On-site & on-line Valve Testing - Industry 4.0 in Maintenance

We live in a time of significant changes in the technologies used in all spheres of human life. This applies to everyday communication, transport, power industry, health and industry in general. The progressive development of industrial technologies especially in the area of digitization and automation is known as Industry 4.0 to everyone. Similarly in the industrial sector we can encounter the related term Maintenance 4.0. This is a rapid development in the use of digital diagnostic equipment which differs sharply from the technologies used 10 to 20 years ago. The main focus of maintenance activities is shifting to diagnostics and predictive maintenance.

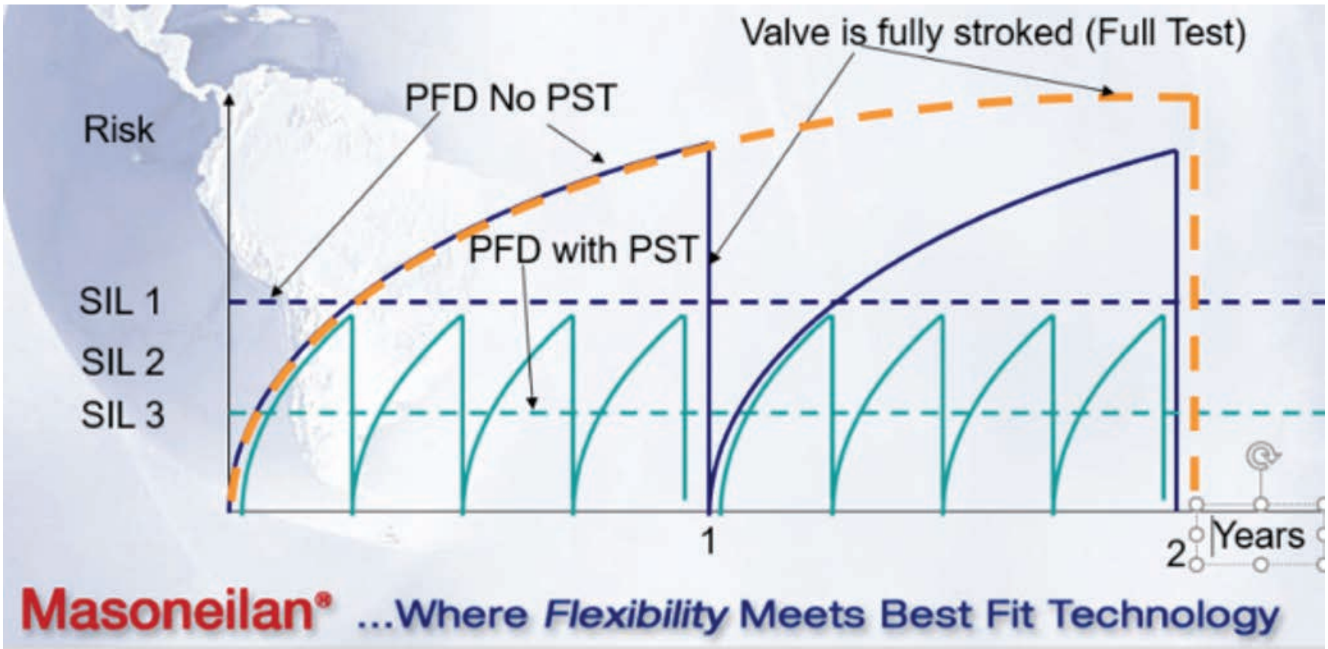

Fig. 1 - illustrative comparison of Full stroke testing vs. PST

The intention is to prevent faults, diagnostics during operation, targeted preparation equipment repairs with minimized cost and time, all to maximize performance of technological unit.

The subject of this article are valves and their testing during operation therefore when describing modern diagnostic methods will focus only on those that are bound with plants using valves, i.e. power plants, refineries, petrochemicals, gas industry etc. Technology units such as boiler, turbine, cracking unit, gas storage are fitted thousands of vlaves. Malfunction or failure of the valves can lead to a significant reduction in efficiency of units or even unplanned stop of operation. Today's trend is prolongation of downtime for 4 years which makes great demands for preventive, predictive maintenance.

