MARY KAY O'CONNOR PROCESS SAFETY CENTER
TEXAS A&M ENGINEERING EXPERIMENT STATION

19th Annual International Symposium
October 25-27, 2016 • College Station, Texas

Learnings from Mary Kay O'Connor Process Safety Center (MKOPSC) Instrument Reliability Network's Project on Pressure Transmitter Maintenance Data Collection

Monir Ahammad[1], Logan Hatanaka[1], Hui Jin[2], Keith Lapeyrouse[3*] and Eloise Roche[2]
[1]Mary Kay O'Connor Process Safety Center, Texas A&M University, College Station, Texas - 77843
[2]SIS-TECH Solutions, Houston, Texas - 77034
[3]Process Reliability Solutions, Baton Rouge, LA - 70817

* Presenter's Email: keithlapeyrouse@processreliabilitysolutions.com

Abstract

This paper presents the results of the first phase of the pressure transmitter reliability data project executed by the Mary Kay O'Connor Process Safety Center's (MKOPSC) Instrument Reliability Network (IRN). The quality of the data provided by the six participating companies was checked using self-reporting criteria submitted with each dataset. Out of sixteen reported datasets, only one was excluded due to no devices included in the dataset. The remaining fifteen datasets were used for this analysis. The mean time between corrective maintenance (MTBCM) of the pressure transmitters for the six contributing companies were compared to each other. Even with the limited taxonomy used for this first project phase, it could be concluded that there was a significant difference in corrective maintenance performance between the participating companies and that the company performance seemed to fall into two distinct groups. In addition, it was observed that there could be significant MTBCM variability between multiple datasets submitted by a company, potentially associated to taxonomy details not included in this study.

Keywords: Pressure transmitter, Reliability, MTBCM

Introduction

The Mary Kay O'Conner Process Safety Center (MKOPSC) Instrument Reliability Network (IRN) was founded in 2002 as way for stakeholders join to form a collaborative network to:

- Benchmark current performance of instrumentation and controls in process industry applications.
- Define a common taxonomy to support consistent collection of quality data from maintenance and proof test activities.
- Share lessons learned in improving instrumentation and controls reliability.

Despite equipment and instrument reliability being a major concern for process industries, instrument reliability data is scarce. The major sources of reliability data are OREDA (Offshore and Onshore Reliability Data) and vendor's test data. However, OREDA data is primarily focused on offshore oil and gas industries during the exploration and production phases. Test data from vendors can be expensive to obtain, may require a significant waiting period to develop, usually excludes the potentially significant contributions of process and environmental effects on instrument performance, and is not capable of addressing causes of corrective maintenance other than random physical device failure. These excluded causes may represent a significant fraction of the overall corrective maintenance events and maintenance resource consumption.

The industrial members of Mary Kay O'Connor Process Safety Center's (MKOPSC) Instrument Reliability Network (IRN) are collaborating to develop a reliability database [1]. Using a collective body of observed data to propose improvements that may reduce the frequency of corrective maintenance events might help a participating organization better manage the utilization of limited maintenance resources. It is believed that use of information from the database by participating companies may also help to prevent process safety incidents, such as the events that occurred in Texas City and Hemel Hempstead, through the reduction of equipment/instrument fit-for-service issues.

Vision 20/20 of AICHE/CCPS seeks to drive industry leaders forward in demonstrating actionable commitment to prevent, minimize and mitigate process safety events [2]. IRN participation promotes the CCPS vision by improving standards, enhancing the application of lessons learned, creating responsible collaboration, and contributing to meticulous verification. The principles of risk based process safety are also promoted by creating fit-for-purpose policies and procedures.

The objective of the first phase of this project was to evaluate a very high level reliability parameter measuring the mean time between corrective maintenance (MTBCM) for single and dual sensing (differential) pressure transmitters in service across multiple companies. This study provides valuable data for pressure transmitter reliability, while simultaneously validating the organizational design and project methodology processes used by IRN. .Mean Time Between Corrective Maintenance is defined as any corrective maintenance activity.

$$MTBCM = (\#LO * SI)/\#CM \quad \text{where} \tag{1}$$

LO is then number of Locations Observed

SI is the Surveillance Interval (time studied) and

#CM is the number of corrective maintenance events for all locations included in the study during the study time frame.

This includes unplanned maintenance activities where adjustments were made, activities where no adjustment was required, cleaning activities or replacement activities associated with any part of the transmitter system. It should not include planned inspections or calibrations/validations, scheduled replacements, re-ranging of instruments for new process conditions or other conditions not indicative of a perception that the instrument is not performing per its design requirements.

Methodology

Data Submittal

Data was generously submitted by six industry members of IRN. MKOPSC handles all data according to IRN framework documents. To create an anonymous environment for the submittal of data, only persons approved to fill the roles defined in the IRN framework documents receive the initial data, perform the data quality check, and otherwise handle the data until it is entered into the IRN database under an anonymous identifier.

