Control by water

WHITEPAPER

Water Hydraulic process valves with unprecedented precision

1. Introduction

Beyond precision! Get the broader picture of the patented HYDRACT water hydraulic process valve for the liquid processing industry. The system is the way to significant energy savings in the food and beverage industry saving >90% compared to a similar pneumatic system. The water hydraulic valve has unpreceded precision allowing the user to precise inline mixing of fluids – which will lead to changing the ways mixing and/or blending of e.g. alcoholic and non-alcoholic beverages are produced.

The sustainable revolution that is sweeping across the industry is a challenge for an industry that already have picked all the low hanging fruits. How is it possible to find savings without new technology or new ways of thinking production? How to lower the production waste? Is it sustainable to use electricity from alternative energy sources and not reducing how much we use? A reduction of product waste and less cleaning is possible if processes are turned around and looked at in new ways.

The achievement is especially late product differentiation of beverage will revolutionize the beverage industry making it possible to produce just in time and on-demand – small volume production will help the industry to better profits and unprecise forecasts will be over. The dynamic market situation that is currently happening in the beverage industry is challenging the lifetime of products. The late product differentiation will help the industry overcome this hurdle. The system brings operational scalability and flexibility to the industry where it is much needed.

A lot of companies cannot envision a world that operates differently than how they work (and how they have been successful) for years.

In the following, the key features of the HYDRACT water hydraulic valve are explained, and some experimental results exploiting these features are shown. In the reference section, the reader can find a selected list of publications on water hydraulic.

2. Features

Energy Savings - an astonishing >90% energy saving compared to compressed air – equal to saving approximate 5-10% of the total energy consumption in a beverage plant.

Precision - fast, and precise positioning to ± 0,05mm for both single, upper, and lower seat – with a regulating frequency of 0,5 seconds.

Reliability - experience no oscillation in fluid mixing – boosting operations with smaller rejection rates, more consistent product quality, and increased output.

Water hammer avoidance - eliminates hydraulic shock in process valves – a positive effect on the lifetime of the pipe system and no unintentional mixing of fluids.

Regulating - minimizing fluctuation in the production – a versatile valve with bi-directional product flow.

Flow and design - designed according to EHEDG and optimized for flow, stability, less turbulence, and vibration.

Communication - full digital system – get insight into operations, experience real-time control, and operational excellence.

Monitoring, Enable industry 4.0, and a full digitalization of your production.

3. Working principle

When most people think hydraulics, they think of oil. This should not come as a surprise as the majority of hydraulic systems uses oil as the hydraulic medium. Water hydraulics has traditionally been used in fire-fighting applications. But surprisingly enough, Water hydraulics is used in a broad variety of applications from food processing to automobile manufacturing and mining and hot metals.

The main benefits of water are evident. Opposed to Oil, water is inflammable and an environmentally friendly solution. Water has a lower viscosity than oil and will therefore have a lower pressure drop. Ergo water can transmit power through the system faster and more efficiently than oil. Water has a lower film strength than oil, meaning that water is less likely to retain bubbles and foaming is less likely to occur.

The challenge with waters lower viscosity is the sealing. Leakage from the hydraulic system will not pose as significant a problem as with oil – but must be dealt with and taken into the design. The solution to the lower viscosity includes a non-metallic Teflon coated sealing.

Even more crucial is that the low viscosity of water obstruct the forming of film lubrication as in oil systems. To overcome this, the right material and an ultra-smooth finish are required.

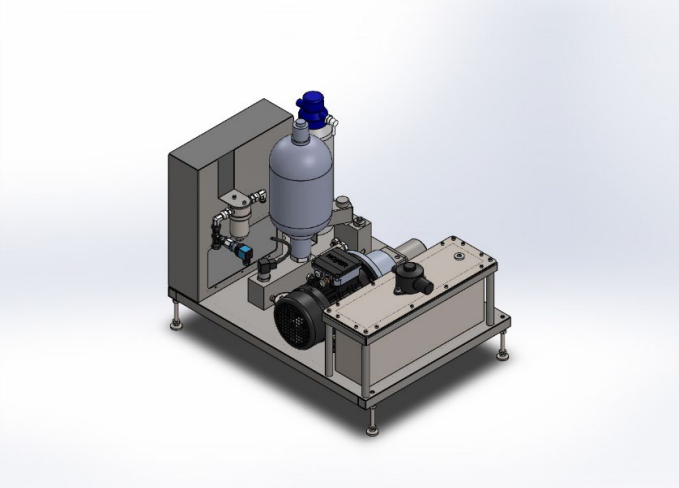
Long lifetime and safe operation are crucial in the process industry and this requires high-quality materials.

