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PROBLEMS, CONCERNS AND POSSIBLE SOLUTIONS FOR TESTING (AND DIAGNOSTICS COVERAGE) OF FINAL CONTROL ELEMENT OF SIF LOOPS

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ABSTRACT

Safety Life Cycle of E/E/PE Safety Instrumented System incorporates testing, as one of the steps in order to achieve required Safety Integrity Level.

Testing other components of SIF (Safety Instrumented Function - Safety Function with specified Safety Integrity level) loop, like Sensor and Logic Solver, may impose challenges but not as serious as Final Control element of SIS. Because Final Element remains in one static position for long time and its mechanical movement may affect process, when tested on line. Conventionally, Final Control Element (FCE) of SIF loops are tested during annual turnaround but present day economy is forcing such event to go from annually to once in three to five years.

Though OSHA 1910.119, "Process Safety management" and EPA 40CFR Part 68 recognize as good engineering practice to test safety system on a periodic test interval but plant operational constraint restrains the testing. On one hand final control element represents significant failure contribution but at the same time, its testing is a big challenge.

This paper will discuss on issues and industry concerns while testing FCE in field. It will try to highlight all the concerns and issues related to various methods used to testing final control element and at the same time, will evaluate various solutions, addressing those concerns. This paper will also try to discuss on diagnostics coverage as a result of testing for using in SIL calculations.

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INTRODUCTION

Major accidents worldwide have raised awareness in improved plant, personnel and properties safety, especially in the chemical, refinery, oil & gas industries, which involves inherent risk due to the leaking of dangerous chemicals, gases, and flammable wastes to the environment.

Growing concerns in the arena of safety instrumented systems (a layer of protection) and enforcement of governing industry standards is creating a significant demand for a device that can provide a method for testing safety valve operation without disturbing the process and providing diagnostic information about the final control element.

Safety Instrumented Systems (SIS) consists of Sensor, Final Control Element and Logic Solver. Final control element of SIS is not continually moving like typical control valves, but are normally expected to remain static in one position and then operate only when an emergency situation arises.

Previous industrial data indicates major failure contribution source of SIF loop is final control element. The typical failures being stuck in last position and may not operate when needed. This could result in a dangerous condition leading to an explosion, fire, and/or a leak of lethal chemicals and gases to the environment. To ensure the needed reliability and availability of these safety shutdown valves, they need to be tested frequently.

Unfortunately, the traditional method of testing these safety valves does not provide any internal valve diagnostics. It just allows mechanical movement but does not specifically provide inputs like if, the valve friction is increasing, process build up is occurring on bearing / shaft area, pressure is decaying, valve torque requirement is increasing etc. The purpose of this paper is to review how Digital Valve Controllers diagnostic capabilities can be used to dramatically improve the reliability of these safety systems. At the same time significantly reducing, the risk of spurious trip, unscheduled maintenance, manual laborious test procedures, associated cost, as well as gaining a multitude of additional advantages.

COMMON CAUSES OF VALVE FAILURES AND CONCERNS

Safety Instrumented Systems are dormant or passive. Final control elements in these systems under normal circumstances are not moving. They remain in one position without mechanical movement and may never be called into action. Many potential failures of safety shutdown valve can remain “covet” or hidden, if valve is not exercised for a long time.

Typical Problems associated with SIS valves are:

1) Increased packing friction over time
2) Build up of process fluid material on shaft
3) Seize of shaft in bearing

4) Fracture valve shaft / stem
5) Corroded bearing
6) Broken spring of actuator
7) Permanent set of spring
8) Linkage breakaway friction
9) Slow air exhaust
10) Air exhaust path blocked
11) Spring return actuator dented not allowing valve travel
12) Increased valve break away friction
13) Actuator stem / shaft bent
14) Increased friction of closure element in seal

The main problem of shutdown valves, which represents significant failure contribution to SIS, is difficulties in testing to detect the valve health. Testing can be conducted Off Line or On Line. If, the valves need to be moved to its full 100% travel, it can only be done during annual turnaround. Now a day's turnaround being shifted from its normal course of time to higher time interval, due to economic reason, Safety shutdown valves remains as a biggest concern for plant safety management.

