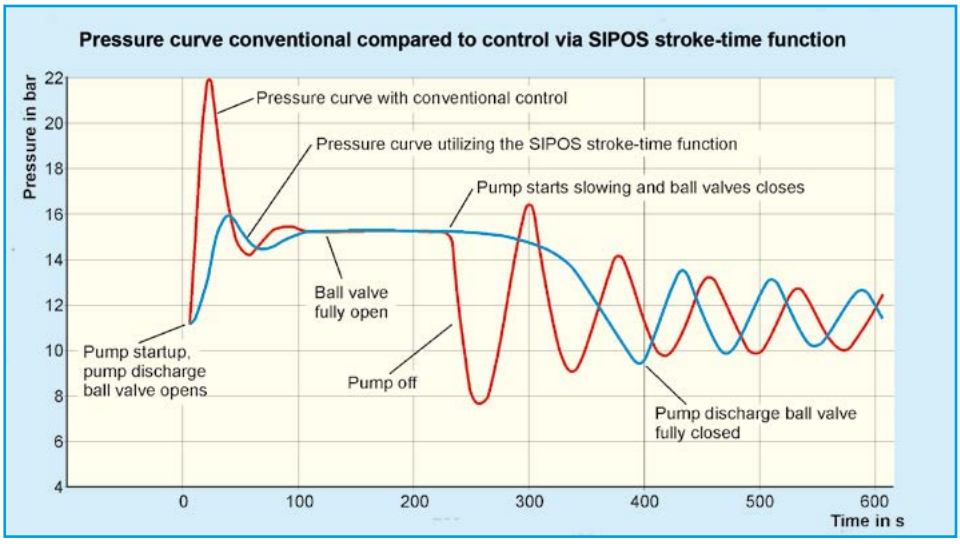


Figure 3: Pressure curve measured at the pump or after the pump valve (ball valve) for starting up or shutting down at a pump station project. The blue curve clearly shows the reduction of pressure surges when using the SIPOS 5 travel positioning time function.

ATEX product and service range extended

Following recent ATEX certification of the LabTecta bearing protection product range, AESSEAL has additionally announced ATEX certification of all its standard mechanical seals.

The products are certified to comply with ATEX directive 94/9/EC, and are backed by an ATEX assessment and support service included at no additional charge to the customer.

Some of AESSEAL's ATEX-certified mechanical seals

ATEX is the certification that allows product installation in environments with potentially explosive atmospheres. It is extensively specified in applications throughout South Africa and Europe.

Compliance was achieved after considerable investment in developing the necessary technical expertise, experience and know-how to assess ATEX applications and ensure compliance with this standard as well as ISO 29001.

AESSEAL is actively involved with various industry bodies to ensure that the mechanical seal industry properly advises its users in hazardous area applications.

The AESSEAL range of mechanical seals and seal support systems is suitable for a wide range of industries including oil and gas, mining, water and wastewater, power generation, pharmaceuticals, chemicals, and food and beverage.

For more information contact Rob Waites on tel: +27 11 466 6500 or email: rwaites@aesseal.co.za.

Test tank facility gives Integrated Pump Technology the edge

Integrated Pump Technology of South Africa has commissioned its new 90 kW test tank facility at its 1 200 m² premises in Bartlett, Johannesburg, which includes a warehouse, rental division and full service and repair capability. "More and more customers are demanding test curves for their repaired pumps, which is critical for reliability. The issue is that while a pump can be repaired, you can only determine if it is operating at optimum efficiency by testing it," Lester Fine, managing director, says.

Integrated Pump Technology is the exclusive distributor in Southern Africa for Grindex of Sweden, the world's third largest submersible pump manufacturer. The main innovation of the Grindex dewatering product family is the capability of the sub-18 kW range to run dry. This is due to a unique air valve integrated into the pump which allows the impeller to pass air instead of water past the motor in a dry run condition. A patented smart motor protector ensures thermal overload, phase loss and phase rotation protection.

The Grindex sludge range has all the advantages of the dewatering range, coupled with a recessed vortex impeller and split hydraulics with replaceable rubber linings. This makes the sludge units capable of greater solids handling, with increased abrasion resistance. Lightweight aluminium construction means that these highly portable and robust pumps are ideal for underground face dewatering.

Grindex dewatering and sludge pumps are also available in 316 stainless steel, with a capacity of handling pH values between 2 and 13, which means they are ideal for process applications. Grindex also manufactures a range of pedigree slurry pumps. Boasting a total hard chrome construction, these units are designed to move medium to heavy slurries with high abrasive content without sacrificing efficiency, abrasion resistance or production downtime.

"Our rental pumps are tested as soon as they are returned, and if they do not pump at about 90% of their performance, they are stripped, serviced and repaired," Fine explains. "All our repaired pumps are issued with a warranty certifying that they have been repaired to original standards."

A front view of Integrated Pump Technology's new 90 kW test tank facility, commissioned at its Johannesburg premises.

PIC 02: The first test run at Integrated Pump Technology's new 90 kW test tank facility, carried out on a Grindex Bravo 800 pump.

For more information contact Klint Bawden on tel: +27 076 840 6527; email: klint@pump-technology.com or go to pump-technology.com.

Globe valve with membrane actuator adept at control tasks

The universally compatible GEMÜ 536 globe valve has a robust design and is reliable in operation. This valve was developed with a long service life and low maintenance requirements in mind.

The GEMÜ 536 pneumatically operated 2/2-way globe valve has a low maintenance membrane actuator which can be controlled by inert gaseous media. The valve plug is fixed to the spindle in such a way as to allow flexing during closure in order to ensure tight shut off. Steel and PTFE as well as a fibre glass-reinforced PTFE version are available as seats.

The valve spindle is sealed by a self-adjusting gland packing. This provides a low-maintenance and reliable valve spindle seal even after an extended period of operation. The wiper ring which has also been introduced additionally protects the gland packing from contamination and damage.

The customer has a choice between cast stainless steel 1.4408 or SG iron GGG40.3 for the material of the valve body. A flange in accordance with EN 1092 or ANSI cl. 125/150 RF is available for the piping connection.

A good flow rate and controllability is achieved due to the globe valve design. Standard regulating cages are used in the control valve design. Thanks to the high-quality design, GEMÜ 536 is also suitable for high operating temperatures and pressures. A version according to ATEX is also available as an option.

Further information can be found at www.gemu-group.com or contact Eva Zink on tel: +49 (0) 7940 123 708 or email: eva.zink@gemue.de.

GEMÜ 536 globe valve with GEMÜ 1436 cPos® process controller.

Water production, technical issues and economics

by Perialwar (Regu) Regunathan

Can calcium and magnesium ('hardness') in drinking-water contribute to preventing disease? Typical diets are often deficient in calcium and magnesium, both essential for strong bones and teeth, and for cardiovascular function. There is also evidence that 'hard' drinking-water may be associated with reduced risks for some diseases.

Central softening

The issue of having calcium and magnesium in finished drinking-water can be of importance not only for those water suppliers that utilise desalination processes, but also for the broader water industry internationally. The Global Water Research Coalition, as representative of many water-related research institutes worldwide, has prepared a review on the reasons and criteria for softening and conditioning (Mons *et al* 2007). It recommends that in addition to nutrition, other health-related and other pertinent aspects should be considered. Both very soft and very hard water can interact with piping materials, which may negatively impact the water quality and the integrity of the piping system. It is therefore important that those other considerations, including the optimal composition of piped drinking-water to prevent corrosion and scaling, are taken into account.

In several countries, softening is sometimes applied centrally (eg, Netherlands, Germany, Belgium, France, United States). Point-of-entry (POE) softening at the individual residence is the most frequently applied method of softening. Central softening of drinking-water offers public health and environmental benefits. Moreover, consumer comfort is increased, and there are also several financial benefits for the consumer.

Reasons for central softening include:

- reduced exposure to trace metals due to reduced corrosion of plumbing in the distribution system and household plumbing;
- reduced costs because of reduced consumption of detergents and energy as well as lessened need to use private softeners;
- fewer discharges to the environment (eg, less detergents,

less leaching of copper, less salt usage by private softeners, lower use of chemical inhibitors); and
- better consumer comfort due to better looking clothes, glassware, etc.

It is essential to arrive at an optimal composition of the drinking-water to be distributed, and the central aspects of this optimal composition of the public drinking-water should include:
- calcium–carbonic acid equilibrium;
- a non-corrosive pH; and
- sufficient alkalinity.

