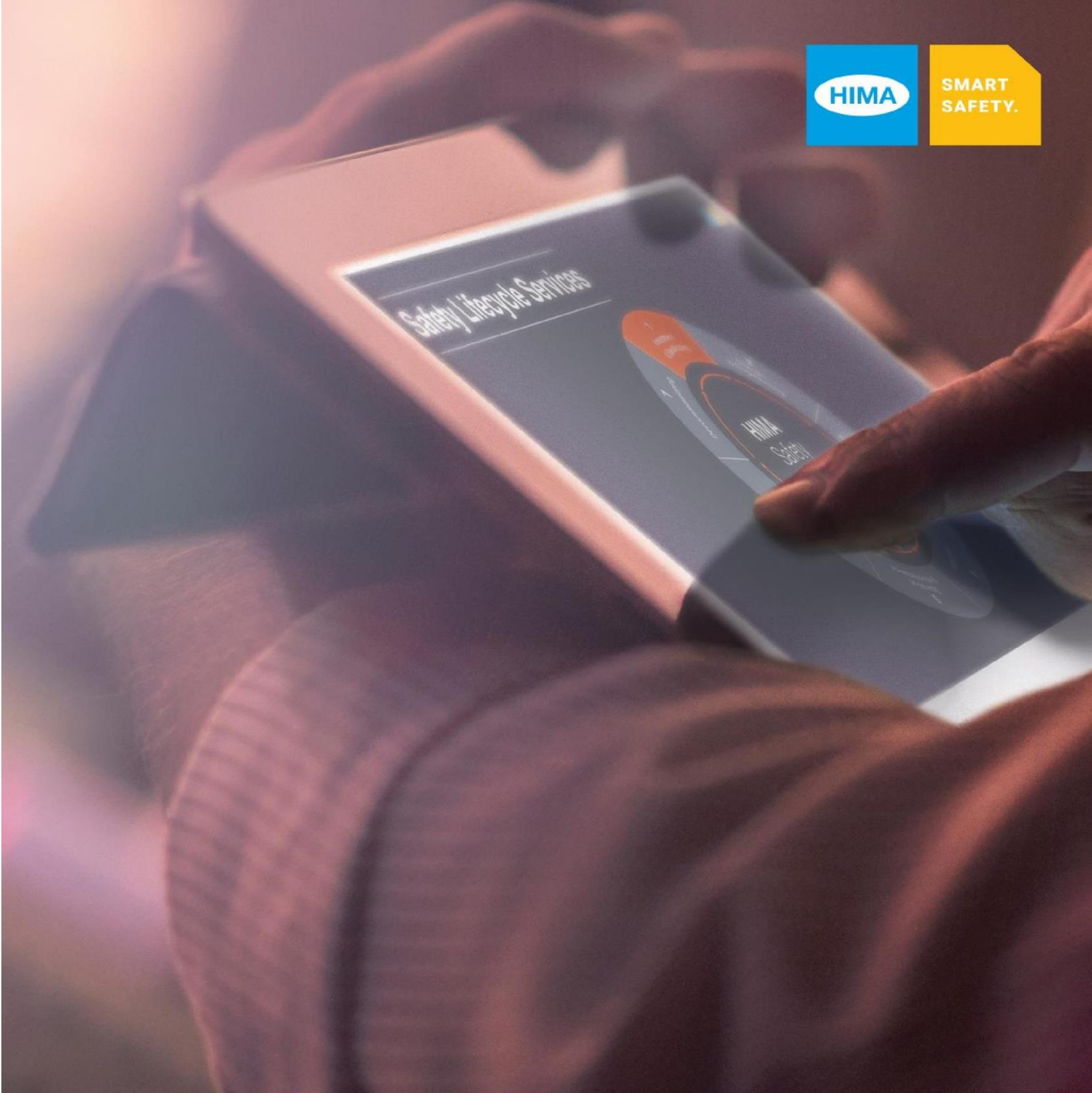

Leveraging Prior Use to Build an Actionable Instrumentation Reliability Database

Safety Lifecycle Manager

Conformance to IEC61511

MANGAN Software Solutions

Leveraging Prior Use to Build an Actionable Instrumentation Reliability Database

SLM®
Safety Lifecycle Manager

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The process industry can leverage software tools to meet IEC 61511 requirements for component selection based on Prior Use.

As increasing attention falls upon managing Safety Instrumented Systems (SISs), industry leaders are looking for more reliable device and equipment options when designing their safety instrumented functions – the goal being to achieve the highest possible Risk Reduction Factor (RRF) per instrumented function, while minimizing construction and maintenance costs.