Maintenance 4.0 and valves

If they are placed on us so high requirements, i.e. ensure up to 4 years continuous operation without removing and repairing the valve, at the knowledge of statistical data when about 50 % of unplanned stop of operation is associated with failure it is obvious that we have to test the valves and diagnose during normal operation. This cannot be done without the use of modern ones digital diagnostic methods. We can see analogy in medicine where we see constant development of imaging diagnostic methods such as CT, magne-

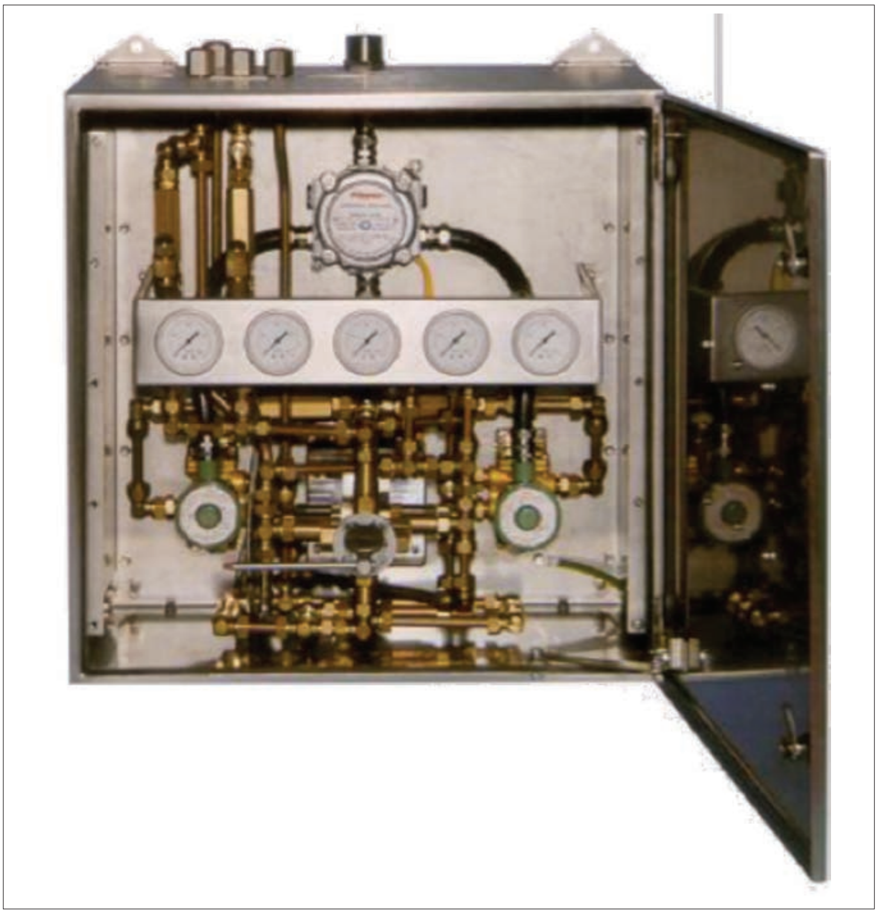

Fig. 2 – pneumatical cabinet

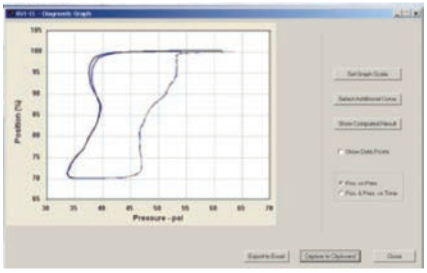

Fig. 3 - graph of PST progress

tic resonance imaging, ultrasound etc. Just as a surgeon does not proceed with surgery without a diagnostic without patient examination by the above methods, so our goal in the field of valves is to approach to repair of valves with knowledge of their condition and in particular to diagnose serious defect before it happens. Our next task is to diagnose every defects even minor that could lead to a reduction of the unit performance. This is particularly inaccurate regulation and leaks. Based on the complex measurements which took place in power plants (USA, Netherlands) it´s known that due to small leaks in dozens of valves there is a loss of up to 3 % in plant efficiency.

At a time of pressure to maximizing of performance and minimizing of the environmental burden this represents a huge field for improvement.

Functionality of valves

We will focus on diagnostics and on-site testing of shut-off, control and safety valves in the above mentioned industrial fields. To put it simply, the operators of power plant, refinery or gas storage are interested in the following main parameters of valves:

• The valve performs its primary function - it closes/ opens when it is needed (shut-off, ESD, safety valves); if applicable accurately, quickly and smoothly turns into the desired position (control valves). Primarily, it is a diagnostic of ability of valve to change the position.

