INCREASING SAFETY COST EFFECTIVELY

Taking safety valve testing to the next level

Today's safety engineers face increasing challenges every day. Safety requirements are becoming more and more demanding, while the global market situation is simultaneously creating constant pressure to reduce costs. The IEC61511 safety standard requirements state that industrial processing plants must determine the Safety Integrity Level (SIL) for all the different areas of the plant. Based on the area SIL classifications, the plants must then be able to dispatch quantifiable proof of compliance with the requirements.

TEXT Juha Kivelä

Reprinted with the permission of Hydrocarbon Engineering magazine.
The article has been published in Hydrocarbon Engineering December 2009 issue.

For these reasons, safety engineers need to reassess the safety-loop testing methods at their plants. In particular, greater attention must be paid to safety-valve testing procedures, because the safety valve is the final element in the safety loop and is operating in the most challenging environmental conditions and is constantly in actual contact with the process media in the pipelines.

What makes safety valve testing important?

A potential accident at an industrial processing plant could have devastating results. The task of the safety loop is to minimize the risk of toxic emissions and to prevent such disasters from happening, should process upsets occur. It is therefore easy to understand the importance of the different components of the safety loop and the significance of the operational reliability of the whole safety loop.

As explained earlier, the safety valve can be considered as the most important element of the safety loop. To quote an example, the OREDA (Offshore Reliability Data book) study (see Figure 1.) shows that approximately 50% of all safety loop failures are caused by final element failures. One of the main reasons for this is that the final elements, such as the safety valves, are moving mechanical devices that operate in harsh field conditions, whereas most of the other components of the safety loop work

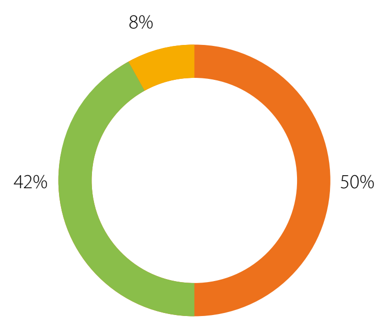

Fig. 1. Safety Loop Failure Sources.

Safety Systems · Sensors · Final Elements

Fig. 2. SIL levels in accordance with PFD values.

SIL	PFD
4	$10^{-5} - 10^{-4}$
3	$10^{-4} - 10^{-3}$
2	$10^{-3} - 10^{-2}$
1	$10^{-2} - 10^{-1}$

in less aggressive environmental conditions – quite often in temperature-controlled indoor control rooms.

Safety valves can be either emergency shutdown (ESD) or emergency venting (ESV) valves. Normally, when the process is up and running, the safety valves are immobile. Depending on the working methods at different plants and on the safety requirements, it is quite possible that the safety valves are not cycled at all during the process run time. When this is the case, it always creates doubts as to whether the safety valve will move when the demand for safety action arises. In practice, unless safety valves are periodically stroked, there is a high probability that when the valve receives the command to execute safety action, its performance may not be up to the required level.

It is evident that until recently many plants have overlooked the importance of testing their safety loops. However, there are also companies that have been proactive in implementing the safety standards and in enhancing their safety loop testing methods. At present, the IEC standards are pushing instrumentation and safety engineers and other company personnel in the same direction. In order to meet and maintain the desired SIL requirements in all the different plant areas, plant operators are forced to increase the testing frequency of their safety valves in order to maintain the duration of shutdown periods. In addition, there is a tendency for plants to try to increase the length of continuous uptime, which also increases the need for safety valve online testing.

Safety valve testing methods

The main purpose of safety valve testing is to prove and ensure safety valve availability. Safety valve testing consists of both offline and online testing, which complement each other. Traditionally, offline testing has been the most commonly used method of testing safety valve functionality. Basically what is done is that during a shutdown, an ESD valve is first stroked to a fully closed position and then returned to its normal position. For an ESV valve, the same procedure is carried out, but to the reverse direction. The information received from this full stroke test is usually only that the valve is moving and that it closes or opens fully in a specific time.

Depending on the SIL rating of the plant area in question, there is a possibility that running full stroke tests during shutdowns is insufficient to maintain the required SIL levels for the whole process uptime period between shutdowns. This is a case where the need for online testing arises.

When the process is online, it is usually impossible to stroke the valve fully without disturbing the process. This is why the online tests are done as Partial Stroke Tests (PST). In PST, instead of a full stroke, the valve is stroked only partially. Conventionally this has been conducted so that by jamming the actuator, for example, it is ensured that the valve can only move to a certain opening angle, typically between 10 to 20%. After reaching this opening angle, the valve is returned to its original position. When the valve is moved only partially, the PST can be run without disturbing the process. The information received from the PST, when doing it the conventional way, is basically to check that the valve starts to move.

