4.1.3 A description of the main S&T results/foregrounds

WP1- Cost engineering and qualifications testing

Task 1.1 - Specify end–user process plant operating requirements

The pre-demonstration and second optimised demonstration took place on several different plant modules within the same production area of the Carlsberg Brewery in Fredericia, Denmark.

Plant operating requirements, system layout, valve types and the control system interface were different for each demonstration and required frequent meetings and communications between the partners and Carlsberg.

The pre-demonstration involved retro-fitting the Hydract actuator to three different types of valve while using the existing control top, and so relied heavily on detailed valve information. The layout of the system was important as the hydraulic power unit was centralised and connected to the distributed actuators via flexible hoses running in overhead trunking. The actuator design had to be capable of meeting the varied requirements of the four plant locations; GT 1, Rest beer, CIP 3, Urte matrix.

The choice of site for the main demonstration was not taken lightly and involved several meetings with the partners and the brewery spanning a period of around a year. The site had to be challenging enough to prove the full potential of the technology, but also had to be within the original budget and timescales of the project.

Carlsberg proposed a complete replacement of the main CIP modules in the brewery with Hydract water hydraulic actuator systems. This showed great confidence in the technology, but would have been impossible to do within the limitations of the present project. After much negotiating it was agreed that the project could stretch to replacing the main CIP module 'CIP-2', and that even this would be a challenge to complete by the project end date of 31stMay, 2013.

The main demonstration equipment was to be long-term and as such required considerable planning to fit within the existing plant and to conform to Carlsberg's requirements for new plant. The full specification for the system was drawn up from meetings and communications at different levels within Carlsberg from the Production Manager, Automations Manager, Senior Project Managers, Engineers, and Technicians.

Task 1.2 - Cost and design engineering on actuator and hydraulic system

The cost engineering work for the actuator and hydraulic system for the pre-demonstration was limited by the short time available for implementation of improvements prior to the trials that had to be completed before Brau Beviale 2011. The evaluation of the pre-demonstration showed a real benefit of making further production orientated modifications, such as integrated control valves, cheaper hoses and simplified actuator construction.

Integrated miniature control valves were by far the biggest change to the actuator between the pre-demonstration and main demonstration. VP investigated the options for miniature control valves and concluded that a packed spool valve showed the highest potential of meeting the aims of the Hydract product. GFD worked closely with VP on this approach as it required bespoke seals to be made as there were no commercially available seals in the required size range. GFD also designed and manufactured test rigs to measure the static and dynamic leakage of the actuator seals. Their work was focused on manufacturing low friction/low leakage seals that are crucial to the success of the new control valves.

By integrating the control valves into the actuator body the number of hoses could be reduced from 6 to 2 per actuator in the fully hydraulic double-seat configuration. By using a dedicated pressure and return line to the actuator only the pressure line needed to be of a high pressure rating, while the return line could be a much cheaper plastic hose.
Commercially available stepper motors have been used to operate the spools in the control valve, and although they are not necessarily expensive, there appears to be little room to further reduce the cost of these components.
The spools themselves were expensive to make at a prototype stage, but several dedicated plastic component manufactures were sourced in the UK who supplied them at an acceptable price in large quantities.

The control valve bodies are the most complex and expensive part of the actuator and have undergone several design changes throughout the project. Early designs had to be machined form aluminium to meet the deadline of the 2012 Brau Beviale Exhibition in Germany, but this was not a practical solution in the long term. Later designs were made from stainless steel with long/small bore drillings and require relatively expensive flow machining followed by plugging of the exposed passages. Although the control valve bodies have proven to be expensive to manufacture to date they have driven down the overall cost of the system. We have several ideas that will hopefully reduce the cost of manufacturing the units in the future without compromising the performance.

Time constraints and tooling costs did not allowed the previous actuators to utilise the benefits of deep drawn parts. KM and VP have spent considerable time designing and cost engineering the main actuator, and it does not easily lend itself to deep drawing. When all aspects are taken into consideration using production thick-walled tubing and laser or friction welding of the cylinder flange has proven to be the best option.
One reason for using thick-walled tubing is the benefit of running fluid passages along the cylinder wall, which in turn means that the cylinder is relatively thick for deep drawing. Not only does the design look much cleaner when the passages are hidden, but it also saves the cost of tubing, fittings and assembly.
As with many cost savings in manufacturing there is an initial capital cost associated with the equipment. This has been the case with gun drilling, roller burnishing, right-angled drilling and flow machining and has meant that some of these operations have been outsourced. These

techniques have all helped to reduce the cost of manufacturing the actuator and will become more cost effective as production numbers increase.

The actuator design for the main demonstration attempted to reduce the number of internal component parts as much as possible while making them suitable for manufacture by traditional turning machines. Being able to turn and roller burnish on the same machine saved setting time. The use of a telescopic piston for the lower seat made the design compact, as did a pressure feed through the main cylinder rod.
Although engineering plastics have been considered for the main actuator components, there use has been confined to the control valve spools at present as there has been insufficient time to properly test and validate other uses.

Task 1.3 - Cost engineering on remote control system for production actuators

Task leader NS were responsible for identifying the benefits and cost savings associated with using RFBT (radio frequency based technology) as an alternative to the present hard-wired communications systems. NS designed and built critical modules of the system to check that they perform as required and would indeed lead to overall cost savings.

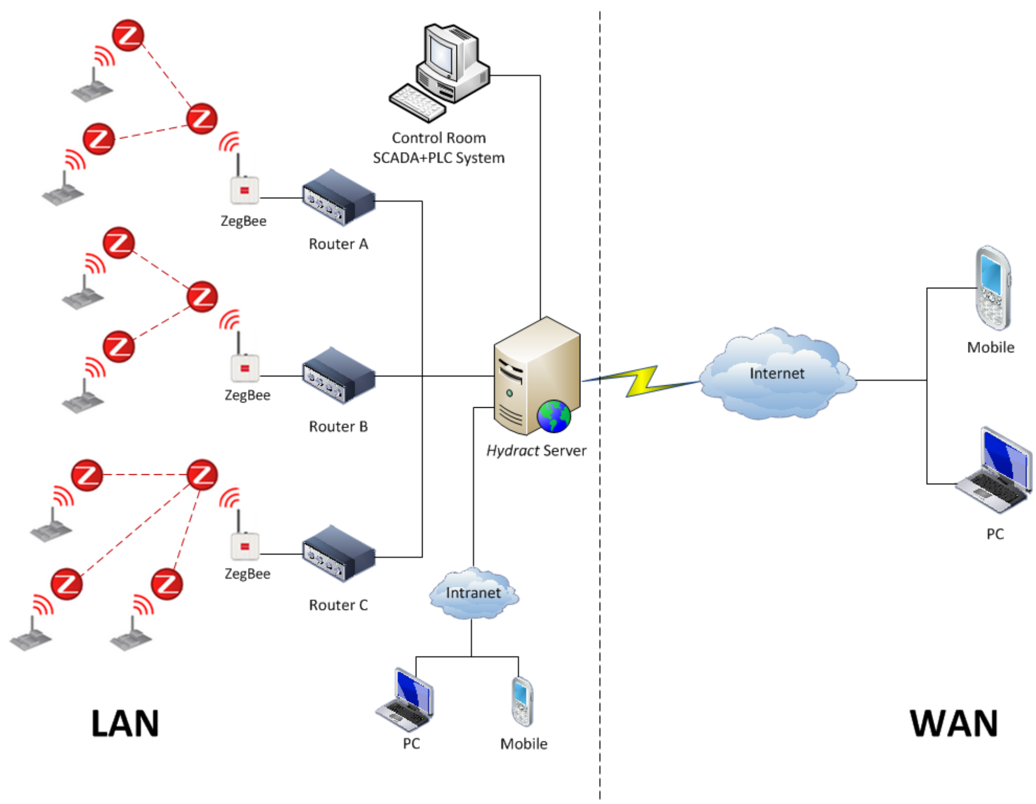


Figure 1. HYDRACT architecture overview

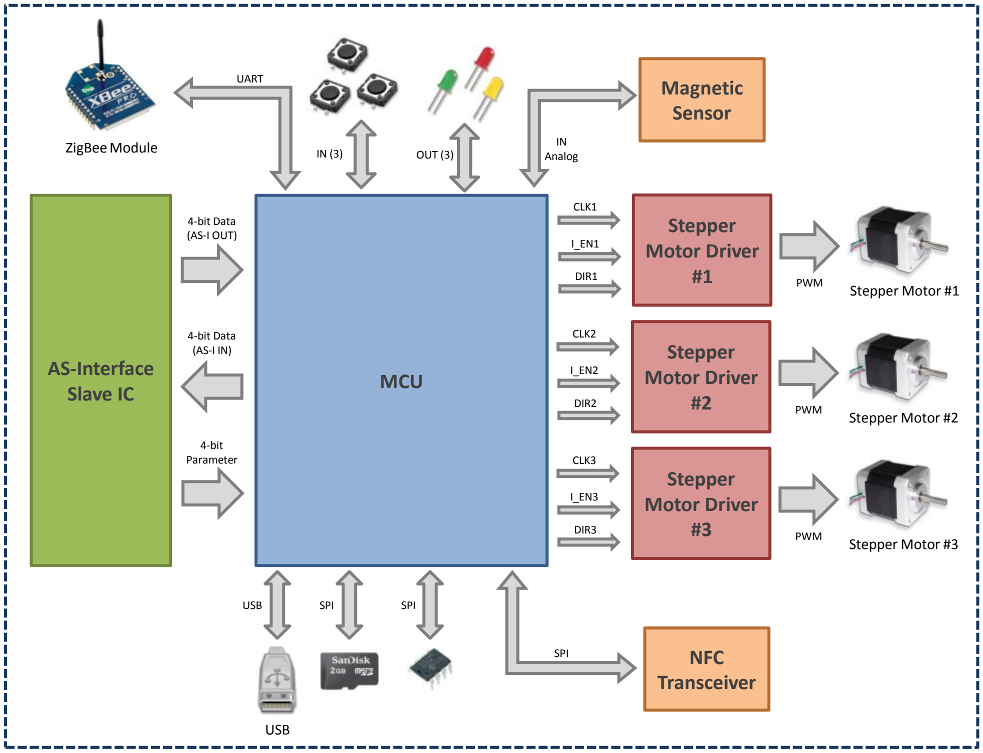


Figure 2. Block diagram of control system

The overall cost savings of wireless communication systems are not confined to the elimination of hard wiring but are significant in reduced time associated with planning/design and installation. The added benefit of flexibility should also not go unmentioned as it is much easier to make changes and additions to the communication network as required.

