Predicting Valve Reliability
Combining Focused Field Studies and Advanced Modeling

Abstract

• The performance of valves and other final elements have a significant impact on the operations and safety performance of a process plant. Establishing effective programs based on realistic performance expectations is necessary to balance both cost and risk. Cost drivers include equipment cost and maintenance cost while risk can come from health and safety concerns as well as equipment availability. Gathering trusted information that can help inform decisions related to these factors can prove challenging.

• This presentation will review the current methods available and present a comparison of the relative strengths and weaknesses. An analysis of functional failure modes, field studies, and the impact of application dependent stresses will be discussed. A proposed hybrid approach will be presented along with example data results and key learnings that can be drawn from them.
Chris O’Brien

Chris O’Brien is a Partner with Exida Consulting. He has over 25 years experience in the design, manufacturing and marketing of process automation, reserve power systems, and safety related equipment. He focuses on supporting new and existing customers with their implementation of the IEC 61508 and IEC 61511 functional safety standards as well as reliability analysis for mechanical devices.

He was formerly Vice President of the Power Systems Business Unit of C&D Technologies, a business that specialized in the design and implementation of high reliability back up power systems. Prior to that, he was with Moore Products/Siemens Energy and Automation where he held several positions including General Manager of the Instrumentation Division.

Chris is the author of Final Elements and the IEC 61508 and IEC 61511 Functional Safety Standards and has been awarded 5 patents, including a patent of the industry’s first safety rated pressure transmitter. He has a Bachelors of Mechanical Engineering from Villanova University.

Topics

• Getting Failure Rate Data
• Functional Failure Modes
• Field Reliability Studies
• Application Stress Considerations
• Proposed Hybrid Approach
Getting Failure Data

- **Industry Databases**
  - OREDA Offshore Reliability Equipment Data Association
- **Company / Group Failure Data Estimates**
  - Committee meets and agrees of numbers to use
  - What is included?
- **Manufacturer Field Return Data Studies**
  - Cannot know what percentage of actual failures are returned
  - Different definition of “FAILURE” (Not a problem scenario)
- **B_{10} Data**
  - Based on cycle testing for mechanical / electro-mechanical products
  - Assumes application has constant dynamic operation
- **End User Field Failure Data Studies**
  - A quality data gathering system can provide excellent site specific data
  - Many existing systems are weak
- **FMEDA**
  - A predictive technique
  - Uses a component database that accounts for design strength

Industry Databases

- **OREDA** – Consortium of offshore companies, North Sea
  - Operated by DNV in Norway
  - Data Analysis by SINTEF in Norway
- Provides useful data on process equipment
- SINTEF publishes PDS Data Handbook, a set of failure rate, failure mode and common cause factor estimates for use in Safety Instrumented Function verification calculations
- Kept up to date with latest public release in 2009 / 2010
- All realistic failures are included, Site and Product
Company / Group Committee

- Typically experienced experts share their memories of failure events and estimate failure rates.
- Results may vary depending on specific experience.
- But results can be valuable as an indicator of opinion especially for comparison purposes.

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Manufacturer Field Return Studies

- Manufacturer Field Return Data Studies
  - PLUS: Real Data
  - MINUS:
    - Cannot know what percentage of actual failures are returned
    - Different definitions of “FAILURE” (Not a problem scenario)
- Many manufacturers classify returned items as a “failure” only if a manufacturing defect is found.
- Many returned items are marked “no problem found.”
- In some calculations operational hours are estimated based on shipping records and it is assumed that all failures are returned.
- The data can be valuable to identify root causes and compare to establish upper/lower bounds on failure rates.