1 The Challenge

As dictated by IEC 61511, there are two methods for justifying the selection of SIS components. First, companies can use manufacturer-provided failure rate statistics, so long as they are approved by standards outlined in Sections 1 and 2 of IEC 61508.

Secondly, and the focus of this white paper, companies can rely on in-service performance data, or Prior Use data to assess component reliability. Any safety instrumentation expert or process safety manager would rightfully say this process is easier said than done.

Synchronizing across a multi-site organization with existing industry go-to tools such as Excel, Access Database, SAP, SmartPlant® Instrumentation (SPI), etc. brings with it vast challenges. There are benefits and drawbacks to both approaches which are listed in Table 1. The challenge becomes, how can a multinational company uniformly collect real-time data and implement methods to compute their own equipment failure rates?

2 Understanding the Approach and Design

The approach starts with the equation for Failure Rate, or λ.

$$\lambda = \frac{\text{Total \# of Failures}}{\text{Total \# Proven Hours } / 8760} \text{ (failures per year)}$$

2.1 Assigning Failure Types

The approach hinges on the uniform assessment of device failures recorded in operations and maintenance programs across an organization. Without the correct failu λ information, it is impossible to determine the dangerous undetected failure rate (DU) used in Fault

Data Collection Type	Benefits	Drawbacks
Manufacturer-Provided	• Requires no additional PIU data collection effort from sites	• Questionable accuracy • Overly conservative
Proven Hours	• Visibility of variance based on location • Identify 'bad actors' • In-house failure rates • Transparency • Wider array of FR options	• Data is difficult to standardize and collect by location

Table 1

Tree Analysis and Markov PFD calculation methods. Table 4 proposes one such approach to determining the failure composition based on the observance of overt and covert failures. Upon each documented component failure, the investigating team would make a determination of covert/overt status and categorize the failure (DD, DU, SD, SU).

2.1.1 Determining Proven Hours

An in-service device will accumulate a paper trail (performance history) over the course of its useful life. Scheduled maintenance, testing, activation demand, device change, and audit events are all opportunities to collect data on a particular device that provides evidence for proven time. At each of these operations and maintenance events, a Pass or Fail event may be recorded for the device based on its As Found/As Left event status. The table below shows when installed hours can be counted as proven hours.

Proven Hours Counted Towards PIU Denominator	
Install to Pass Event**	Yes
Install to Fail Event**	No
Pass Event to Pass Event	Yes
Fail Event to Pass Event*	Yes
Pass Event to Fail Event	No
Pass/Fail Event to Present Time	No

Table 1
*Assume as left after the fail was a Pass
*Assume a pass status just after install

2.1.2 Data Requirements

In order for the proven hours and failure rates to filter to a particular generic model, or device type, all devices and device events require the basic information shown in Table 3. A mature database would reveal the full performance history for each device (installed or decommissioned) at a site.

Required Device Data	
Device	**Device Event**
ID or Tag Number (PT-1001)	Event Type (Proof Test)
Install Date (11/27/2005)	Event Date (03/04/2014)
Generic Model (ROSE3051)	As Found Status (Fail)
Manufacturer (Rosemount)	As Left Status (Pass)
Device Type (Pressure Transmitter)	Covert/Overt (Covert)
	Safe Fail/Dangerous Fail (Dangerous)

Table 3

2.1.3 Data Collection Methods

- Real time data collection: Device Pass/Fail data per event is collected and directly entered into the database via a specialized workflow.
- Import from existing industry tools: Data is exported with the appropriate data fields, then imported into the Prior Use database.
- Direct data connections: Establish a live data link from an existing industry tool to the Prior Use database.