Task 1.4 – Development of pre-demonstration unit

Ten pre-demonstration actuators were built for three different manufacture double-seat valves. The actuators were of a modular design and featured similar internal components for a fully hydraulic main stroke and spring return on the upper and lower seat lift functions (figure 3).
A completely new control valve module was also built with 30 solenoid operated plate valves on 10 manifolds and the necessary power supply/relays/hoses and wiring to communicate with the plant controller through the actuator interface. The new control valves were a considerable improvement on the valves used in the original HYDRACT project, but were too large to be mounted on the actuator and relatively expensive (figure 4).

Figure 3. Pre-demonstration Südmo actuators

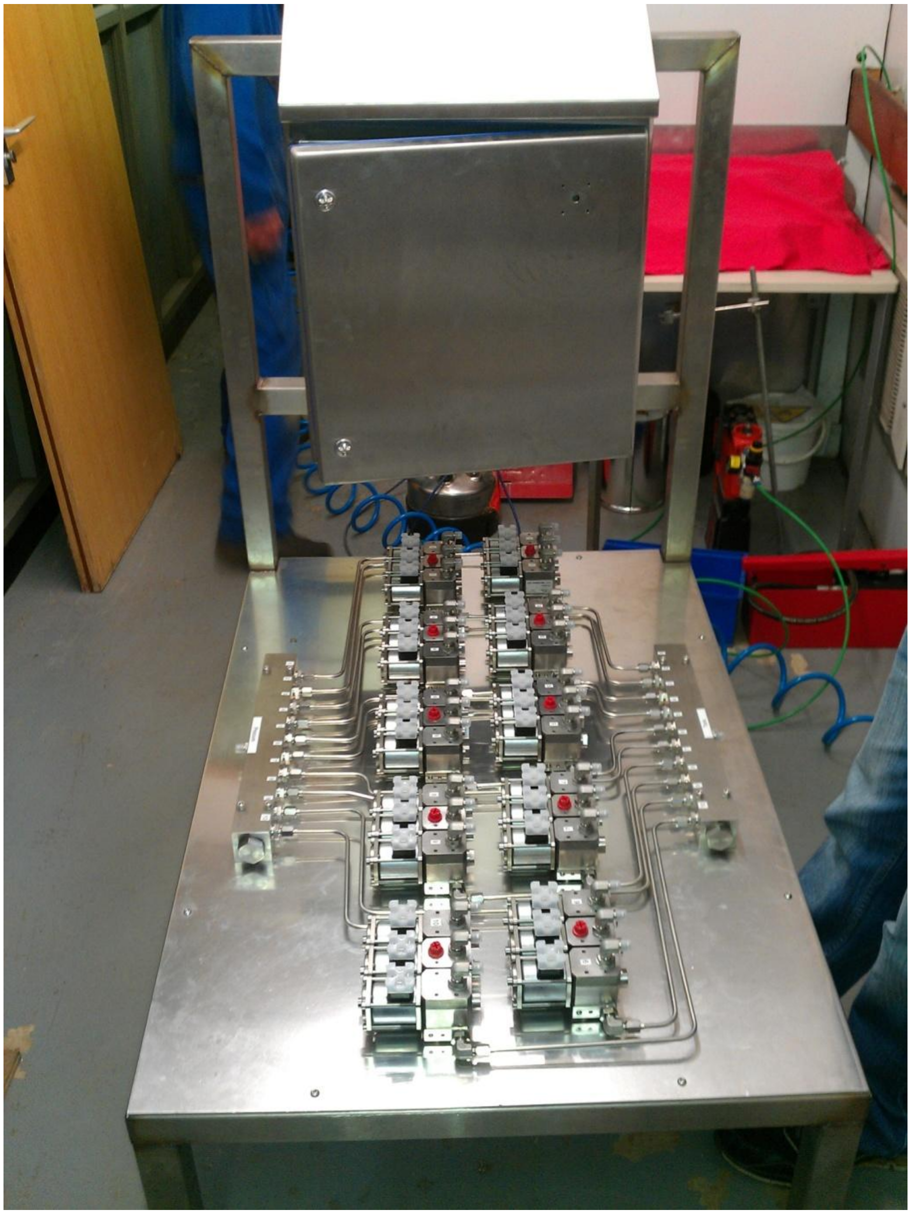


Figure 4. Hydraulic control valve module

Experiences with the pre-demonstration system lead to major redesign of the water hydraulic actuator and further design improvements to the hydraulic system.

Task 1.5 – Qualification testing of pre-demonstration actuator prior to demonstration test

The pre-demonstration actuators were individually pressure and functionality tested prior to integration into the complete hydraulic network for laboratory testing. The generic design was also subject to flow/pressure drop testing on a flow loop using proportional control valves to obtain useful operating data that can be used in dissemination activities.

The laboratory testing program was sufficient to prove the site worthiness of the system ahead of the pre-demonstration, but had to be extended to full qualification tests for the main demonstration units.

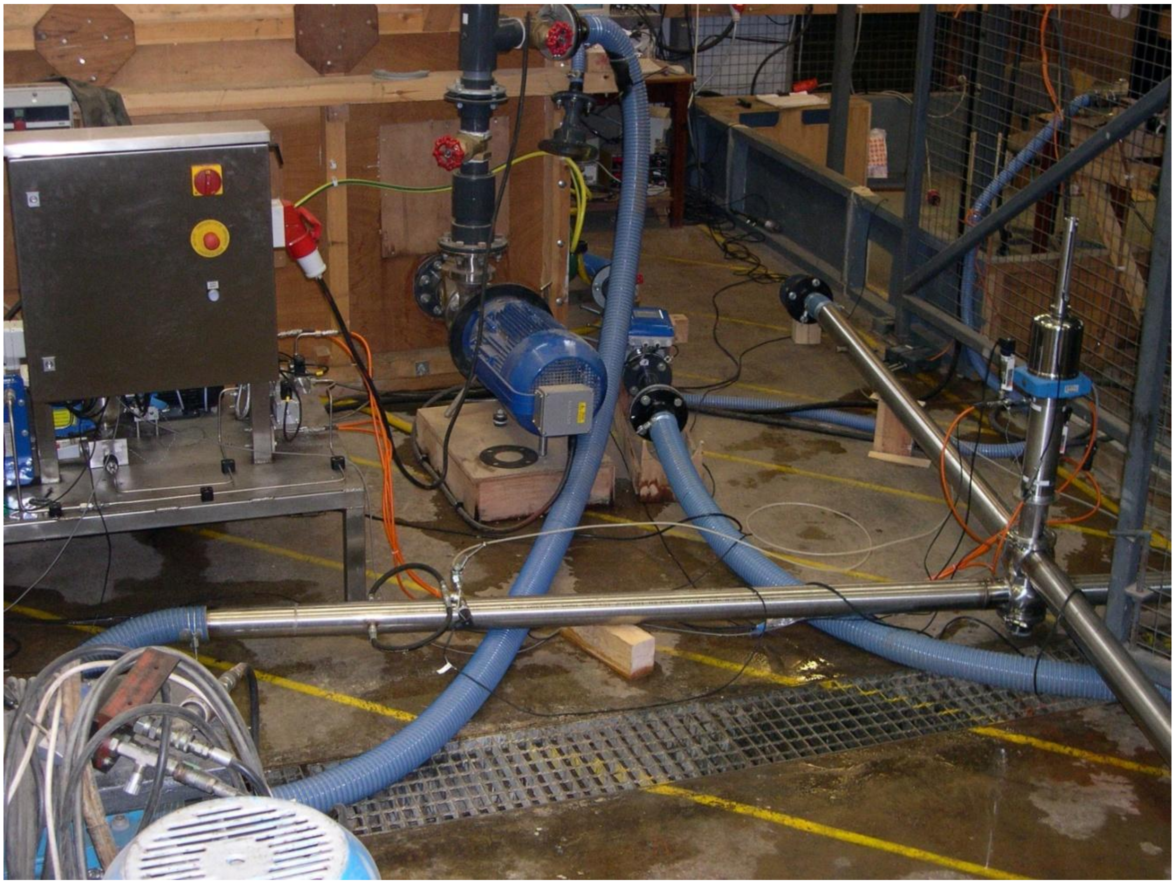


Figure 5. Flow loop used for qualification testing of actuator

Task 1.6 – Evaluation of qualification testing

Qualification testing ensured that the pre-demonstration equipment would be fit for purpose in the following site trials and would meet the general functional requirements.

Pre-demonstration laboratory tests were generally successful but did reveal some problems with the adapters used between the hydraulic actuator and different valve models. The adaptors were either modified or new parts made to solve the problems, and these modifications were retested prior to dispatch to site.

Problems were also experienced with the return on the upper and lower seat functions, specifically a slow operation. This was traced to a number of factors and it was only possible to produce a partial solution for the pre-demonstration trials. As a result of this it is proposed that all the actuator functions for the full demonstration are fully hydraulic, with no return spring inside the main actuator body.

WP2 – Up-scaling of hydraulic actuators for testing in situ

Task 2.1 – Manufacture of 50-actuators for in situ demonstration

The Hydractdem actuators were designed to be a direct retrofit to the Südmo D630 DN 80 valves installed within the brewery in April 2013 and provided mix-proof security by fully hydraulic means. The outline design is shown in figure 6 and is discussed in detail in the D2.1 manufacturing report.

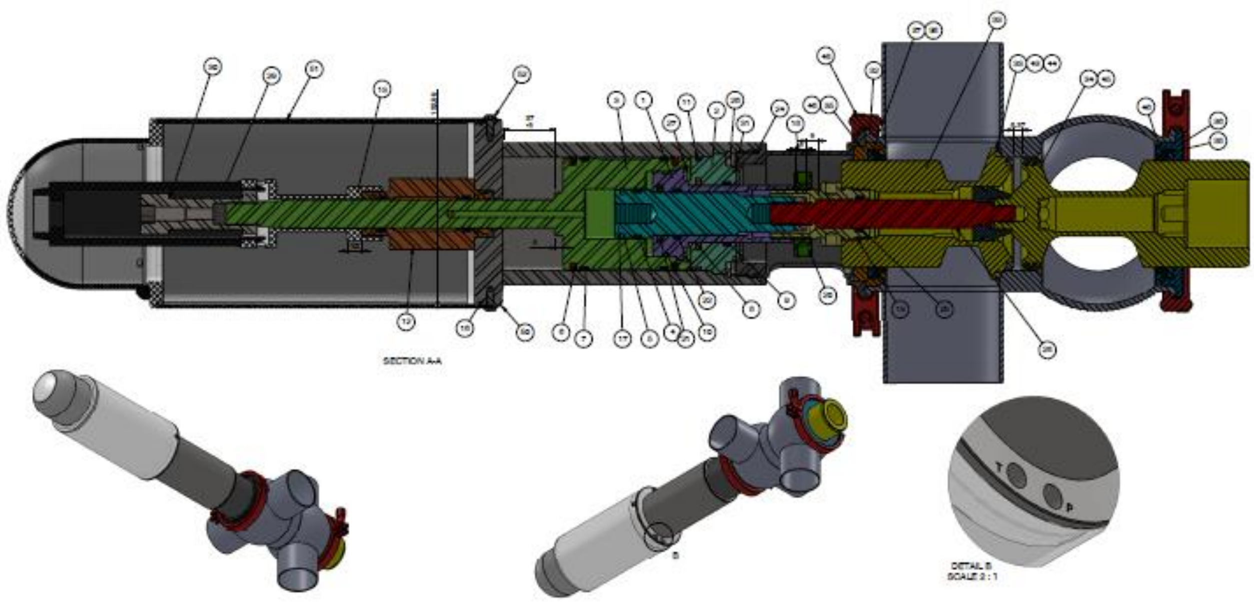


Figure 6. Outline design of demonstration water hydraulic actuator

KM Rustfri were responsible for manufacturing the majority of the actuator components in Denmark, but also subcontracted some of the machining out to Germany. KM also sourced the main actuator seals through Trelleborg's Danish distributor while GFD supplied the seals for the control valve spools. Pentair Südmo supplied all the process valve components as well as some 'Intellitop' components such as the position sensor, target and domed plastic cover.

