WHITE PAPER

Test Procedures, FMEA and SIF Proof Test Coverage

Understanding Test Coverage Factors is crucial because they reveal how effectively safety checks can identify potential issues in complex systems, such as industrial processes or critical equipment, ultimately contributing to safer operations and peace of mind for everyone involved.

Safety Instrumented Functions (SIFs) are critical components of a Safety Instrumented System (SIS). They are designed to reduce or mitigate risks in industrial processes. A measure used to assess the reliability of a SIF in achieving its safety function when called upon is the Probability of Failure on Demand (PFD). In calculating the PFD of a SIF, you must take multiple factors into account, including Failure Rates, System Configuration, Diagnostic Coverage, Proof Test Interval, and Test Coverage Factors. In this blog post, we will explore Test Coverage Factors and their importance in calculating PFDs.

What is a Test Coverage Factor?

The test coverage factor reflects the effectiveness of testing and maintenance activities in detecting and preventing failures within the SIF. It quantifies the probability that a diagnostic test will detect a dangerous failure before it affects the SIF's performance. Test coverage is typically expressed as a percentage, ranging from 0% (no test coverage) to 100% (perfect test coverage).

Car Analogy

Imagine your car's yearly checkup at the garage. It's like a routine health check for your vehicle to ensure it's safe for you and your family. During this inspection, mechanics examine various safety features built into your car, like seatbelts, brakes, lights, oil levels, tires, and indicators. They do this to verify that these safety mechanisms still work as intended, with no hidden issues that could jeopardize your safety while driving.

Now, let's suppose your car has a total of 10 safety features designed to protect you in case something goes wrong while you're on the road. During the checkup, the mechanic can test and verify the functionality of 9 of these safety features. However, there's one safety feature that they can't assess in the garage.

In this scenario, we can say that the Test Coverage Factor of the yearly checkup, which checks 9 out of 10 safety-related features for any concealed problems, is 90%. This percentage represents how comprehensively the inspection assesses the safety mechanisms in your car, helping ensure your peace of mind while driving.

Understanding Test Coverage Factors is crucial because they reveal how effectively safety checks can identify potential issues in complex systems, such as industrial processes or critical equipment, ultimately contributing to safer operations and peace of mind for everyone involved.

How does a Test Coverage Factor affect SIF PFD Calculations?

When the Test Coverage Factor is high (close to 100%), it means that the diagnostic tests and maintenance procedures are very effective in detecting and preventing dangerous failures. In this case, the PFD of the SIF is reduced because the probability of a dangerous failure going undetected is low. A high Test Coverage Factor leads to a lower PFD, which is desirable for safety.

Conversely, when the test coverage factor is low, it indicates that the diagnostic tests and maintenance procedures are less effective in detecting and preventing dangerous failures. In such situations, the PFD of the SIF will be higher because there is a greater likelihood that a dangerous failure may go undetected. A low Test Coverage Factor leads to a higher PFD, which can be undesirable for safety.

Ensuring the Safety and Reliability of SIF in Industrial Settings

In the world of Safety Instrumented Function (SIF) design, we are often asking a critical question: Can our SIF hardware design live up to its safety promises? To answer that, we delve into complex calculations, and one significant player in this equation is the Test Coverage Factor used during SIF design verification.

However, in the early project stages, we often have to make assumptions about these Test Coverage Factors because we might not have fully developed SIF Proof Test Procedures just yet. This is a common and accepted practice. However, it's essential to remember that before the project gets the green light for commissioning, those procedures need to be not just created but thoroughly tested themselves. We want to be absolutely sure that they can achieve the Test Coverage Factor we relied on in our initial SIF design verification calculations.

The bottom line is that the synergy between our design assumptions and real-world test procedures is the key to a reliable and, most importantly, safe SIF in industrial settings.

Perfect vs Imperfect Testing

Imagine you've calculated the Average PFD of a SIF assuming perfect testing, where the Test Coverage Factor is a robust 100%. Over time, the PFD follows a predictable pattern: it increases until the perfect proof test is executed, and then it resets to zero. However, in reality, perfect testing is often an ideal rather than a reality.

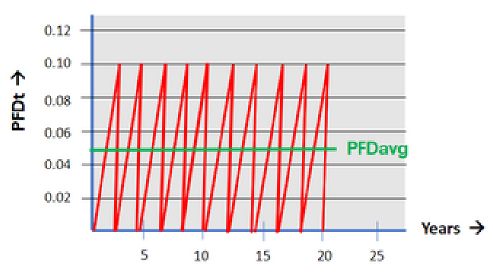
In the majority of cases, we're dealing with imperfect testing, where the Test Coverage Factor falls short of 100%. Here's the twist: over time, the PFD increases until the imperfect proof test is performed, and when it resets, it doesn't quite return to zero but lingers at a small fraction. This lingering fraction represents the probability of dangerous failures that weren't detected, and it accumulates over time.