The above examples show clearly indicate that water hydraulics is the best way to go for the process industry. With its distinct advantages over other technologies like pneumatic or electric – the strength of the system lies in applications that demand power, precision, safe, fireproof, and environmental compatibility. Which makes water hydraulics a commercial sound and technically feasible.

As the hydraulics medium is tap water that is being filtered and cleaned by Reversed Osmosis - Water hydraulics offers a very clean system with no airborne bacteria being distributed to the products or surroundings.

Powering water hydraulics

The system to power the water hydraulic system is made with a pump, a water tank with a 3 µ m filter, a water tank, an accumulation tank, and a Reverse Osmosis system to keep the system clean. The Powerpack delivers 50 bar of pressurized water. The accumulator works as a pressure storage device as well as a hydraulic transient damper to ensure that the pump does not need to continuously run or cause pressure transients in the system. For larger systems, an uninterruptible power supply and accumulators are specified. The Ro runs 3 times a week to keep the water clean and hygiene, without affecting the system's ability to power the valves.



System Safety
In all plant systems there need to be a safe shutdown action in the event of power failure or system failure. In the hydraulic system, there are two ways to do this. 1 is an accumulator. 2 is back up power for the pump and actuators. If a power failure occurs the valve will return to its normal position which is set in the valve configuration and locks itself in the position. The accumulator is specified by how many valves it has to close down at the same time.

If a valve should lose hydraulic pressure, emergency spring-loaded valves can be designed into the system as a shutdown procedure, this would be incorporated into either inlet/outlet of the pipe system or both. The pipework or the hydraulic system consists of a press-fit system that has a maximum working pressure of 90 bar. The maximum pressure of the system is 180 bar. Giving the system a safety factor of 3,6.

Pneumatic or water hydraulics

Pneumatic and water hydraulic systems use fluid to move force and energy through machines. But if both types of fluid power do similar jobs why chose water hydraulic over pneumatics?

For high power, soft action, or force absorbing applications where accuracy is critical water hydraulic systems are preferred and have no problem with variations in air temperature. The incompressibility of water gives accuracy and precision to the actuator as the density of the medium stays the same under pressure. This will give the system an energy advantage from pneumatics that use approximately 90% energy creating heat.

Fluid controlled actuators have relatively little momentum so they can be started, stopped, and reversed more quickly. Further, the fluid disperses heat so there is no chance of overheating.

Water hydraulic actuators are much more silent than their pneumatic counterpart.

4. Energy

It is a common fact that compressed air is very energy-consuming. Approximate 90% of the energy is transferred to heat – and another approximate 3-5% vanish through leakage which is equivalent to mechanical work of approximately 3-7 %.

The Hydract water hydraulic system would only need a 2,2 kWh pump to drive the same mechanical work as a 200-300 kWh compressor, running somewhere between 5000-8000 valves. A full stroke of the actuator needs approximately 100 ml of water which combined with the incompressibility of water makes a very energy-efficient system.

Taking the difference between the two systems we end up in savings of 99,2% energy. As the two systems both need standby power for the actuators, we need to calculate this into the equation ending at an astonishing 96,2% energy saving.

This will be equal to saving 5-10% of the total energy consumption in a brewery.

5. Precision

High accuracy is essential for the food and beverage industry leading to more consistent products and less waste. The precision of the Hydract actuator is standard 5/100 mm. The precision tolerance can be as low as 1/100 mm, but precision is a balance between speed and accuracy. At 5/100 mm precision, we have found the best balance between speed and precision.

Precision however only works if you get a fast and reliable regulation signal. The solution is a laser refractometer that can give a signal every 0,005 second, or 200 times a second. We have set up the system to get a regulating signal every 0,5 seconds from the laser refractometer – that will be sufficient to reach the precision regulation needed. The signals from the laser refractometer can be set up as quality insurance – measuring the content of each e.g. can more than 8 times. The ultra-precise action comes with a tremendous force of up to 12.500 N, assuring that the valve will not be affected but any external force. Making the Hydract valve extremely suitable for precision inline mixing.