VirtualPiE supplied the stepper motors and spools for the control valves and assembled/tested the complete actuators both in the UK, Germany and at Carlsberg in Denmark.

Figure 7. Actuator factory acceptance testing at VirtualPiE

Pressure impulse fatigue testing of the main body of the actuator was required as part of the qualification testing of the actuator and was done in general accordance with BS ISO 10771-1:2002.

The test was performed using the fatigue testing facility at VirtualPiE that is regularly used to test aerospace and automotive components and adopted a trapezoidal pressure cycle as shown in figure 8. The test unit was cycled for 500,000 cycles with no visible leaks or mechanical failure.

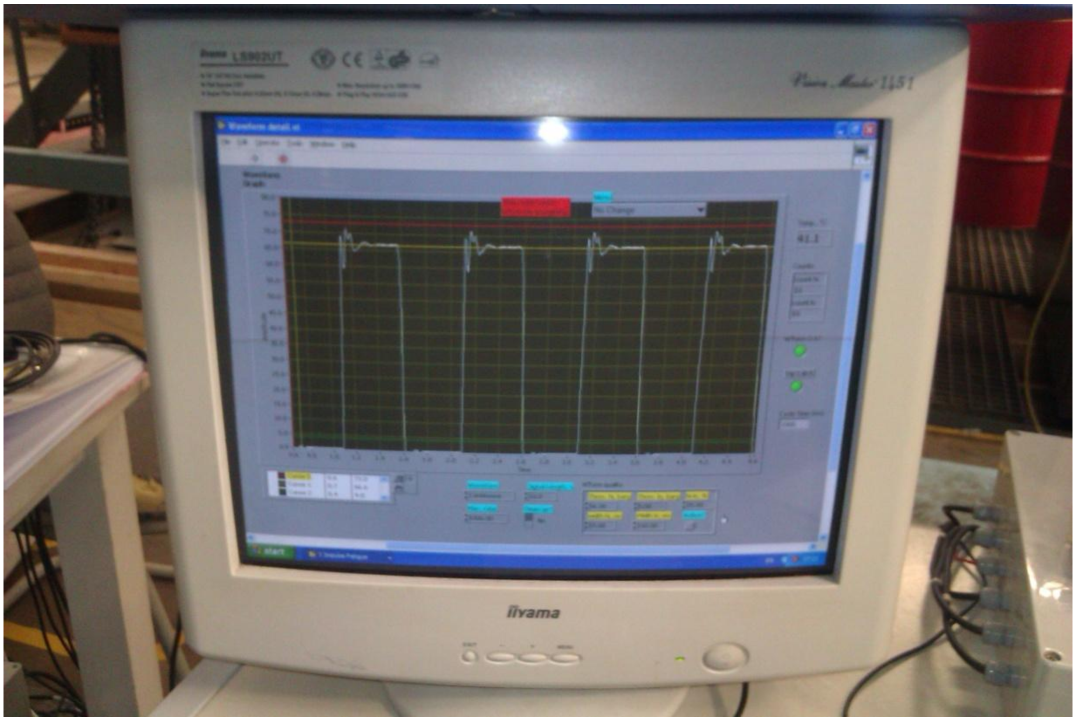


Figure 8. Impulse pressure waveform used in actuator fatigue test

The first ‘production’ actuator was taken to Pentair Südmo in Riesbürg, Germany for endurance testing on their 10 bar steam rig. VirtualPiE installed and commissioned the actuator system using a water hydraulic power unit and data acquisition system from previous Hydract trials. Figure 9 shows the actuator undergoing endurance tests at Pentair Südmo.

Figure 9. Hydractdem actuator on test at Pentair Südmo

The endurance tests at Südmo ran continuously for a period of three weeks over a range of operating conditions from water at 10 bar to steam at 120ºC. The main actuator was trouble free except for an o-ring leak at high temperatures due a material selection issue at this extreme duty.

The control valves operated reliably, but would occasionally drip water because they could not be roller burnished in time for the trials. This would be resolved in time for the full production run of 40 valve bodies.

It was intended to build 40-actuators for project, 1 for fatigue testing, 1 for endurance testing, 19 for the forward matrix of CIP 2, 15 for the return matrix of CIP 2 and the rest as spares. VP assembled 37 main actuators in total, but had quality issues regarding the valve bodies. A simple machining error on the valve bodies existed in approximately half the units supplied, and only sufficient numbers were usable for the forward valve matrix alone.

Task 2.2 – Manufacture of up-scaled remote controlling system for actuators

Linear Position Measurement

Based on the findings of the Hydract project the following solution was adopted for the linear position measurement of the piston position of hydraulic actuator. Following sketch provides a simple vision of this option:

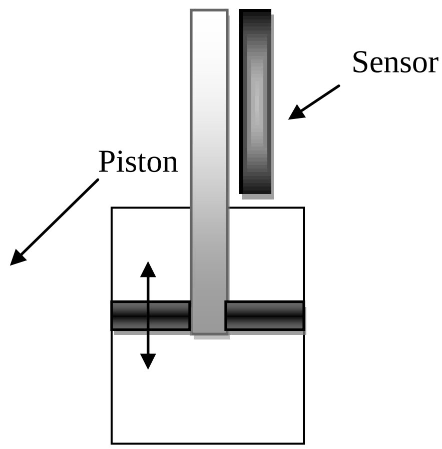


Figure 10. Method with external shaft contactless measurement

This method requires and external shaft with the known mechanical disadvantages, using this option several sensing techniques could be used; using a contactless sensor with a magnet attached to moving part (shaft), enough precision can be achieved for the purpose of controlling the position of the sensor if desired.

Control Parameters, Operating environment, Specification and Test program

Taking into consideration new concept for valve, actuators (solenoids) are now located on the valve head, i.e., the electronics on top of valves are responsible for direct actuation of solenoids. In opposition to what was developed in Hydract project, the electronics sitting on top of the valve are now responsible for driving of actuators, sensing, control and communication together with electronics for powering this system. Due to high power consumption of solenoids, the each valve head must be wired for by power and all the communications are carried out wirelessly.

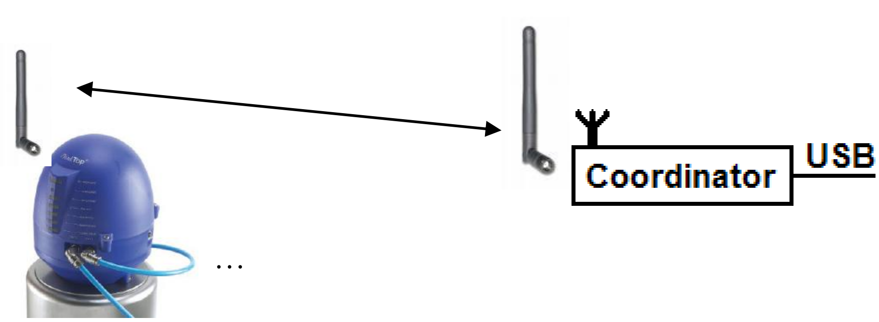


Figure 11. Gateway Ethernet Interface

Inputs
There are several inputs, analog and/or digital signals that need to be acquired by both units
The most relevant inputs that have been identified so far are:

- Monitor voltage
- Monitor piston position using sensing methods previously discussed to find out if valve is open or closed with accuracy in the range of tenths of millimeters.
- Measure time of fly of valve switching
- Monitor tamper input
- 2 push buttons for setup, remote actuation…

Outputs
The are several outputs that need to be driven by both units, on top of valve and remote unit (actuator)
We must also be able to present some information to the user, like the state of the valve, the need for maintenance, the need to replace the battery and maybe other important information.

- Leds indicators: Signal Strenght, Valve Position, Low Power, RF jamming or Radio communication problems
- Solenoids for hydraulic fluid controlActuator
- Any standard digital outputs for external connections with other devices

Communication

The communication methods must be based on a RF based technology in order to lower installation costs and simplify installation.
This technology must have some important requirements, for example:

- Minimize the installation costs by reducing the signal strengtheners (repeaters) to a minimum and at the same time establish a robust network able to operate in industrial environment;
- Have low energy consumption;
- The transmission bandwidth is not an important aspect to have in consideration when choosing the technology since this kind of application needs a very low data-rate.
- The network must be able to recover from interferences. This can be achieved using some modern techniques like channel hopping and good error handling algorithms implemented already in several standard protocols;

Thanks to the knowledge acquired in Hydract project, Zigbee based transceivers were selected to implement all the tasks related with communications, monitoring, supervision, installation and commissioning of system.

What is ZigBee?

ZigBee is a specification based on the IEEE 802.15.4 standard for wireless personal area networks (WPANs). ZigBee operates in the ISM radio bands and its focus is to define a general-purpose, inexpensive, self-organizing, mesh network that can be used for industrial control, embedded sensing, medical data collection, smoke and intruder warning, building automation, home automation, and domotics, etc. There are three different types of ZigBee devices in a ZigBee network:

Coordinator (Master): Only one coordinator exists in each ZigBee network. Its function is to store information about the network and determine the optimum transmission path between each point.
Full function device (Router, Repeater): Routers act as an intermediate repeater that passes data from other devices.
Reduced Function Device (End Device): This device contains a minimal amount of functionality to enable it to talk to its parent node (either the coordinator or a router); it cannot relay data from other devices.

There are three topologies defined in the IEEE 802.15.4: standard, Star, Cluster Tree and Mesh.

