top engineer

The Elomatic Magazine 1 · 2014

Thinking and awareness

The mystery of the human mind has fascinated mankind over the centuries. Ancient philosophers and current day cognitive scientists have tried to understand what makes the human brain the ultimate tool and such a unique instrument.

The ability to learn new things is a lifelong process and different individuals absorb knowledge differently depending on their specific backgrounds. Experience and age are commonly perceived to be the main determinants when analysing the development of a person's cognitive ability. One should not, however, underestimate the importance of motivation, emotion and a healthy life style in successful learning processes.

According to cognitive scientists intelligence and learning ability take various forms. Components such as perception, memory, association, concept formation, problem solving and mental imagery play an important role when trying to figure out the holistic outcome of the learning process. Some educational institutes offer scholars courses such as "Theory of Knowledge" in their curriculums. Students are encouraged to discover the views of and justifications for different issues, rather than debating the rights or wrongs of those phenomena.

The strength of mankind lies also in our ability to work together and produce something called "group cognition". In addition to traditional physical group work, collaborative learning can benefit from different networks that can easily be accessed across digital media applications.

It is not farfetched to claim that nations without vast amounts on natural resources are particularly dependent on their ability to innovate and create opportunities to remain competitive. In addition to various academic institutions and research centres, engineering companies play an important role in creating wealth through innovation and research. This technical journal is an example of the intellectual capacity that a modern engineering company must possess and deliver for the benefit of its customers. Hopefully reading the articles will provide you with a positive learning experience and a healthy challenge to your cognitive learning abilities.

Heikki Pöntynen
Editor-in-Chief

The Elomatic Magazine renews its face

The Elomatic Newsletter has received a new face and will from now on be published under the "Top Engineer" banner to better reflect the content and target audience of our magazine. The name has changed, but our goal of providing our readers with informative and cutting edge technical articles remains the same. We look forward to hearing your feedback about your reading experience.

Heikki

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Cover: Milind Shinde works at the Elomatic Mumbai office. Background photo © 2013 Wavebreak Media Ltd.

Gaining a competitive advantage

– Testing products in simulated environments : case Wärtsilä

Taking good products and turning them into world beaters is becoming increasingly demanding as customers' expectations with regards quality, dependability, economical performance and costs show no bounds. User experiences, modern computer simulations and other analysis tools are integral parts of efficient product design, but in some cases they do not suffice to take the product to the next level. In such cases testing real products in virtually real conditions has become a key resource in gaining the extra competitive edge required.

A test bench used to test propulsion devices in real seagoing conditions.

Implementing testing of real products is fairly straightforward when the product is relatively small and its operational conditions close to the norm. Once the product size increases and the operational conditions are more challenging, the situation quickly becomes quite the opposite.

One only has to imagine the difficulties associated with the testing of satellites, space ships or submarines in real-life conditions to understand that in those cases it is almost impossible, or at least extremely costly to conduct the necessary testing in real-life conditions.

The testing of new technologies is often left for maiden voyages and customer projects, which comes with unwanted added commercial risks. Laboratories that can test real products under realistic conditions have, therefore, become a key tool in expediting product or technology development. Such laboratories facilitate learning about the product and its behaviour and speed up the product technology development cycle.

Propulsion device test centre simulates real seagoing loads

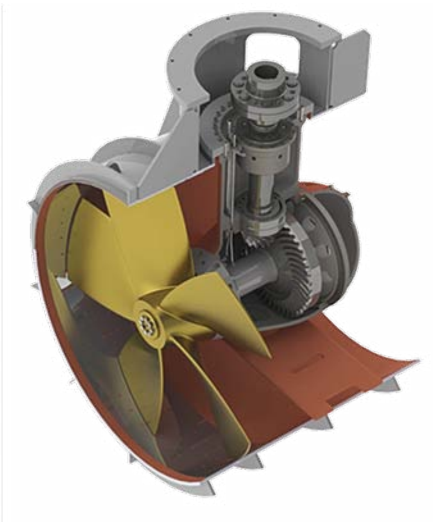
Wärsilä Ltd's recently implemented propulsion device test centre in Tuusula, southern Finland is a good example of a product testing facility that facilitates significant technology leaps in product development. See picture on previous spread. The centre allows real propulsion devices to be tested in virtually real seagoing and harbour conditions, while also allowing for the effects of icy conditions to be taken into consideration. The project was implemented by Wärsilä in cooperation with the VTT Technical Research Centre of Finland and Elomatic Ltd, which delivered the test bench of the centre on an EPCM basis.

The effectiveness of new technological solutions can be tested at the centre, after which they can be transferred directly to end products. This significantly speeds up the development of product performance and the identification of new possibilities. The test centre is a world first and allows the development of more effective and efficient propulsion devices for the global Marine industry.

The testing laboratory is a rather impressive sight. It has to accommodate products for testing that weigh up to 20 tonnes, are 4 metres high and produce almost 3 MW power output. Add to that the creation of seagoing and icy conditions and the extent of the centre becomes clear.

Relatively long testing times

While on the test bench the product can be exposed to the exact fluctuat-



Advanced testing technologies are ideal tools in optimizing product development.

ing loads it will experience at sea. Even the cooling effects of ocean currents has been accounted for. The testing times are relatively long and can last for several weeks. The testing system is very flexible with regards how loads are placed on the tested product, at what frequency and cycle and for how long tests are conducted.

During a typical test the device collects measurement data from over a hundred different measurement points. The measurement points and measurement scales can be altered from one test to the next.

The test centre allows different parties to work together in the development and testing of new technologies. This cooperation includes customers, research centres, universities and suppliers.

The implementation of the propulsion device test centre at Wärsilä is a shining example of how advanced testing technologies can be used to optimize product development and the implementation of new technologies. All eyes are on them now to see what new and ground-breaking features they will develop with the aid of this technology. The sky is the limit.

When should analysis and user experience make way for laboratory testing?

- Product operates in conditions that renders measuring and testing too difficult or expensive
- Product is affected by complex dynamics
- Generating results is extremely time consuming
- User tests are expensive and require lengthy implementation times
- The customer aims for a large technological leap in a short timeframe

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Arto Sampo has extensive experience in production lines and the design of special devices used in production in a wide range of industries. His experience covers design projects and implementation projects as well as different product development projects since 1981. He has also taught special courses related to his fields of expertise at the Jyväskylä University of Applied Sciences for more than 10 years. Arto has worked at Elomatic in different positions since 1990 and his current position is Business Area Manager, Production Development Projects.

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Still Going Strong

Heikki Pirilä
– 30 years in starch processing

"One of my clients once said that starch processing is second in complexity only to nuclear power generation."

Making it in the starch processing business requires a keen eye for raw material quality and the ability to get the most out of your raw materials. A general rule of thumb is: the more refined the product, the more valuable it becomes. The investment payback time on a starch processing plant investment is rather long, so patience and a big wallet come in handy. The strong and growing demand for especially modified starches and valuable by-products is nevertheless enough to keep long-term investors keen. The reason is that starch and starch by-products are omnipresent; they are everywhere you look, that is as long as you know what you are looking at.

Heikki Pirilä has an eye for starch and starch by-products. He has been in the starch processing business for the better part of three decades, so there is not much that surprises him anymore. He started in the business as a design engineer back in 1984 and has been involved in all project phases of starch processing from design, project management, supervision and procurement to maintenance.

His work has seen him travel widely especially in Eastern Europe and Asia. His expertise is not limited to successfully setting up wheat starch processing plants; throughout the years he has gained valuable knowledge of raw materials sourcing regions, cultures and local energy sources, particularly in Russia and China where he has worked extensively.

Developments and future trends

Surprisingly little has changed over the years with regards to how wheat starch is processed. Development efforts have rather been focused on improving devices and the efficiency of the process as well as the further processing of starch.

"We have, for example, invented inline flour/water mixing, which means that there is no dough preparation and no delay before three-phase fractioning. We have also come up with our own maturing drum and agglomerator to ensure holding times that are optimal and even. The system is nearly fully closed, which means that we use less fresh water and therefore also produce less waste water. Due the relatively long payback period it is important to find ways to reduce the investment and production costs and make the whole process more efficient", explains Heikki.

Native starch production is in itself not that attractive and the goal of most producers is in fact to enhance the production of highly valued products such as gluten and other products made of starch as well as by-products.

"I don't really see native starch production as holding much promise, but there is a definite trend in further processing of starch into modified starches, syrups and sweeteners, organic acids, bioplastics, and biofuels and so on. When you look at the revenue structure the reason is very clear. Starch fetches about €400–450 per tonne and gluten up to €2,000 per tonne. It's not rocket science to figure out where the real money can be made", Heikki continues.

"Another noticeable trend is that we are not seeing much in the line of greenfield investments in Western Europe and for existing plants there is usually resistance to make significant process changes. Most investments are related to the renewal of machines and reducing the environmental impacts of production. Eastern Europe, Russia and Asia are definitely where it is happening with regards new investments in wheat starch processing".

Starch processing is a challenging business

Wheat starch processing is known as being rather complex in itself and the investments required can hinder market entrants. Greenfield plants typically require a 5–7 year payback period.

"One of my clients once said that starch processing is second in complexity only to nuclear power generation", says Heikki with a smile.

Investors commonly have to consider the energy dependence of their processes and energy prices. It can, however, be difficult to predict the availability and pricing of energy, especially in the long-term. A process that uses vast amounts of energy is sustainable as long as energy prices remain fairly low. There is a case to be made for investing in reducing energy dependence.

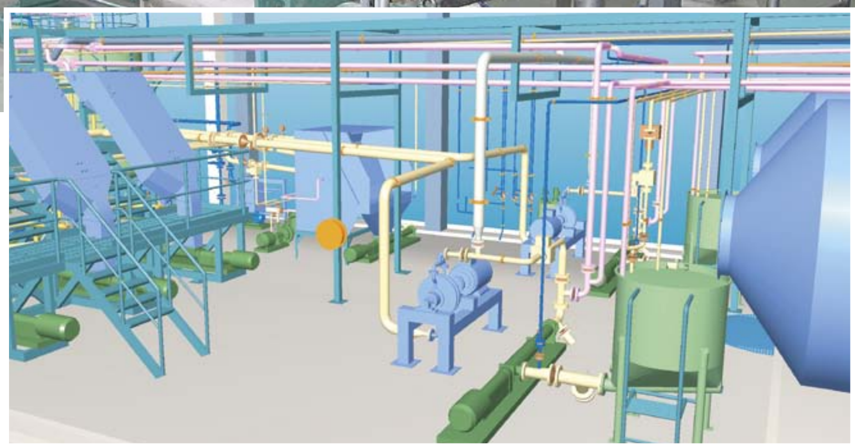
"Look for example what is happening in the Ukraine right now. Their energy prices have doubled in the space of a few days and it seems more pain is on the way. Imagine what that increase does to your bottom line."

Raw material quality commonly changes from year to year and regionally. Early germination can, for example have a profound impact on the Falling Number, an indicator of the degree of germination and starch breakdown.

A further difficulty faced by producers is choosing their equipment and devices.

Basic facts about starch and gluten

1. *Where does starch come from?*
   Starch is a storable energy source found in all green plants. It is commonly found in potatoes, maize, wheat, rye, sorghum, barely, triticale, peas, rice and tapioca
2. *Where and what is it used for?*
   Industries: Food Industry, Paper and Cardboard Industry, Textiles, Chemicals, Pharmaceuticals
   Food Industry: beverages, sweets, chocolates, baking products, biscuits, desserts, canned fruit, food thickeners and stabilizers.
3. *What by-products are produced?*
   Biotech products: citric acid, glutamate, lactic acid, syrup, lysine
   Biofuels: biogas, bioethanol, biobutanol
   Feed: for cattle, pigs and poultry in dry and/or slurry form
4. *What is gluten and where is it used?*
   Gluten is a very valuable product of wheat starch processing. Gluten is a key ingredient in bread products. It makes dough elastic and helps the bread to rise and keep its shape. It also provides the chewy texture associated with doughnuts and bread. Gluten is also used in cosmetics, hair products and dermatological products.



▲ *The maturing drum and agglomerator ensures that holding times are optimal and even.*

"There is great variance in the price and quality of devices. Due to the long payback period there is an ever present temptation to expedite the payback period by reducing device procurement costs. Facilities can run up to 30 years or even more if maintained properly, but inferior quality devices will usually fail no matter how well they are maintained. It is a fine balance that needs to be struck between the short-term financing needs and life-time costs. In most cases it is a good idea to consult with an independent consultant to find the optimal solution", says Heikki.

Staying on top

So what does it take to be successful in this business area?

"It probably sounds like I am stating the obvious, but a crucial element is the ability to make maximum use of your raw materials and to run the process as optimally as possible. Producers that can efficiently produce the highest quality A-starch, gluten and valuable by-products and seamlessly deliver them to the market will always have a competitive edge. Efficiency gains can also be achieved by reducing energy and fresh water consumption", Heikki eludes.