• Tightness of vlave - if the valve is already able to reach the desired „closed" position, is the second essential criterion that sealing is in the required quality. It is a diagnostic of valve tightness during operation.

• Safety of operation of valve - not least the operator must monitor a wide range of operational safety parameters of valve such as body erosion / corrosion, leakage through the packing or sealing, throughput etc. Diagnostic methods in this area are the same or similar as in the checking of general piping elements. Measurement of losses on the body is the same as on the pipe. Leakage of gas through packing is diagnosed similarly as a leakage throught flange joints, etc. Therefore, we will then focus on general testing of piping elements.

• Asset management - the last parameter which is critical to every operating technician is that all of the above diagnostic or maintenance activities are maintained in a structured digital on-line database with the ability to interpret historical data.

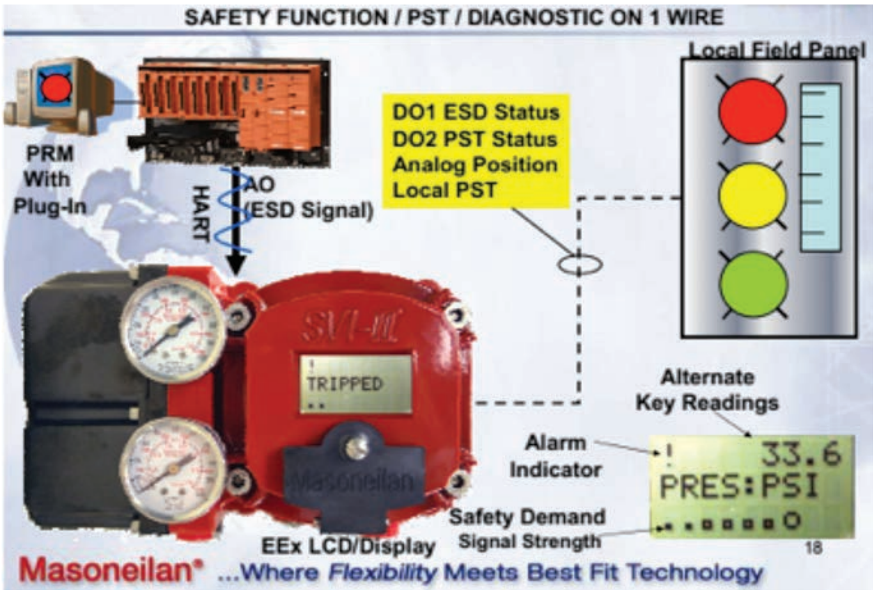

Fig. 4 - smart ESD positioner

Testing of valve stroke during operation

We focus on modern digital and intelligent equipment and methods for testing ESD and control valves. An important area of safety valve testing is given in a separate chapter as it is very specific.

ESD valves - as the name hints (Emergency Shut Down) these are automated valves that on command from SIS or DCS shall reliably shut down the unit. These valves have a unique function and are only activated to shut down the technological unit. They are subjects of conflicting requirements on the one hand they must meet high demands on reliability (SIL3) while most of the time they are in one position (open). How to ensure that a unit which has a shutdown every 4 years has sufficient confidence that the valve shuts down actually when required?

For continuous testing of the reliability of the ESD valve function was chosen concept of PST (Partial Stroke Test) where the SIL evaluation determines the testing interval. The principle of this test is, simply put, if we are able to move the valve by 10-20 % regularly in short time intervals, then we expect with high probability that the valve will shut down, i.e. does 100 % movement. All this without necessary to perform a Full Stroke Test which leads to shutdown of the unit. Because the most of ESD valves are operating with spring pneumatic actuator (single-acting), the leading manufacturers are face of a challenge how to achieve only a partial stroke, i.e. partial air relieving from pneumatical cylinder. The first historical solutions consisted of complex pneumatical schemes where the air was transferred between the elements so that only partial movement occurred. Although this the examples of „watchmaking work" these solutions have serious lacks including high price, problems with reliability due to the great number of elements and last but not least the absence of digital output. Just the absence of digital output and impossibility of simple storage and comparison of historical data are great disadvantages of this method for real diagnostics.