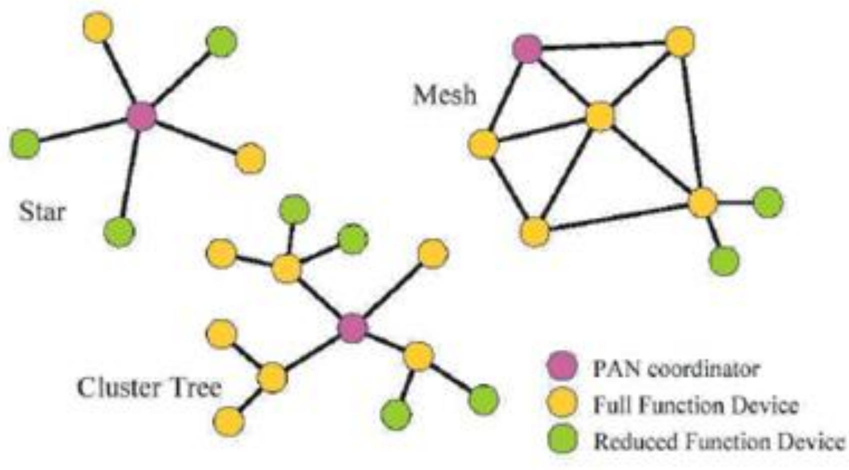


Figure 12. Star, cluster tree and mesh topologies

ZigBee uses a basic master-slave configuration that is suited to the static star networks of many infrequently used devices that talk via small data packets. Up to 254 nodes are allowed.

ZigBee VS Bluetooth

While ZigBee is focused on control and automation, Bluetooth is focused on connectivity between laptops, PDA’s, and the like, as well as more general cable replacement. ZigBee uses low data rate and a low power consumption, and works with small packet devices; Bluetooth uses a higher data rate and a higher power consumption, and works with large packet devices.

Compared to Bluetooth, ZigBee networks can support a larger number of devices and allows a longer range between devices.

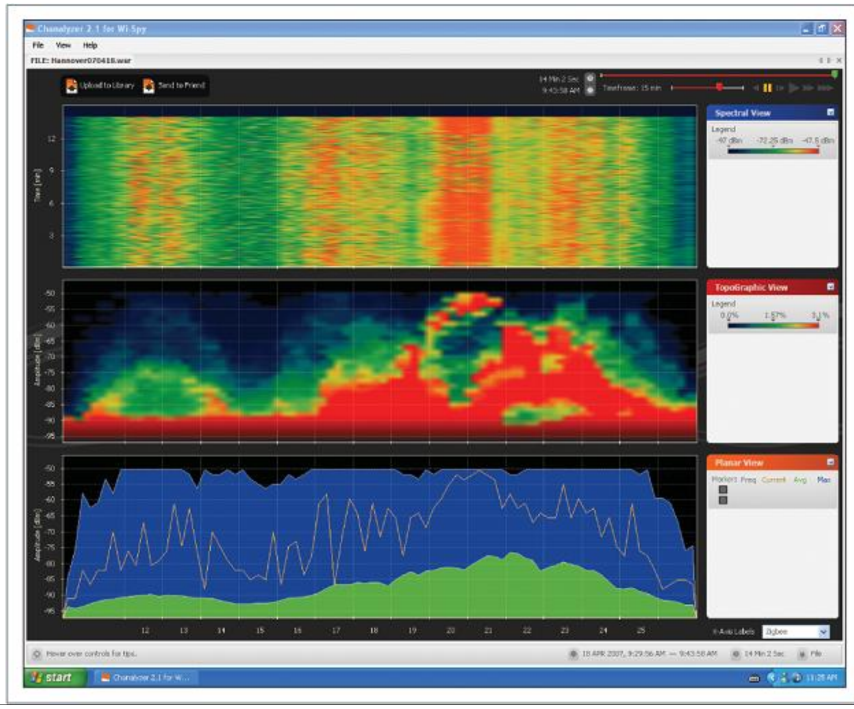
ZigBee VS SST-2450

SST-2450 is used for long distance wireless applications (the maximum is 20Km), and is suitable for simple half-duplex networks. ZigBee supports various network topologies, such as star, cluster tree and mesh. It also supports repeater functionality in redundancy systems.

RF protocol selection

The protocol than suits more the needs of the Hydract project are radio devices based on the ZigBee protocol, actually there are not any other robust, low power, secure protocols available in the market. Despite being a recent protocol there are already some industrial manufacturers adopting this technology which is reassuring for Hydract project.
ZigBee is a low-cost, low-power, wireless mesh networking standard based on the IEEE 802.15.4-2006 standard for wireless personal area networks (WPANs). The low cost allows the technology to be widely deployed in wireless control and monitoring applications, the low power-usage allows longer life with smaller batteries, and the mesh networking provides high reliability and larger range for the network.
The 802.15.4 protocol increases the opportunity for coexistence of several RF signals by employing a technique, generally known as frequency division multiple access (FDMA). This simply means that the standard divides the 2.4GHz ISM band into 16 non-overlapping channels, which are 5 MHz apart from each other. At least two of these channels, specifically the channels 15 and 20, fall between the often-used and non-overlapping 802.11 channels 1, 6 and 11.
This condition makes the protocol sufficiently robust to operate with interference since it uses the channels with less interference.
Many of the intended applications for ZigBee devices require a very low data rate. The obvious example is actuating a valve where it should not take much more than a single byte, to communicate the intention that a valve should be turned on or off.
Although the ZigBee is intended to operate with low data-rates, such as 9.6Kbps, the designers of the IEEE 802.15.4, have chosen the relatively high data rate of 250Kbps. The reasoning here is that one of the best ways to promote coexistence is to reduce channel occupancy. Clearly, a radio with a high data rate will occupy the channel far less and offer fewer opportunities for collision with other users than one with a lower data rate.

ZigBee performance for the network situated on ZigBee channel 17 was measured with the Daintree Sensor Network Analyzer (http://www.daintree.net/). The results are summarized in the figure below.



ZigBee Performance			
Total Tx packets	Total Lost Packets	Average Latency (ms)	Maximum Latency (ms)
25676	555	4.42	874.83

Figure 13. ZigBee Performance

It is important to note that all of these figures are measured at the ZigBee network layer and that the modest 2% packet loss rate at the NWK layer results in an effective loss rate of 0% if application retries are also employed .

Operating Environment

The equipment will have to withstand the standard industrial temperature range (-40°C to +85°C) and up to 85% of non-condensing humidity.
The circuit boards must be filled with silicon to provide isolation against the high humidity of the site.
The RF signal interference and distortion will also be significant, but this problem will be minimized by the mesh topology of the network and the possibility of placing signal strengtheners (repeaters) along the site.

Test Program

During development of control system, several software tools were developed in order to confirm what is really happening with each component of the system as well as communication status. These software packages were packed as an API (Application Programming Interface). It is essential to provide an API (Application Programming Interface) to enable a higher level development from system integrators.
By the end of the project well established procedures were defined so the reliability, full operation and supervision of the system could be assured.
The test program monitored the network topology and also some RF parameters like the signal strength, low batteries, tamper on valve heads to find out the weak points of the mesh and place signal enforcers on those places as required.
Further, there are some other software tools that will not be released for system integrators, but were required for full production of control modules and calibration of sensors.

Gateway

On top of the electronics that sit on top of the valve, a gateway and software tools have being developed for monitoring purposes.
The gateway is based in Embedded Linux with integrated web server where all the information and browser-based tools allow monitoring, installation and commissioning in a simple way.
Further tools for predictive maintenance were included in order to try to forecast and detect any failure of valves operation.

Prototype to production

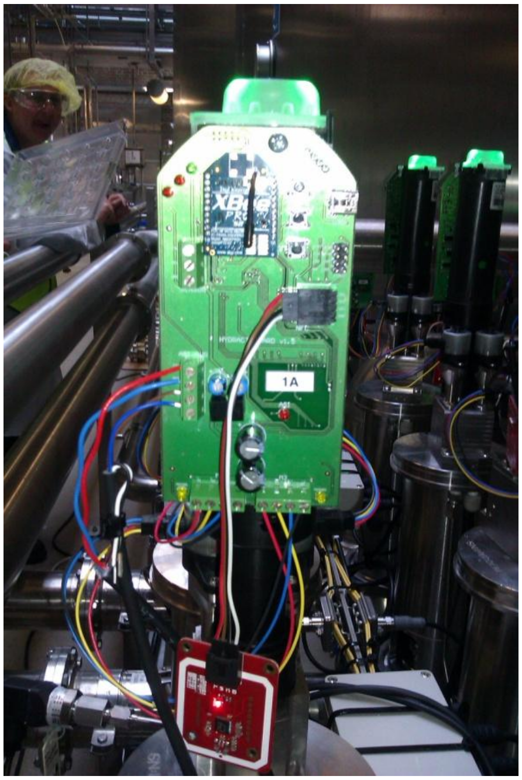


Figure. 14 Control board and position sensor mounted on actuator

Several prototype boards were made and tested with the Südmo position sensor/target and stepper motors supplied by VP.
NS then spent a week at the laboratories of VP refining the software while performing tests on the first production actuator and new hydraulic power unit. Satisfied that the hardware was working, NS manufactured 40 control boards for the main installation at Carlsberg.