If, the test on shutdown valves can not be performed for longer interval then it affects its SIL (Safety Integrity Level) calculation of the loop, particularly valves that are significant contributors to Probability of failure on Demand (PFD). Increase in the test interval directly impacts the PFD value in a linear manner.

In an attempt to get around this problem, many companies have devised methods for testing the SIS valves on-line so they do not have to shut down the process. The typical approach has been to install a bypass valve around each safety valve. By placing the bypass in service, the safety valve can be full-stroke tested without shutting down the process[i]. In addition, maintenance is also easier since a failed valve can be replaced while the process is on line. Despite these benefits, the on-line bypass approach to testing has a number of disadvantages. Prime among these is the fact that the process is left totally unprotected while the bypass is in operation. Also of concern, is the possibility of the safety valve being inadvertently left in the bypass position after testing. This would leave the process totally unprotected until such time as the error is discovered. Insurance companies that provide coverage to the plant do not find either of these alternatives very attractive.

Over the years, a variety of methods have been developed for doing this type of partial testing. While all of them have a definite risk of spurious shutdown trips associated with them, the mechanical limiting method seems to be the most popular. Mechanical limiting methods involve the use of some mechanical device, such as a pin, a valve stem collar, a valve hand jack, etc. that will limit the valve travel to 15% or less of the valve stroke.

While these mechanical limiting devices themselves are rather inexpensive, the pneumatic test panels used to perform the test are complex and expensive. The testing process must be manually initiated in the field and the tests themselves are extremely manpower intensive and subject to error. In addition, a major drawback to this method is that the safety shutdown function is not available during the test period. Likewise, there is always the possibility that the safety valve will be inadvertently left in this mechanically limited condition. Worse yet, this possibility cannot always be determined by a casual inspection. This means that the valve could potentially be out of service for an extended period of time with the operators unaware of the situation.

If, testing is to be performed on on-off shut down valves (Typically Solenoid operated), while plant is in operation to find out health of valve, then test device should have built in intelligence to avoid potential hazard of spurious trip. Should also be intelligent enough, to recognize and differentiate, between real Safety Demand and partial stroke test command. Digital valves Controller have been recently introduced in the SIS loop to not only partially test valve movement but also provides Increased Safety Availability during test and determines health of control element.

DIGITAL VALVE CONTROLLER AS HEALTH DOCTOR FOR CRITICAL SAFETY SHUTDOWN VALVE

Digital Valve Controllers or "Smart" positioners" have proved as remedy to the cause in recent years to solve the diagnostic issues of Safety Shutdown valves[ii]. These Digital Valve Controller are communicating, microprocessor-based current-to-pneumatic instruments with internal logic capability. These Digital Valve Controllers use HART® communications protocol to give easy access to information critical to process operation. The Digital Valve controller have in built sensors for valve travel, pressure (supply and output pneumatic pressures) and pneumatic relay motion. All these data are processed in the microprocessor of Digital Valve Controller. This allows the Digital Valve Controller to diagnose not only itself, but also the valve and actuator to which it is mounted. It enables plant maintenance group to obtain information in advance for any possible deterioration in valve, before any dangerous condition can take place, thus improving safety reliability.

Partial-stroke testing through Digital Valve Controllers confirms the valve is working without disturbing the process, while plant is running. It also allows more frequent on line testing since it is simple, less laborious and reliable. In past main concerns had been availability of safety valve during test to safety demand. With the use of Digital Valve Controller, on line testing has greatly relieved from worries of non-availability during trip. Since the entire test procedure can be programmed into the microprocessor, partial-stroke testing can be performed automatically with no operator attention required. Companion software can be programmed to schedule test automatically. This allows the Test Interval to be as short as necessary (hourly, daily, weekly, etc.) to meet the target SIL values. The testing sequence is completely automatic, thereby eliminating any human errors and possible nuisance trips. However, for safety reasons, it is suggested that the operator initiate the test sequence locally or remotely with the simple push of a button.