Proximity to the source of raw materials and good knowledge of local and regional conditions, cultures and infrastructure are also very important factors. Keeping a watch on market developments and predicting which products will do well in future are further key success factors.

"This is not an easy business, but we do know that the demand for starch and starch by-products remains strong and is increasing. The customers are out there and they will be there for the foreseeable future. Is my job to help my customers to be successful and put my 30 years' experience at their disposal", Heikki concludes.

Modern flue gas scrubbers

– significant improvements in the profitability of bioenergy heating plants

There are many reasons why flue gas scrubber technology should be used. One of the most important is the financial benefits it brings. An immeasurable amount of fully utilisable thermal energy vanishes into the sky through the chimneys of heating plants every day. A modern flue gas scrubber can recover any lost heat and offers effective particle filtration for heating companies.

Changes in the district heating market in Europe place many heating plant companies in a challenging position. There are several diverse reasons for these changes. Competition over heating customers has become significantly fiercer over the past ten years as competing forms of heating have become more popular. The fuel strategies for district heating production in different countries are tied to changes in energy reserves and production in the EU and to the entire global economy.

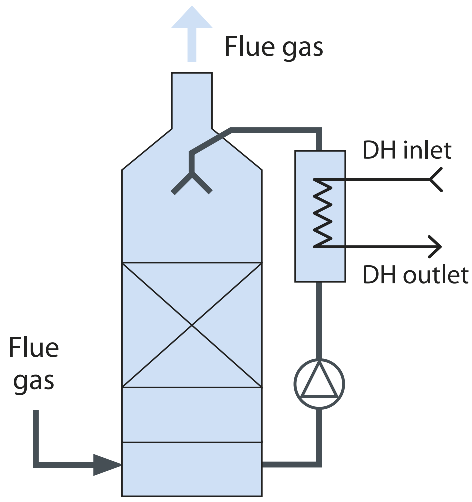
District heating networks are usually old and consumers have inadequate heat exchangers with poor rates of efficiency. In addition, upgrading production plants to meet the current energy efficiency and emission requirements often depends on municipal economies, which may delay or even prevent the completion of financially and environmentally productive investments.

In order to modernise district heating production, we must turn our eyes to financially reasonable small-scale investment projects that serve to increase the energy efficiency of heat production and limit the emissions of plants to cost-efficiently meet the current requirements.

Fuel oil is a financial burden for heating companies

The majority of heating companies still use heavy fuel oil. Fuel oil is consumed especially during periods of extreme cold, when primary production plants do not have sufficient capacity. In many cases, the additional need for

The use of flue gas scrubber technology can bring tangible financial benefits.



▲ *Figure 1. A simplified traditional scrubber process diagram*

heat leads to significant fuel oil consumption, even during shorter spells of cold weather. According to our experience, a typical energy volume of 3,500–6,000 MWh a year is produced using fuel oil in heating companies with solid fuel plants of 5–10 MW. Most fuel oil is consumed in cold weather during the winter.

In addition, heavy fuel oil is used to compensate for the stoppage and maintenance of solid fuel boilers. In summer, solid fuel plants run at the lower limits of their adjustment range where such plants are difficult to operate. The district heat required is then produced using oil or natural gas boilers.

Most heating companies are trying to stop the use of heavy fuel oil. Their reasons are financially and socially sensible: the use of heavy fuel oil is simply too expensive and has much higher carbon dioxide emissions that local biofuels.

Flue gas scrubbing and recovery of lost heat

A flue gas scrubber is a wet scrubber which was originally designed to reduce particle emissions from flue gases. Over time, its development has shifted to improving the recovery of lost heat from flue gases. The particle filtration and heat recovery properties of a traditional flue gas scrubber are based on two consecutive and connected processing stages. Flue gases are led through a scrubbing phase where the majority of small particles are removed. During the same phase, flue gases are cooled down to their wet temperature (60–70 °C).

After the scrubbing stage, flue gases are conveyed to a condenser where they release their thermal energy through condensation in water circulating against the current. Condensation takes place in filler layers (one or two layers) that act as heat transfer surfaces in the process. Circulated water (i.e. generated condensate) is led to the heat exchanger where the thermal energy transferred to the condensate is recovered in the district heating water. (See Figure 1.)

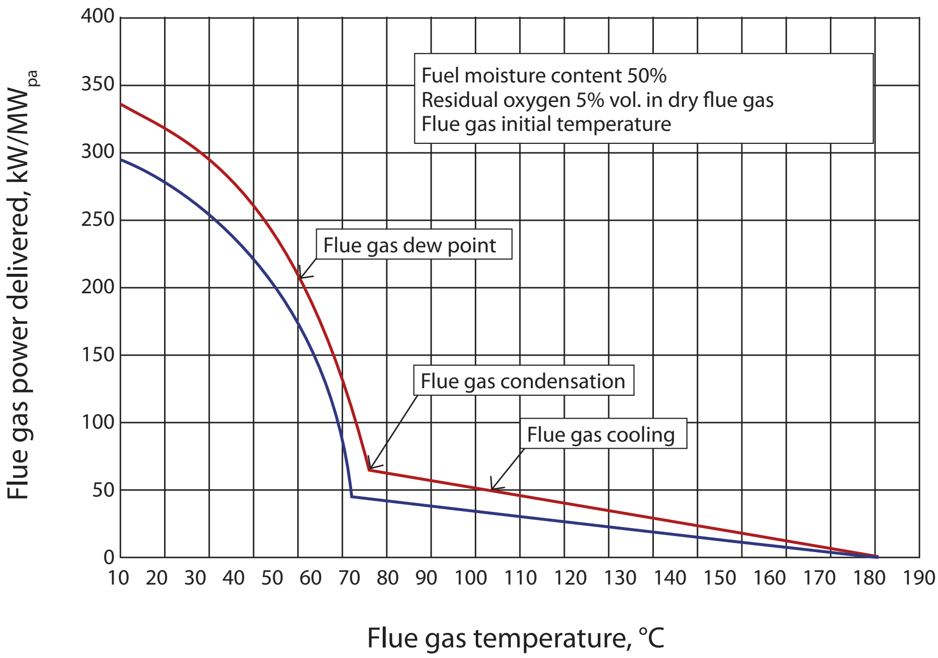


Figure 2. Wet scrubber thermal energy transfer per fuel power unit as a function of flue gas temperature

Figure 3. The effect of a scrubber solution with a heat pump connector on a selected heating plant's heat production duration curve

It is essential to reach the dew point in the condensation zone

The dew point refers to the temperature at which the relative humidity of the vapour contained by the flue gas is 100%. If the temperature falls below the dew point, the vapour contained by the flue gas begins to condensate, i.e. turn into water. When analysing the transfer of thermal energy, we can see that, in connection with different phase transitions of water, enthalpic changes are significantly higher than in temperature changes within a single phase. Therefore, there are significant transfers of thermal energy through water vaporisation and vapour condensation (2,350 kJ/kg).

However, the most important factor in heat recovery is that the temperature is below the dew point when the flue gas vapour condensates and the released thermal energy can efficiently access the circulated water and, ultimately, the heat exchanger.

On the other hand, if the temperature is significantly above the condensation point in the scrubber, the heat recovery capacity falls and the scrubber will, in the worst case scenario, act as an evaporator. To put it simply, the scrubber vaporises additional water into flue gases. (See Figure 2.)

Why does a normal flue gas scrubber not work in extreme cold?

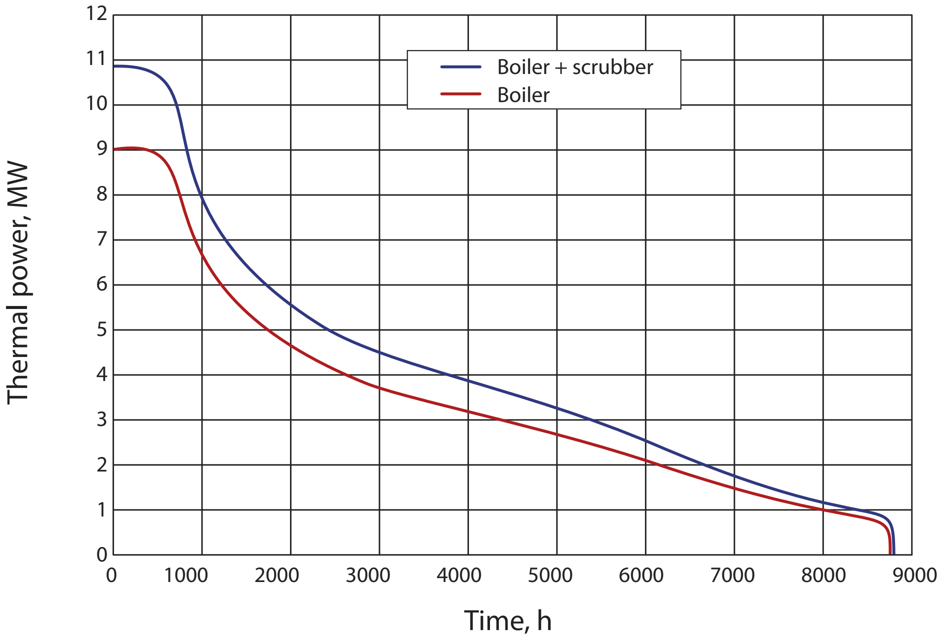
Reaching the condensation point temperature in any situation is essential considering the scrubber's heat recovery. Return district heating water is conducted to the secondary side of the scrubber's heat exchangers. It cools the flue gases below the dew point temperature. Cooling works and the dew point can be achieved if the district heating network's return water temperature remains clearly below the condensation point temperature of the flue gas.

During peak power periods, the aim is to use a high-quality (i.e. dry) fuel. The flue gases of a dry fuel are dry, meaning that the dew point is low. During peak loads, the return temperatures of district heating networks increase. The primary reason for this is that the heat exchangers used in households have poor efficiency ratios. They simply cannot transfer the heat required to households; instead, extra heat returns back to the heating plant.

When this excess heat is fed back to the flue gas scrubber's heat exchangers, the dew point cannot be reached and heat recovery decreases significantly. In other words, the scrubber's heat recovery capacity collapses. Any missing condensation also causes problems with sludge and clogging in the scrubber.

Significant improvements in heat recovery through a heat pump connection

Heat pumps have been used in industrial applications for decades in various recovery processes for waste heat. A heating plant process is a special case where a correct heat pump connection boosts the recovery process four- or eightfold compared with a traditional scrubber. The heat pump regulates the return temperature of district heating



water led to the scrubber so that the condensation point can be reached regardless of the network load and other external conditions.

In a traditional scrubber, the return temperature forces the final flue gas temperature to be 3–5 °C higher than the return temperature. For example, if the return temperature is 55 °C, the minimum final temperature of flue gases can be 58 °C.

Using a heat pump connection, the return temperature of district heating water can be reduced by 20 °C, in which case, according to the previous example, the return temperature of district heating water would be 35 °C and the minimum final temperature of flue gases would be 38 °C.

However, the thermal energy of the return water is not lost in the cooling process. It is transferred to the condenser via the pump's thermal substance and returned to the district heating network. The energy transferred using the heat pump simply passes the scrubber connection.

In more advanced applications, only the exact volume of the network's return water needed by the scrubber is conducted, in which case the heat pump can be dimensioned optimally for the investment.

In the aforementioned example, additional cooling of 20 °C is significant considering the recovery of energy. If peat with a humidity of 35% was used as a fuel and the residual oxygen of the flue gases was 5% by volume, the flue gas dew point temperature would have been 57 °C. In such cases, a traditional scrubber cannot reach the dew point, which means that additional water is needed in the process.

The regulatory circuit and heat pump connection described above enable a significant increase in the scrubber's heat recovery capacity and improve the heating plant's energy efficiency, especially in extreme cold.

The use of heavy fuel oil can be reduced significantly, which guarantees a short payback time for investments. Currently, payback times of even 2–3 years have been reached in investments where heavy fuel oil has been replaced by a scrubber solution with a heat pump connection. (See Figure 3.)

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Virtualisation of automation systems

– a brave new world

Automation has developed at a rapid pace in recent times. The surge in development has seen automation suppliers and component manufacturers for process control launch new generations of process controllers and bus and I/O components on the market. The use of ICT technology and databases has increased in distributed control system (DCS). This increasing use dictates that we to come up with new ways of efficiently utilising the computational power and opportunities computers present. ICT virtualisation can achieve significant savings in the delivery of automation systems and in producing high levels of system flexibility and usability.

Virtualisation refers to the use of virtual computers in one or more servers, the physical resources of which are jointly used by the virtual computers with the use of virtualisation software (Hypervisor). A virtual machine is a program-based object which corresponds to a physical computer in terms of logic and functionality.