With the development of smart digital positioners for control valves and arrival of SIL-3-certified smart ESD positioners about 10 years ago, the PST concept has taken a whole new dimension. Not only do they bring a huge simplification of pneumatic scheme, a dramatic price reduction and significantly simpler control but especially bring so much desired digitalization and the resulting diagnostics. These advanced devices are programmable, so it is possible to program a certain interval of PST execution. Moreover, during the test, the behavior of the pneumatic actuator (valve) during partial stroke is recorded and everything is available in digital data and graphs. The comparing of historical data and tracing any changes indicating deterioration of the ESD valve assembly is simple.

PST concept of testing of ESD valves during operation with smart ESD positioners has become a common practice today and the collection of test data is an essential diagnostic tool for evaluation of ESD valve reliability.

Control valves - the already mentioned advent of digital smart positioners at the turn of the millennium brings the possibility of on-line diagnostics also in the field of control valves. Control valves as remote and automatic (DCS) actuated valves play a key role in the proper functioning of the entire plant.

Their poor function means deterioration of control which, in the best case decreases the efficiency of the unit, in the worst case leads

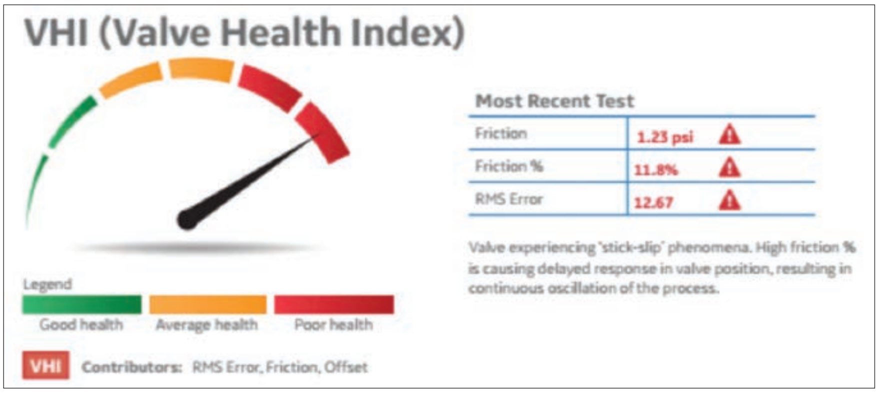

Fig. 5 - Output from ValveAware

Fig. 6 - Graph of friction in packing

Fig. 7 - EVT during the test

to shutdown, for instance of blending unit. Maintaining the exact mixing ratio of the additives is a prerequisite for achieving the desired fuel quality (octane number).

Over the past 20 years there has been a major shift in the testing of control valves in operation but in off-line mode. Additional devices mounted on the control valve such as ValScope are used for these tests and analog positioners or diagnostic tools available in smart digital positioner. These methods already represent a significant advance in predictive diagnostics as they allow on-site testing but unfortunately they do these tests cannot be performed in automatic mode during operation. It is always necessary to change the position of the valve significantly. This is incompatible with operation. A revolutionary change in this area is continuous testing of control valves "on-line", i.e. during operation under using available data from a digital positioner through a communication protocol (HART, FF). ValveAware® SW is an absolutely top and innovative solution from Baker Hughes Masoneilan company. The principle is basically very simple. Over the past 20 years there has been a massive change in control of valves with most units already equipped with smart positioners with the ability to communicate. ValveAware® does nothing but continuously monitoring of the control capability of the valve by comparing the actual position to the required. These data which are constantly available in any smart positioner are collected during operation without interfering in any way with the valve control and by evaluating of 16 key parameters evaluate the valve's "health" and probability of failure through the Valve Health Index. alveAware® software allows you to get a range of important diagnostic charts (on-line!) such as comparing actual vs. required positions, friction in packing etc. In the field of remote-controlled valves, the digitalisation of the control system now has a wide scope for predictive diagnostics "on-site & on-line".