While performing partial stroke test by Digital Valve Controller, it collects travel and pressure data during the test periods. The valve status and its response to mechanical movement can be monitored during the test. Valve performance trends are monitored and automatically analyzed after each partial-stroke test so that potentially failing valves can be identified long before they become unavailable. A cycle counter and travel accumulator will show the extent of valve movement.

The results of a signature test (See Fig. 1) can be used to easily determine packing problems (through friction data), leakage in the pressurized pneumatic path to the actuator, valve sticking, actuator spring rate, and bench set. The data points collected during partial stroke test will provide inferred information about initial inertia force, required pressure to actual movement of valve travel, sticking in shaft/bearing area, linkage dead motion etc. The Digital Valve Controller can save the results of this data for printout or later use. Overlaying the results of the current signature test with those of tests run in the past can indicate if valve response has degraded over time. Analyzed partial stroke test results can provide dynamic error band, dynamic linearity, torque (minimum / maximum) etc. This will enable an early detection of valve related problems. Knowing problem in advance and correcting it in time will increase valve availability, should a demand arise. It also reduces the amount of scheduled maintenance on the valve, because the tests can be used to predict when the valve needs maintenance.

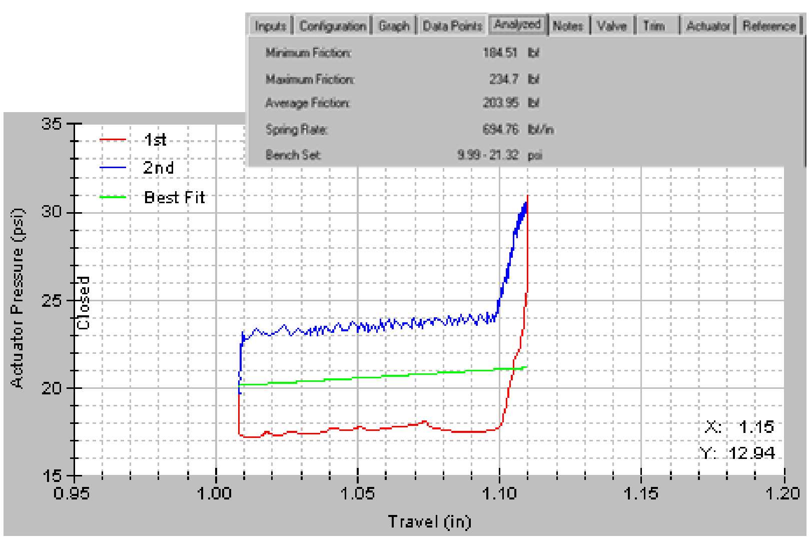

FIG. 1 – VALVE SIGNATURE TEST AND ANALYSIS ON A SIS VALVE

Some Digital Valve Controllers have the capability to alert the operator if a valve is stuck. It can notify key people for critical alerts via email or trigger a pager (See Fig. 2). This means key operational personnel can be continuously informed of alert status.