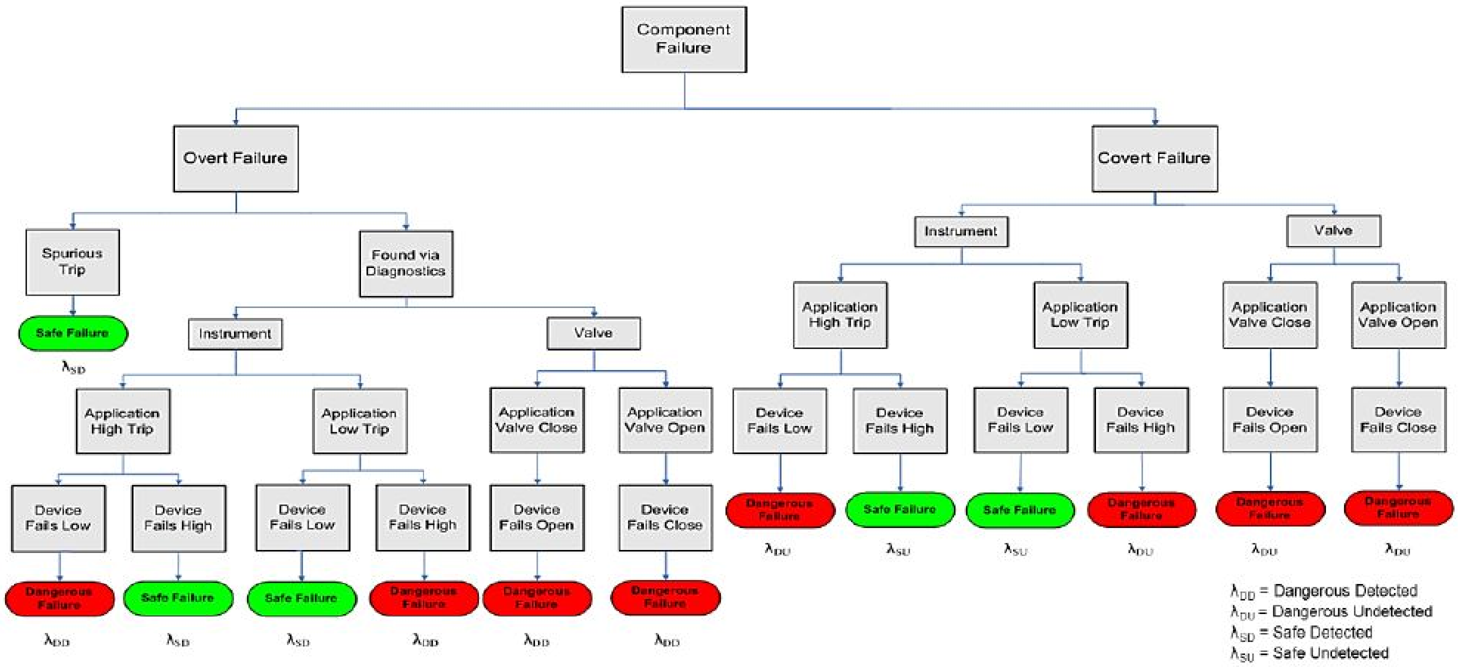

Table 4

Manufacturer:	Rosemount	***Proven Hours:***	130,107,100
Services:	Level, Pressure, Flow	***# Pass Events:***	3410
Generic Model:	Rosemount 3051	***# Fail Events:***	25
Classification:	Medium	***# Installed:***	500
Primary Device:	Yes	***PIU Status:***	Pass
Installed Hours:	7274102 hrs (0)	***Primary Parent:***	Pressure Transmitter
Overt Failure Rate:	5.05E-04	***Covert Failure Rate:***	1.18E-03
PIU Failure Rate:	1.68E-03	***NAMUR Failure Rate:***	3.50E-02
Contributing Sites	Site 2, Site 5, Site 6, Site 9, Site 11		
Criteria:			
a) The manufacturer is in compliance with ISO9000			Y
b) There are in excess of 1000 units in use across industry			Y
c) We have confirmation from the manufacturer of no known issues with the device			Y
d) The device has in excess of 100 operating years recorded			Y
e) The device demonstrates the required PFD with a minimum sample set of 100 units (lambda total < 0.05)			Y
Subject Matter Expert Checks:			
1. Has the Proven in Use event data on this device been updated in last 5 years?			Y
2. Does this instrument have the appropriate documentation and its failure modes are understood?			Y
3. Is the functionality of the equipment limited to process parameter adjustments only during normal operation?			Y
4. Have previous failures of this instrument been documented and reported?			Y
5. Are the manufacturer's installation instructions clear and generally understood by our installation staff?			Y
6. Does the device failure rate look reasonable to the subject matter experts? (i.e., is the device failure rate reasonable when compared with common databases?			Y

Table 5

2.1.4 Uploading Historical Data

All data should be considered despite the medium or age. Organizations maintain device testing and maintenance records in various forms from handwritten documentation to SPI. If possible, all historical device and event data should be exported from existing systems, QA'd, aligned to organizational naming convention, and then imported into the Prior Use database. This will ensure that the performance base, or sample size, is a broad as possible.

2.1.5 Establishing Proven In Use (PIU) Certificate Thresholds

After data is collected and entered into a central location, an organization will have the ability to calculate failure rates based on a generic model. Devices vary in complexity – this must be considered when making a determination of whether or not a particular generic model is 'Certified' as PIU. Table 5 shows an example PIU certificate for a basic device. Medium or Complex devices would have more stringent requirements to achieve PIU. The table below shows an example approach to classifying devices.