First of all, the water will need to be in calcium–carbonic acid equilibrium. This means that the Saturation Index (SI) should be close to 0. The preferred range for SI values is -0,2 < SI < +0,3. In this region of SI, the corrosion of cement pipe will be minimal, while at the same time the scaling effects will be low as well. Secondly, to keep the metal-dissolving properties of the water sufficiently low, the pH needs to be maintained in an optimal range. In hard water, it will not be possible to have a sufficiently high pH, because the water will then become supersaturated with respect to calcium carbonate and cause scaling. Allowing for a sufficient pH increase, together with the need to have water in calcium–carbonic acid equilibrium, necessitates the softening of water. On the other hand, it should be recognised that the efficacy of chlorine disinfection decreases as pH increases, and it is especially weak beyond about pH 7-8.

Water treatment practices in the Netherlands

Central softening has been applied in the Netherlands since the late 1970s. Almost all drinking-water in the Netherlands

Table 1. Water quality parameters of several raw and treated drinking-water supplies in the Netherlands (from Hofman *et al* 2006)

		Waternet (Leiduin)		Vitens (Rodenmors)		Brabant Water (Nuland)	
		Pellet softener NaOH		Nanofiltration		Pellet softener $Ca(OH)_2$	
Parameter	Unit	Raw	Treated	Raw	Treated	Raw	Treated
Ca	mg/l	76.8	43.1	100	53	94	56
Mg	mg/l	9.7	9.5	6.3	3.5	5.9	6.1
Total hardness	mmol/l	2.3	1.49	2.8	1.5	2.5	1.6
Na	mg/l	46.6	76.4	34	21	99	77
Cl	mg/l	87.2	93.5	9	11	153	108
HCO_3^-	mg/l	197.0	157.2	341	200	308	199
SO_4^{2-}	mg/l	52.5	52.1	10	5	21	13
pH		7.89	8.35	7.0	7.9	7.3	7.8
$TACC_{90}$[a]	ammol/l		0.32	0.95	0.5		0.97
SI		0.37	0.48	-0.2	+0.26	0.04	0.16
Cu solubility	mg/l	2.21	1.21	4.6	1.3	3.59	1.55
Pb solubility	µg/l	166	102	298	168	249	179

[a] $TACC_{90}$ is theoretical calcium carbonate scaling potential at 90 °C.

Table 2: Examples of the effect of marble filtration on water composition in the Netherlands (from Hofman *et al* 2006)

		Vitens (Eerbeek)		Brabant Water (Vessem)	
		Marble filtration		Marble filtration	
Parameter	Unit	Raw	Treated	Raw	Treated
Ca	mg/l	21	35	22	60
Mg	mg/l	1.8	1.8	5.8	5.8
Total hardness	mmol/l	0.6	0.9	0.79	1.74
SO_4^{2-}	mg/l	11	11	65	65
HCO_3^-	mg/l	35	95	40	140
pH		6.6	7.9	6.1	7.7
SI		-2.3	-0.3	-2.7	-0.1
Cu solubility (calculated)	mg/l	1.7	0.4	3.5	2.2
Pb solubility (calculated)	µg/l	324	141	395	169

is conditioned to prevent corrosion and excessive calcium carbonate scaling. In approximately 50 % of the production capacity of the country, softening is required to achieve the required water quality. All of the 101 million cubic metres of water supplied annually by Waternet, the municipal water supply company of Amsterdam, is softened, as well as large percentages of the water supplies in the other regions of the country. Naturally soft waters are often treated to add some calcium carbonate alkalinity by having these waters flow through 'marble filters'.

Softening is mainly done in *pellet softeners*. It is initiated by the addition of a base, calcium hydroxide or sodium hydroxide. Calcium carbonate will crystallise at the surface of sand grains present in a fluidised bed. The sand grains will grow until they are approximately 1 mm in size. These grains are extracted from the fluidized bed periodically, and new sand grains are added. Several design variations of the reactors exist, but all are based on the same approach with the same end goals.

Nanofiltration, a membrane filtration technique, is also applied in several utilities to produce low-hardness permeate, which is then aerated and mixed with untreated raw water. The pH is corrected for optimal water composition. Table 1 gives an overview of the values of hardness-related water quality parameters attained in these efforts to produce an optimum composition of water. The pellet softening process reduces the calcium carbonate content in the water, leaves the magnesium concentration unchanged and increases the sodium concentration (where sodium hydroxide is used as base). Furthermore, the scaling potential of the water is reduced significantly.

One of the main reasons for the introduction of central softening was the potential environmental and health effects of copper and lead releases. Significant reductions in copper and lead solubility were experienced by the processes of softening and nanofiltration, as can be seen in the values for the three regions shown in Table 1. Copper concentrations are below the standard in the Netherlands of 2 mg/ℓ at the tap. For lead, 90 % of the observations were below the standard of 10 µg/ℓ. However, conditioning alone has not been sufficient to comply with the lead standard, as 10 % of samples showed higher than the standard level of 10 µg/ℓ. Therefore, use of lead pipe materials in the distribution system has been banned by the authorities. The occasional high lead values found (up to 200 µg/ℓ are probably due to the presence of old lead pipes in house installations that are outside of the control of the water supply company.

Central softening at large scale is relatively inexpensive. On average, the costs are approximately €0,02 per cubic metre. When central softening is applied on a smaller scale, the cost can, however, increase to approximately €0,25 per cubic metre. An average family (annual use 100 m^3) will therefore pay approximately €2 to €25 extra for their drinking-water due to the introduction of softening. The overall cost savings, resulting from lower maintenance on warm water equipment, less detergent use, reduced staining of sanitary fittings and less energy demand, are estimated at about €20 to €300 per year. Thus, softening has been shown to be economical even in small utilities.

In the Netherlands, as in some other countries, the amount of naturally very soft groundwater is a significant portion of the total available drinking-water. In many cases, marble filtration is applied or milk of lime is added to reach the optimum water composition and only for conditioning of the drinking-water to reduce copper and lead solubility. Marble filtration adds only calcium in drinking-water, not magnesium.

Marble filtration at large scale is relatively inexpensive: it is estimated at €0,04 per cubic metre. At smaller scale, the cost increases to approximately €0,10 per cubic metre. Table 2 shows the effect of marble filtration on the water quality for two cases. From this table, it can be concluded that naturally very soft water has about the same level of calcium (after marble filtration) as water softened by central softening. The final water quality depends on the saturation level of the raw water.

This section shows that 20 years of experience with central softening and conditioning of drinking-water in the Netherlands have provided health and environmental benefits at affordable costs. Also, consumers benefit from having softened water at their tap because it reduces their overall costs and improves their comfort.

Bottled water and beverages

The Codex Alimentarius Commission provides an international consensus on the quality and composition of bottled/packaged waters of all types. There are differences between the United States and Europe on some labelling criteria that apply to packaged water. In the United States, the terms used on the labels of packaged waters to describe their characteristics, origin and treatment methods are *artesian water, groundwater, spring water, mineral water, drinking-water* and *purified water*, which includes *distilled water* and *deionized water*. More detailed descriptions of these types of bottled water are given elsewhere in the document.

In the European Union, there are three main types of bottled waters: natural mineral water, spring water and prepared water. Traditionally, and backed up by centuries of historical background, Europe has developed the market chiefly based upon natural mineral water. Natural mineral water means microbiologically wholesome water, originating in an underground water table or deposit. Natural mineral water can be distinguished from ordinary drinking-water by its nature, by certain effects and by its original state. Natural mineral waters often contain calcium and magnesium as well as other elements and ions. The composition of a natural mineral water is a characteristic that cannot be modified; hence, there are no two identical mineral waters. Moreover, no treatment can be applied to natural mineral water besides the removal of unstable elements such as iron and manganese, which can further precipitate in the bottle once the product is in the market.

Spring waters are waters intended for human consumption in their natural state and bottled at the source, and they must comply with certain regulatory provisions for human consumption.

Prepared waters are waters subjected to specific treatments to make them compliant with European Union drinking-water regulations, or just to modify their original composition, mostly for acceptability aspects.

Table 3 shows the mineral content in thermal and mineral waters from Austria, Belgium, Czech Republic, France, Germany, Hungary, Italy, Slovak Republic and Switzerland. It is important to point out that the highest mineral contents correspond to thermal (spa) or medicinal waters, which are not always bottled.

Unlike the mineral waters shown above, concentrations of calcium and magnesium in European bottled waters usually lie within the following ranges: Ca^{2+}, 1,5-600 mg/l; Mg^{2}+, 0,5-90 mg/l.

If and when supplementation is considered appropriate, the key considerations in supplementing minerals in bottled water are:

- potential health benefits;
- taste;
- product stability;
- quality of the salts;
- industrial procedures; and
- cost.