B_{10} Data

- Not suitable for all uses of failure rate information.
- B_{10} data is derived from a cycle test of a mechanical / electro-mechanical product.
- Failure rate is calculated based on 10% failures in the B_{10} time period.
- B_{10d} (dangerous failure rate) is half that number based on the assumption that 50% of the failures are dangerous.
- The B_{10} method assumes that the constant failure rate during the useful life is due to premature wear-out where other failure modes are insignificant.
- Research shows other failure modes become significant when these products do not move frequently – some failure modes become significant if a product is static for 24 hours.
End User Field Failure Studies

MINUS: Variations of amount of data collected:
- Different definitions of “FAILURE”
- Categorizing and Merging Technologies
- Lack of fault isolation

After performing dozens of studies exida experience recognized that the data collection process varies by an order of magnitude or more!
- When is a failure report written?
- What is the definition of failure?
- Are “as found” conditions recorded during a proof test?
- What were the operating conditions?
- Use of new data collection software can improve failure data availability

Field failure studies with sufficient information represent a rich opportunity to obtain failure rate and failure mode information about a product in a specific application.

Establishing a Instrument and Analyzer Reliability Program in Support of Independent Protection Layers

Authors/Presenters: Patrick Sklveres, P.E. and John Thibodaux
Instrument and Analyzer Reliability Core Team
The Dow Chemical Company, Texas Operations

Abstract:
Accurate Instrument/Analyzer performance and reliability data can aid in meeting or exceeding regulatory requirements as stated in OSHA’s process safety Management Standard (PSM) at 29 CFR 1910.119(j)(4) to conduct inspection, testing and documentation based on Recognized and Generally Accepted Good Engineering Practices (REGAGEP, e.g., IEC61511) for new and existing facilities; provide accurate data to minimize use of or improve existing instrument systems; identify efficiency/reliability improvement opportunities and benchmark performance against other in industry. An instrument and analyzer reliability process can be successfully
Getting Failure Data

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- End User Field Failure Data Studies
  - A quality data gathering system can provide excellent site specific data
  - Many existing systems are weak
- FMEA
  - A predictive technique
  - Uses a component database that accounts for design

Problem: Often a product will become obsolete before enough data is gathered to obtain a failure rate.
FMEDA Approach

- Failure Modes, Effects, & Diagnostics Analysis (FMEDA) Concept
- Gathering enough failure statistics at the product level has not happened – failure causes, failure modes, etc. are mixed together in failure reports.
- Therefore – Develop a predictive model that analyzes a product design strength to predict field failure performance.

Using a component database, failure rates and failure modes for a product (transmitter, I/O module, solenoid, actuator, valve) can be determined for any given design as a function of operating environment.
FMEDA Results

- Detailed
- Specific
- All failure modes

The accuracy of the FMEDA method depends on the accuracy of the component database. It must include failure rates and failure mode distributions of each component as a function of operating profile. The useful life of each component should also be listed as a function of operating profile.
Therefore the component database must be based on and calibrated by FIELD FAILURE DATA.

150 billion unit hours of field failure data from process industries

Field Failure Data Calibrates

Public Component Failure Database Used In

Compare Product Level Failure Rates per Mode

FMEDA Analysis

FMEDA Results
\[ \lambda S \lambda D \]
Useful Life

Explain Differences
Adjust as needed

Root Cause Analysis

Compare Product Level Failure Rates per Mode

Public Component Failure Database Used In

FMEDA Analysis

FMEDA Results
\[ \lambda S \lambda D \]
Useful Life

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Functional Failure Modes

Tiered Taxonomy

Tier 1 Operational

Tier 2 Functional

Tier 3 Device

Component

Receive 101

OK

Open

Short

Remote Seal

OK

Loss of EIR

Failure Mode n

Failure Mode n

Failure Mode n

Failure Mode n

Current High

Current Low

Transmitter

Read High

Read Low

Read Stuck

Capture information regarding if the failure was safe, dangerous, no effect, etc.

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Field Reliability Studies

- Random Failures
  - A failure occurring at a random time, which results from one or more degradation mechanisms.

- Systematic Failures
  - A failure related in a deterministic way to a certain cause, which can only be eliminated by a modification of the design or of the manufacturing process, operational procedures, documentation, or other relevant factors.

Consistent Interpretation?

Which failures are random?