Classifying Devices		
Classification	**Description**	**Examples**
Simple	Generic in nature and are unlikely to demonstrate different failure rates across different suppliers	• Pressure switch or 4/20mA transmitter • Level switch • RTD or thermocouple • Solenoid valve • Ball valve
Medium	Highly calibrated or multi-step process devices	• Smart transmitters • Nuclear level • Ultrasonic level
Complex	Devices that perform computations	• Logic solvers • Analyzers

Table 6

Organizations can develop their own definitions for device complexity and adopt various thresholds per certificate. Database users can query the database based on real time Prior Use statistics, and generate the PIU certificate for documentation in a Safety Integrity Level (SIL) calculation result or for reference in a Safety Requirements Specification (SRS). A SIS engineer can then access the database, review various certificates for a given device type, and choose the appropriate failure rate in the SIL calculations.

2.1.6 Confidence Intervals

Confidence intervals can be used to inform the decisions on thresholds of Pass/Fail generic models. More cumulative proven time for a generic mode generally corresponds to increased confidence in the failure rate. Given a confidence level percentage, and assuming a Chi-squared distribution, probability tables can be used to calculate upper and lower failure rate bounds.

Using a Chi-squared distribution table, the equation below can be used to calculate the upper and lower Failure Rate (FR) range associated with various confidence level percentages. The larger the sample size, the smaller the range to be expected between upper and lower failure rates.
#111476

$$\frac{\chi^2_{2r;(1+c)/2}}{2T} \leq \rho \leq \frac{\chi^2_{2r+2;(1-c)/2}}{2T}$$

T = Total cumulative usage
r = # failures
X^2= Chi-squared value from distribution table
c = Confidence Level (0.995, 0.99, 0.95, 0.90, 0.80, 0.50)

Example: For a given Generic Model, there are 1000 total years and 2 failures in the software tool. The organization is assuming a 95% confidence level for all devices

Table G lookup and substitution:

Lower (1+c)/2 = .975 2r = 4	$\frac{.48}{2(1000)} \leqslant \rho \leqslant \frac{14.45}{2(1000)}$	
Upper (1-c)/2 = .025 2r + 2 = 6	$2.00e\text{-}4 \leqslant \rho \leqslant 7.23e\text{-}3$	

X2 Distribution Table

[1] Statistical Methods for Testing, Development, and Manufacturing, By Forrest W. Breyfogle, III

3 Meeting The Challenge

Industry leaders are now leveraging relational databases to collect and analyze Prior Use data on web-based platforms. A uniform, streamlined, and easily-accessible system approach allows organizations to leverage 'big data' and achieve a variety of Prior Use related goals:

- Use Prior Use failure rates to compare with other failure rates: Put the power in the hands of the designers to choose the most appropriate option. Often, the failure rate chosen for a specific application was the only one available at the time.
- Validate SIS performance: During Layers of Protection Analysis (LOPA) re-evaluations, system users can reference an in-service failure rate rather than referring to a possibly outdated SRS SIL calculation.
- Provide PIU certification: Based on random failure rates and device/equipment complexity, determine and implement minimum thresholds for PIU certification.
- Real-time Prior Use evaluation: Criteria evaluation and failure rate calculation for primary and secondary devices that changes with the addition of data to the Prior Use database.

Achieving these goals cannot be accomplished without an organization-wide programmatic effort with buy-in and consistent engagement with participating sites. Using the power of relational databases, managers can leverage Key Performance Indicators (KPIs) to track the population of Prior Use data. Increased accessibility of web-based platforms supports a wide user base and supports consistency of data. Table 7 shows an example Prior Use FR report with confidence intervals.

Referencing the report, management can perform a simple calculation to enforce a powerful participation metric. Proven Hours/Installed Hours show the proven percentage. For sites with a low proven percentage for device type and generic model, management can quickly identify sites that need help with data collection and entry.