Consumer taste preferences play a leading role in determining choice of a mineral water. When the composition is changed, sensory perception also changes, which may lead to an immediate reaction of acceptance or rejection by the consumer.

When considering the addition of salts to a water intended for bottling, the concentrations that can be added without exceeding the solubility of the salts in the water at 20 °C must be calculated so as to prevent precipitation in the bottle. Solubility can be improved if water is carbonated, as lower pH usually enhances solubility. Chlorides and sulfates of both calcium and magnesium can be used to supplement bottled water with minerals; their carbonate salts have low solubility in water at 20 °C.

The procedure for adding minerals to water is quite simple. A mother solution can be prepared in water in a clean reservoir under constant stirring using the same water that will be in the product. The mother solution can also be pasteurised. A pump can be used to inject a portion of the mother solution either directly on-line or to a feed tank maintained under agitation to avoid precipitation of salts. Water with minerals added is then bottled using conventional bottling machines.

Table 3: Mineral content in thermal and mineral waters from various European countries (from Molas 2006).

	Mineral content (mg/l)		
	Maximum	Minimum	Mean
Ca^{2+}	28 826	1.8	549
Mg^{2+}	5 430	0.02	177
Na^{+}	122 500	0.8	5 684
K^{+}	5 493	0.2	106
HCO_3^{-}	9 319	5	975
Cl^{-}	198 000	0.14	9 211
SO_4^{2-}	52 890	0.9	1 180

To add 20 mg of calcium and 20 mg of magnesium to a specific water, the cost would rise by US$ 0,00222 per litre of product (US$ 2,2 per 1 000 litres) if prepared from calcium sulfate and magnesium chloride or by US$ 0,00198 per litre of product (US$ 1,98 per 1 000 litres) if prepared from calcium chloride and magnesium sulfate. These costs do not include the costs of electricity and mixers/pasteurisers.

Impacts on the home water treatment industry

The point-of-use (POU) or point-of-entry (POE) industry in the United States, Europe and other regions of the world produces and markets POE softeners and POU reverse osmosis and distiller units to consumers. These products reduce or totally remove calcium and magnesium present in the incoming waters. While the bottled water industry is not traditionally viewed as a part of POU/POE industry, it is part of the home water provision industry and is often similarly affected by the same rules or regulations.

The recommendations of a World Health Organization

expert meeting (WHO 2005) were reviewed by the United States and European home water industry with general concerns and questions due to the potential effects of these recommendations on this industry and its current operations in the marketplace. Each of the industry groups responded separately to the expert group's recommendations with its own questions and concerns.

One important point raised by the POU/POE industry was the difference between naturally soft or low total dissolved solids (TDS) waters and softened waters. Many of the epidemiological studies have compared health outcomes of consuming naturally soft versus hard waters. However, no known study has compared consumption of hard waters versus softened waters. There are significant composition differences between naturally soft waters and softened waters.

Another point pertained to possible benefits of the concurrent removal of some regulated contaminants by POU/POE treatment methods. Those contaminants are present only in trace levels in drinking-waters supplied by the utilities, as the utilities need to reduce them below Maximum Contaminant Levels or Maximum Allowable Limits stipulated by the different countries. However, the levels of these contaminants are usually not at zero, partly because such an extent of reduction in all the treated waters is usually too expensive. Use of certified devices in reducing these contaminants from only the water that is ingested (ie, drinking-water at the household tap) can possibly further reduce risks in some cases (principally for "non-threshold chemicals").

A POU reverse osmosis membrane system removes almost all the calcium and magnesium in source waters. If properly maintained, a POU reverse osmosis membrane system with an activated carbon filter can also yield drinking-water virtually free of many organic and inorganic chemicals of potential concern. In addition to removing calcium, magnesium and also fluoride, the membrane barrier can reduce many inorganic and particulate contaminants to near detection limits, such as arsenic, perchlorate, lead, copper, radium-226/228, selenium, chromium, turbidity, barium, cadmium, protozoan cysts, TDS, nitrate/nitrite, sodium and sulfate.

Similarly, a POU distiller can remove virtually all inorganic chemicals, including calcium and magnesium, along with volatile and non-volatile organics. Volatile organics can be reduced by these devices with a good venting system or by a carbon filter at the outlet of the product water.

A POE softener is generally considered as an aesthetic device removing hardness ions, but it can also remove other divalent cations from drinking-waters. While some softeners are also certified for their ability to remove barium and radium-226/228, they can also remove copper, cadmium, iron, manganese and other trace-level divalent cations.

The balancing of the potential beneficial aspects of these devices against the potential harm of reducing the calcium and/or magnesium and fluoride levels to below the recommended thresholds in drinking-waters is worthy of consideration. Acceptance of the 'hard water–cardiovascular disease benefits' hypothesis by health experts can lead to several different actions by segments of the water industry as a whole. Some will need to take strong actions, while others may have a set of options:

- Utilities with demineralised waters might be guided to add recommended levels of calcium and magnesium.
- Cities with naturally 'soft' water supplies may face a

dilemma in the form of a conflict between the possible need to add the recommended levels of calcium and/or magnesium and the economy of such action, even if they are not required to do so by their country's laws. The benefit/cost balance of such additions must take into consideration that only a small fraction of the water supply that is used as drinking-water requires this treatment, but all 100 % will end up being treated. Many of the cities may not undertake such a treatment simply for economic reasons. However, consumers may not be satisfied and may choose other means, such as fortified bottled water.
- The POU/POE industry would need to re-evaluate how to realign some of its products and activities.
- The bottled water industry would have the opportunity to augment its product lines with mineralized waters, as some are already doing.

Softener manufacturers and installers may choose to adopt a variety of approaches, even though none of them is desirable in their point of view, although some are already practised:
- a separate hard water line to the kitchen sink;
- a small bypass to achieve target hardness levels in the cold water;
- a new POU mineralization unit under the kitchen sink with a separate tap; and
- hot water softening only in lower-hardness areas.

The POU industry might also develop products capable of adding target amounts of calcium and/or magnesium to drinking-waters of all kinds. These products can be used in naturally 'soft' waters to add minerals just to the drinking-water used in households. The same devices can also be used as add-on devices after the POU reverse osmosis/distiller systems or as a unit under the sink to add minerals to softened water. These products may, however, present a challenge due to the intermittent nature of their use and the tendency of these chemical compounds to solidify and not yield consistent concentrations of minerals in the effluent waters.

The cost of such a product will also be dependent to some degree on the cost of the minerals used in the devices, the quantity of the mineral addition and the mechanism used to introduce minerals into the waters. The unit cost of the minerals is low and has been estimated at US$ 0,002 per gram of calcium and US$ 0,004 per gram of magnesium. Assuming addition of 30 mg of calcium and 10 mg of magnesium, then the cost per litre of water consumed will be only US$ 0,0001.

In spite of the technical feasibility, many in the home water treatment industry are anxiously monitoring the possible outcome of the discussions, because they still have several concerns, including the following:
- although not health experts, some are not convinced of the scientific validity of the conclusions;
- the issue of differences between 'soft' and softened water;
- the public's potential negative perceptions about all types of drinking-waters with lower hardness levels;
- stigma on the industry associated with removing elements beneficial to the consumers;
- potential uninformed regulatory response in different countries and regions; and
- concern about potential uneven treatment of or impact on some segments of the water industry compared with others.

Their concerns should be kept in mind in the public health guidance deliberations to make sure that the most beneficial and scientifically supportable conclusions are made.

Summary

Properly softened waters can have public health, economic, environmental and customer comfort benefits. Controlled central water softening as practised in the Netherlands and some other locations appears to reduce lead and copper corrosion, increase the pH and reduce the potential for scaling in cold and hot water plumbing components. Their practice leaves a certain amount of calcium in treated waters, but has no impact on magnesium concentrations. Additionally, marble filtration can be used to increase pH, alkalinity and calcium concentrations in naturally soft waters (but without an increase of magnesium concentrations).

Addition of calcium and magnesium to bottled water is a process that can be easily undertaken with only minor effects on costs. Taste preferences will determine consumer choices of products probably more than other factors, although a segment would be expected to opt for mineral fortified waters. Addition of calcium and magnesium after the POU/POE installations or to naturally soft waters in a home presents some technical difficulties that would need to be resolved. Some manufacturers have already developed some products to add calcium and magnesium to water. The differences between naturally 'soft' waters and softened waters have been pointed out. So, while health studies comparing soft and hard waters may be valid, they may not apply to softened waters because of their different compositions (ie, higher sodium and TDS and probably lower corrosivity). There is a need to balance the potential beneficial aspects of those POU and POE devices that concurrently remove trace contaminants against the potential negative effects of reducing the calcium and/or magnesium and fluoride levels to below the recommended levels in drinking-waters.