6. Reliability

The presence of oscillations in the HYDRACT valve is non-existing – since the piston is hydraulically locked by water from both sides of the piston. This increases the quality of the end product and there will be fewer deviations - thus causing superior quality, lower rejection rates, lower energy consumption and increase average output.

What is just as important is that the Hydract valve will keep being closed when closed as it is hydraulically locked, avoiding the unintentional mixing of fluids.

Recalibration of the seat position is a manual digital procedure, that is done via the tablet access to the actuator. This procedure takes less than 2 minutes.

The positioning sensors in the actuator are temperature compensated to the manufacture's specification – making sure that we get a reliable position.

The sealing technology for the Hydract valve is produced by leading sealing manufactures.

Function and quality test of HYDRACT actuator.

The HYDRACT actuator is undergoing a strict testing procedure as a part of the quality and function inspection. Each actuator is tested for approximately 5 hours making sure that all parameters, such as power consumption, linearity, alignment, calibration, velocity among others are working and that all components are fully functional. The actuator is leakage and pressure tested during the whole test.

The actuator is calibrated to "null position" and verified from the reference position sensor and from stroke length verifying that the actuator is mechanically correct.

All sensors including temperature and humidity sensors are tested together with the firmware version.

The test is a “go/nogo” test and only approved units are released for dispatch and/or stock. Each actuator will have its own test certificate connected to the unique valve number.

7. Water hammers

Water hammers or a hydraulic shock is a pressure surge caused when a fluid in motion is forced to stop or change direction suddenly (momentum change). Usually due to a valve slamming closed or rapid closing of a valve – and can lead to very high-pressure transients that can cause the pipe to fail.

Water hammers are not happening with Hydract actuators as the valve is programmed to smoothly open and close – thus avoiding the hydraulic shock.

This will have a positive effect on the lifetime of pipe systems, welding’s, and other related equipment such as valves, sealings, pumps, etc. Further, the Overall Equipment Effectiveness will be improved as you will experience less costly downtime due to ex. bursting pipe, missing water push, or unintentional opening of valves.

Unlike traditional valve technology, the Hydract pistons are not lower balanced to try and balance out a pressure transient. The Piston is hydraulically locked and will simply not move if a water hammer should occur somewhere else in the system.

8. Regulating

The Hydract actuator operates with digital positioning which opposite to spring-loaded pressure reducing valves or diaphragm valves are extremely precise and will not be affected by product flow or other external factors. Oscillation as described in the section about reliability does not happen for the Hydract actuator – thus minimizing the fluctuations in product quality and reduced production loss.

No need of changing parts to change control zones or flowrates the Hydract regulating operates from 0,7 m3/h to full flow in a DN80 valve (tested at 1 bar product pressure). Setting the actuator to Normally Closed or Normally Open is done digitally. As the piston is hydraulically locked and as it is not affected by an external force - the product flow can be both upstream and downstream. The regulating frequency of the actuator when in regulation mode is every 0,5 second. With an accuracy of ± 0.05 mm and a programmable opening/closing speed from 0,01 to 11,5 m/s (ranging from 3-10 sec.). The Hydract actuator closes on position and not by force – therefore the valve sealing will last longer as they are not compressed as hard as with pneumatic actuators.

Regulation test

The valves tested was a Südmo valve with a Südmo pneumatic actuator against a Südmo valve with a Hydract water hydraulic actuator and piston. The flow characteristics were plotted by manually recording the flow (from a flowmeter) value at each valve percentage opening and entered into a spreadsheet.

The retrofit process valve opens 13% earlier than the standard valve, this is due to the geometry design of the pistons. The benefit is less stroke length to give the same flow – meaning that the pressure drop is

significantly lower. The maximum flow is reached at approximately 20% less opening compared to the standard valve - the 7% difference is due to the pressure drop reduction when using the Hydract valve. This is achieved through the geometry design of the lower piston in the valve.

It was noticed during the test that the stability of the flowmeter reading for the Hydract actuator had less fluctuation when compared to the pneumatic actuator. This is due to the flow through the valve is less turbulent - this statement is also concurrent with the vibration measurements in the next section.

