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ONLINE VALVE MONITORING SYSTEMS USED ON OFF-SHORE PLATFORMS IN THE NORTH SEA

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ABSTRACT
Monitoring the leakage and condition of Emergency Shutdown Valves (ESVs) on offshore oil and gas platforms is an essential part of maintaining the safety of personnel and protecting the environment. Failure of these valves to operate when they are needed also has an enormous economic impact. The ESVs are intended to isolate each section of the platform in the event of a line break or fire, preventing hydrocarbons from flowing into the affected section. This paper describes a unique approach to monitoring these valves for leakage while the systems are in operation.

INTRODUCTION
On July 6, 1988, 167 people perished on the Piper Alpha Platform. The platform explosion and fire that occurred in the middle of the night was the worse offshore oil industry accident in history. The resulting investigation into the causes and contributing factors led to many changes to improve offshore safety worldwide[1]. One specific area addressed involved Emergency Shutdown Valves (ESVs).

Figure 1: Piper Alpha Disaster [2]

The ESVs are hydraulic, pneumatic and motor-operated rising stem gate valves or ball valves, the largest percentage being ball valves with hydraulic actuators. The ESVs isolate the platform from both the oil/gas source and the distribution headers. They are also located in other flow streams on the platform. An existing emergency shutdown control system monitors many parameters and periodically sends automatic signals to the valves to isolate the platform during emergency shutdown events. The valves are also connected to the platform's main control system, a separate system.

Typical test methods require special test equipment and personnel at the valve and some approaches require shutdown of the process. The methods are expensive but the testing costs are justified by the potential consequences of valve failure. This paper discusses an alternative approach that eliminates any impact on system operation and does not require any personnel present at the valve during testing.

ValveWatch monitors the condition of the ESVs system while the system is online to determine if the valves are leaking, and to estimate whether the leakage is above the capacity of the fire protection. The term "ValveWatch" refers to the entire system – both hardware and software – that is required to monitor a valve. ValveWatch applies a unique methodology for obtaining critical information about the leakage and mechanical condition of the valves.

ValveWatch data is acquired at regular intervals to identify valves that are leaking or degrading, so that more effective maintenance or replacement can be accomplished during planned shutdowns. Data is also acquired during and after each shutdown or 10% stroke testing event so the dynamic performance of the valves can be evaluated. The data is available for analysis and trending for anyone with network access.

Why was ValveWatch developed?

A major contributor to the severity of the Piper Alpha disaster was the inability to isolate the risers that ruptured and provided high pressure gas products from other platforms to fuel the fire. A prior audit had identified the potential for devastation that would result from rupture of these risers and recommended automatic isolation valves at sea level. Unfortunately, this recommendation was not implemented prior to the accident[3].

In 1992, the Norwegian Petroleum Directorate (NPD) issued new regulations regarding critical valves. These regulations are contained in the following sections:

REQUIREMENT – Process & Support plant
§ 17 Diagnostic and Maintenance
§ 42 Valve and Actuator

REQUIREMENT – Safety and Communication
§ 18 Emergency shutdown system

In 1995, NPD sent out a letter asking the oil companies how they had implemented the new Emergency Shutdown Valve testing regulations. Very little had been done, but this started a discussion internally for each Company – how can we test our valves?

Statoil, Norsk Hydro, Saga Petroleum and Phillips Petroleum held joint meeting to look at this challenge. In March 1997, these companies had a meeting with Liberty Technologies, Inc (subsequently purchased by Crane Nuclear, Inc.) and were introduced to a new concept – ValveWatch. Figure 2 shows one the installations used during the development process.

Figure 2: Kollsnes Prototype Installation

How does ValveWatch work?

Valve Leakage

Fluids and gases flowing through a pipe generate pressure variations on top of the static pressure. This is more commonly known as flow noise. ValveWatch takes advantage of this flow noise to determine if a closed valve is leaking or not and also to determine valve seal condition when the valve is in the open position[4]. The following analogy is one way to present this theory.

Imagine that sitting in an office with two doorways located on opposite sides. Consider the office the valve cavity and the doors are the upstream and downstream valve seals. The hallways to which the doors lead is the process piping.

In the office with the doors closed, noise can be heard. Some of it is generated in the hallway on the left-hand side, some of it is generated from the hallway on the right, and some is generated in the office itself. If these sounds were compared electronically, one could determine that the source of each sound was unique and not related.

If the door on the right-hand side is opened the sounds of the hallway are mixed with the sounds in the office. Now an electronic comparison of the sounds would show that the office sound is highly related to that of the hallway on the right. This correlation of sound (or pressure fluctuations) is dependent on how much the door is open. The more the door is opened, the louder the sound. The fact that the noise is coming from the right-hand side does not change. This concept is illustrated in Figure 3.