References

A list of references for this article is available from the editor at chemtech@crown.co.za. ▮

This article which is Chapter 12 (entitled 'Water production, technical issues and economics' by P Regunathan) which appears on pp 154-165 in the document "Calcium and Magnesium in Drinking-water: Public health significance", edited by Cotruvo J, and Bartram J, and published by the World Health Organization, dated 2009, ISBN 978 92 4 156355 0 (NLM classification: QV 276), is reproduced here with kind permission of the publisher, World Health Organization, Geneva.

Engineered measuring solutions

Endress+Hauser (E+H) has increased its install base in water and wastewater plants across the country over the past three to four years, which has shown a positive growth in the industry, according to a recent report, and this was mainly achieved by increasing the confidence of plant builders and end users.

E+H offers individually engineered solutions to ensure integrity of sample collection, continuous measurement, as well as recording of inflow and outflow quality parameters of water and wastewater plants. This goes a long way in assisting plant managers and process controllers to ensure compliance with Blue and Green Drop regulations as well as their water use licenses, said Hennie Pretorius, Industry manager: Water and wastewater.

Consultants from the company work with the end-user to ensure that the correct selection of analytical instruments is made. Afterwards a feasibility study is done to design the most cost-effective solution that will ensure best performance and reliability for the customer. This includes basic engineering and drawings for approval.

A final detailed quotation is then supplied to the customer; delivery will include the turnkey constructed panel and complete project documentation.

E+H also commissions the solution using local trained technicians. There is an Added Value Services available which includes after sales service as required by the customer. This includes calibration, verification and/or repair of installed solutions. In order to ensure the lowest lifetime cost and longest availability of the measurement solution, Endress+Hauser offers service contracts to customers in order to ensure the correct preventative and periodic maintenance is carried out.

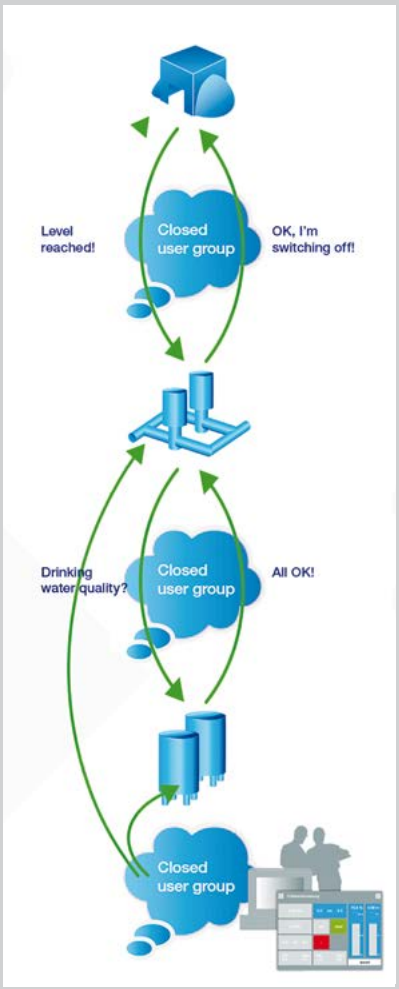
To guarantee the highest availability and traceability of the instrumentation solution on customers' plants, E+H has conceived W@M. This web-based concept is an open information system which offers data flow and archived data retrieval of any instrument's lifecycle from engineering, procurement to commissioning and then through to maintenance and service of the measurement point.

For more information contact Hennie Pretorius on tel: +27 11 262 8000 or email *hennie.pretorius*@za.*endress*.com.

OPC-UA enabled smart devices drive intelligent water management

by Silvio Merz, Divisional Manager, Electrical/Process Technology, Joint Water and Wastewater Authority, Vogtland (ZWAV)

Decentralized, independently acting embedded controllers can form an intelligent network for the control of potable water and wastewater plants. OPC-UA is a powerful technology to establish secure and standardized M2M interaction at these plants.



The movement toward the 4th industrial revolution, or Industry 4.0, is gaining momentum in a wide range of industries, and water treatment can now be counted as an application example. Some of the requirements of the Industry 4.0 initiative, such as platform and vendor-independent communication, data security, standardization, decentralized intelligence and engineering for M2M (machine-to-machine) or IoT (Internet of Things) applications, are already available in the OPC Unified Architecture (UA).

OPC-UA is used for M2M communication between plants for the intelligent networking of decentralized, independently acting, very small embedded controllers. For example, an application with the Joint Water and Wastewater Authority, Vogtland (ZWAV), has around 300 potable water plants and 300 wastewater plants (pumping plants, waterworks, elevated reservoirs, etc.) distributed over 1,400 km² and covering 40 cities with 240 000 people.

Real objects (eg, pumps) were modelled in the TwinCAT IEC 61131-3 PLC software from Beckhoff Automation as complex objects with interactive possibilities. Since the OPC-UA server was integrated in the controller, these objects are automatically available to the outside world as complex data structures for semantic interoperability. The result was decentralized intelligence that makes decisions independently and can transmit information to neighbouring systems. In addition, it can query equipment status and values for its own process in order to ensure trouble-free process cycles.

With the standardized PLCopen function blocks, the devices independently initiate communication from the PLC to other process devices such as OPC-UA clients, while at the same time being able to respond to their requests or to requests from higher-level systems (SCADA, MES, ERP) as OPC-UA servers.

The devices are connected by wireless router. A physical interruption of the connection does not lead to a loss of information, since information is automatically buffered in the OPC-UA server for a time and can be retrieved as soon as the connection has been restored – a very important property in which a great deal of proprietary engineering effort was invested beforehand. The authentication, signing, and encryption safety mechanisms integrated in OPC-UA were used in addition to a closed mobile radio group to ensure the integrity of this partly-sensitive data.

The vendor-independent interoperability standard OPC-UA opens up the possibility for end users to subordinate the selection of a target platform for the required technology in order to avoid using proprietary products or devices that don't meet the needs of the application.

For more information go to http://www.opc-connect.com/2014/12/opc-ua-enabled-smart-devices-drive-intelligent-water-management/

Dutch technology reclaims humic acid at drinking water plants

International engineering and project management consultancy Royal HaskoningDHV has joined forces with Dutch water supply company, Vitens, to help other drinking water companies around the world recover humic acid, an organic fertiliser.

Ms Lieve Declercq (left), chair of the Vitens Executive Board and Ms Esther Bosman, Royal HaskoningDHV's Director: Water Technology in the Netherlands, signed the partnership agreement on 8 January 2015.

Currently humic acid is often discharged as a waste product during the drinking water blanching process. Thanks to this innovation from Vitens it can now be reclaimed sustainably in its pure form, providing an organic soil improver.

Royal HaskoningDHV will be marketing this unique Dutch technology, which won the international Aquatech Innovation Award 2013, on a global scale. Ms Lieve Declercq, chair of the Vitens Executive Board and Ms Esther Bosman, Royal HaskoningDHV's Director: Water Technology in the Netherlands, signed a partnership agreement to this effect early in January 2015.

The drinking water production company, Spannenburg, provided the platform for Vitens to apply its innovative combination of unique technologies ie, ion exchange and various existing membrane technologies, to blanch drinking water. This process creates a residual stream of water and salt as well as humic acid, a highly valuable organic substance from peaty soil which gives water a yellowish hue. Water and salt are completely reused during the production process while the humic acid, once regarded as a waste product, can now be utilised as a soil improver in the agricultural sector.

Ms Lieve Declercq said that, thanks to the sustainable usage of humic acid, the use of artificial fertiliser and phosphates in agriculture and horticulture can be reduced. This will improve the ground water used to produce drinking water, and the growth of crops, as well as being better for the environment.

Humic acid occurs in coal and lignite as well peat, and Europe currently usually uses a chemical process on lignite imported from the US and Australia to extract the acid. This process has an adverse effect on the environment, and is also expensive because of transport costs. The new technology will help drinking water companies recover humic acid from their own water, while also reclaiming a sustainable and local product, easily and without any chemical effect on the environment.

Humic acid (right).

For more information contact Suzette Schreuder, Press Officer Royal HaskoningDHV, on tel: +31 88 3482026 / +31 6 29098238, or go to royalhaskoningdhv.com.

Branson Chemicals forms alliance with Hydrance

An alliance between Hydrance, a specialist water treatment company, and chemical manufacturer, Branson Chemicals, has been established with the objective of creating tailored solutions to reduce costs through water, fuel and electricity savings related to water usage in the processing, food and beverage manufacturing and general industries.

According to Hydrance, water treatment is a major concern in South Africa. Standards in this field are inconsistent and there is a huge need for the transfer of skills and expertise and a commitment to improving service.