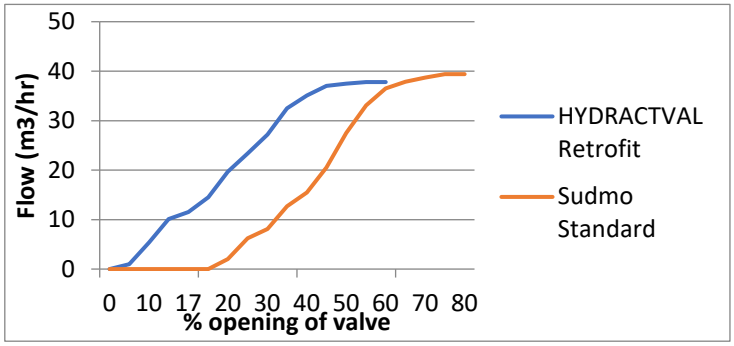


Fig. 1. Flow characteristic comparison

Sound and Vibration test

The sound and vibration (S & V) measurements were conducted during the flow test.

When analyzing the sound measurement, it was concluded that this data was corrupted by the test environment so it could not be used as reliable data. The method used for analyzing the vibration measurements was to determine the point at which cavitation or turbulent flow occurred by plotting the frequency against acceleration, this gave the frequency range that vibrations occurred at, which was caused by turbulent behavior or cavitation.

Figure number 2 shows the data plotted with frequency (Hz) against excitation (m/s^2) using 1/3 octave spectra. The range that has been identified as the symptom of turbulent and/or cavitation behavior is 500 to 10000Hz.

With this frequency range of 500 to 10000Hz the two valves were compared for their efficiency of allowing fluid flow, the lower the excitation across this frequency range the lower the fluid turbulence/cavitation, thereby lowering the pressure drop and increasing valve efficiency.

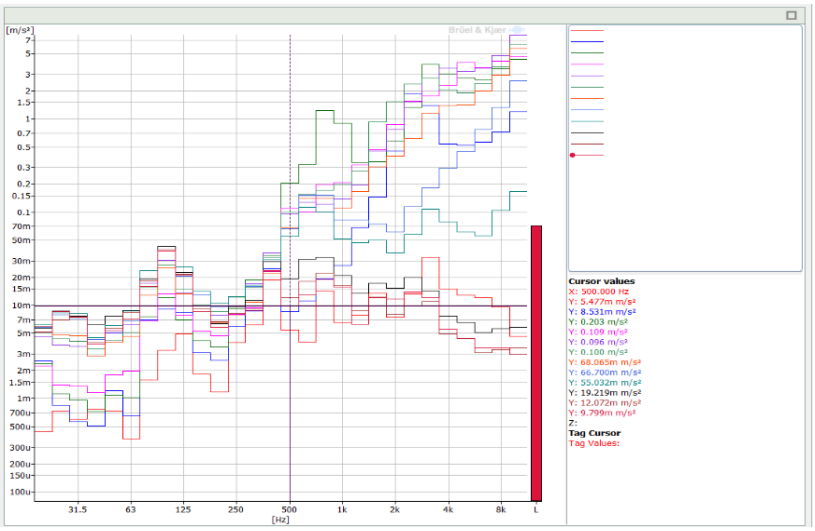
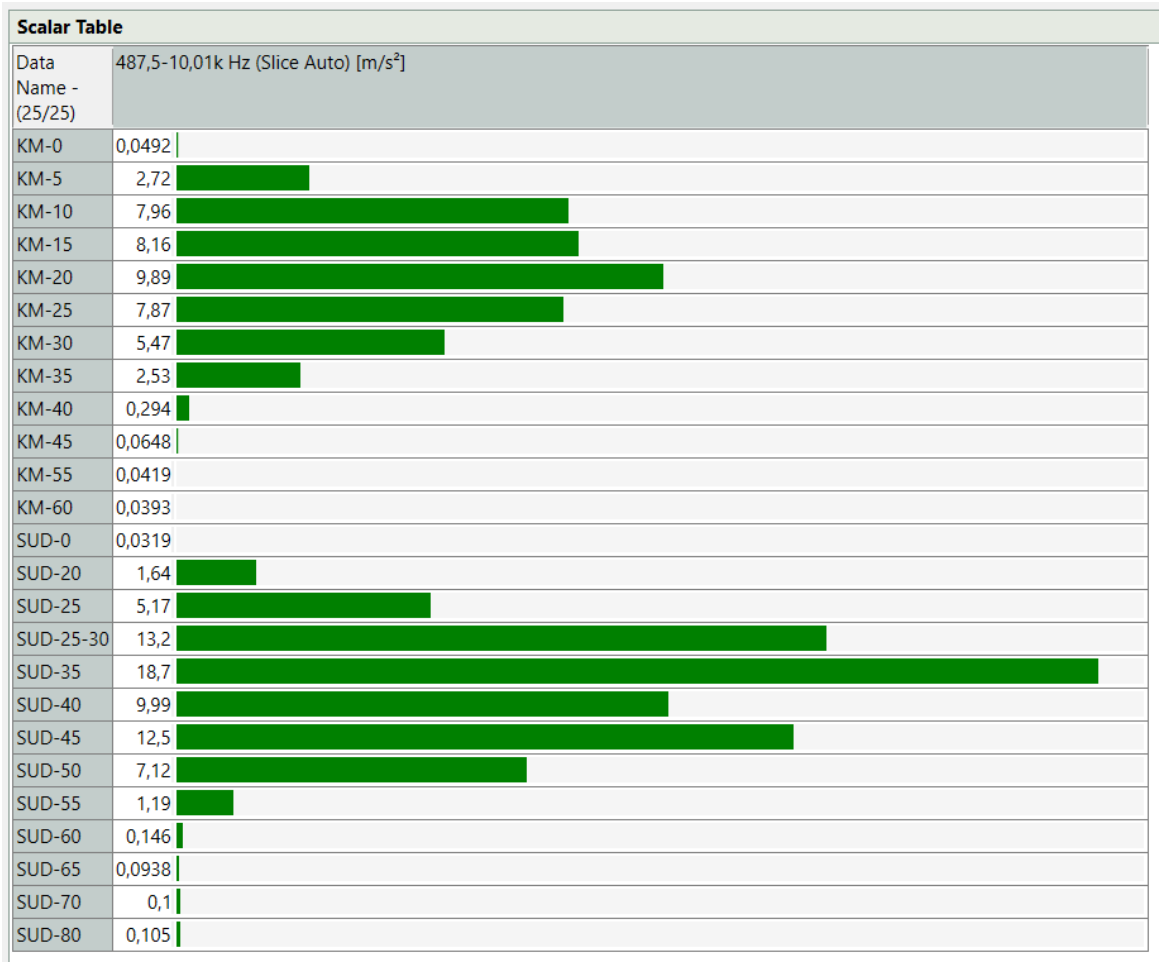