Data Quality Check

MKOPSC reviews each submitted dataset to assure it is complete and of an acceptable quality. The MKOPSC reviewer performing the data quality check will discuss with the submitter any datasets that fail the quality control step, so that the dataset might be improved and subsequently approved. Approved datasets are copied by MKOPSC into a separate database from which the project studies are performed. All original data copies are then destroyed to maintain the anonymity of the data supplier.

For this study, all datasets were required to provide five parameters. First, the total number of observed transmitters is required, denoted ***LO***. Each contributing company was required to provide observations including at least 100 transmitters in one or more datasets, with each dataset containing at least one transmitter. Second, the surveillance interval (the time period over which the data was collected) for each dataset is required, denoted ***SI***. Third, the number of corrective maintenance events observed within the surveillance interval out of the total number of observed transmitters must be submitted, denoted ***CM***. In addition, two quality parameters were requested providing the submitter's assessment of the completeness of the data given in ***LO*** and ***CM***. This is done using one of three describing words. If less than 25% of the observed transmitters are given in ***LO***, the quality is ***low***. If between 25% and 75% of the transmitters are given in ***LO***, the quality is ***medium***. Lastly, if the completeness of ***LO*** is greater than 75%, it is considered ***high***. Similarly, the completeness of the data given in ***CM*** must be quantified, which is done using the same ***low***, ***medium***, or ***high*** criteria.

Data Analysis

With the limited taxonomy of the first project phase, the final analysis was restricted to a comparison of the MTBCM performance at a company level, although initial screening could be performed at the dataset level.

For companies that supplied multiple datasets, the data was aggregated for the first phase of this project, taking into consideration the surveillance interval for each dataset.

For any submissions that included no corrective measures within the surveillance interval for the locations observed, the MTBCM for that submission could be estimated by using method 1 from the paper on estimating mean time between failure (MTBF) with no observed failures by Freeman [3]. This method is equivalent to assuming one event occurs within the surveillance period, and is the method recommended within that paper for this type of analysis.

While the MTBCM calculation uses an equation of the same form as determining MTBF, MTBCM should not be compared to failure rate data from literature such as those from Exida or OREDA. Since the MTBCM in this study reflects other maintenance activities in addition to repairing equipment failures, MTBCM will be different than MTBF for many facilities. This different highlights the importance of detailing the exact methodology in which instrument reliability data is recorded.

Results and Discussion

Data Quality Analysis

Of the sixteen submitted datasets, one dataset included no observed transmitters. This dataset was excluded from the analysis. Of these fifteen datasets remaining, fourteen had high equipment count quality (93% of datasets), with the remaining one dataset having a medium equipment count quality (7% of datasets). In addition, five datasets had medium failure count quality (33% of datasets), while the remainder had high failure count quality (67%).

A summary of the data quality is shown in Table 1. In general, the data submitted in this work is of high or medium quality, with no low quality data submitted. Therefore, no datasets were excluded from the study based on inadequate quality.

Table 1: Quality of Submitted Data

Company	Dataset Number	Equipment Count Quality	Failure Count Quality
A	1	High	Medium
B	1	High	Medium
	2	Medium	Medium
	3	High	Medium
C	1	High	Medium
D	1	High	High
	2	High	High
	3	High	High
	4	High	High
	5	High	High
	6	High	High
	7	High	High
	8	High	High
E	1	High	High
F	1	High	High

Mean Time Between Corrective Maintenance (MTBCM)

A box plot of the dataset analysis (Figure 2) also revealed a significant skew to the data, providing another early indication that the final performance analysis might be multi-modal.

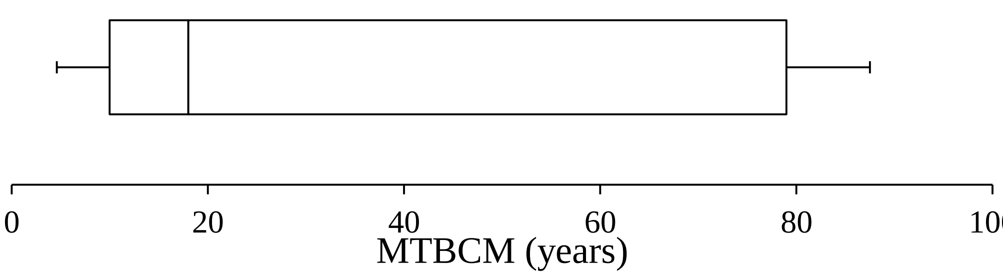


Figure 1: Box plot of dataset MTBCM. Lowest points is 2.5 years, first quartile is 10 years, median is 18 years, third quartile is 79 years, and the highest point is 90 years.

A histogram of MTBCM by dataset, depicted in Figure 2, was also performed to provide an initial view of the submitted data. This figure revealed that there could be significant variability between the datasets submitted by a company and that there was a wide spread of performance between the companies. It was also hypothesized from this initial histogram that the performance-by-company analysis might reveal multiple distinct groups.