Safety valve opening pressure testing during operation

Let us now leave the field of intelligent positioners and remote-controlled fittings, where the name implies that there is scope for modern digital diagnostics and testing, and let us turn to purely mechanical devices such as spring relief valves. Here we face a similar challenge to ESD fittings. Safety valve it has an essential safety function of overpressure protection and at the same time it is a valve that "sits and does nothing" in the long term. Again we need to ask how much we can rely on opening and relieving of the required capacity when the required opening pressure for protection against crash of technology is reached? As this is a truly essential safety device it was usual for the safety valves to be dismounted annually and the opening pressure was checked in a test stands in workshop. This procedure is safe but expensive and it is contradict the requirement to prolong shutdowns (partly resolvable by valve duplication, of course it´s a very expensive solution). As this is a truly essential safety device it was usual for the safety valves to be dismounted annually and the opening pressure was checked in a test stands in workshop. This procedure is safe but expensive and it is contradict the requirement to prolong shutdowns (partly resolvable by valve duplication, of course it´s a very expensive solution). Although it is a purely mechanical device it is possible to do so a sophisticated "on-site & on-line" tests with digital output. The principle is very simple from a physical point of view. The opening pressure setting is defined by balancing the forces generated by the spring and the pressure of working medium on the surface of valve plug. When the spring force is exceeded (pressure greater than opening pressure) valve opens and releases. During operation we have a real operating pressure lower, ideally between 50 to 85 % of the opening pressure) and therefore we know the force exerted on the surface of the plug. If we mount an auxiliary lifting device on the valve pin where we can accurately measure the additional power by implementing additional force and achieving a slight lift of the plug we are able to calculate the actual spring force and thus actual opening pressure. Of course, we need to know the real pressure and area of seat. Sophisticated devices such as Electronic Valve Tester from Baker Hughes Consolidated have a database of effective plug surfaces from all world-class manufacturers of safety valves and allow testing of most spring relief valves. Based on these tests, the operator can choose a schedule for testing the opening pressure to maximize the time of the period between shutdowns while minimizing the costs.

Tightness test during operation

The second important parameter we observe in valves is their tightness (or leakage) in the required class and quality. Here we face an even greater challenge than with the first group (momentum test), since detecting an on-line valve leak in a closed pipe circuit is truly difficult. There are two primary reasons