Device Type	Generic Model	Manufacturer	Installed Devices	Install Years	Proven Years	Failures	FR (MTTF)	Lower FR (MTTF)	Lower FR (MTTF)
Coupling Relay	60.13.9.024.5070	finder	488	1209	1066	1	9.38E-4 (1066)	9.85E-5 (10152)	3.65E-3 (274)
	H4135A	HIMA	392	971	858				
	UF3/RS8235	KUHNKE	2024	5015	4430				
	EMG 17	Phoenix	129	319	282				
	Koppelrelais	Phoenix	112	277	245				
	PLC-RSC-24DC/21HC	Phoenix	191	473	415	1	2.40E-3 (415)	2.52E-4 (3960)	9.35E-3 (106)
Totals			3336	8266	7296	2	3.34E-3 (299)	3.51E-4 (2849)	1.30E-2 (76)
DP Transmitter	FOXBORO_GENERAL	Foxboro	4	15	2				
	ROSE1151	Rosemount	7	27	8				
	ROSE3051	Rosemount	54	133	116	1	8.62E-3 (116)	9.05E-4 (1104)	3.35E-2 (29)
Totals			65	176	126	1	8.62E-3 (116)	9.05E-4 (1104)	3.35E-2 (29)
Flow Transmitter	FOXBORO_GENERAL	Foxboro	4	15	2				
	ROSE1151	Rosemount	7	27	8				
	ROSE3051	Rosemount	54	133	116	1	8.62E-3 (116)	9.05E-4 (1104)	3.35E-2 (29)
Totals			65	176	126	1	8.62E-3 (116)	9.05E-4 (1104)	3.35E-2 (29)
Input Isolator	mc 2/304 EX/EX	digitable	124	307	269	1	3.71E-3 (269)	3.90E-4 (2564)	1.44E-2 (69)
Totals			124	307	269	1	3.71E-3 (269)	3.90E-4 (2564)	1.44E-2 (69)
Level Transmitter	ROSE1151	Rosemount	7	27	8				
	ROSE3051	Rosemount	54	133	116	1	8.62E-3 (116)	9.05E-4 (1104)	3.35E-2 (29)
Totals			61	161	124	1	8.62E-3 (116)	9.05E-4 (1104)	3.35E-2 (29)
Limit Position Switch	SGE985	ECKARDT	236	584	514	1	1.94E-3 (514)	2.04E-4 (4899)	7.56E-3 (132)
Totals			236	584	514	1	1.94E-3 (514)	2.04E-4 (4899)	7.56E-3 (132)
Limit Switch Card	1/209	CEAG (digitable)	612	1516	1333	3	2.25E-3 (444)	8.25E-4 (1211)	5.01E-3 (199)
	5701	Sieger	139	344	304				
	9645	STAHL	344	852	752				
Totals			1095	2713	2389	3	2.25E-3 (444)	8.25E-4 (1211)	5.01E-3 (199)
Thermocouple Transmitter	T32	Unknown	189	468	449	8	1.78E-2 (56)	1.04E-2 (96)	2.89E-2 (34)
Totals			189	468	449	8	1.78E-2 (56)	1.04E-2 (96)	2.89E-2 (34)
Thermocouple Transmitter (head)	T32	UNKNOWN	189	468	449	8	1.78E-2 (56)	1.04E-2 (96)	2.89E-2 (34)
Totals			189	468	449	8	1.78E-2 (56)	1.04E-2 (96)	2.89E-2 (34)
Transmitter (P)	141GP	Foxboro-Eckardt	505	1251	1103	1	9.06E-4 (1103)	9.52E-5 (10506)	3.53E-3 (283)
Totals			505	1251	1103	1	9.06E-4 (1103)	9.52E-5 (10506)	3.53E-3 (283)
Transmitter Supply Device	AH MS270	AH / CEAG	296	733	684				
	MUS-TV80	ECKARDT	348	862	859				
	9160	Stahl	695	1722	1519	1	6.58E-4 (1519)	6.91E-5 (14467)	2.56E-3 (390)
Totals			1339	3318	3062	1	6.58E-4 (1519)	6.91E-5 (14467)	2.56E-3 (390)

Table 7

4 Conclusion:

Using Prior Use data to inform device and equipment selection is an emerging industry interest. Making substantial progress hinges on the use of robust database software tools to capture the data and calculate failure rates. Relational databases are a potential solution to fill this gap and forward-thinking organizations are employing them now to generate their own failure rates.

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Sources: Breyfogle III, Forrest. Methods for Testing, Developing, and Manufacturing. Canada: John Wiley & Sons, Inc., 1992. Google Books. https://books.google.com/books?id=q-IqQvoVkc0C&pg=PA147&lpg=PA147&dq=Chi+square+confidence+intervals+table+G&source=bl&ots=2XSfl8u613&sig=Z9Btk6_QI6vTunULRfHUI9xDY4w&hl=en&sa=X&ved=0CEwQ6AEwCWoVChMI4IP1I8uFxwIV1hCSCh0lkgjM#v=onepage&q=Chi%20square%20confidence%20intervals%20table%20G&f=false. 12.08.2015.