Hydrance has extensive experience in the supply of products and control systems for treating raw/feed water/make-up water, boiler water, waste water, cooling water (both open and closed circuits) and specialty dispersants and on-line/off-line CIP products. Industries serviced cover a vast range from mining, tobacco, air-conditioning, pharmaceutical, mineral processing, paper, and the full gambit of food and beverage-related industries, to name but a few.

Branson Chemicals is considered an established developer and manufacturer of top-class chemicals and cleaning programs for the food and beverage, dairy and dairy farm, institutional and hospitality industries, servicing many high-end producers. It will be responsible for the blending and manufacturing of the Hydrance range of products as well as the warehousing and distribution. The company's fully-equipped laboratory will enable new developments.

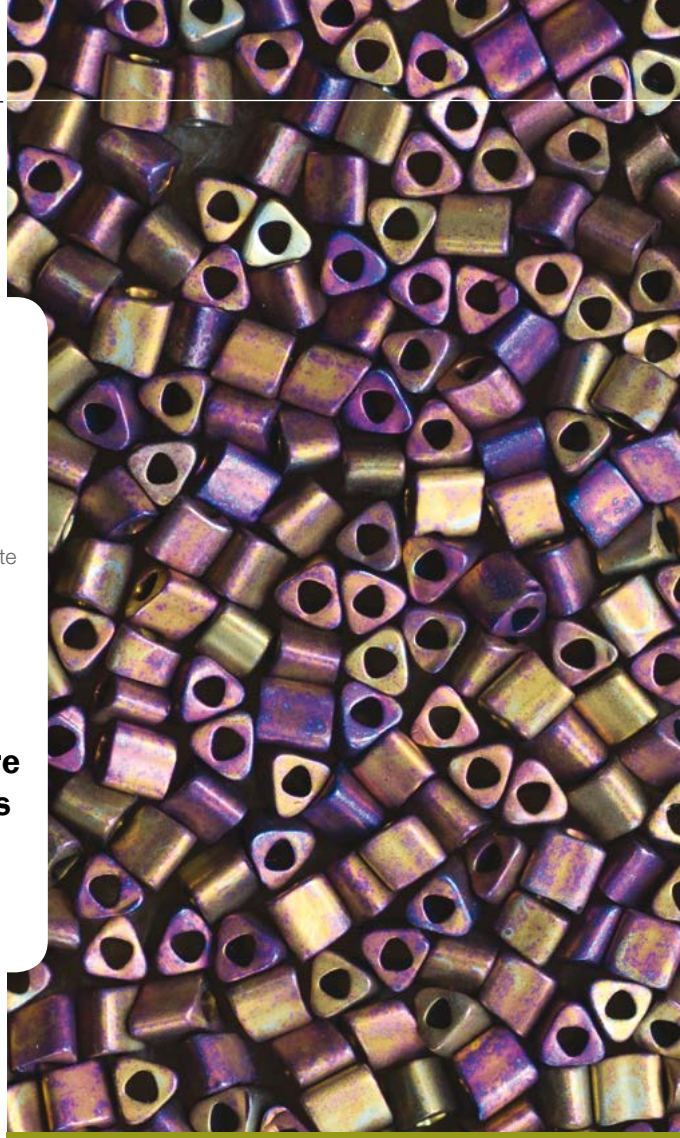
Gerald Brown of Branson commented that the pooling of the expertise of two highly experienced companies and the exchange of knowledge will strengthen capabilities for solving problems for clients. Branson will further gain through Hydrance's partnership with Watericon, a company specialising in all aspects of water treatment-related equipment, including dosing and control, filtration equipment, and full-package treatment plants.

For more information contact Gerald Brown on tel: +27 11 708 6190/082 453 1979, email gerald.brown@mweb.co.za or go to www.bransonchemicals.co.za

Consolidating the alliance agreement (left to right): Gary Moses and Stewart Wasserfal of Hydrance with Eric Brown and Gerald Brown of Branson Chemicals.

Aspects of coloured precious metal intermetallic compounds

by Elma van der Lingen, Department of Engineering and Technology Management, Graduate School of Technology Management, University of Pretoria, South Africa



This article provides a review on coloured gold-, platinum- and palladium intermetallic compounds which are used in jewellery. Some of these compounds are used as barrier coatings on turbine blades for jet engines, and research is ongoing into potential uses as, for example, catalysts, sensors and capacitors.

Intermetallic compounds are compounds consisting of two or more metals in which the number of the atoms of the different metals are at, or near, simple ratio eg, $PtAl_2$. In most cases, intermetallic compounds solidify at a fixed temperature and composition, and have thus a narrow domain of existence. The crystal structure of an intermetallic compound is normally different from those of the individual metals from which they are composed. Fundamental properties of intermetallic compounds are usually high brittleness with associated low toughness, high hardness, good wear resistance, and good corrosion resistance.

Well known coloured intermetallic compounds are: golden-yellow Cu_5Sn; blue NiAl; yellow CoAl; yellow CoGa; blue $AuGa_2$; blue $AuIn_2$; red PdIn; purple $AuAl_2$; blue-grey $NiSi_2$; and dark blue $CoSi_2$.

Colour formation in intermetallic compounds

The formation of colour in metals is based on *metallic bonding* between different metals. The strong metallic bonds consist of positively charged metal atoms in fixed positions, surrounded by delocalized electrons. Colour results from the electrons in the lower energy levels being excited to higher levels. However, colour in metals can also be formed by intermetallic compounds where strong *covalent bonds* replace the metallic bonds.

Some models have been developed indicating the requirements to obtain coloured intermetallic compounds.

Pettifor's structure maps

According to Steinemann [33-35] coloured intermetallic compounds possess a pseudo bandgap, which is an energy range with only a few available quantum states, represented by a valley in the density of states curve. These intense localised bands are found approximately 1,5 to 3 eV below the Fermi level. The following three requirements have been identified by Steinemann in order to obtain coloured intermetallic compounds:

1. the crystal structure of the compound is of high symmetry that has strong features of the band structure, ie, sharp peaks and valleys in the density of states,
2. hybrid *d-sp* bonds for strong covalent hybridization, and
3. an element of late transition or precious metal shifts the Fermi energy appropriately close to the pseudogap.

Steinemann *et al* [35] described how it is possible to establish a relationship between colour and crystal structure in intermetallic compounds by making use of Pettifor's structure maps [23-25]. Pettifor's structure maps plot crystal structures of binary compounds A*x*B*y* of any stoichiometry to a two-dimensional map of some 'coordinates' for elements A and B.

Figure 1 shows structure maps for compounds of stoichiometry AB and AB_2, which could be candidates for coloured intermetallic compounds. The regions marked with dashed lines reveal potential candidates for binary coloured intermetallic compounds. Interestingly, only two crystal structures (Figure 2) dominate these regions, namely

Purple Gold™ Patent Number 82596 Aspial Corporation www.purplegold.com. Jewellery available from Lee Hwa Jewellery and Goldheart, both in Singapore

bcc-based B2 (Pearson symbol cP2) or CsCl-structure for composition AB, and fcc-based C1 (Pearson symbol cF12) or CaF_2-structure for composition AB_2. This again confirms the three requirements stipulated above that coloured intermetallic compounds need to have a crystal structure of highest symmetry ensuring a sufficiently simple electronic structure for distinct absorption bands of high intensity. According to this approach, only the following potential coloured binary gold, palladium and platinum intermetallic compounds can result:

CsCl-structure: PdIn, PdBe, PdMg

CaF_2-structure: $PdAl_2$, $PtSn_2$, $PtGa_2$, $PtAl_2$, $PtIn_2$, $AuGa_2$, $AuAl_2$, $AuIn_2$.

Element B is of Groups 13 and 14 in the Periodic Table with the exception of PdMg. Further, PtAl (tetragonal structure) also exhibits colour according to Figure 1 [33].

Hume-Rothery electron concentration

An electron-to-atom ratio is stipulated for the Hume-Rothery phases, where the electron concentration (e/a) is defined as the sum of the valence electrons per atom of the compound:

$$e/a = 1/100 - \Sigma a_i v_i$$

where a_i is the concentration in at.%, and
v_i is the number of valence electrons of the element *i*.