Fig. 2. Vibration spectra on Hydract valve in range 0 to 60% open (1/3 Octave spectra)

Figure number 3 shows the total RMS vibration comparison for the selected frequency range, between the Südmo Standard ('SUD') and Hydract Retrofit ('KM') valves. Each data-name describes the valve being tested and the percentage opening the vibration measurement was taken at.

It can be seen in the bar graphs, the Hydract Retrofit valve has less excitation than the Standard valve. When comparing the data names 'KM-20' and 'SUD-35' it is noticed that the Hydract valve has half the excitation level of the standard valve. Comparing these 2 valve openings gives a good direct comparison as the Hydract Retrofit valve opens 13% earlier. Overall, it can be seen that the Hydract valve has superior performance when compared with the standard valve, with a reduction in turbulence/cavitation when flowing liquid through.



Scalar Table

Data Name - (25/25)	487,5-10,01k Hz (Slice Auto) [m/s²]
KM-0	0,0492
KM-5	2,72
KM-10	7,96
KM-15	8,16
KM-20	9,89
KM-25	7,87
KM-30	5,47
KM-35	2,53
KM-40	0,294
KM-45	0,0648
KM-55	0,0419
KM-60	0,0393
SUD-0	0,0319
SUD-20	1,64
SUD-25	5,17
SUD-25-30	13,2
SUD-35	18,7
SUD-40	9,99
SUD-45	12,5
SUD-50	7,12
SUD-55	1,19
SUD-60	0,146
SUD-65	0,0938
SUD-70	0,1
SUD-80	0,105

Fig. 3. Distribution of the total RMS in the 500-10000 Hz range corresponding % opening of each valve

This means that Hydract can turn any valve into a regulating valve.

CIP cleaning upper and lower seat

The CIP cleaning of the upper and lower seat is programmable and can be set to open as desired e.g. could be a narrow opening to spray the CIP fluids in for optimal rinsing. As a test of what cycle will be the best cleaning cycle will be conducted at a later stage. Being able to program the cycle will end up in better cleaning, less cleaning fluids used, fewer utilities used, reduced effluent disposal costs, and faster cleaning – giving the benefit of more production time.

