Field Failure Data – the Good, the Bad and the Ugly

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Abstract

There are many benefits to a company when they have access to good field failure data. Most of the benefits are categorized as saving money. At the same time, most of the expenditure to get good failure data is already being spent. Given a small incremental cost of added data collection and better data analysis, the benefits could be achieved.

Good high quality field failure data has often been described as the *ultimate source* of failure data. However, not all field failure studies are high quality. Some field studies simply do not have the needed information. Some field studies make unrealistic assumptions. The results can be quite different depending on methods and assumptions. Some methods produce optimistic results that can result in **bad designs and unsafe processes**.

This paper presents some common field failure analysis techniques, shows some of the limitations of the methods and describes important attributes of a good field failure data collection system.

Introduction

The benefits of having quality product failure rate data include:

- The ability to achieve less process downtime [ISO06],
- identification of efficiency/reliability improvement opportunities[Skwe08],
- optimized (lower cost) maintenance programs,
- opportunities to optimize the timing of equipment overhauls and inspections [ISO06],
- reduced environmental impact [ISO06],
- proper application fit of instrumentation products and
- data that can be used to optimize safety instrumented system verification calculations for a particular application [Skwe08, Gobl05].

All of these reasons can be categorized as simply saving money. Most companies already spend most of the money required to get good data. What is missing in some cases is just a small amount of incremental data and much better data organization / analysis.

Quality field failure data has often been described as the ultimate source of reliability information. However, not all field failure data studies are the same. Results for the apparently same product in the same application/environment vary by over 100X. Consider the variations in failure rate data presented in Table 1 electronic / mechanical pressure transmitters.

Source	Product Type	Failure Rate per hour	Comment
CCPS89	Diff. Pressure Transmitter, low	1.01E-06	
CCPS89	Diff. Pressure Transmitter, mean	6.56E-05	
CCPS89	Diff. Pressure Transmitter, high	2.54E-04	Highest Number
NRPD95	Pressure Transducer	8.31E-06	
Refinery Data [Shel00]	Analog Pressure Transducer	2.71E-06	
Refinery Data [Shel00]	Microprocessor Based Pressure Transmit	7.19E-06	
DOW Plant Study [Skwe08]	Pressure Transmitter	4.96E-07	
Manufacturer Study [Moor98]	Microprocessor Based Pressure Transmit	3.57E-07	Lowest Number

Table 1: Field Failure rate results from different sources for electronic pressure sensors.

The ratio of the highest (most pessimistic number) to the lowest (most optimistic number) is over 500X. Similar results occur for mechanical products as shown in Table 2.

Source	Product Type	Failure Rate per hour	Comment
CCPS89	Solenoid Valve-Operated, low	6.79E-07	
CCPS89	Solenoid Valve-Operated, mean	4.87E-05	
CCPS89	Solenoid Valve-Operated, high	1.89E-04	Highest Number
NRPD95	Valve, Pneumatic Solenoid	1.67E-05	
Refinery Data [Shel00]	Solenoid Valve	Not Available	
DOW Plant Study [Skwe08]	Solenoid Valve	7.02E-07	
Manufacturer Study [AEAT05]	Solenoid Valve	1.70E-08	Lowest Number

Table 2: Field Failure rate results from different sources for pneumatic solenoid valves.

Why the different results? There are many possible reasons including differences in the:

1. technology, old versus new with improved reliability
2. application environment of the site
3. maintenance capability of the site
4. definition of what is a failure
    a. random versus systematic
    b. initial probability of failure
    c. wear-out failures
5. failure recognition method
    a. automatic diagnostic
    b. process upset
    c. manual proof test
6. failure data recording and collection policy
    a. simply not recording the data
    b. product categories
    c. product identification
    d. record only if process trip occurred
    e. record only if outside service required
    f. record only if external failure cause
    g. records retained only until repair completed
7. assumptions used to calculate operating hours
8. assumptions used to calculate number of failures

These variations can result in numbers that possibly change by orders of magnitude. Therefore one must completely understand the methods used to define, collect and analyze field failure data before using it.