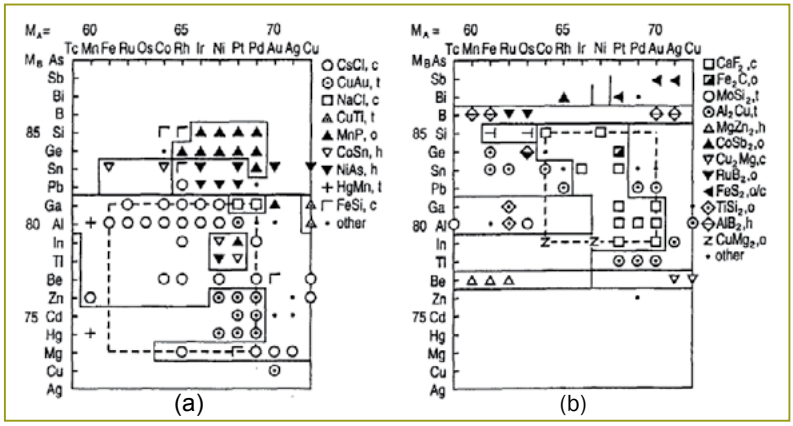


Figure 1: Regions of high-symmetry structure in the AB (a) and AB_2 (b) Pettifor maps. Mendeleev numbers and prototypes (c is cubic, t is tetragonal, o is orthorhombic, h is hexagonal) are shown. Limits for expected coloured intermetallic compounds are shown by the dashed line [33].

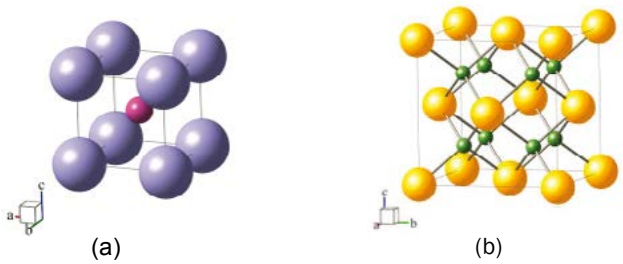


Figure 2: Crystal structures: (a) CsCl-structure, and (b) CaF_2-structure.

Table I. Number of valence electrons for specific elements and the electron-to-atom ratio of platinum and palladium compounds.

Element, i	v
Pd, Pt	0
Al, Ga, In	3
Compound	e/a
PdIn	1.5
$PtAl_2$, $PtGa_2$, $PtIn_2$	2

The number of valence electrons for platinum and palladium is 0 according to Ekman's rule and valence electron numbers 1, 2 and 3 respectively for Groups 1, 2, and 13 (Al, Ga, In) [35]. Table I gives the specific values for the elements and compounds.

Accordingly, the CsCl-structure is stable when e/a is approximately 1,1 to 1,7, for example PdIn. Furthermore, the CaF_2 structure is stable if e/a is approximately 2,0 to 2,67 as in the case of $PtAl_2$, $PtGa_2$, $PtIn_2$.

The valence electron concentration

An extension of the Hume-Rothery electron concentration model is the upper limit on the valence electron concentration [32], which apply to the Zintl phases, for more complex ternary and quaternary compounds. The high number of valence electrons of the precious metals determines the appropriate location of the Fermi level inside the pseudogap, providing absorption bands for creating colour.

Drews *et al* [7] have published interesting results on the optical properties and structures of a number of ternary and quaternary compounds containing platinum or palladium. These compounds are of type Li_xMg_yPS, where P is palladium or platinum and S is tin (Sn) or antimony (Sb). Sometimes x=0, in which case one has a ternary compound. The reflection spectra of all these compounds are similar, indicating colours ranging from yellow to purple,

Applications

Jewellery

Gold intermetallic compounds

The three main colours of caratage gold alloys, namely yellow, red and white, are well known. The less known colours of gold include blue, purple and black. Coloured gold alloys can be produced by three metallurgical routes:

i. alloying with elements such as copper which results in a more reddish colour, or silver giving a more white-greenish colour,
ii. coloured oxide layer formation by alloying with an oxidising element, such as iron, and exposing the alloy to an oxidising heat treatment, and
iii. intermetallic compounds.

The most popular coloured intermetallic gold compound is purple $AuAl_2$, which is formed at a composition of 79 wt%Au and 21 wt%Al. This material can be hallmarked as 18 carat gold, which requires at least 75 wt% gold. Due to the brittleness of intermetallic compounds, jewellers have used the colourful compound as inlays, gemstones, and in bi-metal castings (see Figure 3). The melting point of $AuAl_2$ is 1060 °C.

Figure 3: Bi-metal castings of micro-alloyed $AuGa_2$ blue gold (left) and micro-alloyed $AuAl_2$ purple gold (right) with 95 wt% palladium [9].

Two other intermetallic compounds that are known to produce colours in gold alloys, as also revealed by Pettifor's structure maps, are $AuIn_2$ and $AuGa_2$. The gold-indium intermetallic compound $AuIn_2$ has a clear blue colour and forms at 46 wt%Au, and $AuGa_2$ at 58,5 wt%Au has a slight bluish hue. The latter compound can be hallmarked as 14 carat gold. The reflectivity falls in the middle of the visible spectrum and rises again towards the violet end, giving distinctive colours in each case.

The inherent brittleness of the coloured gold intermetallic compounds can be improved by micro-alloying additions (<2 wt%), such as additional aluminium, palladium, copper or silver [45].

Platinum intermetallic compounds

Unlike gold, platinum and palladium have a strong white lustre and these metals act as bleaching agents, making it very difficult to colour by conventional alloying as in the case of gold. Both coloured gold and platinum intermetallic compounds have the CaF_2-structure with alloying elements X = Al, In and Ga. Klotz [17] found that interesting colour effects can be achieved by an exchange of gold with platinum while keeping a constant atom ratio of $(Au,Pt)X_2$. For blue gold, increasing platinum content changes the blue $AuIn_2$ colour towards apricot $PtIn_2$.

Mintek in South Africa has found that two distinct colours (orange and pink) result by adding different amounts of copper to the $PtAl_2$ compound [13, 12]. The effect of an increase in the copper content results in a change of the colour from the characteristic brass-yellow of $PtAl_2$ through orange to pink. A sample containing 25 % copper has a minimum in the green region of the spectrum (about 500 nm), and the higher reflectivities at the blue and particularly red ends of the spectrum combine to give the characteristic pink colour.

Hurly and Wedepohl [12] found from X-ray diffraction studies of $PtAl_2$ with various copper additions, that the basic fluorite structure (CaF_2) of $PtAl_2$ was found for all the samples tested (up to 25 wt% Cu). The lattice parameter increased with copper content as the colour changed. For $PtAl_2$ with 25wt% copper, the lattice parameter is about 0.8% greater than that of pure $PtAl_2$.

As with purple gold, coloured platinum intermetallic compounds lend themselves to be treated like gemstones and could be facetted by using standard gem cutting equipment and techniques. Figure 4 shows a jewellery item with facetted pink coloured platinum compounds, also known as Platigem®.

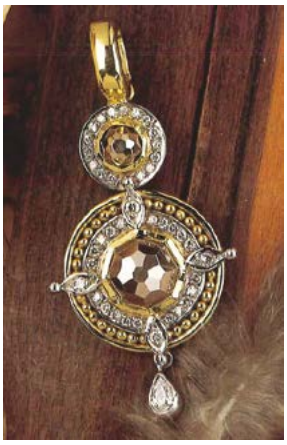


Figure 4: A photograph of Platigems (facetted pink $PtAl_2$+Cu) in a jewellery piece (Mintek brochure).

Palladium intermetallic compounds

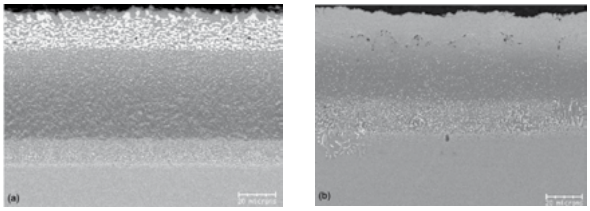
According to the binary In-Pd phase diagram [19], five intermetallic compounds exist, namely In_3Pd, In_3Pd_2, InPd, $InPd_2$ and $InPd_3$. The In-Pd intermetallic compound with composition 50 at.% (48 wt%) palladium and 50 at.% (52 wt%) indium produces a purplish-pink colour. More than 95 % of incident light is reflected by gold in the infrared and longer wavelength range of visible light. At energies higher than 1,9 eV, the reflectivity falls off rapidly with diminishing wavelength. The yellow colour of gold results from its strong absorption of light above energies of about 2,3 eV. The metal reveals the complementary colour of the absorbed frequencies. With PdIn, the absorption occurs at lower energies, and the colour of the compound then appears as purplish pink.

Coatings

$PtAl_2$

Platinum modified aluminide coatings have been used for several decades as diffusion barrier coatings in aircraft and industrial gas turbines. These coatings provide both improved high temperature oxidation and hot corrosion resistance. Hot corrosion occurs in gas turbines due to the presence of contaminants, such as NaCl, Na_2SO_4 and V_2O_5 in the gases, which form molten deposits damaging the turbine blades [27].