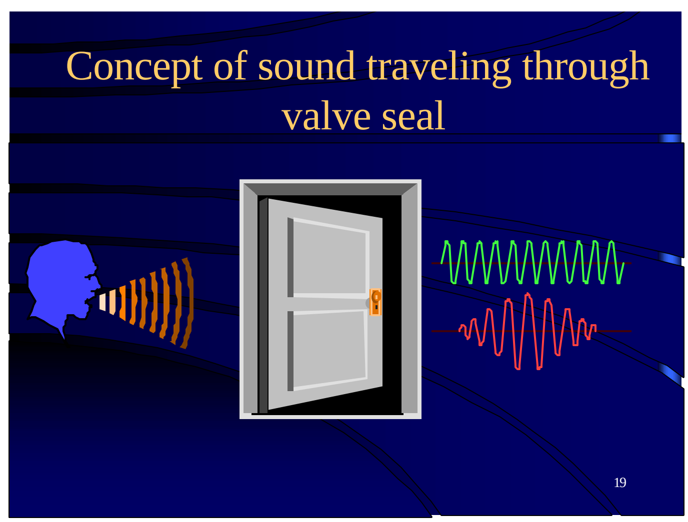

Figure 3: ValveWatch Concept

If the left-hand door is opened, the office has sound coming in from both sides. Performing an electronic comparison of the sound in the office would indicate that the total sound is related to that generated from both the hallway on the left and on the right.

The sound of leakage in a valve is similar to the analogy presented above. AC pressure transducers are located upstream and downstream of the valve. Another transducer is installed to listen to sound in the cavity. By comparing sounds using a ***coherence function***, one can quickly determine whether the sounds are related. The sounds can only be related if there is a leakage path through the valve seal. Once it is determined that the sounds are related, i.e., there is seal leakage, the loudness (amplitude) of the sound is investigated using other functions, to determine how large a leak is present.

Valve-Actuator Mechanical Condition

A strain gage can be defined as a mechanical, optical or electrical device used to measure the deformation (strain) of a material. The strain gage device used in the ValveWatch product is referred to as a “Bonded Resistance Strain Gage”.

A piece of wire, with known electrical resistance, is bonded to the material in question. When a force is applied to this material, the wire will either shorten or lengthen, thereby changing its electrical resistance. Typically, these strain gages are attached to a Wheatstone Bridge and the change in voltage is measured. If this change is measured and the properties of the material to which the strain gage is attached are known, the force required to make the wire shorter or longer can be calculated.

The strain gages are attached to any member of the valve-actuator combination that sees either torque or thrust. (A ball or butterfly valve will experience torque and any rising stem valve, such as a through-conduit gate valve, will experience thrust). The software converts the strain gage’s electrical response to deformation into a graphical depiction of the forces experienced by the valve at various points while it is stroking.

For example, one would expect a ball valve to have higher torque values at three points during its stroke: When the valve starts to move (breakaway torque), at some point in the closing (maximum hydrodynamic torque) and finally when the valve seats (seating torque). The strain gage effectively measures these areas of increasing torque, as well as any other forces experienced by the valve during stroking. By knowing the characteristics of the valve and comparing successive traces, the technician can easily determine if the mechanical condition of the valve is deteriorating. The primary evaluative tools are the shape of the valve curve, the duration of the valve stroke and the amplitude of the curve.

Overall System

The ValveWatch system consists of sensors, barriers, a data acquisition unit (DAU) and software as shown in Figure 4. Typically three dynamic pressure sensors are installed at the valve along with a strain sensor. The sensors are all qualified for EEx ia IIC T4 classification. The outputs are routed to the DAU through barriers to maintain intrinsic safety. Tests are initiated by the DAU whenever the valve opens or closes, whenever an operator on the platform or on shore requests a test, and at predetermined time intervals. The DAU conditions the signals and transmits digital data to a server for data storage. Once the data is stored, an analysis computer can access the data for analysis. The software provides the user with the ability to trend and track valve leakage, as well as providing a graphical depiction of the mechanical condition of the valve/actuator.

The system also includes a spare input for each valve. This input can be used for a variety of applications to give even more definitive operational characteristics. Typical uses are actuator DP sensor for verification of proper input hydraulic forces to the valve and angular sensors to verify the position of the valve.

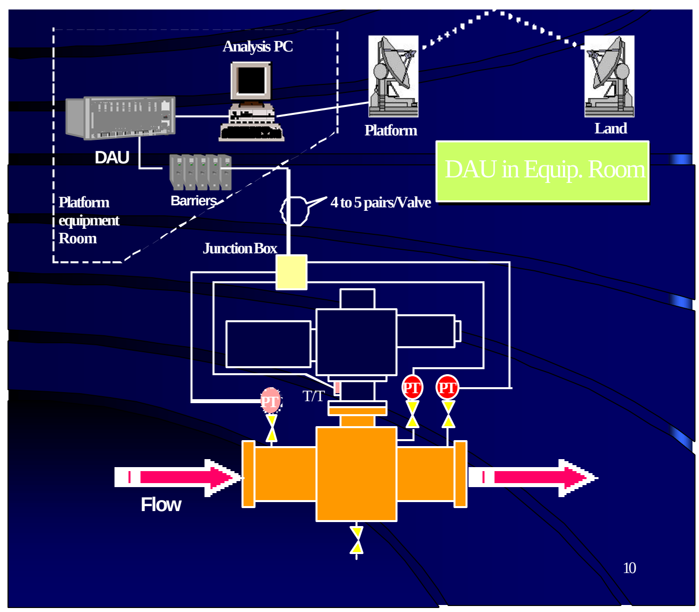

Figure 4: ValveWatch Basic Configuration

The overall system architecture is shown in Figure 5. As indicated, the Oracle server can connect to multiple ValveWatch installations.