This results in the PFD average with imperfect testing being higher than with perfect testing. In other words, relying on a lower Test Coverage Factor can lead to a higher calculated PFD than what you initially envisioned.

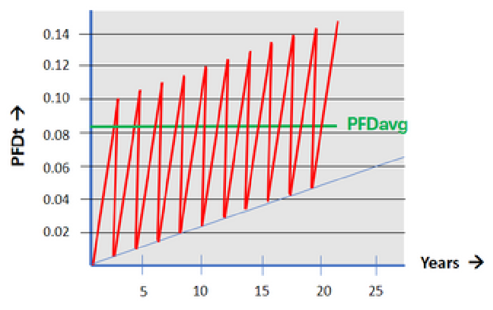
So, when designing SIFs, it's not just about the calculations; it's about aligning those calculations with practical testing procedures. Achieving that balance is the key to ensuring the safety and reliability of our industrial processes.

The image below visualizes Perfect and Imperfect Testing as described above.

PFD as a function of time with “Perfect Testing”.



PFD as a function of time with “Imperfect Testing”.



In SIF design, perfect testing is an ideal scenario where risks reset to zero. However, real-world imperfect testing allows some risks to linger and accumulate over time. This makes the average risk higher than in perfect testing scenarios. Considering these factors is crucial for accurate SIF reliability and safety in industrial settings.

What can be done?

Doing more frequent SIF proof testing will reduce the average PFD of the SIF or SIF element as is illustrated. In the image on the left, you can see an example of a SIF sensor that is tested once every 5 years with a proof test procedure that has a Test Coverage Factor of 95%. Overtime, the PDF as shown by the red line increases until the imperfect proof test with a test coverage factor of for example 95% is done, it will then reset to around 0.01 instead of zero as in the previous illustrations. A small fraction of dangerous failures is not tested for and the probaility of those dangerous failures leading to a failure on demand over time accumulates. This can be seen in the ascending trend of the red line over time.

The image on the right illustrates the same example but with 2-yearly testing intervals. You can see that the PFD average sits a lot higher in the graph of the 5-year interval. This concludes that more frequent proof testing leads to a lower PFD average.
In the examples used above, we use a device lifetime of 20-years, which is the lifetime of the PDF average calculations in our IMS SIS software.

Process Upsets

Even though frequent testing can improve the PFD average, production units typically do not like this solution because of the risk of process upsets. The reality is that most production units like to stretch their SIF proof test intervals to match the Turn Around interval of a production unit. So, then it comes down to adding additional hardware in the design or improving the test coverage factor of your test procedures.

Expert Insights

Experts at Cenosco shared that the reality is that in many projects they have been involved in in the past, they simply did not know what the test coverage factor of their proof test procedures were. They would often be developed or taken from equipment vendor documentation. However, it was not often clear what the Test Coverage Factor of those procedures was or whether that value matched the test coverage factor used in the SIF PFD calculations. This resulted in a lack of accuracy for the test coverage factor used in the SIF Probability of Failure on Demand Calculation.

The conclusion was that the best way to address this issue is to perform a Failure Mode and Effects Analysis (FMEA) for the components of the Safety Instrumented Functions. After completing a Failure Modes and Effects Analysis (FMEA) for a device like a pressure transmitter, a list of potentially dangerous failures is generated. These failures could jeopardize the device's safety functions.

The next step involves scrutinizing this list against the device's proof test procedure to determine if each dangerous failure can be detected and corrected through the test. For instance, if an FMEA study on a pressure transmitter reveals ten distinct dangerous failure modes, a careful examination of the proof test procedure may show that 9 out of these ten can be identified and rectified through the test. This results in a test coverage factor of 90%, a key value for Safety Instrumented Function Probability of Failure on Demand (SIF PFD) calculations.

However, the process is more intricate, with additional complexities like installation conditions, service environments, and the criticality of failure modes influencing the final test coverage factor. Therefore, a structured approach that combines field equipment insights with expertise from the Instrumentation and Maintenance department is essential for producing high-quality FMEA outputs, including precise identification of dangerous failure modes.