Usually the end user uses a virtual machine via a terminal which is connected through a remote connection, such as Remote Desktop Protocol (RDP). Virtualisation technology has rapidly become popular in the IT office environment and is currently finding a home in ITC process automation.

Development work and tests conducted at Elomatic on the use of virtualisation technology in automation systems indicate that ICT virtualisation is indeed possible and the results are very promising.

The development team's vision of an implementation strategy for automation systems is depicted in Figure 2. It shows the most essential parts of the DCS implementation with the use of virtualisation. The device implementation differs from that shown in Figure 1 because the usability requirements differ between the Demilitarized Zone (DMZ) and Process Control Network (PCN). This has an impact on duplication, which means that a single blade server can be used in the DMZ. In the PCN, a cluster needs to be built of separate servers and Network Added Storage (NAS) drives located in different places. The DCS servers of a large ship's control system and other critical IT components are, for example, located in different parts of the ship.

More licences but less hardware

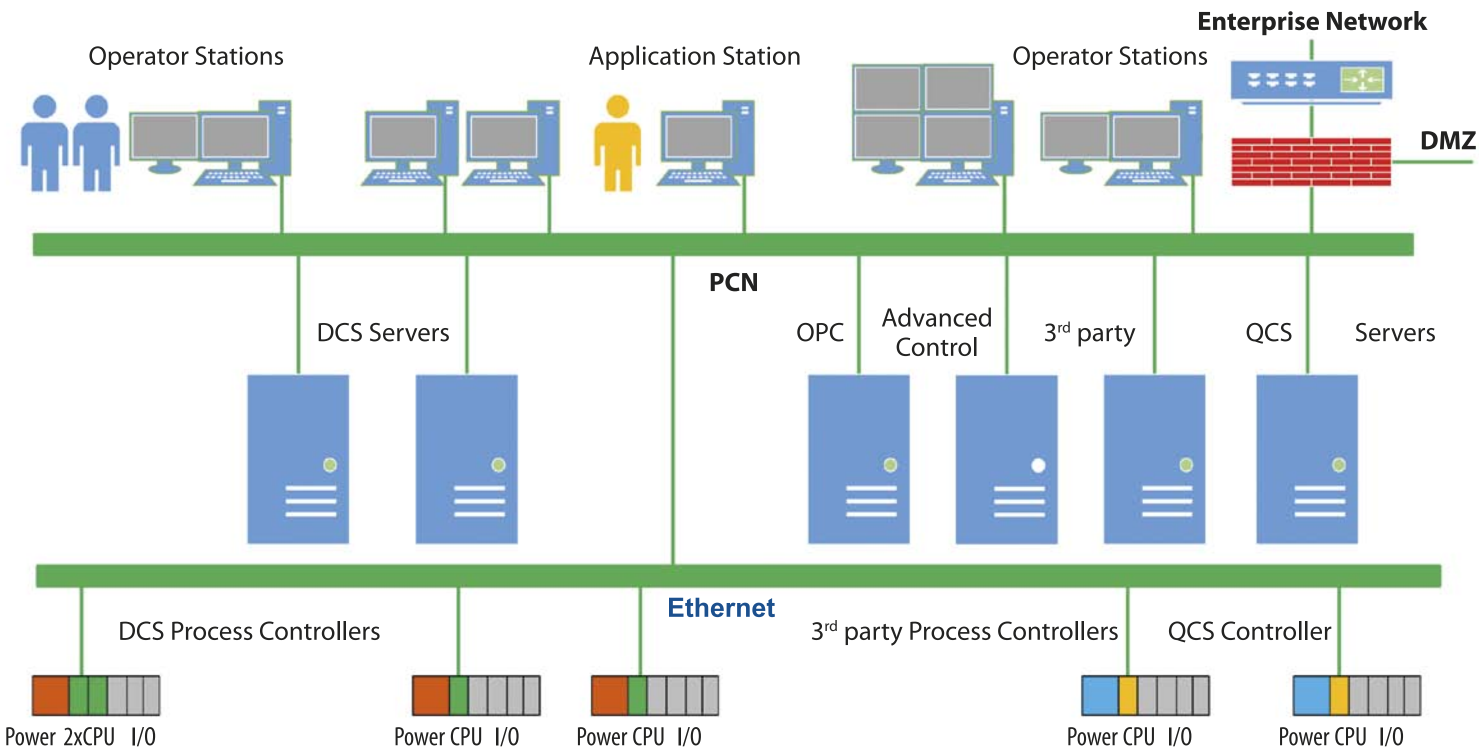
A basic cost analysis has shown that in virtualised systems the share of licences increases and that of hardware decreases. The reason is that the management of a virtualisation solution requires a new software platform and software licences. A redundant NAS implementation, for example, requires not only special hardware, but also software for a high availability (HA) network drive. See Figure 3.

In virtualised systems several computers and servers are replaced by a few more powerful servers and operator terminals, so that the quantity equals the number of desktop computers. In addition to software and hardware changes, the system changes in terms of management, maintenance, usability and its expandability. For example, the migration of a virtual machine is only possible in a virtual environment, and the use of migration in maintenance improves flexibility and efficiency. In other words, the diversity of the new system structure improves efficiency and user-friendliness.

Total cost ownership (TCO)

The total cost of ownership for the automation life cycle plays an important role when analysing the use of virtualisation technology. The initial costs may be higher, but no further hardware and software upgrades are required for the automation system, which means that

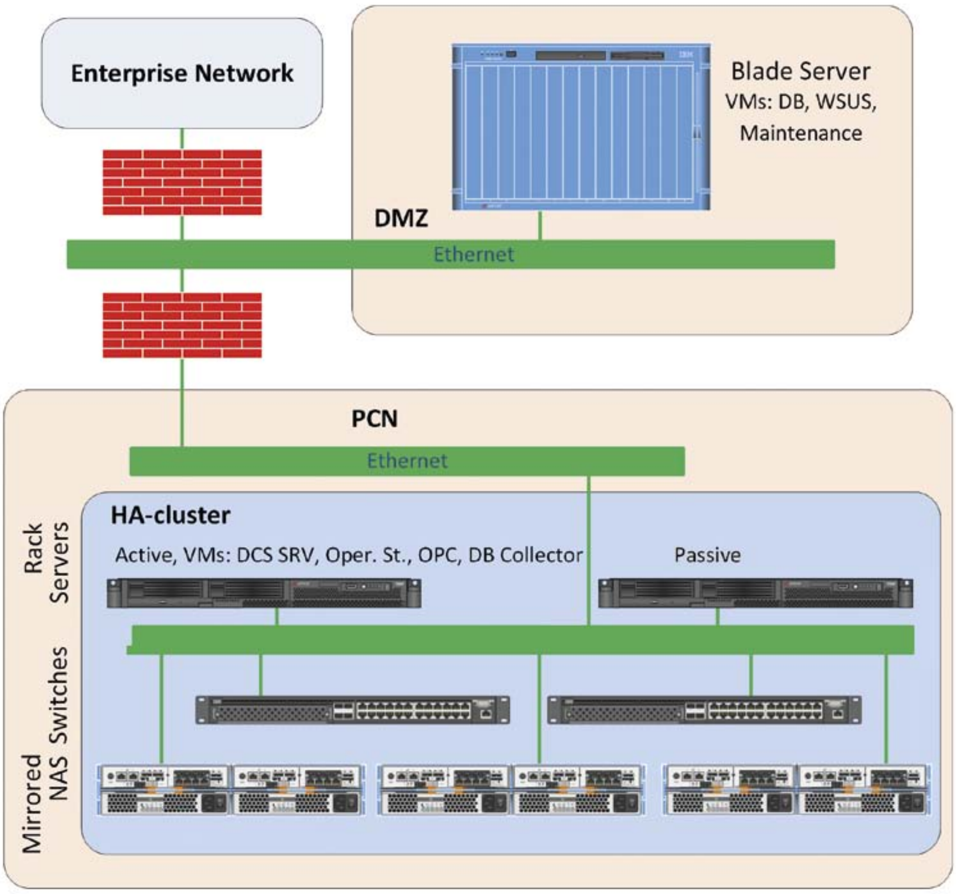
▼ *Figure 1. A common distributed control system (DCS) implementation*



the TCO is significantly lower than that of a traditional implementation.

This factor cannot be ignored, and as a result, large automation suppliers have, in recent years started to offer partly-virtualised solutions. Honeywell stands out from other suppliers as it also offers HA solutions for virtualisation. This technology guarantees flexible and cost-effective automation deliveries.

Automation companies need to keep up with the changing world. Virtualisation expertise and specialisation delivers far superior benefits compared with traditional approaches. It provides companies that embrace these technologies with a clear advantage as they are able to serve their customers in an entirely new way, for example, in automation system procurement and implementation. Learning new concepts as well as developing and applying what was learnt are vital skills in the modern world.



▲ *Figure 2. DCS implementation concept with use of virtualisation*

▼ *Figure 3. StarWind iSCSI NAS implementation*

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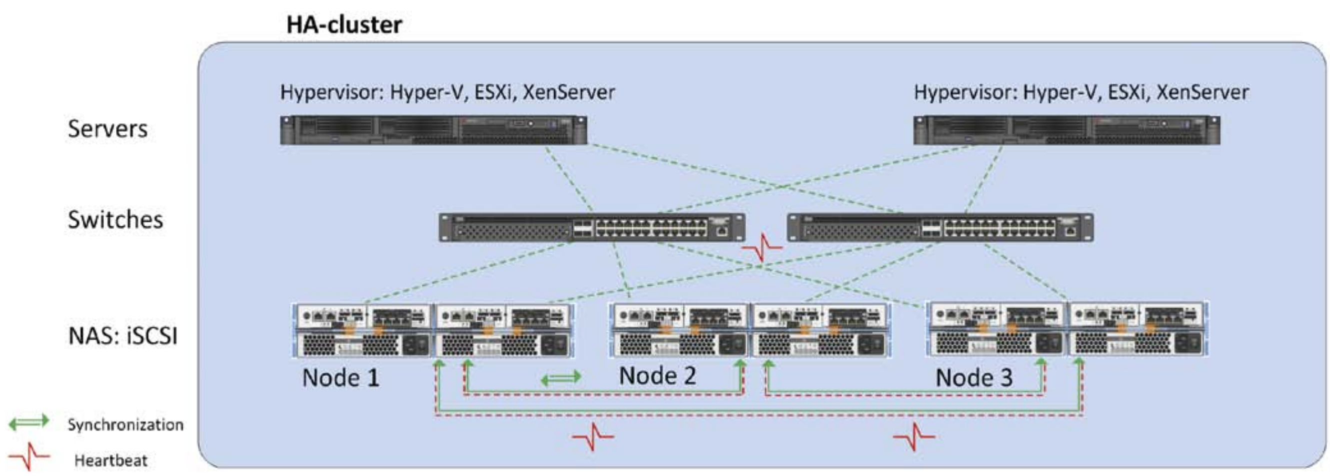

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Human errors

– usability as a safety factor in working environments

Safety is a topic on everyone's lips. When users make a mistake or interpret a critical matter incorrectly, they may hurt themselves or damage the environment. The root cause of an incident may be non-compliance with instructions, incorrectly remembered procedures or a lack of attention – i.e. a human error. By analysing the working environment more closely, an error can sometimes be revealed as the result of logical thinking or foreseeable actions, which could have been avoided if the working environment had been well designed.

A good working environment is comprehensible, where users, such as control room operators, can easily obtain the information they need from the environment and user interfaces, interpret it and act correctly. In fact, the user interface in itself should act as a guideline structure, providing instructions for correct working procedures. This is affected by the design of different elements in the working environment, and the logicality, consistency and informativeness of user interfaces.

Separate instructions and signs are usually necessary, but all too often failures in design are patched up by simply providing additional instructions. This type of working environment stresses employees unnecessarily. If the environment is not intuitive to users, i.e. naturally understandable, it places a strain on perception and memory capacity and causes inference difficulties. Because a human's brainwork-related cognitive capacity is limited, there is a greater risk of human error occurring.

Human errors – are they avoidable?

Errors made by users can be divided roughly into two groups. We all make faulty choices and deductions every now and then, even if the correct solution is clearly observable and easily interpreted. Preventing these kinds of errors is practically impossible.

However, there is another group of situations where users need to act relying excessively on their memory, or

A good working environment is comprehensible, where users can easily obtain information, interpret it and act correctly.

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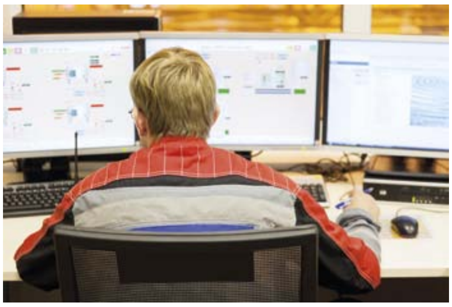

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so that a feature in the environment or user interface activates the wrong operating model. This latter group of errors can be affected by the design of the working environment.