Task 2.3 – Manufacture of hydraulic supply unit for 50-actuator demonstration

The hydraulic system was designed and assembled by VP using mainly commercially available water hydraulic components. A schematic of the system is in the figure below:

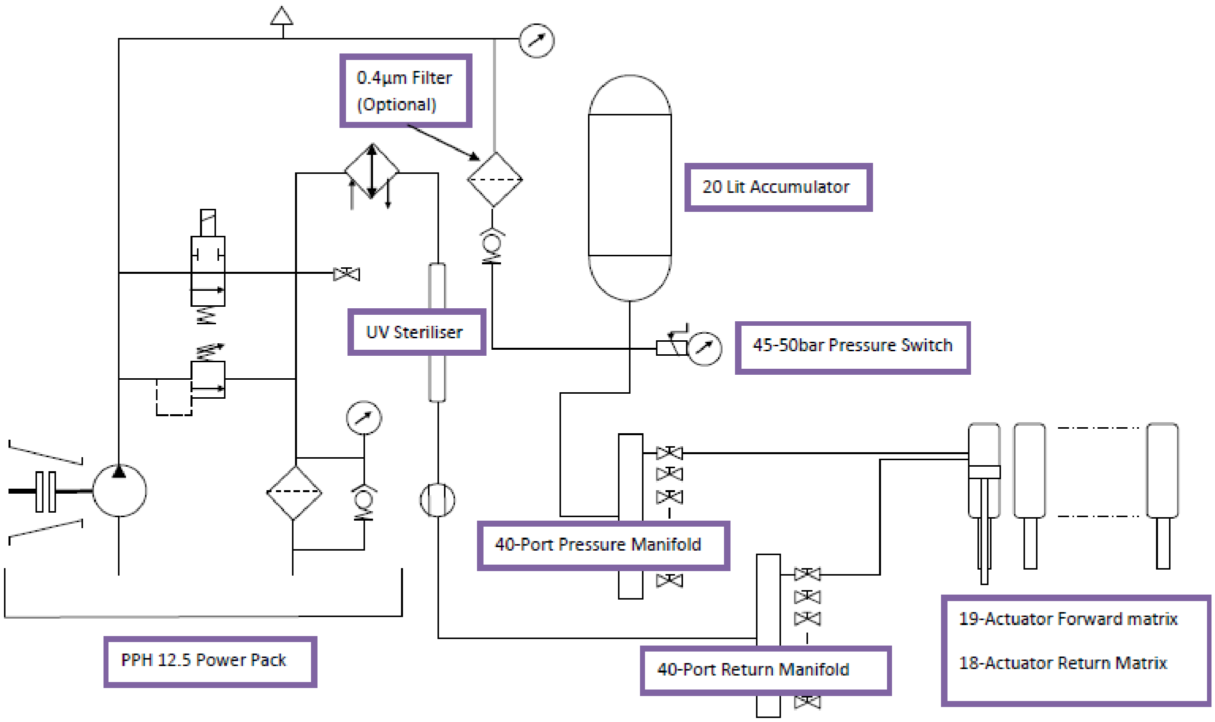


Figure 15. Schematic of water hydraulic circuit

The hydraulic power unit (HPU) comprised of a Danfoss Nessie PPH 12.5 power pack and electrical control cabinet designed and built by VirtualPiE. Additional water filtration and sterilisation units were built into the system ensure a high degree of system cleanliness. The hydraulic power unit was to be located some distance from the CIP 2 valve matrix in some free space between concentrated acid and caustic tanks and was thus mounted on a custom framework designed by VP.

The main system accumulator was mounted close to the CIP 2 valve matrix and connected to the HPU via stainless steel tubing running in overhead trays. This again required the design and fabrication of a support frame by VP.

Isolation and check valves for the pressure lines to each actuator were mounted on custom manifolds for up to four units, while the plastic return lines were manifolded together using push-in fittings used commonly in the beverage dispensing systems. The valve matrix pressure and return pipework was fabricated on a mock-up of the system at VirtualPiE in the UK and then assembled in the Brewery, thus saving considerable installation time (figure 17).

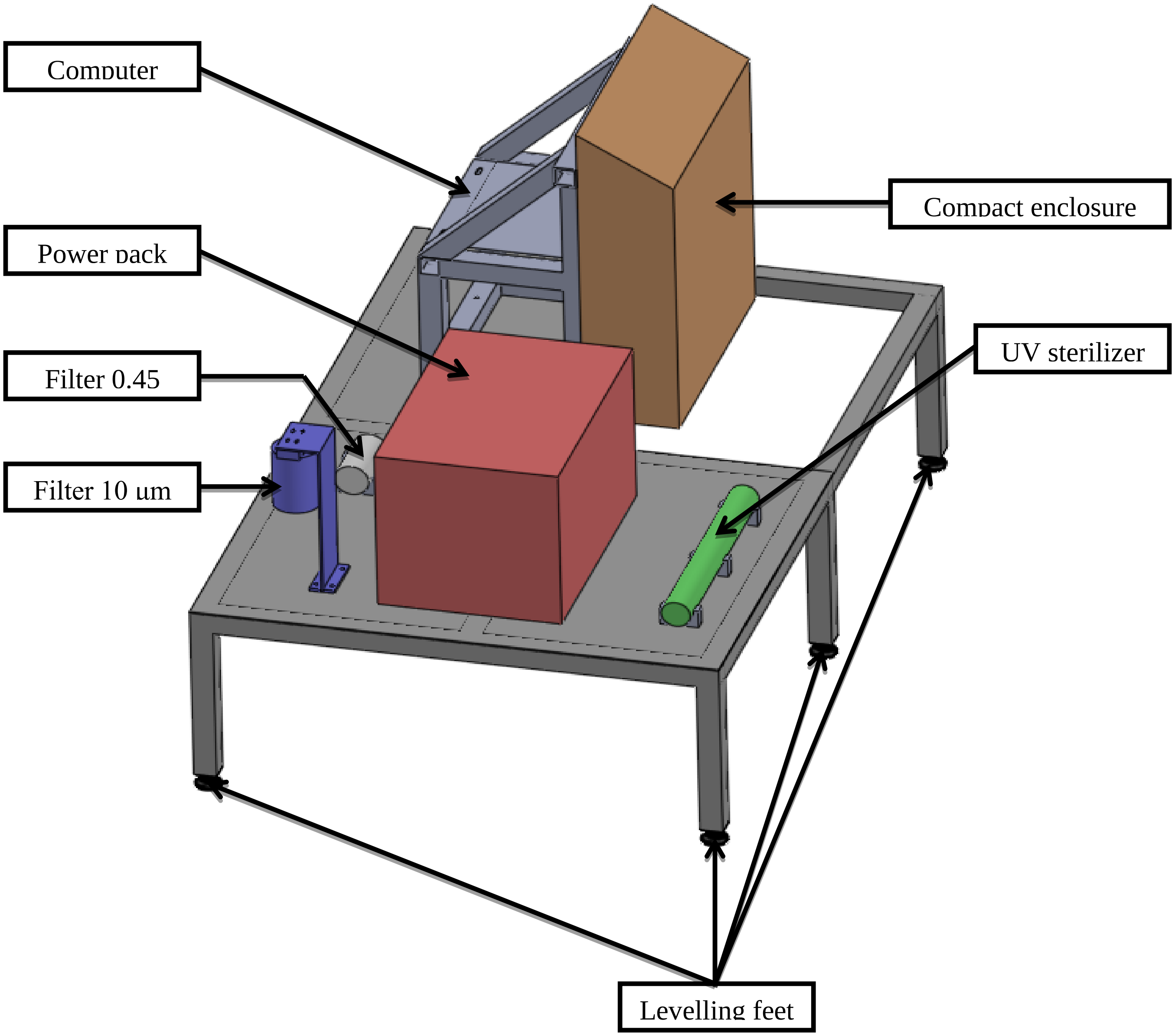
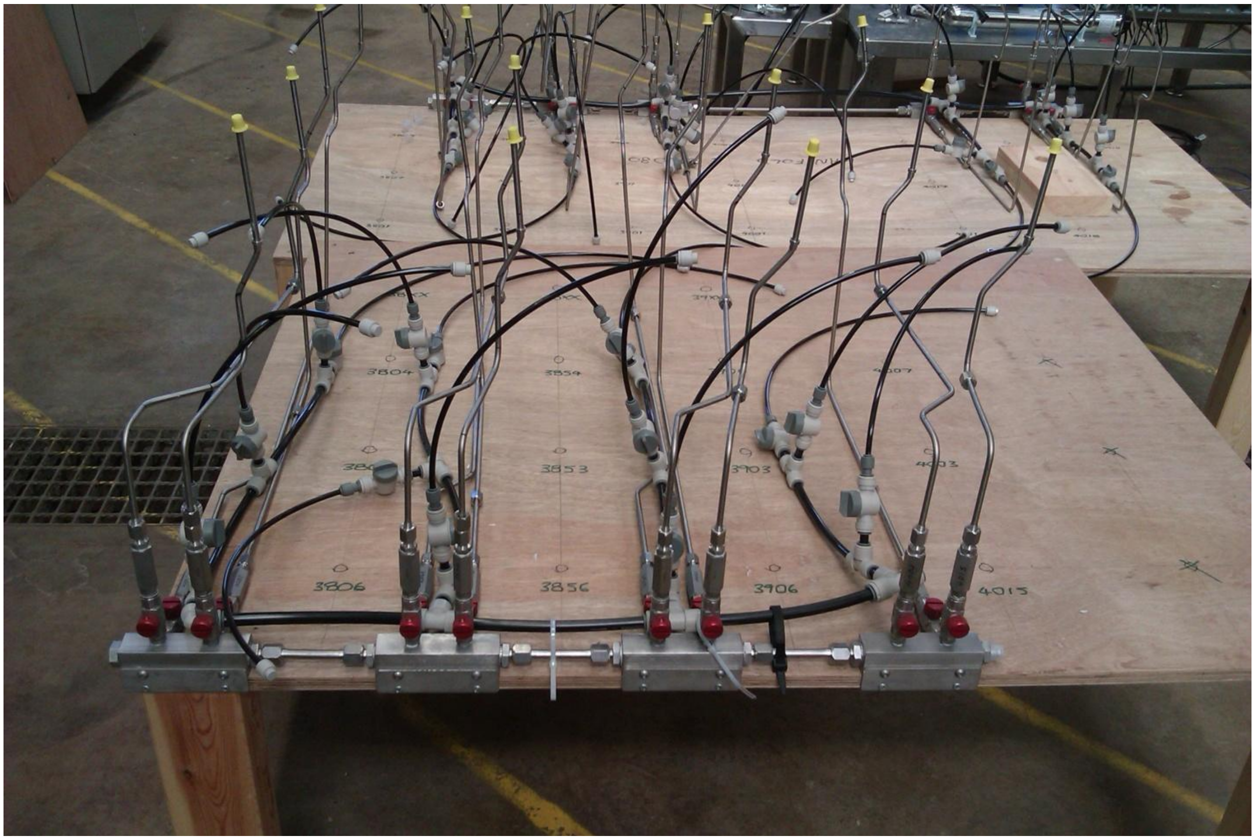


Figure 16. **Design for hydraulic power unit**



Fugure 17. Mock-up of manifolds and pipework for CIP 2 valve matrix

The hydraulic system was pressure tested and run at VP prior to being dismantled and shipped to Carlsberg in Denmark.

WP3 – Demonstration in situ at end-user

Task 3.1 – Installation of hydraulic actuators and remote controlling system

A Hydract water hydraulic system with nine actuators was installed within the Carlsberg Brewery at Fredericia, during October 2011 (M5). The actuators were retrofitted to three different manufacture double seat valves, Südmo, GEA and Alfa-Laval, using the original control top from each valve. The valves were typically 20 metres from the hydraulic power unit and were fed with pressurised water through overhead flexible hoses which greatly eased the installation.

It was not necessary to use a remote controlling system for the pre-demonstration as the primary aim was to prove the reliability and versatility of the hydraulic system. Also, the early execution of the pre-demonstration would have left insufficient time for manufacture and integration of RFBT, and thus it was felt best to leave this until the full demonstration.

Figure 18. Hydraulic system for pre-demonstration

Task 3.2 – First demonstration phase in situ

The first demonstration ran successfully for a two-week period during October 2011 (M5), and during that time there were no reported malfunctions at the plant control computer.