- Mechanical failures are predominantly of systematic nature.
- One of the key requirements for Functional Safety (IEC 61508) is to eliminate systematic failures to the extend possible.
- All relevant systematic aspects determining the reliability and occurring during operation cannot be considered within the assessment / certification of valves, often they are even not specified by the manufacturer.
- Long term performance tests, accelerated ageing tests in labs and FMEAs, failure rate data from handbooks are delivering only reliability data of a component.
A failure occurred where a de-energize to trip remote actuated valve snapped closed and shut down the process during normal operation. The failure was traced to the PLC logic solver (rated to 50 °C) where an output module failed de-energized. A component in the output module, a transistor, had failed such that it could no longer conduct current. The ambient temperature was quite hot, 55 °C. An X-ray of the transistor showed a burned out bond wire likely due to an electrical overstress.

A maintenance technician routinely checks and adjusts the trip points on a generator activation relay. The procedures for checking and adjusting the relay were correct. Although a rare event, occasionally a mistake is made with the adjustment. In one case the trip point was set too low and the power generator did not start as needed and a power system failed.
After four years in a hot environment (35 °C), a solenoid valve burned out. The solenoid coil was continuously energized and designed as de-energize to trip. The valve which was open during normal process operation closed as a result of the solenoid coil burnout causing a process unit to shut down.

Is this spelling error a systematic failure or a random failure?

**Application Stress Considerations**
Failures: Product vs. Site

- During a detailed study of field returns at Moore Products in the late 1980s we discovered that the return rate for the same module type was 4X different from one site to another!
- Why? Some failures result from product attributes and some failures result from site specific attributes.
- After a visit to the worst site, two clear systematic issues were identified. After resolution, the ratio of best to worst almost 2X.

Product Failures
A failure due to:

RANDOM
- manufacturing defect
- unexpected stress event
- random support equipment failure
- etc.

SYSTEMATIC
- design flaw
- documentation error
- manufacturing process flaw
- etc.

Site Specific Failures
A failure due to:

RANDOM?
- maintenance error
- testing, calibration error
- unexpected stress event
- etc.

SYSTEMATIC
- product selection process
- product test procedure flaw
- product calibration procedure error
- etc.
Failures: Product vs. Site

Typical Manufacturer View – not all failures are due to product attributes and should not be part of a product failure rate.

**Product Failures** A failure due to:

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**RANDOM**
- maintenance error
- testing, calibration error
- unexpected stress event
- etc.

**SYSTEMATIC**
- product selection process
- product test procedure flaw
- product calibration procedure error
- etc.

**FMEDA**

Failures: Product vs. Site

exida View – while exida agrees that all real failures must be included in a PFH/PFDbvg calculation, these are modeled differently.

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- testing, calibration error
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- etc.

**SYSTEMATIC**
- product selection process
- product test procedure flaw
- product calibration procedure error
- etc.
Proposed Hybrid Approach

• FMEDA sets base failure rate for “typical”
  – Publish minimum, maximum rates
• Publish failures according to Functional Failure Modes
• Develop factors for application stress, site capability
• Refine with actual plant data after it is collected and analyzed
Predictive Analytic Analysis

- USE DESIGN STRENGTH KNOWLEDGE from actual products and
- Accumulated/Validated Field Failure History

A study of design strength on 35 different pressure transmitters combined with field failure data shows upper and lower bounds on total failure rate.

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Results Distribution

Field Failure Data
Statistical Analysis (1)
Study Data Collection Process and Failure Categories
Out of Range
OK?
Field Failure Database
Predictive Analytics Model for each device type.
• Upper Bound
• Lower Bound

Predictive Analytic Analysis

The predicted $\lambda$ bounds are used to compare estimated $\lambda$ from a set of field failure data. Results that are out of range indicate further analysis is needed.

Issues in the data collection process can be detected and resolved.

(1) Statistical Signature Analysis: Modeling Complex $\lambda(t)$ from Proof Test Data and the Effects on Computing PFDavg. Julia V. Bukowski, Ph. D., www.exida.com
Key Takeaways

• The source and method used to generate data is necessary to make informed decisions on how to use it.
• The intended application of the data should impact the method and rigor applied.
• Increased adherence to standards such as IEC 61511 will make more data available.
• The ability to test the fit of smaller sets of data against a large data set will increase analysis speed.
• These smaller sample sizes can provide valuable information on application issues to further improve the data model.