Working environments and their user interfaces should progress logically for their users and be consistent for the actions required. Instead of using technical language, information should be understandable to users. This also refers to the use of clear and understandable symbols.

In order to be in control of their work, users need to receive correctly timed feedback from the systems they are using. Working should not strain our short-term memory, also known as working memory, to an unreasonably high extent. Separate instructions are needed in many cases but written instructions are not an efficient means to patch up defective usability found in user interfaces. We should first think how users could be guided towards the correct action by developing user interface features without resorting to separate instructions.

Safer working through usability design

In a technical sense, we are working hard to make the working environment safe. Examples include the Atex safety requirements set for safety-critical environments, which define technical solutions and material choices acceptable for various categories of work premises. Similarly, machine safety regulations include a large group of requirements related to various sorts of protection.

Technically speaking, we can never build a completely safe working environment. For example, gaps need to be left in automatic safety mechanisms in the process industry. There are many areas and situations where operators need to be able to make decisions and have an impact on the process. Emergency states are a completely separate area in this regard.

When planning working environments, safety-critical ones in particular, we need to see people as human actors. In practical development projects, the user's point of view and human factors are coupled with technical design and user interface design.

The design is also tested with end users before the final implementation stage. In other words, procedures of user psychology and system usability supplement technical safety solutions. They form a single layer in a "sieve", which serves to prevent critical errors and verify safe operations. Working environments can be developed controllably when the user perspective is considered throughout the design process.

There are ways to reduce human error. Through working environment and user interface design, we can have an impact on the probability and frequency of unintentional errors being made.

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Air tightness testing for biosafety level 3

In search of an international standard and sound practice

All bio-containment guidelines and inspection documents set requirements for airtight containment boundaries around biohazards. Current international containment guidelines only scratch the surface for biosafety level 3 (BSL-3) and the available tests proposed are not entirely suitable for such facilities. Some steps in the right direction have been taken, notably as outlined in the standards put forth in the Australia-New Zealand model for their Physical Containment 3 designation.

There are several reasons why airtight containment boundaries are required, the most obvious of which is that they prevent the escape of airborne biohazards. A much less obvious function is that they also prevent the escape of the decontamination gases or vapours used. These gases and vapours are, in fact, the most likely dangerous airborne agents.

Key questions regarding what exactly constitutes acceptable leakage levels, however, have to be answered before quantitative testing can become the standard. Until then qualitative methods will see continued use.

One of the principle requirements of BSL-3 is ensuring inward airflow into a contained area from a less contained area. This can generally be achieved by maintaining the facility under negative pressure with respect to the atmosphere, using two interlocked door airlocks at the containment boundaries and pressure cascading, etc. The effectiveness of all measures depends directly on the integrity of the room / facility.

Guidance with regards BSL-3 containment barrier integrity is relatively superficially provided by the "Biosafety in Microbiological and Biomedical Laboratories" (BMBL) guidelines. According to the BMBL 'surfaces should be sealed' and 'openings should be capable of being sealed to facilitate space decontamination'. In addition, there are no criteria for verifying that these conditions have been met in the BMBL or in any official certification BSL-3 checklist.

Pressure Decay Test not suitable for BSL-3 validation

Methods to validate the air leakage of a containment boundary can be classified into two main categories: qualitative and quantitative. The only quantitative test prescribed in the U.S. and Canada is the Pressure Decay Test. However, the Pressure Decay Test is not well suited to BSL-3 performance validation.

The Pressure Decay Test is an extreme test in that it represents the highest standard for room integrity in the U.S. and Canada. It is designed for BSL-3Ag/BSL-4 containment construction validation, which is historically constructed with specialized and very expensive high performance containment barrier systems. Typical methods for constructing a BSL-3 space will not pass the Pressure Decay Test criteria and the risks associated with aerosol hazards in a BSL-3 space do not warrant constructing barriers that will pass this test either.

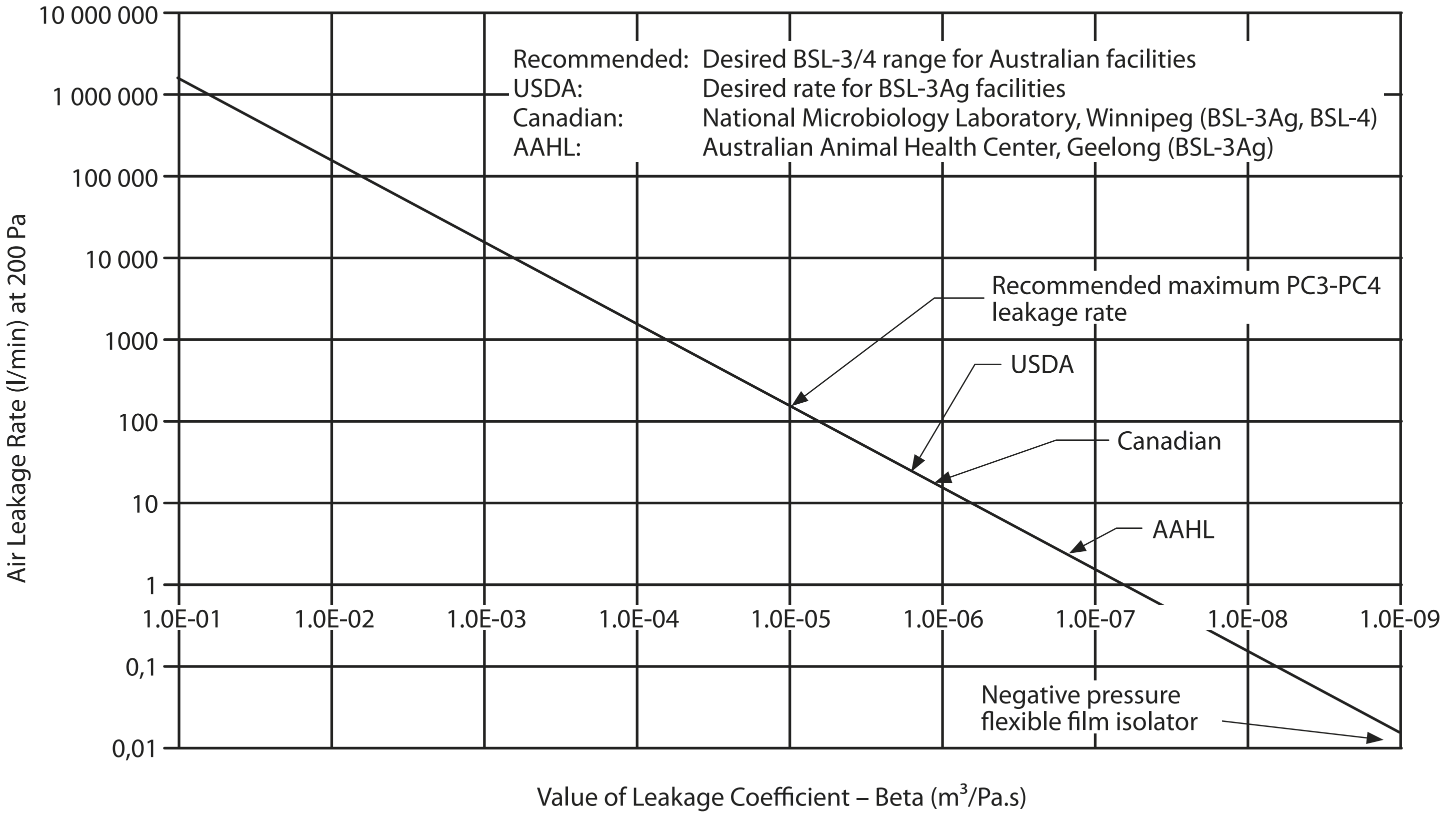
Without a relevant quantitative test to use, the most common methods of testing BSL-3 barriers are qualitative tests designed to find and fix holes in the barrier. That is pretty sound logic overall, but the devil is in the details and in how one records those details in the course of a construction project.

Identifying air leakage

The two most common methods of identifying air leaks are smoke testing and soap bubble testing. Regrettably, there is no guidance or consensus on what parameters should be used to perform these tests. The parameters have to be defined on a case by case basis via laboratory operations and failure scenarios.

◄ *Room impermeability tests*

▼ *Air leakage rates at 200 Pa differential pressure*



AS/NZS 2243.3:2010 guidelines

The only current quantitative tests in practice for BSL-3 have been developed in Australia and New Zealand for their Physical Containment 3 (PC3) designation. These tests are relatively simple to execute and do not subject containment level 3 rooms to pressures they are not designed to withstand. (Level 3 rooms are tested at 0.8" 200 Pa pressure difference.)

The standard has been developed to set acceptable leakage rates appropriate for containment level 3 that are achievable with common construction systems, i.e. drywall or sandwich panel constructions with appropriate penetration details. Careful attention to joints and penetrations is required for the rooms to pass the test. Normal workmanship for non-containment spaces will not suffice. Spaces that pass the test criteria are considered capable of gaseous fumigation and secondary containment protection.

Details regarding tests for leak tightness (BSL-3Ag and BSL-3) and the room leak tightness test (Pressure Decay test BSL-3AG) are provided in tables 1 and 2.

Practical difficulties and limitations of current testing methods

Acceptance criteria for all leakage testing methods are defined for single rooms with sturdy constructions, a limited number of penetrations (for ducting, electrical cables, doors, view panels etc.) and airtight view panels as well as airtight doors.

It is feasible to qualify of single room laboratory or one animal room with airtight doors, but if you are testing a BSL-3 laboratory facility that consists of several laboratory rooms connected with a BSL-3 corridor, the laboratory door is not airtight. The doors on a BSL-3 containment barrier are airtight, but internal doors normally leak. While testing for leakage, single rooms with leaking doors need to be qualified. The acceptance criteria cannot be met unless the non-airtight door/doors is/are sealed with adhesive tape or sealant.

For large rooms with multiple doors, large surface areas and several penetrations it is difficult to fulfil the acceptance criteria. It is necessary to define the acceptance criteria in terms of litres/min per square meters of the room's surface area.

In pressure decay testing the test is sensitive to changes in the ambient temperature during the course of the test. Therefore, an appropriate correction factor has to be applied that considers the temperature before and after the test.

The Australia-New Zealand model (AS/NZS 2243.3:2010) provides a common approach and platform for designers, builders, and owners to engage, deliver, and qualify the facility. The standard is meant to ensure that containment laboratories are designed and constructed to perform their functions safely and consistently, to a standard that is deemed appropriate and fit for the purpose by an independent body.

The Australia-New Zealand model can be improved upon with a more evidence-based rationale for performance requirements. What level of air leakage at a given pressure correlates to a safe measure of containing hazardous gases in likely scenarios? Is the acceptable leakage amount dependant on room volume or the same for all room sizes? Answering these questions, as well as identifying the relationship of airtightness to the reduction in

Table 1: Leak tightness testing – BSL-3Ag and BSL-3

The basic procedure for room air leakage testing under negative pressure for BSL-3Ag and BSL-3 according to AS/NZS 2243.3:2010 is as follows:

Air leakage can be quantified by using an equilibrium pressure/flow test. For smaller rooms a vacuum cleaner connected to the supply or exhaust duct by a hose and a control valve can be used. For larger rooms a blower may be required.

1. This test usually involves the introduction of clean, dry compressed air into the space while monitoring the pressure in the space through separate pressure tapping (a vacuum cleaner with a hose and integrated anemometer could be used for low leakage rates).
2. When the pressure is stabilized at the required test pressure (200 Pa), the inflow of air required to maintain this pressure is measured using a flow meter such as a variable gap meter.
3. The leakage is then recorded in litres per minute.
4. Prior to the test care needs to be taken to ensure that all sources of air or gas pressure within the space are isolated. Doors should be taped with PVC tape and physically restrained to prevent movement under the positive room pressure. This test can also be performed by extracting air from the room, thus placing the room under negative pressure.

Acceptance criteria
Leakage must be < 20 litres per minute for BSL 3Ag, and < 200 litres per minute for BSL 3. All instruments should be appropriately calibrated by an accredited laboratory.

"Until a rational and defendable standard exists we can only do what is reasonable to ensure sound and appropriate laboratories."

risk of airborne pathogen release, even in a qualified way, would take us a long way towards setting a standard that is rational and defendable and which will satisfy industrial, regulatory, and public interests.

Until that exists, we can do what is reasonable to ensure sound and appropriate laboratories, which I believe means qualitative testing with well-considered test protocols based on what the laboratory is intended for. As we perform these tests and share the outcomes we will build a common approach and standard that will begin to standardize this important containment protective measure.

References

1. Australian/New Zealand Standard per AS/NZS 2243.3:2010
2. Biosafety in Microbiological and Biomedical Laboratories – U.S. Department of Health and Human Services

Table 2: Room leak tightness test (Pressure Decay test BSL 3Ag)

For pretesting, an initial pressure of 125 to 250 Pa is recommended to identify major leaks.