Harmonizing Design Assumptions and Real-world Tests

In Safety Instrumented Function (SIF) design, the Test Coverage Factor is critical for hardware reliability. Early assumptions about these factors are common, but before commissioning, thorough testing of SIF Proof Test Procedures is essential. The synergy between design assumptions and real-world tests is key to a safe SIF. Imperfect testing can increase the Probability of Failure on Demand (PFD), highlighting the importance of more frequent proof testing. However, production units often resist this due to the risk of process upsets. Addressing Test Coverage Factor uncertainties through Failure Mode and Effects Analysis (FMEA) is a structured approach for accurate SIF design and dependable performance.

Cenosco and the IMS Suite

INTEGRITY MANAGEMENT SYSTEMS

Learn More

Cenosco is the leading provider of asset integrity management software.

For over 20 years, we have been leading the way in product innovation across asset-heavy industries, including Oil and Gas, and chemical manufacturing. Our IMS Suite of solutions was designed to support users in making smart inspection and maintenance decisions to increase safety, maximize asset availability, and optimize asset management costs. We created the IMS Suite in collaboration with world-renowned Oil & Gas leader, Shell.

Meet IMS

IMS is a unified asset integrity management solution suite for all your equipment types and processes. The range of IMS products can be deployed individually or together, and each component complements the others seamlessly.

IMS PEI
Pressure Equipment Integrity

Manage equipment integrity using Shell's RBI methodology or advanced corrosion calculations.

IMS RCM
Reliability Centered Maintenance

Optimize preventive maintenance plans based on risk and take advantage of our library of maintenance strategy templates.

IMS SIS
Safety Instrumented Systems

The perfect solution for your end-to-end Safety Life Cycle analysis.

IMS FCM
Flange Connection Management

Manage critical flanges with a strict guided maintenance protocol.

IMS PLSS
Pipeline and Subsea Systems

Manage pipeline and subsea system integrity, performing In-Line Inspections (ILI) and Fit-For Service (FFS) calculations.

IMS CIVIL
Manage Civil Structures

Manage equipment integrity with RCM and RBI methods adapted for civil degradation dynamics.

Why IMS?

The IMS Suite of solutions was designed to support users in making smart inspection and maintenance decisions to increase safety, maximize asset availability, and optimize asset management costs. Our domain expertise goes deep into the assets, and with our fully integrated software, you can centralize your maintenance and inspection efforts.

- Keep your people safe
- Gain control over your assets
- Manage your assets with ease
- Comply with regulations
- Avoid leaks and other disasters
- Exclusive Methodologies and Libraries

OUR SOLUTIONS ARE USED GLOBALLY

We're deployed in over 40 countries across the globe.

5,000+
ACTIVE USERS

120+
DEPLOYED ASSETS

20+
YEARS OF EXPERIENCE

Industry Expertise

Oil and Gas

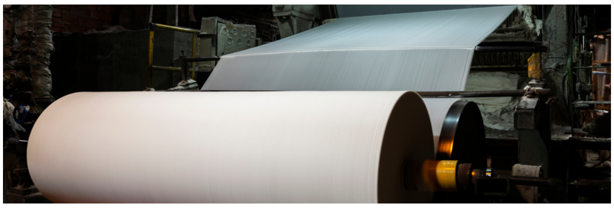
We have over 20 years of experience in the Oil and Gas industry, and our solutions cater to all the needs within the industry thanks to our years of close partnership with Shell.

Chemicals

Our software enables chemical refineries to ensure the safe, efficient, and compliant operation of your assets contributing to the longevity and reliability of your operations.

All Asset-Heavy Industries

Effective asset management is essential for asset-heavy industries to minimize downtime and ensure compliance with regulations and standards.



Core Features

The IMS Suite is a unified set of software solutions for all your equipment types and processes. Below is an overview of the core features that all solutions within the IMS Suite can benefit from.

Asset Hierarchy

Keep your asset register clean and organized.

Interface to ERP systems

Such as SAP, JDE, Maximo, and many more!

Offline mobile functionality

Ease inspections when out in the field.

Configurable Dashboards

Visualize the most relevant data to you.

2D and 3D Capabilities

Enhance your inspection data by visualizing it into 2D drawings or 3D models.

Compliance

Meet compliant regulations through proper condition history.

Insights into bad actors

Use your data to stay ahead of the curve of bad actors and your equipment's performance.

Tailor-Made Roles

Set up your user profiles based on different disciplines.

Condition History

Track all events in the lifetime of your equipment, from inspections to leaks to temporary repairs.

Scheduling

Transform all your analyses into a planned schedule or maintenance strategy.

Proven Results

- 20% Inspection cost reduction
- 30% Turnaround time reduction
- €100K - € 100M Savings per leak prevented

Trusted by world leaders

equinor PBF Energy BOREALIS KNPC PEMEX CANFOR Global clean energy AIR PRODUCTS MARAFIQ