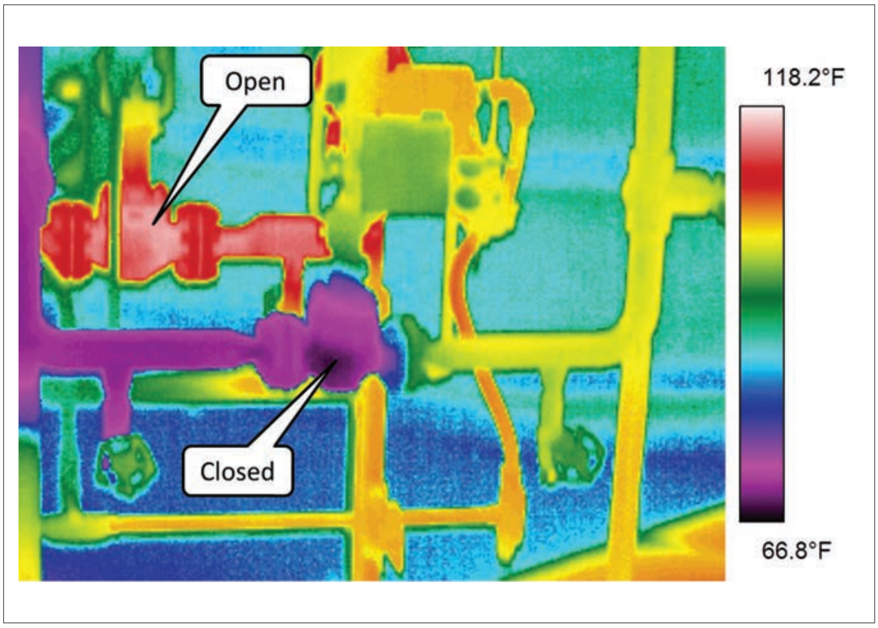

Fig. 8 - A representative image of a thermal camera

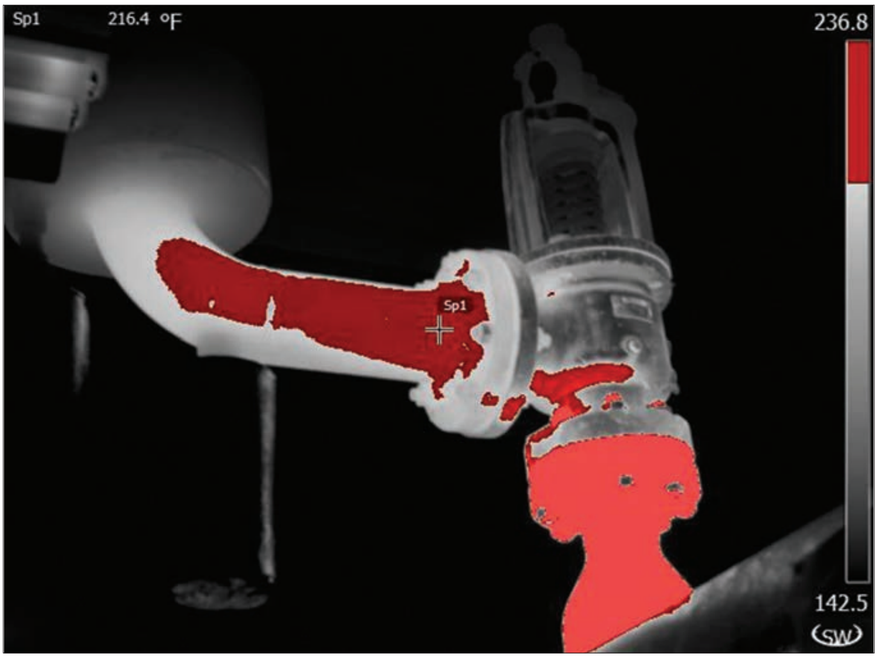

Fig. 9 - SV Leak detection

for the valve leakage. The first reason is that the valve is not function and the medium passes through it to the part where it should not get. This can have more or less impact on the operation of the unit, in critical cases it leads to shutdown, in better cases to loss of efficiency. The second reason why we are interested in the valve leakage is the fact that it indicates a trim defect which may be due to unwanted phenomena such as cavitation, excessive erosion, etc. Detection of even small leaks can help us diagnose a more serious problem and we can take action in advance before an emergency occurs.

The external manifestations of the valve are used to detect leaks that cannot be measured explicitly. These external manifestations are in particular temperature and noise propagation. We are able to measure temperature and noise from around the valve and therefore we can obtain a lot of valuable diagnostic information during operation. We face a number of limitations such as an isolation of valves and piping, overall unit noise, unavailability of valves etc. It cannot be argued that we can detect all positions and media using these methods but many applications do. Especially in the area of steam, hot water (even flashing) and compressed gases we can achieve very conclusive results.

Thermal imagers - in the area of thermal cameras we can meet a number of designs and a wide range of price levels. Portable thermal imagers with a temperature sensitivity of 0.1 °C, a temperature range up to 550 ° C with a thermograph are used to detect heat transfer in piping systems. In industry, these thermal imagers are used mainly for the possibility of measuring high temperatures, high resolution and excellent temperature sensitivity. The cameras have a high degree of protection to suit the most demanding industrial conditions. Figures 8 and 9 show representative measurement results (Infrared Training Center ® database) where it is possible to see how an „open" or „closed" valve behaves or how a safety valve leak can be detected.

Ultrasonic detection - current portable digital ultrasonic devices are used for fast, reliable and cheap leak detection in industrial technologies with pressurized gaseous media (air, steam, natural gas, etc.). Use on liquid media is more problematic, however there are references (flashing water for boiler blow-off, etc.). The principle of measurement is basically simple. If the valve is closed and leaking, gaseous media pass through defects (scratches, scratches, erosion) with enormous expansion (depending on delta P before and after the valve), reaching medium sonic velocity which naturally generates increased aerodynamic noise that can be detected by an ultrasonic probe. Obviously, the obstacle here is the thickness of the pipe and especially the thermal insulation.

Therefore permanent holes are drilled into the insulation to insert the probe. These small holes have no effect on the overall functionality of the insulation and allow the probe to reach the pipe surface just behind the valve and detect even relatively small leaks. In liquid media the detection of leaks by ultrasound is more difficult as very often the liquid medium does not generate any noise when passing through a sealing surface defect. Exceptions may be situations where cavitation occurs which generates increased hydrodynamic noise and especially a flashing liquid, where the phase of working medium changes inside the valve and the emerging gas phase (steam), due to expansion and high velocity generates noise which is noticeable by an ultrasonic probe.

I have described two frequently used "smart" methods for general detection of leak for valves. Of course, this list is not exhaustive. There are types of fittings, such as trunion ball valves with Double Block & Bleed construction, which already have a built-in design for "manual" leak detection. In any case, leak detection "on-line" is a relatively complicated diagnostic procedure that requires knowledge of valve design, knowledge of technology and technological data (medium, pressure, temperature, etc.) and experience with the diagnostic equipment used. It is ideal to choose a combination of measurements and to compare and evaluate the results.