The platinum modified nickel aluminide coatings can exist in two forms depending on how the coatings were formed. Figure 5 [26] shows the two forms, where (a) indicates the two phase $PtAl_2$ + (Ni-Pt-Al), and (b) a single phase (Ni-Pt-Al) coating. Platinum is initially deposited onto the nickel-based superalloy via electroplating, whereafter it is heat treated under a protective atmosphere. The heat treatment conditions influence the formation of a single- or two phase microstructure. Subsequent aluminising results in the platinum modified NiAl coating.



(a) (b)

Figure 5: Microstructures of Pt modified aluminide coatings on nickel-based superalloy where (a) two phase $PtAl_2$ + (Ni-Pt-Al), and (b) single phase (Ni-Pt-Al) coating [26].

The advantages that platinum offers in barrier diffusion coatings can be summarised as follows [27]:

Platinum:

- improves the high temperature oxidation resistance by delaying transformation of β-NiAl into γ'-Ni_3Al in aluminides. The life of the diffusion coating is depleted when all β-NiAl has transformed into γ'-Ni_3Al.
- acts as a catalyst promoting the reaction between aluminium and oxygen.
- improves the adhesion between the coating and substrate.
- suppresses deleterious spinal formation.
- retards the diffusion of certain refractory elements to the coating-Al_2O_3 interface providing improved isothermal oxidation resistance.

$AuAl_2$, $AuIn_2$ and $AuGa_2$

Supansomboon *et al* [38] prepared $AuAl_2$ coatings by vacuum deposition onto heated substrates. The coloured coatings varied in colour from dark-silver to light purple, whereas the transmission colours of these coatings varied in colour from light to dark greenish-brown. The colour observed by the human eye was dependent on the texture of the substrate, the crystallized microstructure and the coating thickness affected the transmission colours. The potential use of $AuAl_2$ as a spectrally selective coating on architectural glass was explored, but found to be inferior to that of gold in terms of selective attenuation of the infrared radiation. Furrer *et al* [10] found that the light purple colour for $AuAl_2$ coatings is due to point defects in the film resulting from the deposition method. The intense purple colour can be obtained by heat treating the coating at 350˚C.

Studies by Keast *et al* [16] indicated that $PtAl_2$ and $AuAl_2$ coatings have dielectric functions suitable for sustaining localized plasmon resonances as verified with EELS and reflectivity measurements. The results suggested that the $PtAl_2$ compound is a better candidate for the development of strong localised surface plasmon resonances compared to $AuAl_2$.

In a project funded by the European commission on surface engineering of the colour effect for gold alloys, Klotz [17] found that the electroplating/annealing process was very successful for producing $AuIn_2$ layers, whereas surface cladding worked well for both $AuGa_2$ and $AuIn_2$, and liquid metal dip-coating for $AuGa_2$ (see Figure 6).

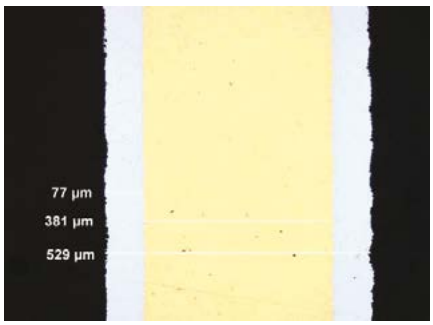


Figure 6: Gold dip-coated with blue $AuGa_2$ [17].

PdIn

Wang *et al* [44] developed a thermally stable, low-resistance PdIn ohmic contact to *n*-GaAs. A ~5nm layer of $In_{0,4}Ga_{0,6}As$ covered the interface between the single phase intermetallic layer PdIn layer and the GaAs substrate. Specific contact resistivities and contact resistances of approximately 1×10^{-6} Ωcm² and 0,14 Ωmm respectively, were obtained.

Catalysis, sensors and capacitors

Mesoporous, also known as nanoporous, gold and platinum can be prepared by dealloying $AuAl_2$ and $PtAl_2$ in a manner analogous to that used in the preparation of Raney nickel catalysts [40]. The aluminium is then dissolved from the $AuAl_2$ precursor by means of NaOH to produce a highly porous gold structure (see Figure 7). Van der Lingen *et al* [41] produced heterogeneous catalysts by incorporating transition metal oxide(s) with the porous gold. Furthermore, promoter elements could also be melted with $AuAl_2$ to improve catalytic activity. These catalysts were tested for CO oxidation activity.

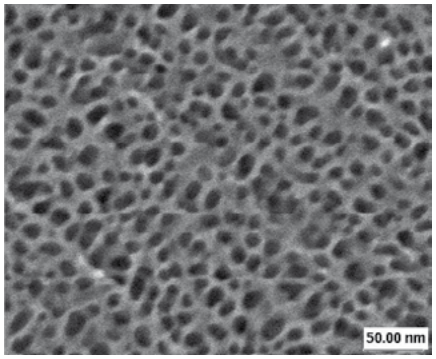


Figure 7: HRSEM image of dealloyed $AuAl_2$ surface [41].

Pattrick *et al* [22] studied mesoporous gold catalysts prepared via dealloying of $AuAl_2$ for the selective catalytic reduction of NOx by propene under lean-burn conditions for potential autocatalyst applications. It was found that relatively low additions of platinum group metals (1 at.%) caused shifts to lower temperature regions of activity, with the largest shift obtained for rhodium most likely due to a strong synergistic interaction between rhodium and gold.

Cortie and Van der Lingen [3] investigated the potential of mesoporous gold for ultra-capacitors, and preliminary work revealed a perceived capacitance of about 15 to 28 mF as demonstrated for a sample containing 2 g of gold when connected as a cathode. No storage of energy was observed when the gold was connected as the anode.

A significant number of papers have been published recently on nanoporous gold, but the precursor material is 30 wt% gold and 70 wt% silver. A similar dealloyed structure is obtained for the gold-silver system as for the $AuAl_2$ system. Potential applications for the nanoporous gold includes: catalysis for oxygen-assisted coupling reactions [36]; CO oxidation [29]; electro-catalysis/fuel cells [15]; electrochemical immunoassays and sensors [37, 29, 46, 18].

Conclusions

Precious metal intermetallic compounds are used in various applications as shown in this article. Although intermetallic compounds are inherently brittle, which could restrict their use in applications, this limitation is overcome by using the compounds in powder form, coatings and inlays with bi-metallic castings.

References

References for this article are available from the editor at chemtech@crown.co.za.

Acknowledgements

1. The Southern African Institute of Mining and Metallurgy, 2014. Advanced Metals Initiative, Department of Science and Technology.
2. This paper was originally presented at the Precious Metals 2013 conference held in Cape Town, South Africa.
3. The Precious Metals Development Network (PMDN) is also thanked. ∎

Unitrans wins mining industry accolades

At the recent Logistics Achiever Awards ceremony held at Montecasino in Johannesburg, Unitrans received two awards in recognition of supply chain excellence for work in the mining industry. The company received the LAA Silver Award 2014 along with its customers NPC and Idwala Industrial for "Outstanding achievement in logistics in optimising efficiencies of inbound and outbound transport through integration of operations".

As Unitrans has demonstrated in many engagements in the sector over decades, one area in which costs can be reduced, and efficiencies increased, is in the mining supply chain. While parts of the supply chains of many mines are commonly outsourced, such as bulk road transport or warehousing, these outsourcing arrangements are commonly conducted at arm's length, via service level agreements. But even greater efficiencies and cost savings may be available in a more collaborative approach between supply chain service providers and mining companies.

This is evident in the client work for which Unitrans won their industry accolade. In Simuma on the KwaZulu-Natal South Coast, NPC and Idwala operate out of the same mine, extracting different deposits within the same quarry for their respective requirements.

NPC is one of the original four cement manufacturers in South Africa with a history spanning decades. They now form part of Intercement, one of the largest international cement players with a presence in nine countries with 36 plants. Idwala mines a scarce white calcitic and dolomitic limestone at Simuma.

Unitrans has been a distribution partner to NPC for over 25 years. When NPC commissioned their new cement mill in 2008 at Simuma, Unitrans secured the distribution of their bulk and bagged product, rapidly progressing to operate the cement company's load and haul work within the quarry that supply blasted rock from the rock floor to the crusher. The work by the supply chain specialist reduced the miner's operational costs and also the need to replace expensive earth moving equipment.

When Intercement took over NPC, serious cost cutting exercises were undertaken. Says Ray Singh, head of Customer Solution Development at Unitrans: "Negotiations began on sharing staff and infrastructure which was essential to the success of the whole project. The companies embarked on a new structure for the operations, which brought about immediate savings.