The whole Hydract system was assembled and tested at BHR Group prior to dismantling and shipping to Carlsberg for the proving trials.

VP and KM Rustfri re-assembled the actuator system in the Carlsberg brewery, laying out the actuators near to their intended locations and again checking operation before installation. The actuators were installed in batches, working with the Carlsberg plant engineers to ensure that each section of pipework was safely isolated for valve removal. Each pneumatically operated valve was removed in turn, the valve parts and communication system were then transferred to the Hydract actuator, and this new assembly installed in the plant line.

Area 2 Südmo valves were installed on the morning of 06/10/2011, with area 3 GEA valves installed during the afternoon, followed by area 1 Südmo valves the following morning.

It was decided to modify the lower seat lift function of the Alfa Laval valves before installing them at a later date.

Figure 19. Pre-demonstration Hydract actuators fitted to GEA valves

Figure 20. Pre-demonstration Hydract actuators fitted to Alfa laval valves

Following the demonstration, the original pneumatic valves were re-installed along with the control tops and original wiring to the plant computer.

Task 3.3 – Evaluation of result from first demonstration phase in situ at end-user

A PC based data acquisition system was used to display and record the important measurements from the proving trials. Important data were the power consumption, pressure and flow time history of the overall system. It was not practical to instrument each individual actuator, so we can only infer the actual duty cycle of the actuators based upon the overall system data.

The system was installed in the brewery for a two-week period from 6th October to 20th October 2011. The total power consumed by the hydraulic power unit was measured as 15.4 kW hr. The stand-by power consumption was only 12W, with a peak power demand of 1000W for a period of a few seconds each time the hydraulic accumulator was re-pressurised. Figure 21 shows an example of power recorded every 900 sec or every time in excess of 200W. When the available records are sorted in terms of the number of power peaks every 5 minutes, it can be seen in Figure 22 that:

- Normally the power supply came on 2 to 3 times every 5 minutes
- It was however higher on 7th October 2011 when measured between 12:36 and 13:16
- It was again higher on 19th October 2011 at approximately 11:15, 17:45, 19:45, 20:30 to 21:00

It is unclear whether the higher power requirement on 7th October was a result of the running-in of the new control valves, or generally higher duties. The higher power requirement on 19th October 2011, however, is likely to be the effect of higher duties during the identified time periods.

Figure 23 shows that the number of power peaks corresponds to the number of water flow peaks, and Figure 24 shows that the number of water flow peaks corresponds to the number of pressure peaks. Peak water flow rate for the system could be as high as 2.7 litre/min, but it was normally around 1.6 litre/min. The total flow circulated through the system in the trial period was $7.5m^3$, with a stand-by flow of between 0.2 lit/min and 0.02 lit/min. The stand-by flow was seen to significantly reduce during the trial, presumably due to running-in of the new control valves.

There were no reported malfunctions of any of the Hydract actuated valves in the plant as they all moved when signalled to do so by the main plant control system.

VP/KM staff observed no external leakage from any of the actuators or hoses during the trial, but there was one leak from a manifold connection on a control valve station. This was easily rectified by replacing the seal during a 'quiet' period in the plant operation, and was found to be due to a manufacturing fault on the manifold pipe connection.

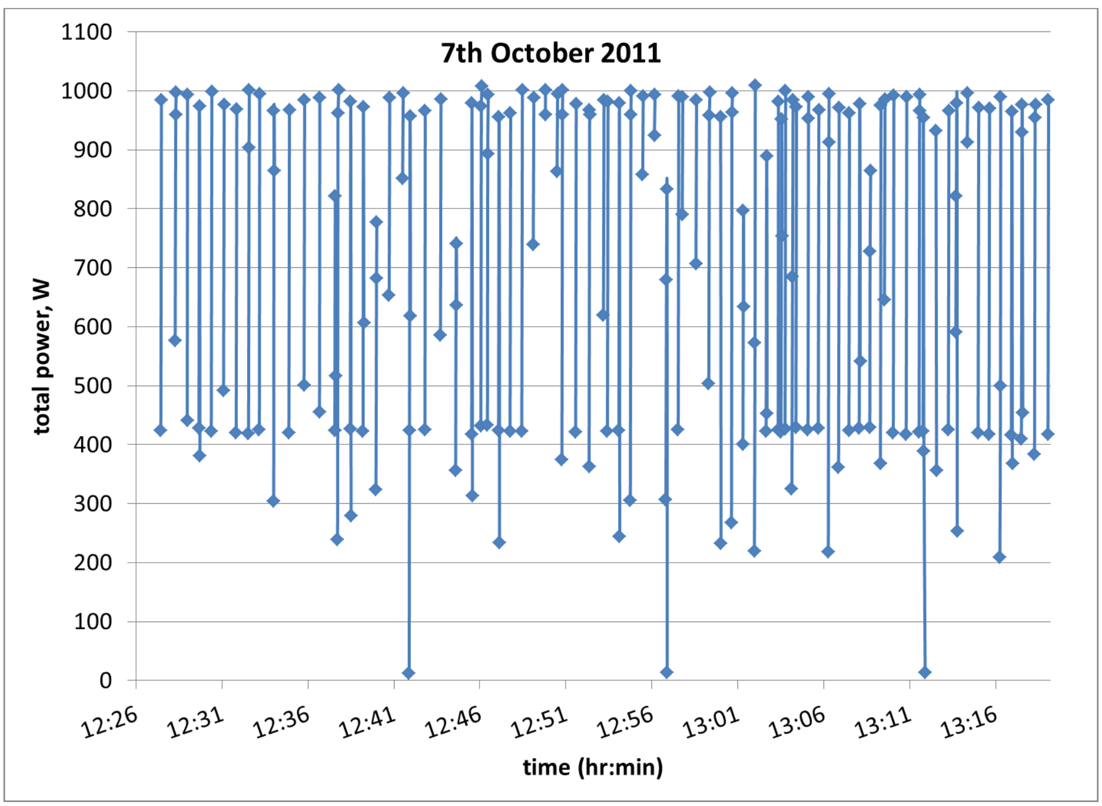


Figure 21. **Records of Hydract Power Peaks**

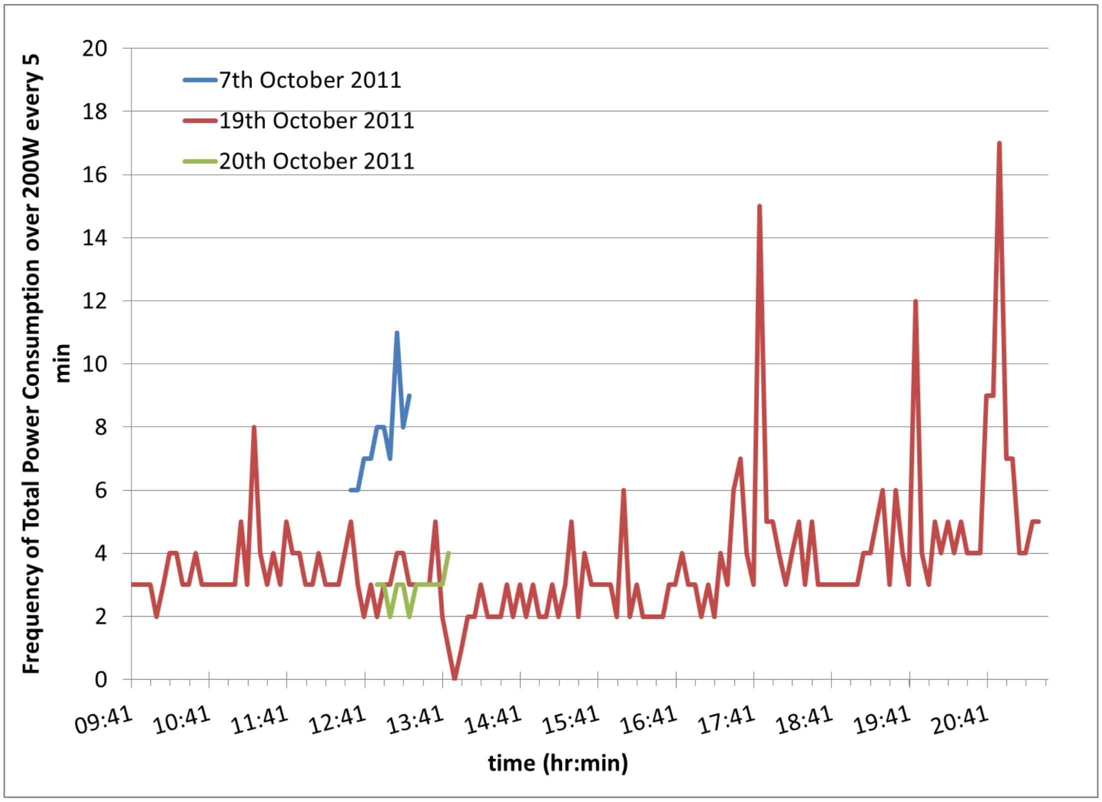


Figure 22. Trends of Hydract Power Consumption for 7th, 19th & 20th October 2011

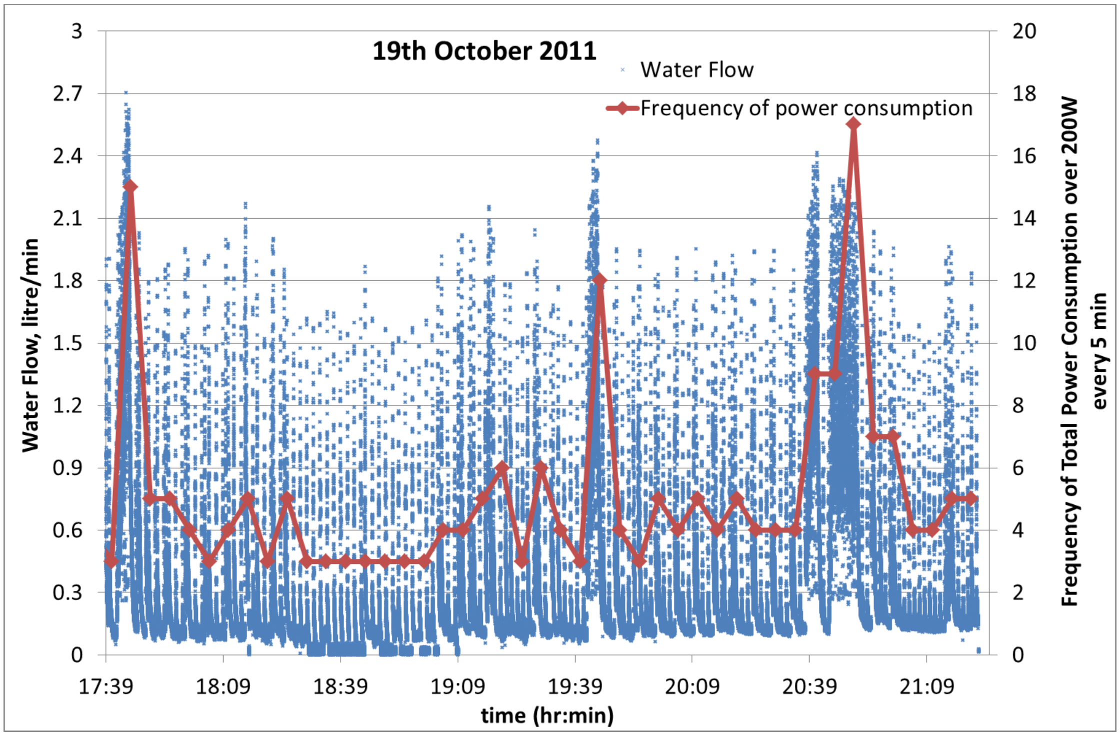


Figure 23. Trend of Hydract Power Consumption and Water Flow Rate on 19th Oct 2011