For certification the basic procedure for room pressure decay testing under negative pressure is as follows:

1. Isolate the area by closing and securing all doors, valves and bubble tight dampers at the containment barrier (avoid temporary sealing measures indoors, windows and services that would cover permanent seals); plug all pressure sensor lines, e.g. magnehelic gauges.
2. Install a calibrated inclined manometer across the containment barrier so that it is not affected by air distribution. The minimum accuracy of the manometer should be 10 Pa (0.05 in. w.g.) and capable of reading pressure up to 750 Pa.
3. Install a ball valve in the piping between the vacuum pump/fan and the room to allow the room to be sealed once the test pressure has been attained.
4. Connect a vacuum source to the room and create a 500 Pa negative pressure differential; allow the room to stabilize and close the valve between the vacuum pump/fan and the room to seal room at 500 Pa.
5. Dynamically trend pressure loss starting at 500 Pa negative pressure differentials; record the differential pressure at 1 minute intervals for 20 minutes.
6. If repeat test is required, allow for a 20 minute waiting period.
7. Disconnect the vacuum pump/fan and open the ball valve slowly to allow room pressure to return to normal.

Acceptance criteria

Two consecutive tests with a minimum 250 Pa (1 in.w.g.) loss of pressure from an initial 500 Pa (2 in. w.g.) over a 20 minute period. All instruments should be appropriately calibrated by an accredited laboratory.

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Milind Shinde has over 10 years' experience in Pharmaceutical and Biopharmaceutical projects. He has conceptualized and executed many projects for protein purification, vaccines, OSD, LVP, sterile API and formulation, as well as fill & finish. Over the past 10 years, he has worked with prestigious organizations such as Reliance Life Sciences and with leading consultancy firms executing projects, among others, for Baxter (USA), ShreyaLife Sciences, Reliance Pharmaceuticals, DaburPharmaceuticals. He currently works as a project manager at Elomatic Pharmalab Consulting & Engineering Pvt. Ltd in Mumbai, India.

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Containment Engineering

– A systematic approach to handle highly potent active ingredients and pathogens

The need for the contained handling and processing of pharmaceutical materials and pathogens is on the rise due to the increased focus on health and safety and the growing interest in the development of High Potency Active Pharmaceutical Ingredients (HPAPIs). A wide range of containment equipment is available on the market to meet the processing and operational needs of development and manufacturing. Selecting suitable equipment, however, requires an in-depth understanding of containment aspects in order to avoid operational hazards and large capital investments resulting from an 'oversizing' approach.

In containment equipment selection the focus is on preventing the personnel from being exposed to hazardous substances. The equipment cannot, however, fully prevent exposure. It is thus important to ensure that exposure through containment equipment over the operational course of time is less than the product/pharmaceutical material exposure limit.

The selection of suitable containment equipment requires a thorough understanding of product and equipment related exposure limits.

Product exposure limit

The product exposure limit is defined in terms of the occupational exposure limit (OEL), which is calculated based on the No Observable Effect Level (NOEL). The NOEL value is obtained by testing the pharmaceutical material on the species with daily dosage increases until the observable effect or reaction can be seen. The OEL can thus be calculated with the following formula:

$$OEL = \frac{NOEL \times BW}{V \times SF1 \times SF2}$$

OEL: Occupational exposure limit
NOEL: No Observable Effect Level
BW: Body weight of the humans
V: Volume of breath per human per day (8–10m^3/8-hour of shift)
SF1 and **SF2**: Safety factors for establishing a correlation between species and individuals if data for the humans is not available.

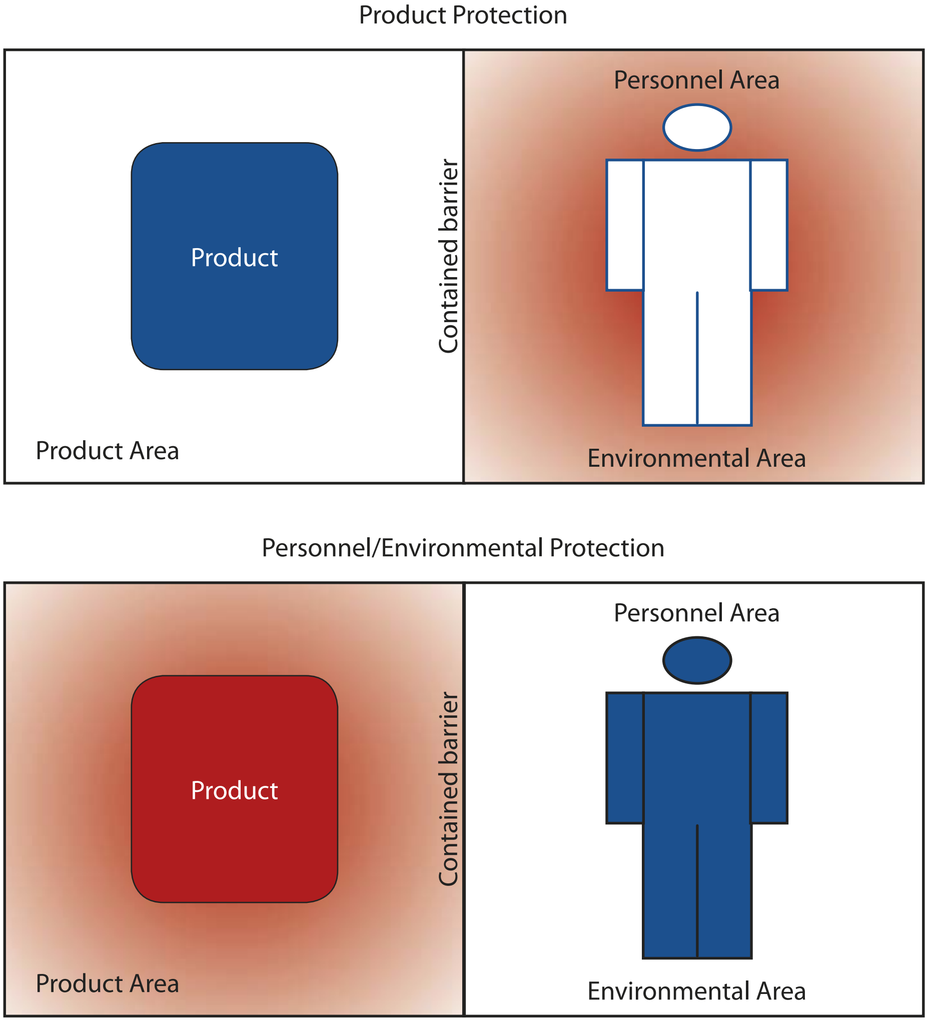
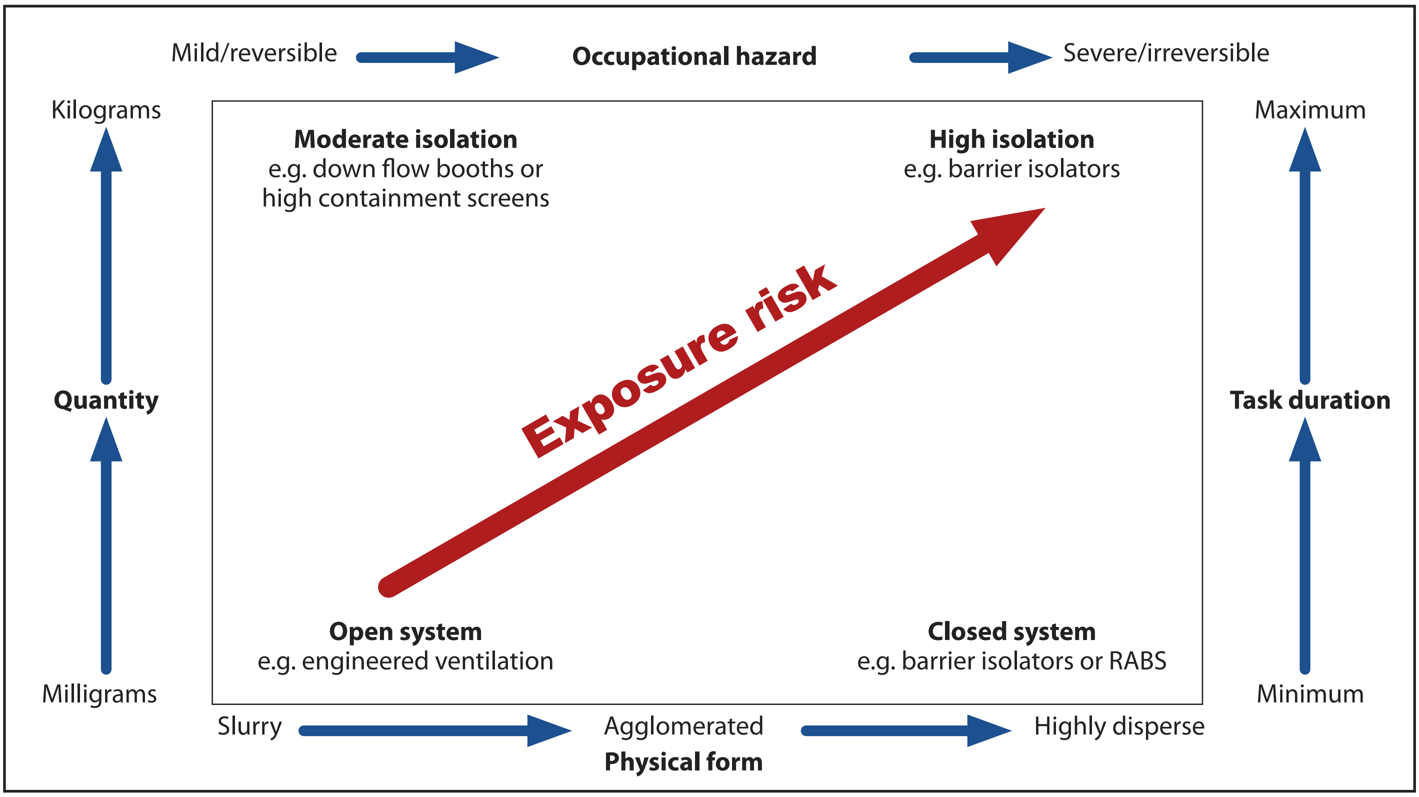


Figure 1. Containment is the isolation of a product or pharmaceutical materials from personnel and the environment or vice versa with the use of a physical barrier.

Figure 2. The appropriate containment system for each process is based on the quantity of materials, the occupation health hazard posed, the duration of the task and the physical form the handled materials.



Equipment exposure limit

The exposure limit of the equipment can only be determined through air sampling procedures and then analysing the collected airborne particle samples. This amount is then divided by the volume of air sampled and the sampling time to give the Time Weighted Average (TWA) values of the exposure limit.

The TWA for evaluating pharmaceutical material is defined for 15 min as the Short Term Time Weighted Average (STTWA) and for 8 hours as the Long Term Time Weighted Average (LTTWA).

Correlation between OEL and TWA

Containment equipment needs be designed or selected in order to achieve **LTTWA** < **OEL**. The LTTWA can also be obtained from the STTWA considering the actual exposure time in the operational shifts. For example, the general industrial shift duration is 8 hours and the STTWA values for an exposure time of 15 min are available, then LTTWA based on STTWA can be calculated as follows.

$$\text{LTTWA} = \frac{\text{STTWA}}{32} \times \text{NoC} \times \text{DF}$$

TWA: Time Weighted Average
LTTWA: Long Term TWA
STTWA: Short Term TWA
NoC: Number of cycles
DF: Dilution Factor

Table 1: Isolation methods

Particulars	Down Flow Booths	High Containment Screens	Restricted Barrier Access Systems (RABS)	Barrier Isolators
Flow direction	Unidirectional flow through ceiling HEPA	NA	Flow through clean room air circulation system or dedicated air filtration and conditioning system	Uncompromised continuous flow through supply and return HEPA of dedicated air filtration and conditioning system
OEL levels of material handled	Highest	High	Moderate	Least
Health Hazard level	Mild	Moderate	High	Severe
Level of Isolation	Least	Moderate	High	Highest
Level of Automation	Least	NA	High	Highest
Application	Effective protection when handling dusty material.	Effective way of boasting down flow booth capabilities.	Physical barrier between operators and production areas but barrier is limited.	Uncompromised continuous isolation of its interior and external environment, including surrounding clean room and personnel.
	Air flow carries the material away from the breathing zone of the operator into the low exhaust grill.	Effective solution for air suits due to operational constraints.	System's interior atmosphere can be controlled however pressure control is limited.	Effective pressure control in the interior of the system.
Classification	Recirculatory Booths Once Through Booths	NA	Passive Open RABS Active Open RABS Passive Closed RABS Active Closed RABS	Positive Isolator Negative Isolator

NA: Not Applicable
HEPA: High Efficiency Particulate Filter

The selection of suitable containment equipment requires a thorough understanding of product and equipment related exposure limits.