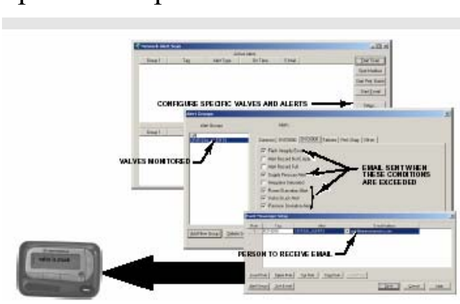

FIG. 2 – CRITICAL VALVE ALERTS VIA PAGER

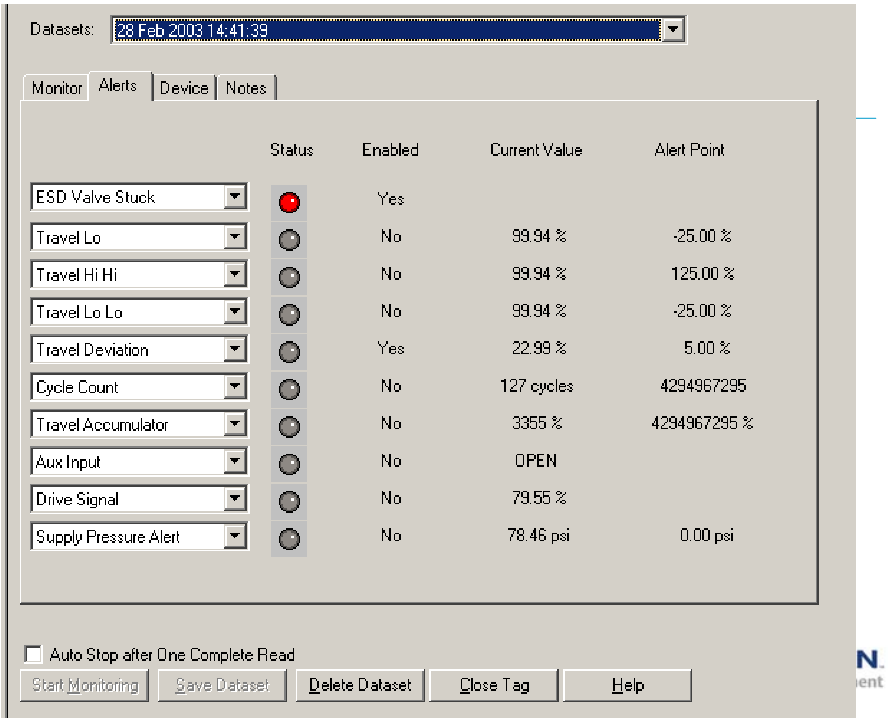

FIG. 3 – VALVE STUCK ALERT

As the Digital Valve Controller begins the partial stroke, it continually checks the valve travel to see if it is responding properly. If it is not, the Digital Valve Controller will abort the test and alert the operator that the valve is stuck (See Fig. 3). This will prevent the valve from slamming shut if the valve does eventually break loose. This will avoid spurious trip.

In short, a Digital Valve Controller can provide complete diagnostic health information on the final control element, including the Digital Valve Controller itself. If, valve is found stuck or having excessive friction or leaking air supply, an immediate alert notification will be provided. In addition, the Digital Valve Controller can provide complete documentation of any emergency event as well as documentation of all testing. Insurance companies will accept this Safety Audit Documentation for proof of testing. Best of all, this document can be completely automated so that expensive operator time is not required (See Fig. 4).

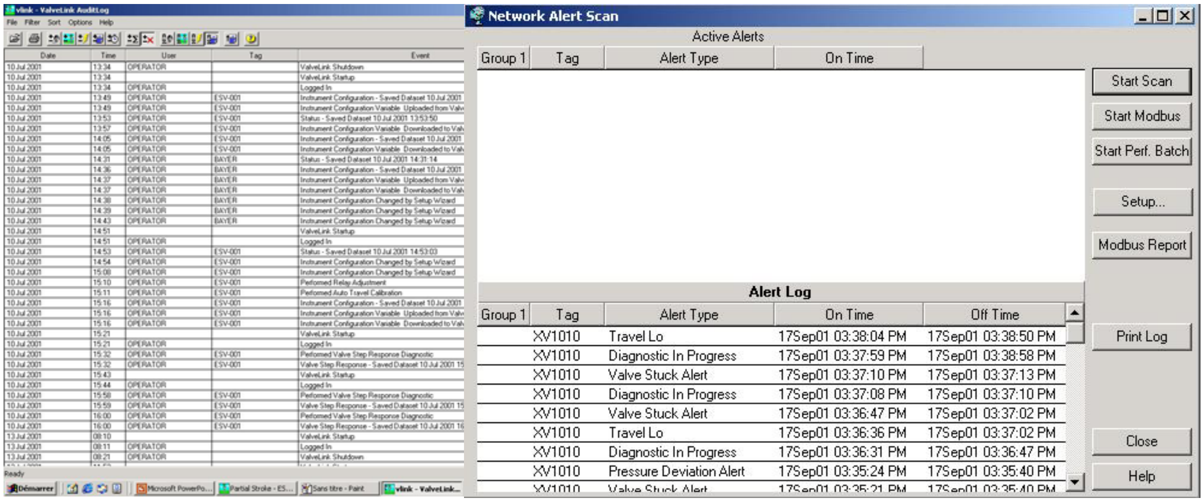

FIG. 4 – DOCUMENATION FOR TEST AND ALERT RECORDS

Digital Valve Controller provides diagnostic as well as positioning information. The valve status and response time can be monitored continuously by its companion software (See Fig. 5)