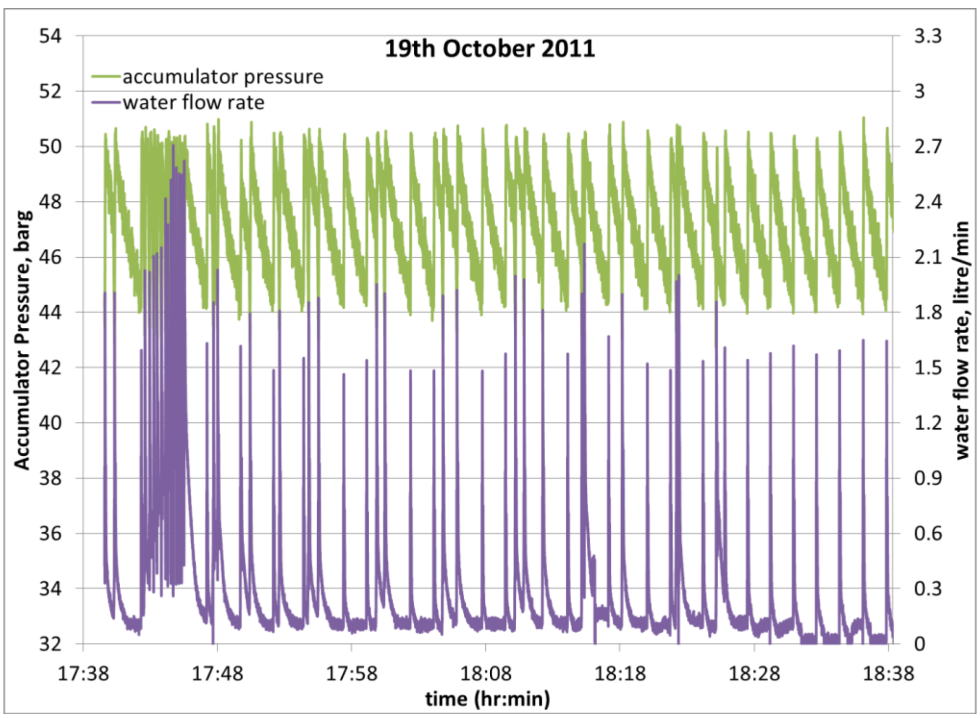


Figure 24. Trend of Hydract Accumulator Pressure and Water Flow Rate on 19th Oct 2011

Conclusions

From a plant operating point of view the HYDRACT pre-demonstration system performed faultlessly. The power consumption and leakage were improved compared with the trials on the previous HYDRACT project, while the sterility of the system fluid was more than adequate. However, there were some aspects that the system that could be improved ahead of the full demonstration and these are captured in the cost engineering exercise and first demonstration report.

Bringing forward the pre-demonstration by 12 months provided the consortium with valuable information on the in-plant performance of HYDRACT actuators which was essential in their up-scaling for the full site trials.

The early pre-demonstration was successful in achieving end-user support and has secured the interest of major valve manufacturers. The full demonstration most certainly benefited from the pre-demonstration results as it more ambitious than originally planned.

Task 3.4 – Optimised second demonstration phase in situ

In June/July 2013 a water hydraulic system with 19 actuators was installed in CIP 2 at Carlsberg, to replace the forward valve matrix. A further 15 actuators were planned to replace the return line matrix, but manufacturing issues prevented this installation before the project deadline.

Figure 25. Hydraulic power unit for CIP 2 hydraulic valve actuators

Figure 26. Hydraulic accumulator local to valve matrix

This second and main demonstration involved the complete removal of the original 30-year old valve matrix with new Pentair Südmo pneumatic valves during a ‘quiet’ period in brewery production (late April 2013). This meant that the Hydractdem water hydraulic system and actuators could be installed in small batches without causing major disruption to production in the busy summer brewing period.

Figure 27. Matrix of 19 Hydractdem actuators in the forward valve matrix of CIP 2

The remote controlling system was installed at the same time as the hydraulic system but was restricted to demonstrations and DAQ due to understandably strict brewery protocols. Each actuator was in RF communication with the server computer conveniently mounted at the hydraulic power unit, but the brewery was in complete control of the valve matrix through the existing AS interface with the plant controller.

Task 3.5 – Evaluation of demonstration in situ

The in situ demonstration at Carlsberg is viewed as a permanent installation and as such will be available for future evaluation. The project team had envisaged a series of trials to be done within the project as listed below:

- Hydraulic system performance in terms of power consumption, duty cycle, flow/pressure requirements, temperature effects.

- Hydraulic system reliability in terms of valve operations, fluid leakage, control system operation, maintenance level.

- Benefits to process plant from reduced pressure transients

■ Valve regulating capability by position control using internal position sensor

■ Valve regulating capability by using downstream sensor such a pressure, flow or temperature

The reality is that there has been very little time to run trials and evaluate data from the installation due to the fact that the forward matrix was only completed on 12 July, 2013. We thus only have some preliminary data from the first few days of operation with the Hydractdem water hydraulic actuator system at present. Some examples are shown in the figures below:

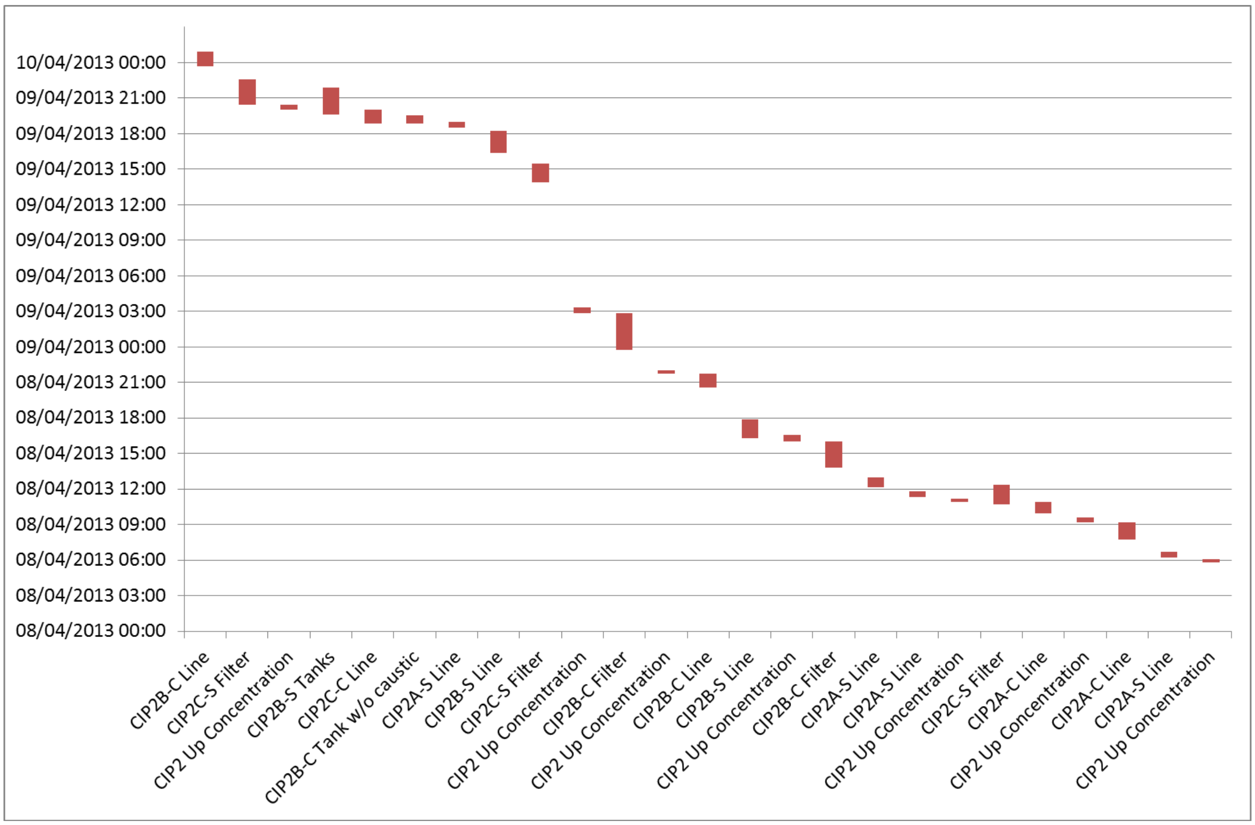


Figure 28. Operations between 8th April 2013 06:05:18 and 10th April 2013 00:52:38