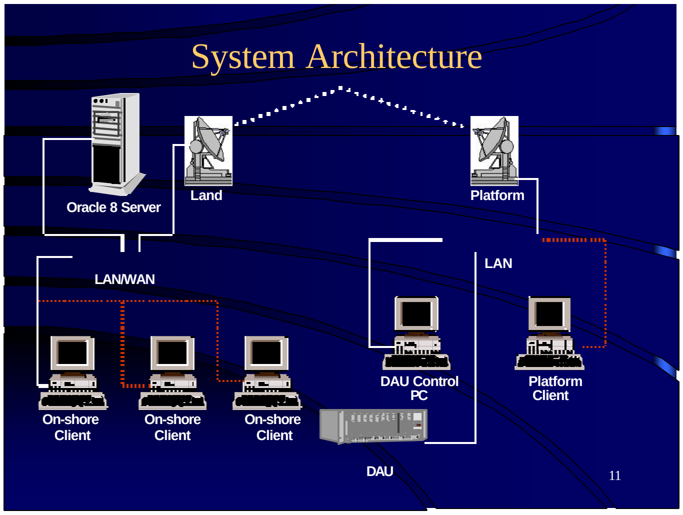

Figure 5: ValveWatch System Architecture

How to identify critical Valves

On a platform there is always a risk that a pipe may burst or a significant leak may occur. If either of these occur, the ESD valves are designed to shutdown and stop the flowing medium. Any leak through an ESD valve in these emergency conditions will impact on platform safety and/or the environment. By looking at the amount off energy that can leak through a damaged valve and comparing it with firewall rating, we can decide if the leak will have any escalating effect on:

- Release of additional medium - fire from leak can influence surrounding equipment/structures
- Loss of escape routes
- Loss of importance communication between control room and fire fighting
- Loss of evacuation equipment and evacuation room.

Engineering process needed to apply ValveWatch

Before applying ValveWatch an engineering assessment is necessary. Typical questions are:

1. How can the valve be tested?
   - manual leak test
   - using process pressure in the cavity to leak test when the valve is open
   - using process pressure in the cavity to leak test when valve is closed
2. Is it possible to close in a pipe segment and measure increasing/decreasing - pressure when valve is closed?
3. OR is this valve suitable to use with ValveWatch?

The following process is recommended:

1. Look at "ESD report" – info regarding manual leak method.
2. When the critical valves are selected, determine how each valve will be tested. Key parameters to consider are cost, safety, and test accuracy
3. Perform a survey on the platform
   - Determine whether any pipeline modifications are necessary to install DB&B valve.
   - Determine where the DAU can be located.
   - Determine whether the cable trays are accessible.
4. Prepare drawings – general and loop.
5. Develop work package.

Some Limitations of the ValveWatch System

As with any new technology, there are situations where it is not practical or cannot be fully utilized. Some of the specific limitations are:

- To detect leakage when a valve is open there must be a cavity that is sealed on both sides when the valve is good condition. Small equalization holes may be acceptable on larger valves provided they do not result in significant leakage into the cavity. Valves that do not have a cavity and valves that do not fully seal the cavity must be tested for leakage when they are closed.
- The system cannot detect leakage when the valve is open unless there is ~~no~~ flow in the pipe.
- The system detects leakage in a qualitative manner and operates on the basis of trends from a known condition. Quantifying leakage when the leak geometry is random in nature has been a goal sought by many but not achieved with any degree of accuracy.

Why ValveWatch is a good solution

ValveWatch significantly enhances platform and personnel safety:

- Performance of condition based monitoring allows operators to detect trends in performance before a dangerous condition develops. In this case, undetected leakage in a valve that might be needed to isolate a rupture can spell disaster.
- The test approach does not require changing the normal operation of the system. Placing fluid systems in an abnormal configuration for testing always increases risk.
- ValveWatch is passive and is not affected by other systems.
- Manual testing puts platform personnel at risk because conditions at the valve can be dangerous. ValveWatch

performs its testing remotely so that no one needs to be at the valve when it is tested.

- Monitoring strain provides additional information that can warn of developing valve problems.

ValveWatch not only improves safety but also reduces cost

- Condition based monitoring identifies equipment needing work so that overhauls can be planned. Significant saving result when parts can be ordered and work crews organized before the work.
- Condition based monitoring also avoids unnecessary maintenance so that attention can be given to components that have problems and not to equipment that is in good condition.
- Forced outages result in loss of production. Repairing a degrading valve before it fails always saves money.
- Testing manually has much higher labor cost that can far exceed the life cycle cost of ValveWatch. In some cases, production losses occur because of changes necessary to perform manual testing.
- Major accidents result in enormous costs that can devastate a company financially.

ACKNOWLEDGMENTS

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