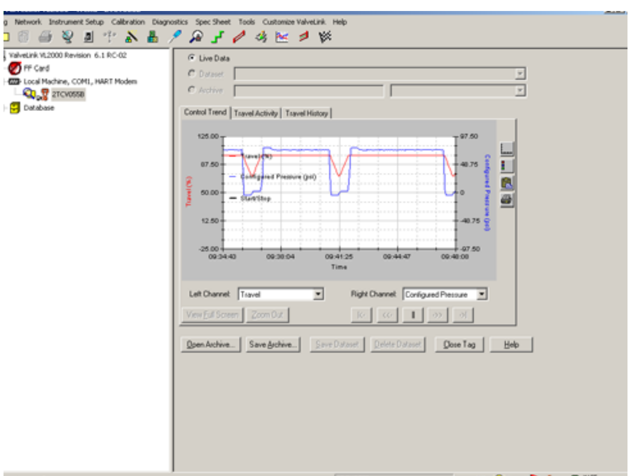

FIG. 5 – CONTINUOUS MONITORING OF VALVE HEALTH

Finally, should an emergency shutdown demand occur during testing, the Digital Valve Controller will override the test, driving the valve to its safe position. This increases availability of shut down valve to plant emergency demand.

Last but not least, while conducting partial stroke test, as the name indicates, will uncover some of undetected failure modes. Diagnostics credit can be claimed for such uncovered failure modes.

Diagnostic coverage factor[iii] for mechanical devices (Final Control element) not only depends on type, size, geometry, but to a larger extent on process fluid (clean, dirty, abrasive) & its physical properties (temp, pressure, density, viscosity etc), type of application, history of past operation, failure records, work practice for maintenance, etc. FMEDA (Failure Mode Effects & Diagnostics Analysis) data from manufacturer but large contribution from end user maintenance record can lead to a reasonable number on diagnostics coverage factor calculation for computing PFDavg (Probability of Failure on Demand) for final control element.

CONCLUSION

Digital Valve Controllers are a great aid to predictive maintenance by providing a Valve Degradation Analysis, which is important for critical valves in safety related systems. This also reduces the amount of scheduled maintenance. While performing the partial-stroke test, if for any reason the valve is stuck, some Digital Valve Controllers will not completely exhaust the actuator pressure. This assures that, if the valve become unstuck, it will not slam shut. These Digital Valve Controllers will then abort the test and send an alert signal to the operator warning that the valve is stuck.

If, pressure deviation or travel deviation occurs, Digital Valve Controller will provide an alert notification accessible through either the HART communicator or associated software. This will be an indication of possible leak in packing area, change in friction, change in pressure etc, which may need either immediate attention or later planned maintenance of valve.

The Digital Valve Controller provides a time and date stamp on all tests and reports, which is very important for complying with the requirements of statutory authorities. It also provides the capability for comparing, storing and interpreting diagnostic data.

Digital Valve Controllers allow partial-stroke testing while the process is running with no threat of missing an emergency demand. This type of test applies a small ramp signal to the valve that is too small to disrupt the process, but is large enough to confirm that the valve is working properly.

While obvious diagnostics, performance and safety benefits can be gained through partial-stroke testing, many additional benefits can be obtained by using a Digital Valve Controller. Lower base equipment cost is achieved with considerable reduction in testing time and a reduced manpower requirement through the elimination of expensive pneumatic test panels and skilled personnel presently required for testing. In addition, remote-testing capability requires fewer maintenance trips to the field, as well as the establishment of an automated test routine that can produce great timesaving.

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