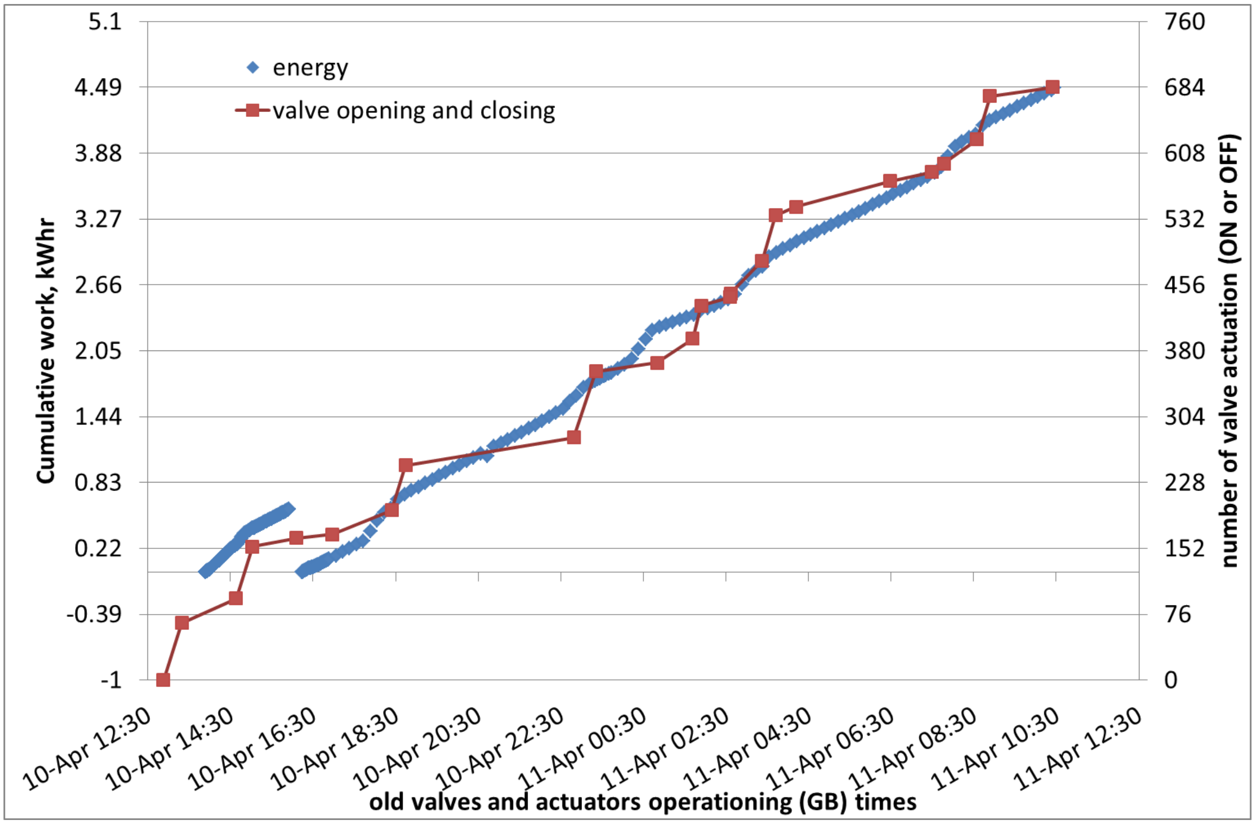


Figure 29. Cumulative compressor energy and cumulative number of valve actuations for old valves and actuators

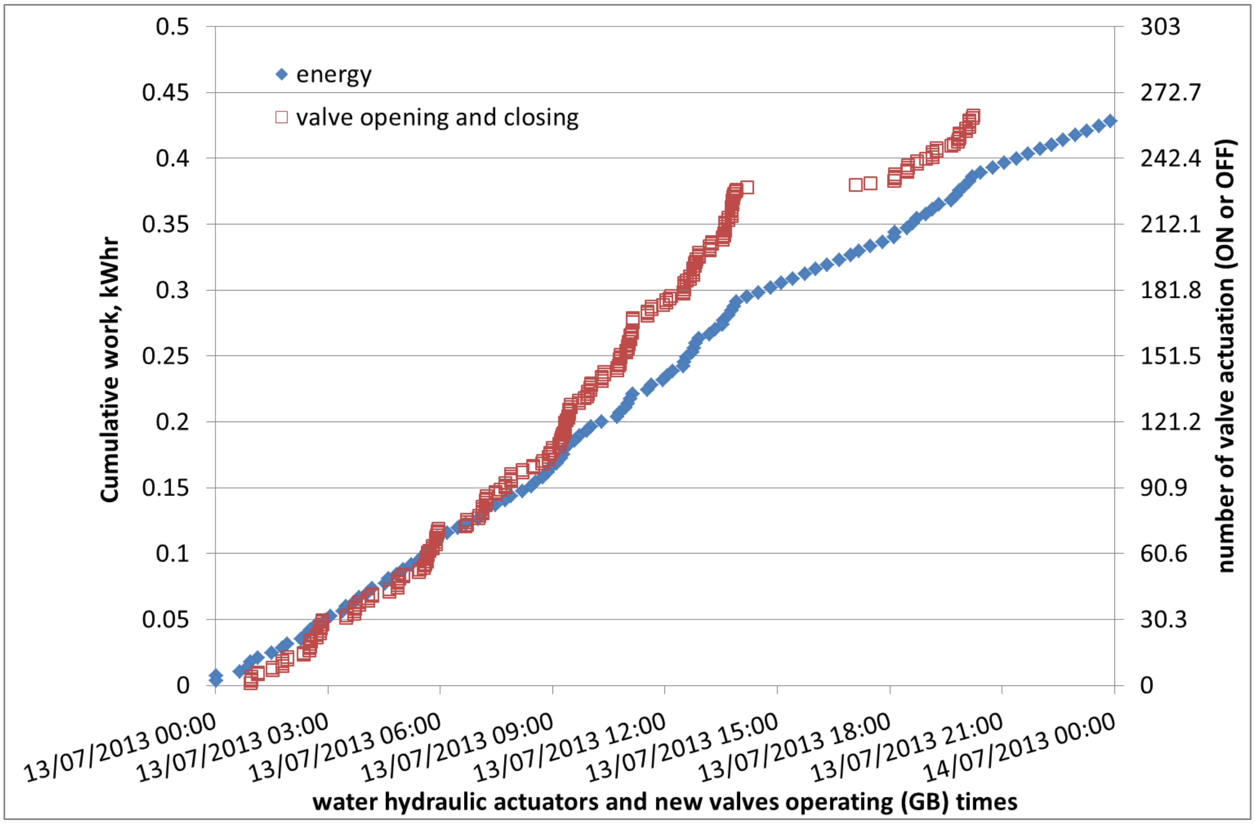


Figure 30 Cumulative energy and number of valve actions for new water hydraulic actuators and Südmo valves

WP4 – Market exploitation studies and dissemination

Task 4.1 – Detailed Market analysis of the demand for water based hydraulic actuators systems in the sanitary industry

A through market analysis was performed using external consultants and covered the following aspects:

- The installed volume of actuators on a world-wide scale
- Drivers for the water hydraulic actuator system
- Analysis of the market situation within the competing valve industry
- Identification of demand from maintenance, investments and new plants
- The short term demand for Hydract water hydraulic actuator
- Long term demand for Hydract water hydraulic actuator

The market analysis concluded that the Hydract water hydraulic actuator has the potential to revolutionise the actuator industry and become the market standard within its field. Reducing energy costs by 65% and improving the flexibility and reliability of valves were seen as the three most important requirements for global beer producers.
The study indicated that Hydract will be able to gain customer recommendation benefits and momentum from its collaboration with Carlsberg by starting up in the brewery industry. The diary industry was seen as more fragmented than the brewery industry and tends to adapt new production technologies and processes from other areas within the sanitary industry.
The pharmaceutical industry reflects a less attractive market potential for Hydract, due mainly to a highly conservative mindset in the industry. This industry needs to see results and are not first movers in regard to new technologies.

Additional market information was sought in a workshop with a second Danish consulting company that specialises in providing services to the brewery industry. This helped identify the market value, x-factors, estimated energy costs for present installations, market preferences and additional information on present valve numbers and pricing.
Market research indicated that KMR should initially focus on production and distribution of the water hydraulic actuator, as the actuator is the component most often serviced in the total valve solution. The advice was that KMR should enter the market through OEM's rather than sell directly to customers.

Task 4.2 – Business plan for market launch in the sanitary industry

To be completed by KMR.

Task 4.3 – Market analysis on the potential demand for water based hydraulic actuators systems in other industrial sectors

To be completed by KMR

Task 4.4 – Market study of the demand for valves developed specifically to accommodate the full potential of the hydraulic actuator

To be completed by KMR

Task 4.5 – Dissemination to targeted industries and the wider public

The Brau Beviale Exhibition in Nürnberg, November 2011, was seen as the premier event to launch the Hydract prototype product. With Carlsberg's endorsement secured, Hydract was well received by sterile valve manufacturers and the exhibition stand was busy for the full three days of the event. The exhibition proved to be the ideal opportunity to disseminate the technology to a wide audience and to receive feedback from competitors in the market
Five of the major valve manufacturers seen at the exhibition were keen for individual demonstrations at their premises, and were combined into a road trip across Germany.

The road trip included GEA (Büchen), SPX-APV (Dortmund), Kieselmann (Kittlingen), Krones (Neutraubling), and Pentair Südmo (Riesbürg) and involved a live demonstration of HYDRACT at each location. Each demonstration was accompanied by a presentation of the technology and the Hydractdem project, and resulted favourable signs for supporting the full demonstration at Carlsberg.

Following on from the success of the 2011 exhibition it was decided to exhibit at Brau Beviale 2012 with a new actuator. The exhibition actuator contained many improvements over the design used in the pre-demonstration and was the basis of the design for the main demonstration.

Launch of actuator with integrated control valves at Brau Beviale 2012

Many of the OEM's returned to the stand for the second year, and were complementary about Hydract having reflected upon the potential advantage that water hydraulics offers to the sanitary valve industry. The exhibition also marked an agreement with Pentair Südmo to participate in the forthcoming main demonstration at Carlsberg, buy providing a temporary pneumatic installation that could be switched to the Hydract system.

List of projects meetings, dates and venues

Date	Venue	Purpose
05-05-2011	EU Brussels	Pre-project meeting – EU, KM, BHR, GFD
10-05-2011	KM Denmark	Engineering meeting- Pre-demonstration actuators and system- KM, BHR
19-05-2011	Carlsberg Denmark	Engineering meeting - site for pre-demonstration and potential valves - CA,KM,BHR
17to18-08-2011	VP England	Management meeting – Resourcing and finance of pre-demonstration, KM, VP.
29-09-2011	EU Brussels	Project meeting – Consortium structure, DOW, project timing - EU,KM,VP
01to02-02-2012	VP England	Partner meeting – Agreement/engineering – KM, VP
07-05-2012	Middlefart, Denmark	Partner pre-review meeting
08-05-2012	Carlsberg, Denmark	1st Period review meeting
09-05-2-12	Middlefart, Denmark	Partner planning meeting
22-08-2012	KM Denmark	Design and planning meeting KM, VP
02-10-2012	Carlsberg, Denmark	Discussion meeting with GEA, CA, KM, VP
30-10-2012	Pentair Südmo, Germany	Discussion meeting with Südmo, KM, VP
15-11-2012	Nürnberg, Germany	Business meeting with Südmo, KM, VP
30-11-2012	Carlsberg, Denmark	Design and planning meeting with CA, Südmo, KM, VP
05 to 06-02-2012	VP England	Design and planning with VP, NS
12-02-2012	VP England	Planning and business meeting with KM, VP
14-03-2012	Carlsberg, Denmark	Planning meeting, CA, Südmo, KM, VP
10-04-2012	Alectia, Denmark	Workshop with Alectia, KM, VP