As explained earlier, online testing complements offline testing, but it cannot completely replace it. How often must the plant then run a full stroke test and a PST? The required frequency can be determined through safety calculations. To reach and maintain the desired SIL level, the value for the statistical measure of availability in an emergency situation, the Probability of Failure on Demand (PFD), must be at the equivalent level. Figure 2 below shows the relationship between different SIL levels and PFD values.

There are several different ways of calculating the PFD. Figure 3 shows one equation that is well known and commonly used in the industry. The equation shows that there are basically a couple of ways to extend the uptime period between shutdowns. Besides PST, the other way is to increase the diagnostics coverage factor. The diagnostics coverage factor is related to the amount of information received from tests.

Automatic partial stroke testing devices

When doing PST in the conventional way, it always creates additional work – conducting the tests, and documenting and analysing the results. Besides the additional work, there are also other disadvantages when

"On-line diagnostics" (= partial stroke testing)   "Off-line diagnostics" (= periodic maintenance)

$$PDF_{1oo1} = DC \cdot \lambda_d \cdot \left(MTTR + \frac{TI_a}{2}\right) + (1\text{-}DC) \cdot \lambda_d \cdot \left(\frac{TI_m}{2}\right)$$

λ_d	Dangerous failure rate = $1/MTBF_d$
$MTBF_d$	Mean time between dangerous failures
MTTR	Mean time to repair
DC	Diagnostic coverage factor
TI_a	Test interval for partial stroke testing
TI_m	Test interval for manual testing (= shutdown period)

Fig. 3. Example of a PFD equation.

doing PST the conventional way. Because human interaction is always needed, it generates the risk of making mistakes and also puts the safety of the workers in question at risk. Another significant disadvantage is that the safety loop must be disabled when doing the PST, and for this reason, the safety loop cannot carry out the safety action, if required, during the PST.

These challenges encountered with conventional PST methods created the basis for the development of automatic partial stroke testing devices. Metso was the first to launch such a device on the market. Metso's first-generation automatic partial stroke testing device, Neles ValvGuard VG800, was released for sale during 2000. Over the ensuing years, also other vendors have brought their own solutions to the market.

What is an automatic PST device?

An automatic PST device is one that can be used to test the functionality of safety valves when the process is online. Using an automatic PST device provides the answer to many of the challenges that are encountered when doing PST conventionally. When the PST is run with the automatic device, there is no longer any need for human intervention. Therefore the amount of work needed to conduct the test can be significantly reduced, and there will no longer be any need for the workers' safety to be put at risk. One of the most important benefits, however, is that there is no longer any need to disable the safety loop when doing the PST.

When using the automatic PST device, the target is basically the same as when doing the test in the conventional way. The safety valve is moved to a specific predefined opening angle and then returned to its original position. With Neles VG800, the PST can either always be started when the operator sees there is a suitable time to conduct the test or the VG800 can be set to run the tests to a schedule that can be chosen at random. The latter is naturally the more practical option from the workload point of view if there are a lot of safety valves at the plant.

In addition to the fact that automatic PST devices reduce the amount of work and the costs involved in running the PSTs, the information received from the PST is much more comprehensive than with conventional solutions. For example, VG800 collects and stores different diagnostics information based on the PSTs, such as breakaway pressure and load factor trends. These trends give valuable information about the condition of the valve and help to predict potential valve failures. When going back to the PFD calculation formula presented in Figure 3, this gained diagnostics information helps to increase the diagnostics coverage factor, which is one of two ways of extending the shutdown period.

New-generation safety valve controller, Neles ValvGuard VG9000

Up to the present day, nine years have passed since the first automatic PST device, Neles VG800, was launched on the market. As with other high-tech devices, the life cycle for one generation seldom exceeds 10 years. During this time, the end-users have also gained more experience with the PST devices and plenty of valuable feedback has also been received from end-users giving their point of view. The product development work has continued since the launch of VG800 and in 2009, Metso launched a new-generation automatic PST device, Neles ValvGuard VG9000. The FOUNDATION Fieldbus version of VG9000 was already released for sale at the beginning of 2009 and the HART version was released for sale at the end of the year.