9. Flow and design

The need for strict adherence to standards in food production requires that the Hydract valves are designed to comply with the food and beverage industry's maximum hygiene demands and are designed according to EHEDG.

The valves meet high hygiene requirements and allow for a precise and programmable CIP procedure.

Piston

The piston is designed so that the opening of the valve will have an equal percentage of opening, making the mixing of fluids much more reliable and easier for the software engineers to implement into the plant software.

Valve housing

The Hydract single seat valve housing is designed in cooperation with hygienic design specialists to offer a great range of hygienic and cleanable valve houses for the process industry. The design of the valve house creates optimal conditions in terms of cleanability and flow and is done according to the EHEDG guidelines.

The flow is bi-directional (flow can be both upstream and downstream), this also applies when using the valve for regulation.

The O-ring compression on the upper seat can be adjusted by connecting the actuator to a tablet using the Hydract app.

Flow conditions

The conical shape of the lower seat allows for optimal flow when opening, closing, or using the valve for regulation. The reduced pressure drops inherent with this design, is used to gain more control over the same stroke, thus giving more stability, especially when used in the regulating operation. The shape of the flow controlling surface can be engineered to meet the need of the process, i.e. quick opening, equal percentage, and other types of valve control.
The valve houses are clamped together with the actuator using standard tri-clamps to ensure the fast and easy assembly of the total valve system.

The portfolio includes single and double-seat valves that range from DN40/1½" to DN100/4"

10. Communication

Communication with the actuator is done via AS-I BUS, PROFIBUS, and Bluetooth. Other types of communication like ProfiNET and IO link is being integrated as well and will make the data handling much faster. The standby power for the actuator is supplied from the bus system.

Bluetooth connection is used to pair the actuator with a tablet. This action is needed when taking control of the actuator when calibrating and/or maintaining.

The system can via Profibus or IO-Link well give you access to performance operational matrixes that can tell you what it is doing, how well they are doing, and instantly alert you to problems. This will give you insight and real-time control over your process and to calculate equipment effectiveness. Along with being able to predict problems before they escalate and optimize maintenance. Historical data will enable you to predict and prevent downtime.

The status and error codes can be found in the below table.

Error code table	
Error Code value (Decimal)	**Error Description**
0	No Error
1	Illegal Operation
2	Actuator timeout
3	No actuator response
4	Failed to Open
5	Failed to close
6	Positioning Lower seat failed
7	Positioning upper seat failed
8	Upper motor worn
9	Lower motor worn
10	Upper seat seal worn
11	Water in top detected
255	Other Internal error

Fig. 4. Status table Hydract communication

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Error code table Hydract communication

11. Monitoring

The Hydract actuator is fully digital enabling Industry 4,0. You will have full digital control of all your valves and your mixing. Making it possible to analyze data from the actuators enabling faster, more flexible, and more efficient processes to produce higher-quality goods at reduced costs -ensuring timely delivery and much more precise forecasting.

Because the food & beverage industry faces unique challenges (seasonal demand changes, increasing demand for differentiated Stock Keeping Units, increasing regulatory/quality restrictions, complicated production planning, and the sheer scale of the industry production), it is uniquely situated to take full advantage of the benefits of digitalization – being the ability to predict rather than react and to be considered as another way to increase efficiency and as an upgrade to the entire business model.

The regulation, position, and any possible data can be monitored to be a part of the quality system, giving you full control of your quality control. The data from the Laser refractometer can measure the BRIX of each can more than 7 times enabling a digital inline non-invasive quality control. This will bring your quality control/assurance to bright new levels.

Monitoring the sealing and the status of the valve is bringing predictive maintenance to your facilities. As the actuator closes on position and not by force the pressure on the sealing can be digitally monitored and logged – using data analysis to predict and measure the wear and tear of the sealings. Thus, allowing you to maintain when you want and avoiding downtime.

As the actuator is fully digital, anything can be programmed to meet your need.

As the level of automation goes up the more critical the adaption of digitalization becomes. Increased automation attempts to drive human involvement out of the processes – increasing the need for documentation and information and the need to interpret this information to understand what is happening in the process.

12. REFERENCES

1. Erik Trostmann et. al. Water hydraulics control technology
2. Erik Trostmann et. al. Tap water as a hydraulic medium
3. Thomas Foster Mortensen, Danfoss high-pressure water solutions, Milwaukee, USA. Article: Understanding the distinct benefits – and challenges – of water hydraulics.