Maintenance database

The above methods are modern diagnostic methods for predictive „on-site & on-line" valve diagnostics, however, in themselves represent only „icing on the cake". What it connects all methods and give them evaluation power is a long-term monitoring and the ability to

Fig. 10 - Ultrasonic leak detection principle

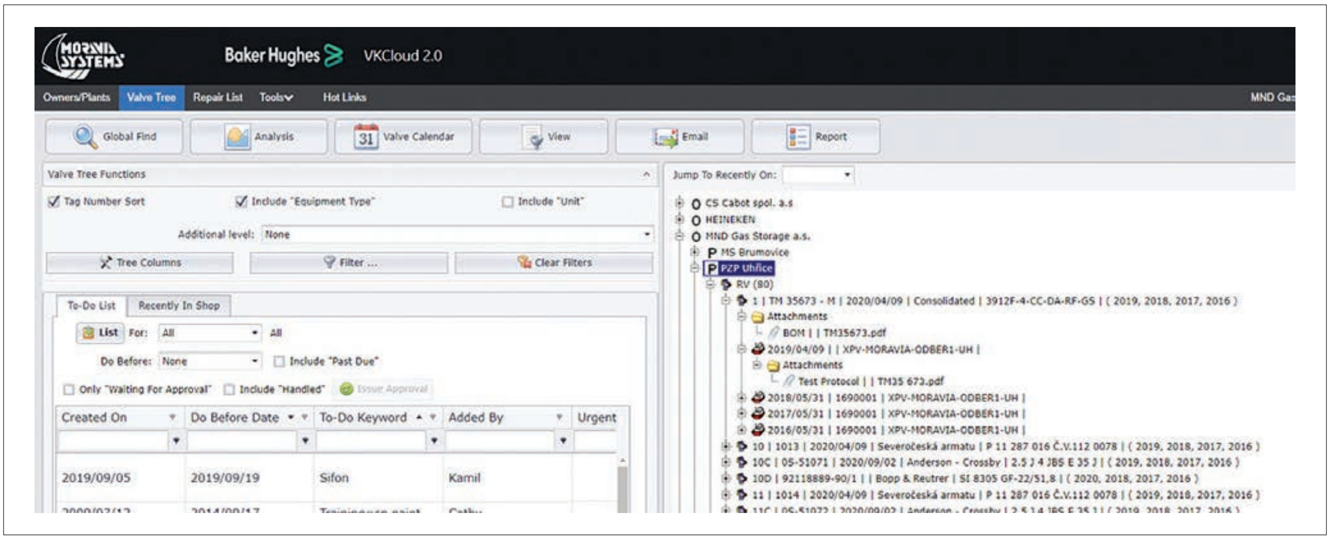

Fig. 11 - Detail of VK Cloud database

quickly and efficiently compare historical data. Real effective predictive maintenance is the long-term, systematic and careful job of recording tests in the database. In the field of Asset Management, there are a number of comprehensive software solutions that allow the management of a number of elements from pumps, valves to pressure switches. The advantage of these solutions is the complexity where everything is in one place, the disadvantage is too generality which does not allow working with details typical e.g. only and only for valves.

The author of the text in this area prefers to maintain the maintenance database in dedicated solutions for valves. Only such solutions effectively recognize the nuances between shut-off, control or safety valve. Outputs such as protocols, analysis tools, etc. correspond to this. Professional software solution for valve maintance as is ValvKeep from Baher Hughes (VK Cloud) it provides the user with easy and intuitive operation and efficient work with data. It records individual maintenance, spare parts deliveries, photos, protocols, etc. throughout the lifetime of the valve; all in digital database form for filtering, sorting and analyzing. Modern and digital processing of maintenance data is a prerequisite for achieving the above-mentioned new level summarized under the term Maintenance 4.0.

Conclusion

In this text we tried to present some modern digital methods of testing of valves during operation. Although the list is not and even cannot be complete, it is important to understand the current trend where more and more valve checking and testing moves from workshop to their position.

It is too late to detect faults after disassembly of valves in the workshop during the stop of operation. The aim of modern predictive maintenance is to have a comprehensive overview of the "health" of the valves during the entire life cycle and detect the occurrence of malfunctions in the early beginning and during operation.

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