Neles VG9000 is called a safety valve controller, because of the additional features and benefits it offers when compared with a traditional automatic PST device. In addition to the automatic PST, VG9000 also includes two additional tests that can be used to test safety valve functionality. The Internal Pneumatics Test can be used to test how the ValvGuard itself is working, and the Emergency Trip Test (ETT) can be used to simulate an emergency action. The Internal Pneumatics Test can be run very frequently without disturbing the process, as the actual safety valve is not moved during the test. The ETT is a test that can typically be run only during shutdowns, because the safety valve is moved to its safety position during the test. The benefit of this test is that it significantly reduces the amount of work needed during maintenance shutdowns, as the ETT can be used as a proof test when creating proof of compliance with the safety regulations.

Fig. 4. PST testing example with VG800.

Fig. 5. New-generation safety valve controller, Neles ValvGuard VG9000.

Probably the most common feedback that has been received in relation to the first-generation ValvGuard, VG800, has been that it would be good if the device could stay alive during a trip. Based on customer feedback, this feature has been incorporated in the new-generation device. The new VG9000 has power during a trip situation, and it can provide diagnostics data from the event.

One other major improvement is the high pneumatic capacity of the new-generation VG9000. The tendency in the process industry has been for safety valves to get bigger and for safety-valve stroke times to get faster. This sets a challenge for the safety valve controller's pneumatic capacity, and with the first-generation devices, there was often a need to use extra instrumentation to reach these fast stroking times. With VG9000's big pneumatic capacity, the need for this extra instrumentation can usually be eliminated. This, together with another feature that makes it possible to install limit switches inside the VG9000 housing, helps to reduce the number of separate components in the safety loop and thereby increase the reliability of the safety loop.

In addition to enhanced features, development work has concentrated on diagnostics presentation, with particular emphasis being put on presenting the diagnostics information received from the intelligent safety valve controller in as user-friendly format as possible. This makes it easier to interpret the information and to use it for maintenance purposes.

The benefits of FOUNDATION Fieldbus technology in safety valve applications

Besides the HART communication, which is typically used in safety valve applications, the VG9000 also has a FOUNDATION Fieldbus version. The FOUNDATION Fieldbus version, VG9000F, is the first automatic PST device that has been specially designed for the FOUNDATION Fieldbus environment.

Traditionally, FOUNDATION Fieldbus (FF) technology has only been used in control valve applications, but recently the end-users have begun to see the benefits of using it in safety valve applications. When compared to HART, the FF-based safety valve controller can give much faster response times for the status information and easier integration of diagnostics information into the host system. One additional advantage of using FF is the possibility for network diagnostics. Network diagnostics provide the opportunity to detect noise, corruption and faults in the network, which is not possible in traditional analog-based networks.

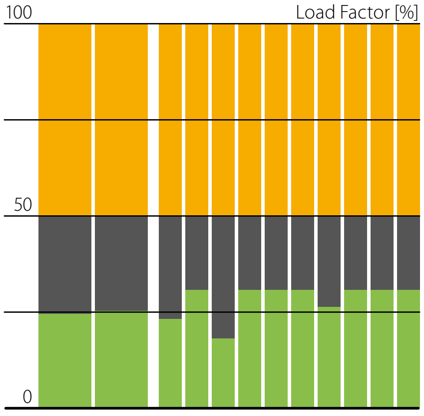

Fig. 6. Example of the trends received from VG9000.

Because end-users do not yet show enough confidence in FOUNDATION H1 technology to base safety action on it, VG9000F still uses a separate binary signal to implement the safety action. The FF is used for device configuration and diagnostics.

Increasing safety cost effectively

Intelligent safety valve controllers, such as Neles ValvGuard, are devices that have been specially designed for safety applications. When bringing new features and functions to the device, safety has always been the driving factor. At the same time, the target has been to help end-users to reduce costs and to make their everyday work easier.

For example, here are some of the features of the new safety valve controllers that can help the end-user reduce costs:

- High pneumatic capacity helps to increase reliability and reduce costs in the purchasing phase by eliminating the need for extra instrumentation
- Easy and fast guided start-up that reduces the amount of work needed in the commissioning phase
- The device runs the required partial- and full-stroke tests, and collects and analyzes the received data, which reduces the amount of safety valve testing work significantly
- The possibility to install limit switches inside the safety valve controller housing simplifies the installation and reduces the amount of separate components.

Altogether, new-generation safety valve controllers bring many new possibilities in the field of safety valves and safety valve testing. They give the end-user the possibility of reducing costs, while simultaneously increasing the safety of their plants.

Juha Kivelä
Product Manager
Helsinki, Finland
juha.kivela@metso.com