A factor of 32 is used as there are four cycles of 15 minutes in an hour and the dilution factors is available data for STTWA for a 100% concentration of pharmaceutical material.

The containment equipment should as such be selected so that LTTWA is lower than the product-specific OEL.

Equipment evaluation

The selected equipment can be evaluated by considering a worst case scenario where **LTTWA = OEL** and then calculating the $STTWA_{required}$ from the aforementioned formula as follows:

$$STTWA_{required} = \frac{OEL \times 32}{NoC \times DF}$$

TWA: Time Weighted Average
STTWA: Short Term TWA
NoC: Number of cycles
DF: Dilution Factor

The containment equipment can then be physically tested through appropriate methods to evaluate the following:

$$STTWA < STTWA_{required}$$

Methods of isolation and selection

As indicated earlier the OEL of pharmaceutical materials is the basis for the selection of the containment level required for processing the material. Thus, as the OEL limit shows a tendency towards lower values a more sophisticated level of isolation is required to carry out the safe processing of the pharmaceutical material.

The different types of isolation methods available are provided in Table 1. The appropriate isolation method is selected based on the criticality of the material handled or processed. In essence it is based on the OEL, the physical characteristics of the materials, the quantity handled and the duration of pharmaceutical material processing. See Figure 2 on page 29.

Proper selection and meeting owner's requirements

HPAPI is currently one of the fastest growing segments in the pharmaceutical industry, with a growth rate of 8 to 10 per cent. This high growth rate is attributed to their application in the formulation of high potent drugs used to combat some of the severest diseases. The market opportunities and treatment capabilities have resulted in the increased interest shown by pharmaceutical companies in investing in the development and manufacturing of HPAPI.

Handling these materials, however, requires sophisticated isolation methods, which demands an understanding of the basic concepts of containment engineering. This understanding assists in the proper selection of the suitable isolation method thereby meeting the operational and financial requirements of the owner.

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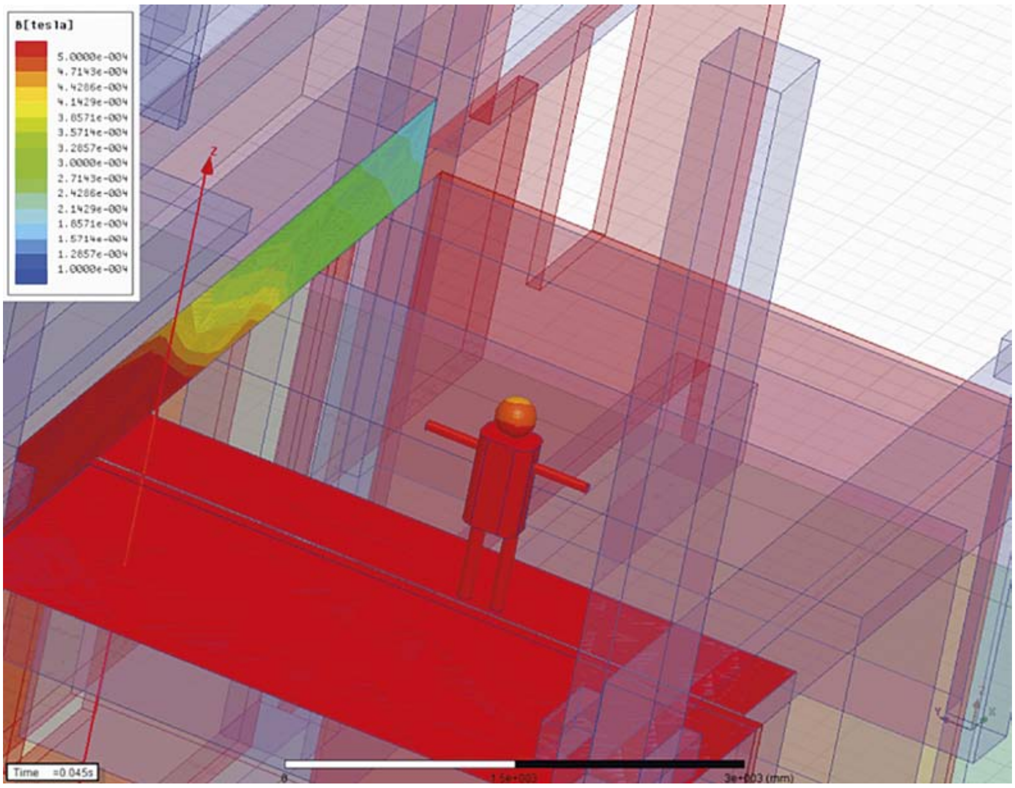

Computational Electromagnetics

– simulating the harmful effects of electromagnetic fields

The 2004/40/EC European Union Directive governs the minimum health and safety requirements with regards workers' exposure to electromagnetic fields. Overexposure to electromagnetic fields can have detrimental health effects and employers, as such, are responsible for taking preventative measures to protect workers in this regard. With the help of computational electromagnetics the exact interaction between electromagnetic fields and physical objects and the environment can be established. Making use of this technology not only ensures the health of workers, but can also reduce costs in the process.

Electric fields are caused by voltage differences and therefore powerful electric fields are often found in close proximity to high current power lines. Powerful magnetic fields, on the other hand, commonly occur near industrial transformers, welding devices or induction heaters.

According to the directive any electromagnetic field in excess of 500 micro Teslas (at 50Hz frequency) is a health risk. This is due to the fact that high voltage lines induce an electrical charge inside the human body while low frequency (below 50Hz) time-varying magnetic fields induce internal electromagnetic fields and circular currents. This can lead to internal warming of the body and result in several debilitating symptoms. High frequency dryers that use microwaves can cause warming on the body surface. Lower frequency waves penetrate deeper into the skin and cause more damage than higher frequency waves.

Employees with pacemakers are particularly vulnerable to electromagnetic radiation and should not be exposed to electromagnetic fields in excess of 100 micro Teslas. Low frequency magnetic fields are also known to interfere with the functioning of pacemakers and my lead to pacemaker malfunction.

It is worth noting that many apartment buildings are located near high power transmission lines, while workstations are sometimes also placed in close proximity to high power transformers. Humans that use those spaces are potentially placed at risk of overexposure to electromagnetic fields.

Overexposure can cause headaches, nausea, depression, hyperactivity and skin redness to name a few of the most common symptoms.

Employing shields to reduce exposure

The magnetic field caused by a transformer decreases considerably the further away one is from the transformer in question. When a human is close enough to the source of the electromagnetic radiation shields need to be employed to reduce the exposure to acceptable levels.

A common misconception is that concrete walls provide sufficient shielding, but this is simply not the case. In order to effectively reduce exposure levels, lead plates and grounded steel nets have to be employed. The dimensioning, positioning and material composition of shields have clear cost implications and this is where technical analysis tools come in handy to find optimal solutions.

Computational electromagnetics simulates exposure levels

Computational electromagnetics can be used to simulate the effects of electromagnetic fields and the effectiveness of shielding devices. It allows designers to define the optimal shield thickness, positioning and materials used by testing, for example, how transformers in different positions affect the surrounding environment.

The simulation provides the designer with a clear view of no-go areas for employees. This ensures that the shields employed are optimally proportioned not to take up unnecessary space, but sufficient to maintain exposure at safe levels.

In order for the simulation to be run the average power load and technical data of the transformer is required as well as the building dimensions and the materials that the transformer and building are made of.

Typical simulation takes a few days

The analysis can be conducted, for example, with the ANSYS Maxwell software package. The modelling for a typical site usually takes a few days depending on the size of the site, the number of transformers and how close together or far apart they are. The scope of the study naturally also affects the time required; are magnetic fields or electrical fields being studied or both, and are the shield positions and dimensions also covered etc?

The information gathered during simulation can be used by employers to remove or reduce health risks effectively and reduce costs by ensuring optimized installations.

A safer working environment and one that complies with the applicable EU directive reduces sick leave, work accidents and other harmful effects. The result is a win-win situation both for employer and employee.

Link to EU directive:

http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2004:184:0001:0009:EN:PDF

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Kari Haimi graduated as a graduate engineer from the Tampere University of Technology in 2013. He started working at Elomatic in 2012. His expertise area is technical analysis and he has particular know-how in the technical analysis of electromagnetic fields.

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Creativity and Method

– the cornerstones of success

When offering product and service solutions, many details need to be taken into consideration from customer needs and ideas to production and launch on the market. The core competence of product design and development needs to be supplemented by expertise in the strategic development of services and business operations. Motivated multi-industrial professional teams produce the best results. The will to create solutions that are sustainable and purposeful is of particular importance, while the time spent on and the risks associated with development must be minimised to create new space for new innovation. The innovative capacity of new products is what puts you ahead of your competitors.

Management and leadership of creativity and innovative capacity is the responsibility of business management, but every employee can play a part. Innovation can be defined as the organisation's ability to build new features that improve competitiveness (products, production processes, business ideas, services, etc.). This requires specific working methods.

The innovative capacity of an organisation is built on three foundations: **atmosphere** (a working culture that encourages innovation), **channels** (innovation process, team, etc.) and **guidance** (innovation direction). Real innovation refers to a new product or service that revolutionises the market.

Achieve the true value of innovative capacity

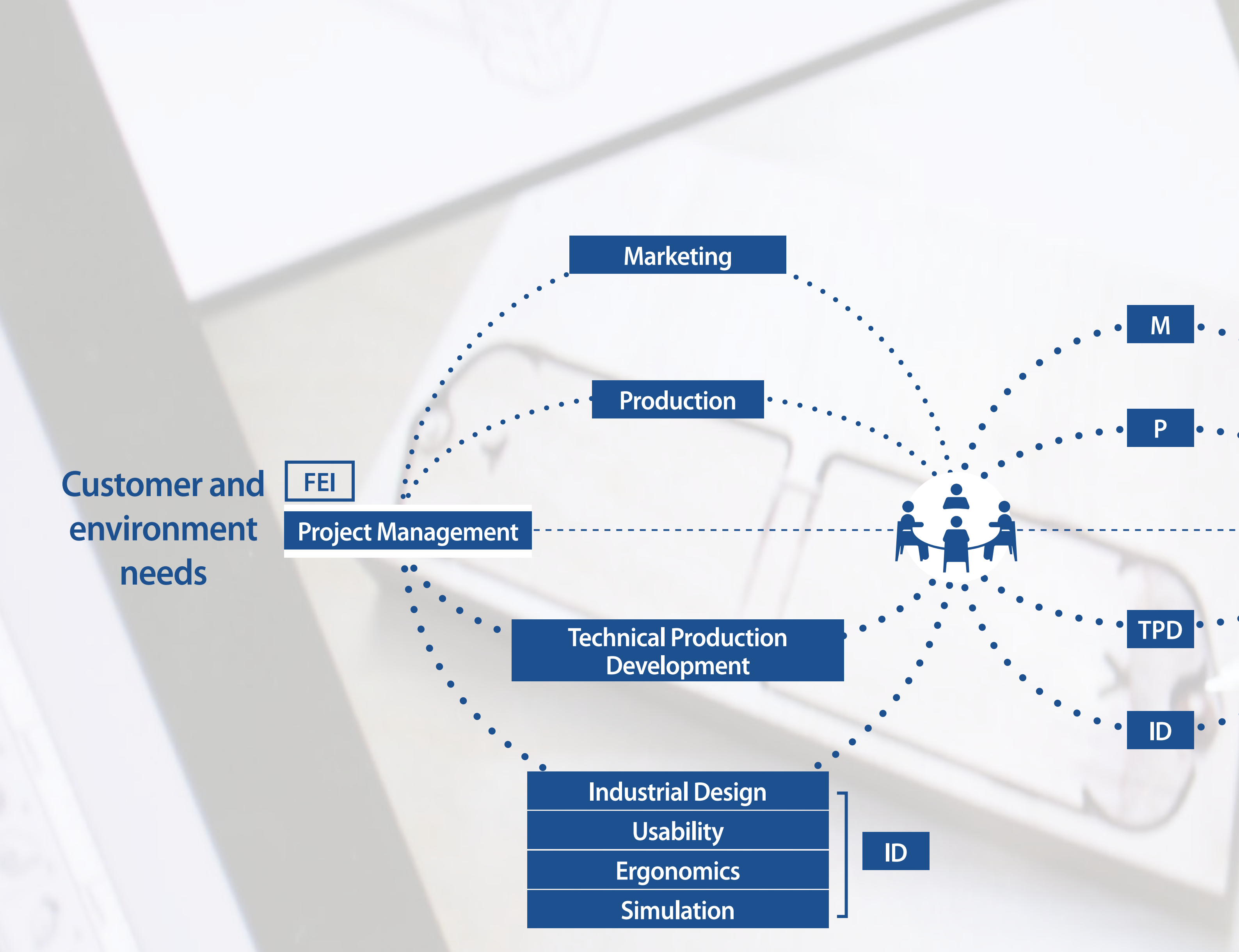
- By **rewarding** people or teams that have made improvements or produced something significant.
- By performing regular **measurements**. Measurement and analysis of results focus on a single point.
- By making the best representatives into **everyday heroes**. Creating hero tales and spreading them through internal communications channels is effective, but it is important to direct them correctly and equally. The management can also create value by keeping a topic continuously visible.