The Good – A good data collection program

A good field failure data collection program needs to be founded on a good reliability/safety culture where there is management support, the field failure data is valued and procedures for gathering the data are well defined and followed. The system must allow for easy capture of the data right after a failure is resolved not the next day, the next week or the next month. Generally, a good system is tied to the plant work order system.

The collected data must be carefully analyzed and actually used to identify opportunities for cost savings. There is nothing like a documented cost saving to generate continued “management support.”

Inventory Database – information about each instrumentation product

A good field failure data collection program has a number of important attributes. It specifies a site inventory database that includes for each instrument:

- Product manufacturer and model number
- Serial number
- Design version level
- Product classification
- Commissioning date and decommissioning date
- Operational duty cycle (e.g. 24/7 or other?)
- Installation site
- Operating environment as installed – ambient and process
- Failure event records and proof test records – dates, methods, results
- Calibration information

This information clearly allows the technology vintage to be determined. Knowing that manufacturer’s have been working hard for many years to improve the reliability and quality of their products, it is a mistake to mix and average the results from products designed years ago to products made with newer improved designs.

The information in the site inventory database also allows sorting of wear-out failures from random useful life failures. This also is important as predictable failures due to wear-out should not be included in the random failure rate. It is also very important to understand when wear-out occurs so that preventative maintenance programs can reduce unanticipated downtime by replacing the products before failure occurs.

The product classification scheme in the site inventory database must separate products into groups with similar failure rates and modes. For example, a poppet type solenoid valve will have different failure rate data than a spool type solenoid valve. A butterfly valve will have different failure rates than a gate valve. A product grouping where apples, oranges and bananas are grouped and called “fruit” gives failure data of reduced accuracy for all elements of the group.

The commissioning date, decommissioning date and operational duty cycle should enable accurate calculation of operating hours for each instrument. If the product automatically keeps track of power-on hours as some smart instruments do, the power-on-hours information can be extracted and recorded as well.

The actual installation location and the operating environment for each product at that site must be recorded in the database. The site description is also used to assign a maintenance capability rating.

Failure Events – information about each event in a product history

For each product in the site inventory database ALL failure related events are recorded. This includes all failure events detected by any automatic diagnostics, any process disruptions or false trips, failures caused during maintenance activities and any failures detected during manual proof tests. For each event, the date/time should be recorded. The person responsible for the repair must be recorded along with failure type, ideally from a short pick list of defined failure events. Any suspected causes should be recorded even when caused by a maintenance mistake. The failure rate database should NEVER be used to reprimand or even evaluate the maintenance team. Any correlating events that might be related to the failure should be recorded. For example “Failure occurred during lightning storm” or “Failure occurred during product calibration” would be important information. For proof test results, the proof test method should be recorded so that proof test effectiveness can be evaluated and considered during failure rate analysis.

The data should be analyzed by an experienced reliability engineer with specialty knowledge in field failure data analysis and statistics. The data analyst must understand the technology of the instrumentation products as this allows faster and more accurate separation of the data between random, systematic and wear-out. Data analysis requires careful review and validation. When a system has this kind of data and analysis, good high quality failure rates can be calculated when enough data is gathered.

A good field failure data collection system also involves full management support and evergreen training of those involved (Engineering, Maintenance and Operations) [Skwe08].

“The Bad” – A less than good data collection program

When the kind of data described in “The Good” field failure data system is not available, assumptions must be made. Even without all the information, very useful data can be obtained [Buko07]. However, depending on several variables, the quality of the data can vary considerably.

If the application environment and site information is not recorded for each product it is possible that a wide variety of different stress conditions can be mixed together giving results not quite right for any environment.