Unitrans was able to reduce the overall fleet, yet increase efficiencies and availability. Spare capacity is now shared between the two companies, which reduced the cost of ownership of spare capacity. NPC immediately saved 15% in costs, and Idwala's savings were based on reductions in capital expenditure."

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SAIChE IChemE

SAIChE IChemE would like to wish their members a great new year. The Annual SAIChE-IChemE (Dual Membership) invoices will be emailed to all our active members during January/early February 2015.

Please use your membership number as beneficiary reference and email the SA office your proof of payment. Nominations are now open for the SAIChE IChemE Innovation/Gold Medal Awards and will close on 17 April 2015. More information on www.saiche.co.za.

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SAIChE IChemE Western Cape: (Still in process of being re-activated)

Hamied Mazema (Chair) and Adrian Rudolph (Secretary)

Global action needed on water usage in food production

The Institution of Chemical Engineers in the UK (IChemE) is urging coordinated action to reduce the amount of hidden water used in food and drink production – estimated at up to 1,8 million litres per person every year, approximately equivalent to an Olympic size swimming pool. (A 50 m x 25 m swimming pool will hold between 1,25 million litres of water (1 m depth) to 2,5 million litres of water (2 m depth).

Each person consumes between 2 000-5 000 litres of water embedded in their food, every day – or between 730 000-1 825 000 million litres annually.

Currently, around 90 % of all freshwater is used by agriculture (70 %) and industry (20 %), leaving just 10 % for domestic use. However, as the population grows and more people move to a western-style diet, water extraction is estimated to increase by over 50 % to 6 900 billion m^3 per year. By 2050, the overall impact will see around two thirds of the world's population living in 'water scare' areas, compared to just seven percent at present.[5]

Andy Furlong, IChemE director of policy, said: "Chemical engineers provide many of the high level skills needed to provide the water, food, medicines and energy to sustain our ever-growing population. In recent years and decades, we have seen how difficult it has been to agree and set targets to manage issues like climate change. Population growth will throw up similar challenges and will have a direct impact on two of the building blocks for life – food and water.

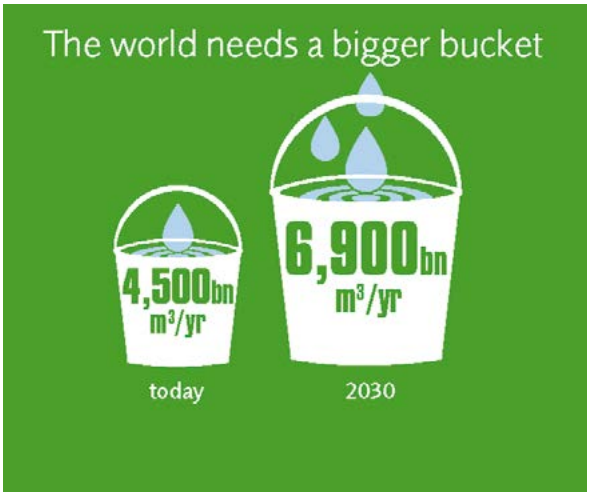
"Estimates suggest that we will need to produce 60 % more food by 2050. Agriculture will need around 19 % more water to produce that extra food. It is clear that current production methods are unsustainable and there are genuine risks of food shortages, rising food prices, droughts and social unrest for future generations unless we make more efficient use of water."

Furlong continued: "There are solutions, but these will require political will, major investment and lifestyle changes. Chemical engineers are recommending that a global target is set to reduce the amount of water used in food production worldwide by 20 %. In addition, a combination of regulations and incentives should be introduced to require industries to monitor their water usage, as well as be rewarded for using alternative and sustainable water supplies.

"Revised planning frameworks and investment will be needed for the construction of new capacity, infrastructure and appropriate technologies to improve efficiency of water management in food and drink production. Education also has a role to ensure that consumers understand better how their food is produced to enable them to make informed choices.

"None of this will be cheap or easy, but like the mitigation of climate change, it will be necessary to guarantee our quality of life," concluded Furlong.

For further information, please contact Tony Osborne, communications officer, IChemE on tel: +44 (0) 7825 266 811 or email: tosborne@icheme.org.



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	3				6		4	7
9				8				6
					7			1
				9			1	
	8				3	2		
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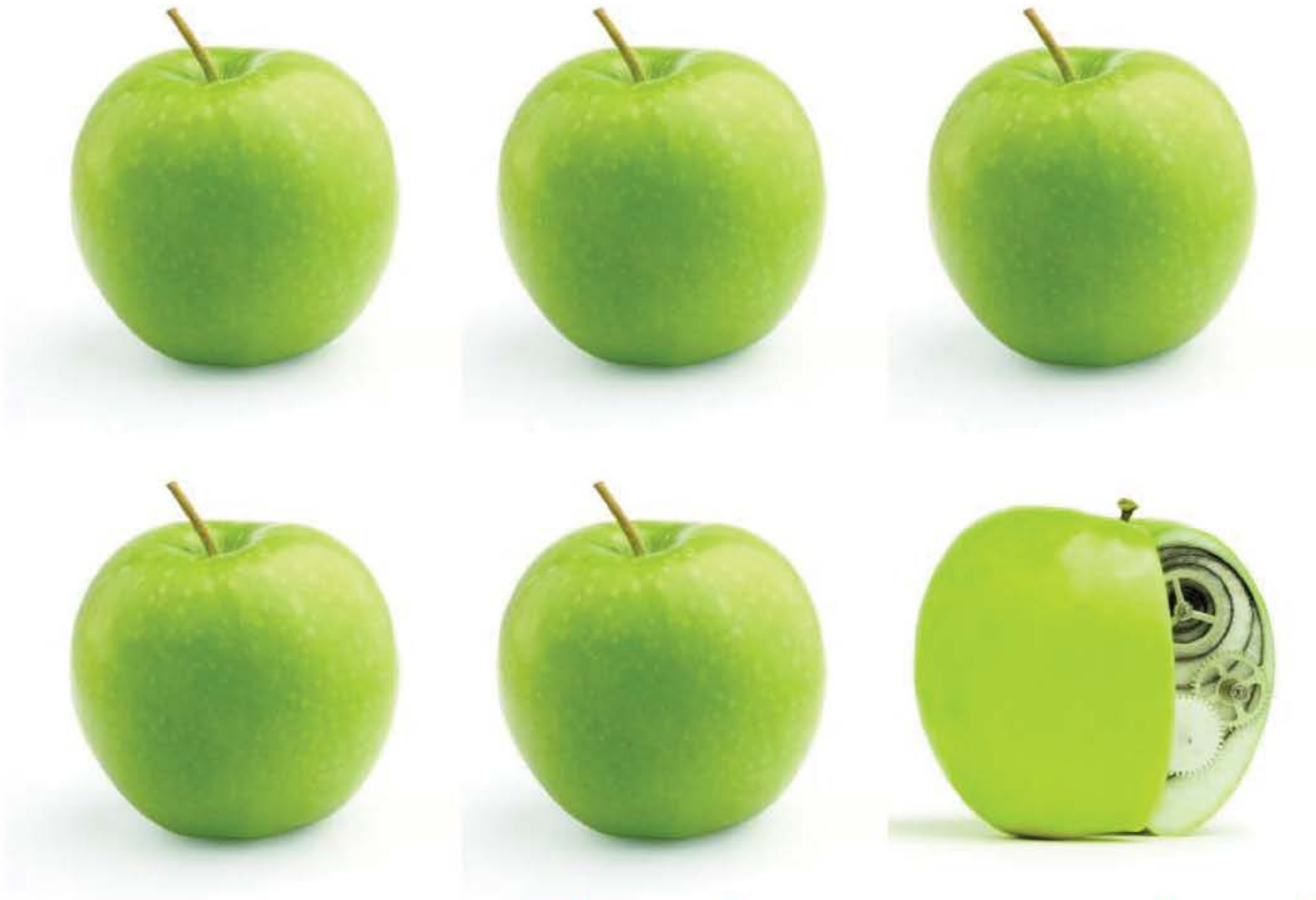
5		9					8	
				5				4

Solution for SUDOKU 100

5	8	3	1	4	6	7	2	9
2	4	1	9	5	7	8	6	3
9	7	6	8	2	3	1	4	5
8	1	7	3	9	2	6	5	4
3	5	2	6	7	4	9	1	8
6	9	4	5	1	8	3	7	2
4	2	9	7	8	1	5	3	6
7	6	8	4	3	5	2	9	1
1	3	5	2	6	9	4	8	7

Comparing apples with apples?



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