Creativity is a key factor in innovation and often the most crucial one. The core of innovation lies at the very beginning of the innovation process where numerous ideas must be generated. Selected ideas are turned into product development, strategies, new markets, production development and personal development.

Product features and usability are not created by themselves, but they need systematic action at the very first stages of product development. User-centred design provides product development with the means to build good product usability. As a result of good user-centred design, product development is more controlled. It results in end products that are more effective, pleasant and safer to use. At the same time, costs related to product launch and use are lowered. The further the product development progresses, the more expensive any product changes are as capital is tied to the product throughout the process. Usability is not just a topping that can be added to a finished product.

Product and user segmentation ensures that the visual appearance of the product is purposeful and well planned. The product appearance must communicate its purpose, method, environment and users in as much detail as possible. During a brainstorming session the idea is to come up with various design ideas and different technical solutions. As the process progresses, the most feasible ideas will be selected for further development.

The product concept or prototype already includes the new product's technical features and dimensions in relation to the product's appearance and usability. A well-designed product



is more attractive, desirable and more functional in terms of technology and ergonomics. Product graphics comprise a significant part of the finished appearance. They strengthen the product image by furnishing the designed product with the company's visual elements and brand. What is more, the purpose of product graphics is always to support and improve product usability.

Required: vision, strategy and diverse competence

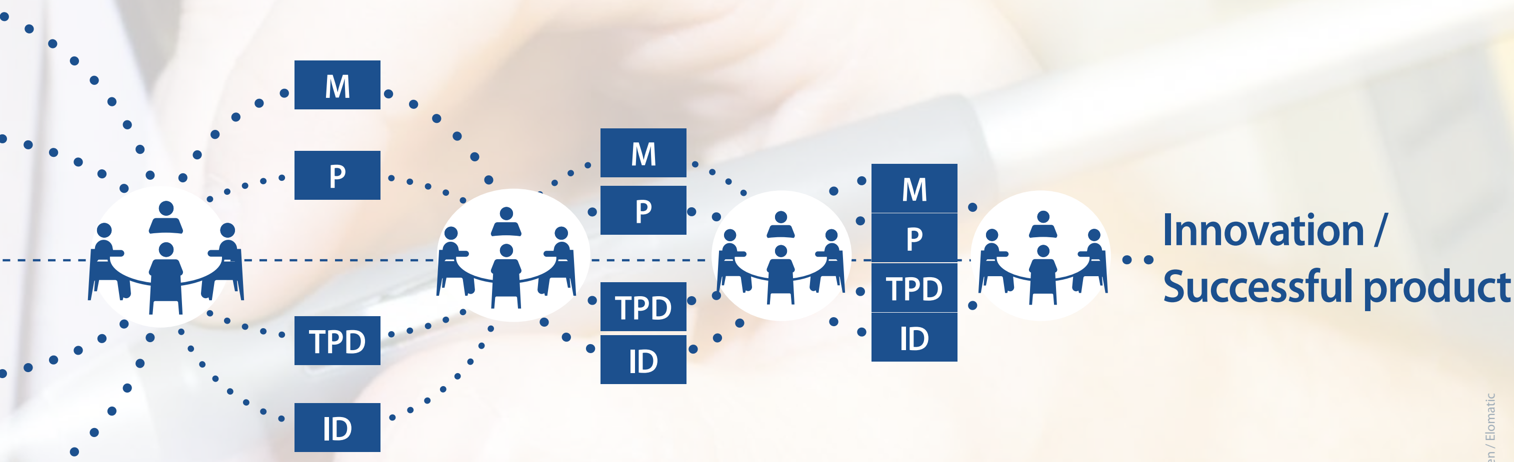
A creative base can be expanded by a large group of experts. Experts in mechanics, production, innovation, usability and strategy, industrial design, graphic design, programming, animation and application development form a productive group. By setting up innovation teams and committing experts to solving various customer problems and meeting expectations, true innovation can be created. This competence serves to produce results that secure the success and competitiveness of industrial plants, products and services. The ultimate goal is to provide people with solutions that are sustainable and practical.

Strategic planning usually focuses on offering solutions for critical operational success factors so that they can be implemented using controlled long-term and efficient means. Strategic work is often allocated to products, technologies, innovation and design. It is necessary and important to respond to strategic questions when looking for the correct path towards initial development and innovation processes. The objective is to recognise opportunities for innovation or business operations.

The birth of innovation and working based on systems and solutions

Innovation can be, or should be, carried out systematically in companies. The phase preceding product development, i.e. FEI (Front End of Innovation), can be modelled and systemized to form an excellent basis for a successful product development project. Innovation starts from a problem, and above all, the recognition of customer needs, which together form the true starting point for innovation.

"Innovation starts from a problem, and above all, the recognition of customer needs."



Process diagram design Niko Ihalainen / Elomatic

▲ *With the aid of diverse know-how the customer and the environment needs are processed into innovations and business growth*

We can successfully approach a development challenge through **systematic thinking**. We should seek answers to the following questions. What are we dealing with? What is the correct question to ask? What do we need to develop? We try to understand the customer, the user and the problem. We should perform functional analyses and product specifications.

When analysing successful innovation projects, one usually finds an underlying and well-recognised customer need and a well-defined problem, from which the process was initiated. Once the problem has been identified, it should first be investigated, analysed and reshaped – in more ways than one.

There are many ways to reshape the problem. When developing a new version of an existing product, it is important to analyse the good features of the product, looking at what works and what should be retained in the new version. Often, product problems are well-known, but good features may be forgotten and hidden under the surface.

A few leading guidelines related to the product development project offer responses to the previous questions. These may include user-centred surveys and technological research.

User-centred research provides understanding of the product or service users' world and any of their conscious and unconscious needs. Research methods offer a means to transfer an understanding of user needs, usability, ergonomics and design to the product or service.

Through **technological research** we can strengthen our understanding and increase know-how in order to analyse the functionality and performance of current products and production processes. Research serves to develop existing products and processes from a technological point of view, and to ensure that the objectives of ongoing development projects are met or even exceeded.

When developing a new product, it is useful to become familiar with similar products on the market and analyse their features as accurately as possible. Databases also offer many solution proposals and ideas that have never been put into practice. They may contain feasible ideas that should be analysed alongside our own ideas. This saves time and money compared to a

situation where all problems are verified in connection with the development project.

The starting point for all product and service development solutions is a deep understanding of customer needs, demands and their related functionalities. In addition, we need to understand how we can produce added value for end customers through customer products and services. This means considering how we can allocate our resources to offer solutions that maximise this added value in the entire product and service network. By following these main principles, we can deliver various solutions for different business challenges.

Introducing a refined idea to the rest of the world

A refined idea must be systematically polished into a concrete product or service. The process starts from initial questions that define objectives and the operating environment and mirror our ideas and goals with respect to the target group. It requires a large group of experts to solve and plan a successful outcome.

By asking and answering the right questions one can achieve much. Who is the customer? What are the customer's needs? What problem or need are we solving? How much is the customer ready to pay for the product or service? Where is the product or service available? Who are our competitors? What are the superior competitive factors of our product or service? Does our idea need protection? What kind of image should the product or service reflect?

If our resources run out, we should look for a reliable partner that can help us with the questions above. The partner may offer help in the productisation of ideas, products and services.

There are partners that are involved in product and service development from the very first ideas to the launch to the market. The advantage of such an arrangement is that the partners are

able to react thoroughly to various development needs with the help of their numerous experts.

Everything is based on product planning competence. Technical and engineering challenges are no strangers when it comes to product development.

By investing in **integrated product development**, results can be achieved through the simultaneous performance of different competence areas and project stages. The integrated development model often plays a key role when refining an idea into a market product or service, while keeping risks and costs effectively under control.

The design of concrete products and services is supplemented by focussing on the first phases in the development process. And that is where we play our role investigating, innovating and conceptualising the most important content solutions in order to achieve successful products and services. We refine products into services when they require control, guidance, maintenance or marketing. Our expertise produces the most benefits when we can solve challenges related to products and their surrounding services.

About the authors

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Timo Piirainen holds a Mechanical Engineering degree from the Wärtsilä Technical Acadamy from where he entered working life after graduation in 1985. He has gained diverse work experience in different positions in numerous product development projects over the years. His know-how also covers engineering method development, and current areas of involvement include a digitisation and future product development projects. Mr Piirainen joined Elomatic in 1995 and currently holds the position of Vice President, R&D Projects.

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Jet pump technology

for artificial lift in oil and gas production

The barren desert environment is as far removed from Finland as it could possibly be. One should nevertheless not be surprised if the jet pump technology and equipment used there to pump oil to the surface is provided by a company based in Pori on the west coast of Finland. Wellquip Ltd (WQ) has quietly made a name for itself in developing state-of-the-art oil and gas production equipment packages and software (FloWQ systems) and in supplying turnkey deliveries worldwide. Development of its own oil and gas surface and downhole equipment and technology began in 2004. In this article we highlight some of the development phases and technological advances of this remarkable journey into the unknown.

What makes WQ's specialisation in oil and gas technology even more surprising is that Finland does not have its own oil and gas reserves and consequently the culture in this area is very thin or non-existent. There are also no faculties at Finnish universities that offer studies in the field.

In 2004 WQ nevertheless took up the challenge and began studying feasible areas in oil and gas field development technology. Their efforts were focused on identifying future trends and related requirements. At the time the development team identified the need to produce wells with high paraffin, sand and gas content and the production of heavy oil as growing future needs in the FSU market.

According to Wellquip Managing Director, Sakari Oja, the surface equipment package has been under continuous development since they decided to enter the field in 2004.

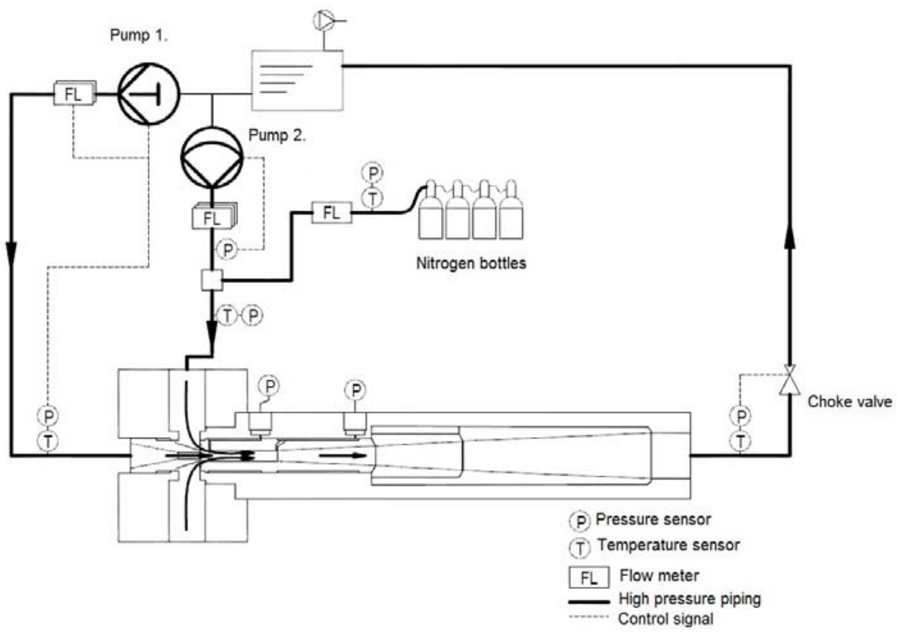
"In the beginning the equipment package was based mainly on foreign technology and both the analysis work to define the equipment configuration best suited for each well and the actual equipment was mainly contracted from the USA. We realised very soon that we needed to develop our own technology in order to gain a better understanding of related phenomena and to reduce the risks associated with dependence on external suppliers", explains Oja.

"We also needed to develop software to determine the optimal equipment configuration for each separate oil well. We cooperated with the Tampere Technical University to create our own software for this purpose."

Elomatic acquires share of Wellquip

In May 2014 Elomatic acquired a share of Wellquip Ltd after which Elomatic and Wellquip's Offshore operations were integrated. The company continues to operate under the Wellquip name. Wellquip provides offshore technology, oilfield solutions and services with a focus on major hydrocarbon production regions. It has strong experience oil and gas related activities in arctic offshore and demanding onshore climates. According to the agreement Elomatic has an option to acquire a majority share in the company during 2014.