Perhaps the biggest issue is the recording of all failure related events. The definition of “failure” varies substantially. In one site “failure records” were kept only when a product had to be sent off site for repair [Sieb07]. All failures were not recorded. If the data analyst did not know that, resulting numbers would be very optimistic.

Some field failure data systems record only failures that cause a process upset/trip. Any “failures/issues” discovered during manual proof testing are not recorded. In some systems all items “replaced” during a repair are considered a failure. Often multiple items were replaced because it is faster and cheaper to replace them all rather than troubleshoot to the point of identifying the actual failure.

Data analysis work can be done in several different ways depending primarily on the assumptions used and the review process used to sort the data. In one field failure study [Buko07], it was discovered that many failures were being caused by an error made sometime during installation and commissioning. This resulted in many units having what appeared to be random failures during the next manual proof test. A “failure rate” calculated without recognizing the pattern in the data would be quite pessimistic. This situation is more correctly modeled with “initial probability of failure,” a random failure rate during useful life and a limit on useful life.

In other studies it is common to discover that product serial numbers are not recorded, commissioning dates are not recorded and there is little information available to calculate unit operating hours. So assumptions are made. These assumptions can, of course, have a major impact on the result.

Of course, a system not supported by management has very little chance of providing reliable data.

The Ugly

One of the most abused and potentially misleading field failure study methods is the manufacturer's warranty field return study. Problems are caused not by the calculation method itself but rather the lack of information. Often the assumptions used result in highly optimistic failure rates being published. A typical analysis method includes an estimate of operational hours in the field and a count of "failures" reported. The failure rate calculation is simply the number of failures divided by the total operational hours.

$$\lambda = \#\ \textbf{of failures} / \#\ \textbf{of field operational hours}$$

Quality training during the 1980s and 1990s [Jura91] taught these simple techniques but never explained the information required or the assumptions needed. Many of the analysts working for product manufacturers do not understand the limitations of their methods. Consider what information does an original equipment manufacturer really know? The number of units manufactured is known. The shipping dates are known. Therefore the estimate of operational hours usually assumes some period of time between shipment and operation. Many manufacturers estimate a period of two to four weeks between shipment and operation. Knowing the total number shipped each week allows the "operational hours in the field" to be calculated [vanB98]. While this sounds reasonable the assumption is typically quite optimistic. The time it takes from shipment to usage in the process industries will likely be much longer, six months or even one year.

The failure count is typically based upon field return records where the failure is verified by testing the returned product. As products are returned they are tested. Many times the test shows "no problem found." Therefore it is assumed that those returns must not be real failures and are not counted. This is optimistic as it assumes that the test can detect all possible failures. What if the failure occurs only under specific field conditions not duplicated in the manufacturing test? What if the test simply is not complete and does not detect all failures? Very optimistic results can occur.

Perhaps the biggest level of optimism comes with the assumption that all field failures are reported. A survey of end users done by one of the authors found that often it is cheaper to throw away the product than send it back to the manufacturer. Overall survey results indicated that roughly 10% of failed items were actually sent back to the manufacturer. The number is higher during the warranty period but some reported that 0% were sent back after the warranty period.

Overall this collection of assumptions results in very optimistic failure rate calculations as can be seen in the last line of Tables 1 and 2.

Conclusion

Ultimately field failure data is the source of all reliability information. Therefore the importance and value of high quality field failure data cannot be argued. However, high quality data depends on accurate recording of enough information so that assumptions are minimized. Since this does not always occur, field failure data must be provided along with a full explanation of the failure event definitions, methods for data collection and methods for data analysis including all assumptions. Without this, the results can be dangerous.

Standards [ISO06] are being written to help define field failure databases and collection methods. The Process Equipment Reliability Database (PERD) initiative of AIChE (http://www.aiche.org/CCPS/ActiveProjects/PERD/index.aspx) is developing taxonomies, methods and software to help promote higher quality field failure data [CCPS98]. As these methods mature, the data will get better.

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