▼ *Diagram 1. A schematic presentation of the testing package. Pump 1 (180 l/min 130 bar) produces the working fluid flow and pressure and Pump 2 (140 l/min 80 bar) the flow and reservoir pressure of the produced fluid. Both have suction from the water tank. Gas can be added to the produced fluid from the nitrogen bottle battery before reaching the jet pump.*



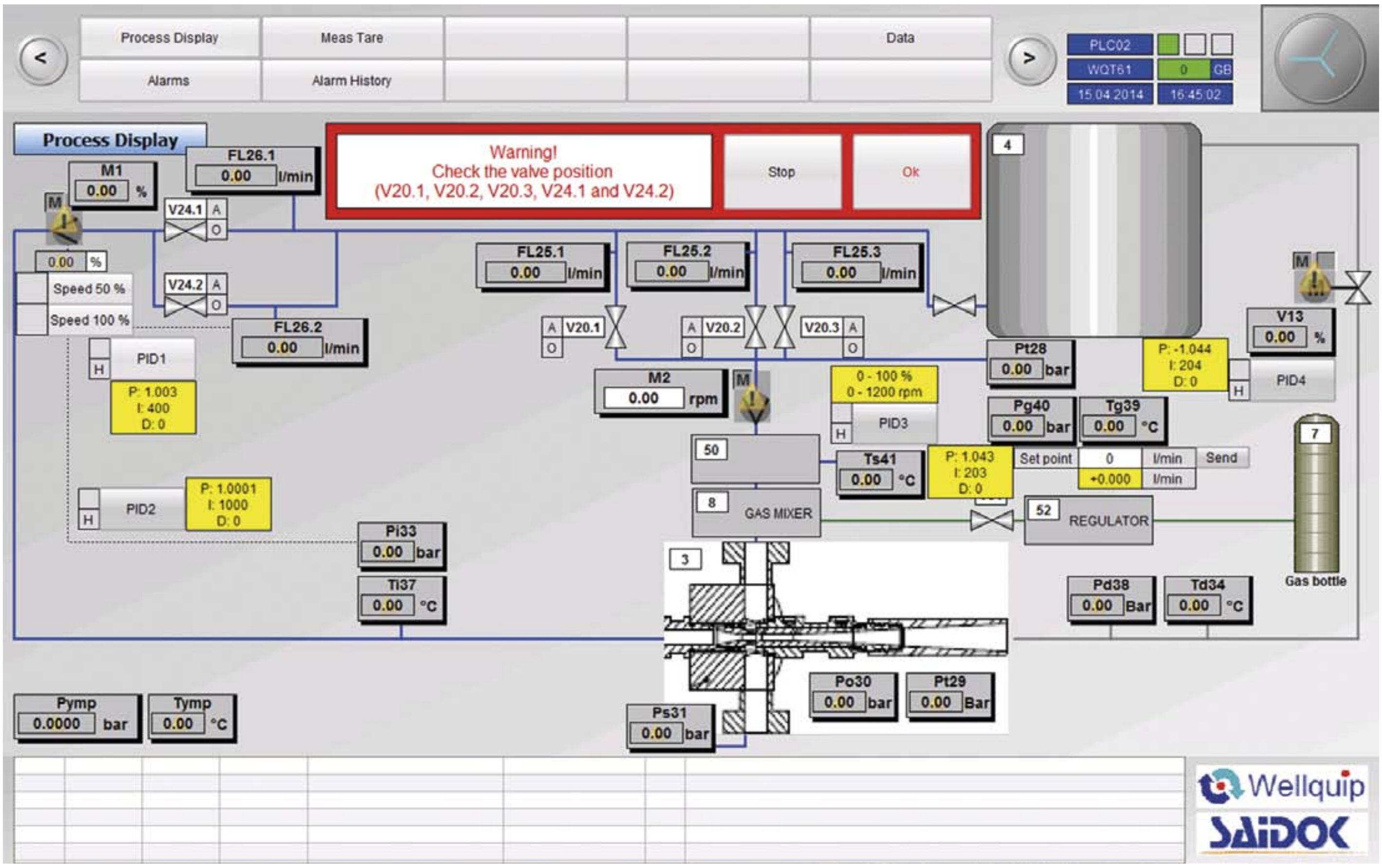
▲ *The WQ laboratory testing device used to simulate oil well features*

What is artificial lift and when is it required?

In oil production artificial lift is required when the natural pressure in the underground oil reservoir is not sufficient to push oil to the surface in a self-flowing system. Most oil wells require artificial lift, which is generally provided by a pumping mechanism. Beam pumps are the most common and constitute about 80% of all pumps used in artificial lift production. Jet pumps are worth noting as they have no moving parts, which again means an advantage concerning down-time in production.

How does a jet pump function?

In essence a jet pump is an ejector, located at the bottom of an oil well, modified for oil and gas production in order to ensure easy operation. It mainly consists of a nozzle, throat and diffusor. The working fluid from the surface is pumped through the nozzle, which creates suction for produced fluids. The working fluid and produced fluids are mixed in the throat after which the mixture continues through the diffusor to the surface. The nozzle/throat combination is crucial in determining jet pump performance. Each oil well needs to be analysed separately and finding the optimum nozzle/throat combination from the 150–200 possible standard and tailor-designed combinations with optimum equipment on the surface is a complex task. An extensive software package is required to make the necessary calculations.



Testing equipment to analyse hydrodynamic flow inside jet pump

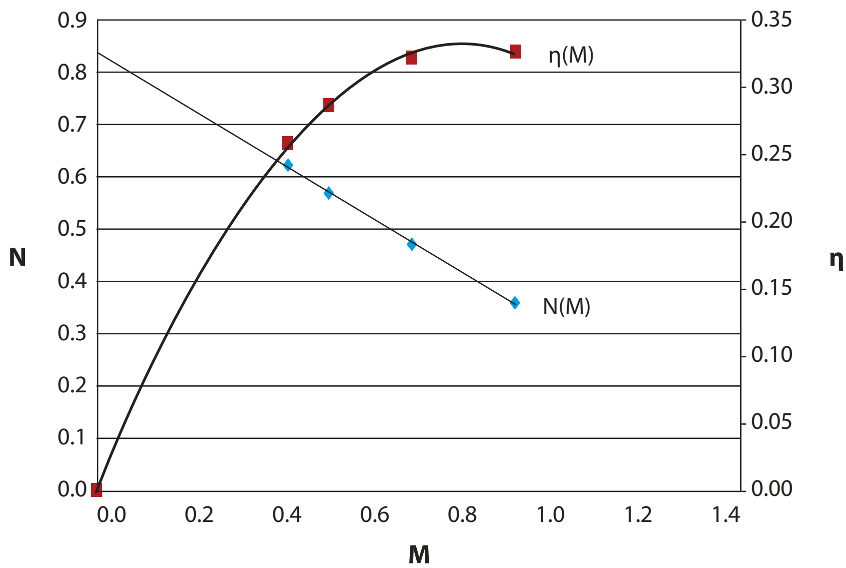
▲ *Diagram 2. The operator's process view*

In order to analyse the hydrodynamic flow inside a jet pump the pressure reduction factors at the nozzle, throat and diffusor for each nozzle/throat combination have to be determined. There are, however, a vast number of possible combinations and taking the required measurements is extremely time-consuming.

"For this reason we tried to identify dependencies between pump pressure reduction factors and other factors such as the nozzle/throat diameter ratio, spacing between the nozzle and throat, gas presence and Reynolds number etc. With the help of this information the software could automatically use the correct pressure reduction factors once the pump geometry and liquid properties were defined", Oja explains.

See diagram 1 for a detailed overview of the test equipment setup.

▼ *Diagram 3. The practical efficiency of the nozzle/throat combination as a function of M*



$$M = \frac{\text{produced fluid}}{\text{working fluid}}$$

η = Jet Pump's coefficient of efficiency

N = Pressure Ratio $\frac{p_d - p_s}{p_i - p_d}$, where

p_d = pressure after the pump,

p_i = pressure of liquid fed into pump

p_s = the pump's suction pressure

Sensor / Time	Fl 25,1	Fl 25,2	Fl 25,3	Fl 26,1	Fl 26,2	Pt 28	Pt 29	Po 30	Ps 31	Pi 33	Td 34	Ti 37
15:13:28	0	0	11,270	0	44,423	5,863	11,874	5,791	5,783	28,443	17,925	17,882
15:13:29	0	0	11,579	0	44,809	5,921	12,019	5,588	5,982	28,258	17,925	17,911
15:13:30	0	0	11,656	0	45,195	5,921	12,106	5,762	5,841	28,536	17,925	17,882
15:13:31	0	0	11,656	0	45,195	5,863	12,164	5,762	5,841	28,304	17,925	17,911
15:13:32	0	0	11,502	0	45,427	5,921	12,135	5,704	5,899	28,073	17,925	17,882
15:13:33	0	0	11,038	0	45,195	5,863	12,019	5,762	5,841	28,351	17,925	17,882
15:13:34	0	0	11,038	0	45,891	5,892	12,164	5,704	5,841	27,61	17,925	17,882
15:13:35	0	0	11,038	0	44,886	5,892	12,019	5,588	5,899	28,073	17,925	17,882
15:13:36	0	0	11,038	0	43,882	5,805	12,048	5,762	5,697	28,258	17,925	17,882
15:13:37	0	0	11,270	0	44,732	6,008	12,164	5,559	5,899	28,258	17,925	17,882
15:13:38	0	0	11,193	0	44,655	5,805	11,816	5,791	5,783	28,304	17,925	17,882

▲ *Table 1. An example of measurements taken (20.3.2012) from 12 sensors once a second. The location of sensors shown in Diagram 2.*

All the testing procedures were controlled with the operator's PC. The measurements taken from 18 measuring points every second were saved in the PC memory. See diagram 2 for the operators process view.

Overcoming challenges

Initially testing produced unexpected results while the automation system proved to be unstable. The cavitation plane had a few surprises in store for the testing team too. The work fluid discharge pressure showed variations despite the installation of pressure dampers. Over time the testing team's know-how and accuracy, however, increased until proper results were achieved.

"This is what engineering and research is all about. We had to figure out what to do and how to do it. We found solutions to all these challenges", Oja says proudly.

The immediate test result allowed a performance curve to be drawn for the nozzle/throat combination in question. The curve showed the practical efficiency of the nozzle/throat combination as a function of M. See diagram 3.

The next step included saving the measurements on the computer and manipulating them with a custom-made software program, which calculated all the necessary pressure reduction coefficients in the jet pump. An example of the measurements taken is displayed in Table 1.

Software developed to select optimal equipment configuration

While the measurements were being taken and results analysed the software to select the optimal subsurface and surface equipment was also developed.

"The program is ready now to be used as a practical tool and it has been tested in real conditions and the results are very encouraging. It contains many quality features such as vertical two-phase flow with gas compressibility and analyses of extreme conditions", says Oja.

"Actually of most value to us now is that we know exactly how the system works. The entire development process has provided us with a deeper overall understanding of oil production. Originally we thought that we would concentrate purely on pumping the fluids from the reservoir to the surface, but we noticed very quickly that the characteristics of the reservoir could not be ignored. Our clients are often interested in the special features of the reservoir, which now can be addressed and presented. We now have a better understanding of parameter influence on the system efficiency and economy. The program has been loaded onto our server and is ready for use by our clients", Oja concludes.

Text: Martin Brink

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CONSULTING & ENGINEERING

Scientia vires est

At Elomatic we believe that our human capital is our most precious asset. With knowledge comes the power to shape the future.

We continuously develop our employees' know-how and strive to be leaders in our respective technical fields. We focus on packaging and delivering this know-how to ensure that our customers stay ahead of their competition.

The Top Engineer magazine offers our experts the opportunity to share their expertise and knowledge and to engage other technical experts with their writing. It is a publication by engineers, for engineers, and other technically-minded readers.

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Elomatic and Wellquip merge offshore business operations

– Joint venture company aims for growth in Arctic market

In May 2014 Elomatic acquired a share of technology firm Wellquip Ltd. As a result of combining their business operations an internationally significant player in the offshore business has been formed in Finland. The company's core knowhow is offshore and oil and gas production solutions and it aims in particular to achieve growth in the arctic marine business in the Russian and Caspian Sea markets.

Wellquip provides offshore technology and oilfield solutions and services. The company has extensive experience of the Russian and Central Asian markets.

Elomatic and Wellquip have in recent years cooperated actively in different business areas. They have, among others, founded a joint venture company, Caspian Offshore Solutions, in Astrakhan Russia with a Russian partner. Elomatic and Wellquip are also currently undertaking a joint engineering project for a Caspian Sea jackup vessel.

According to the agreement Elomatic will initially acquire a significant minority share. Elomatic has the option to acquire a majority share in Wellquip during 2014.

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