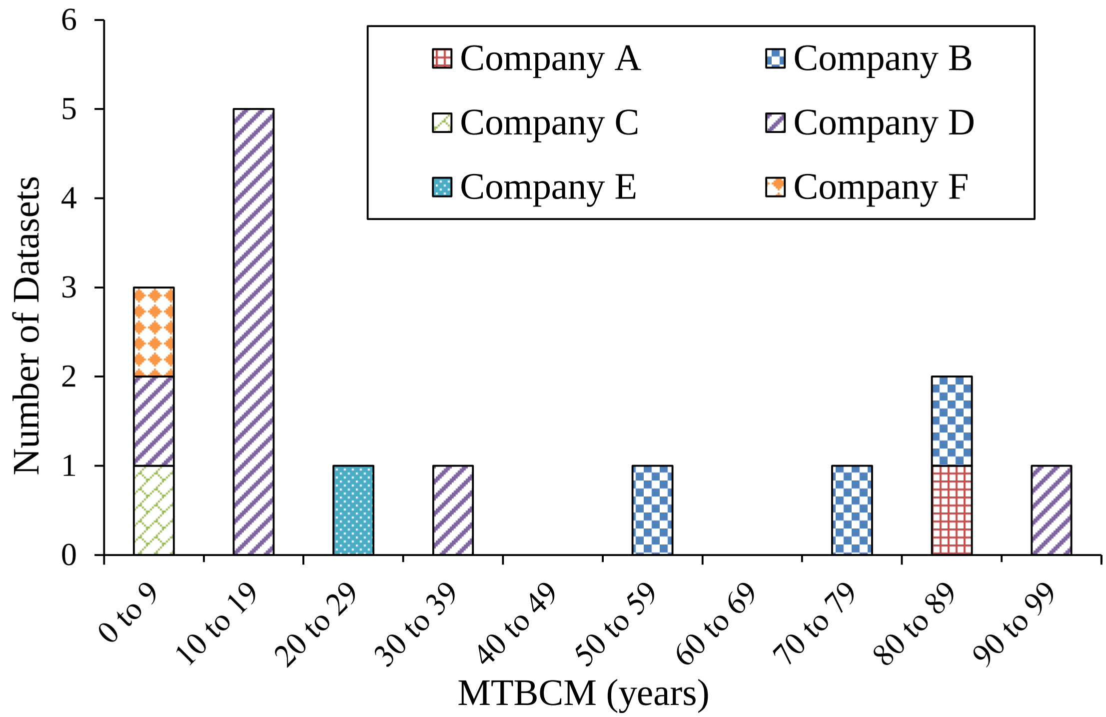


Figure 1: Initial histogram of MTBCM by dataset

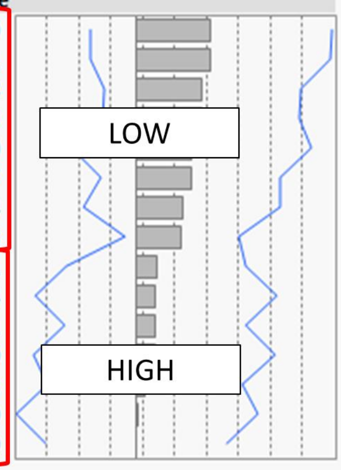
Upon detailed analysis of the datasets, it was observed that two contributors submitted multiple sets of data breaking down the information according to taxonomies that were not consistent across the study. Performing further analysis required aggregating the data from the companies that provided multiple data sets, as there was insufficient detail in the taxonomy to support a more granular grouping. In addition, while each company provided data on over 100 devices, per the analysis requirements, some of the individual dataset submissions contained too small a number of observed locations for a more granular analysis to be relevant.

The Tukey-Kramer method, using JMP 12 statistical software, was used to determine whether the difference between each company's MTBCM results were statistically significant. Table 2 shows the ordered difference Table of Tukey analysis.

Table 2: Ordered difference Table of Tukey Analysis

Ordered Differences Report

Level	- Level	Difference	Std Err Dif	Lower CL	Upper CL	p-Value
A	C	81.50000	36.59455	-48.490	211.4899	0.3120
A	F	80.20000	36.59455	-49.790	210.1899	0.3261
B	C	71.83333	29.87933	-34.303	177.9696	0.2488
B	F	70.53333	29.87933	-35.603	176.6696	0.2633
A	E	60.00000	36.59455	-69.990	189.9899	0.5960
A	D	59.36250	27.44591	-38.130	156.8549	0.3377
B	E	50.33333	29.87933	-55.803	156.4696	0.5714
B	D	49.69583	17.51831	-12.532	111.9237	0.1383
D	C	22.13750	27.44591	-75.355	119.6299	0.9591
E	C	21.50000	36.59455	-108.490	151.4899	0.9894
D	F	20.83750	27.44591	-76.655	118.3299	0.9681
E	F	20.20000	36.59455	-109.790	150.1899	0.9920
A	B	9.66667	29.87933	-96.470	115.8029	0.9993
F	C	1.30000	36.59455	-128.690	131.2899	1.0000
D	E	0.63750	27.44591	-96.855	98.1299	1.0000



Higher p-value of the relationships between D-C, E-C, D-F, E-F, A-B, F-C and D-E indicates that the similarity relationship of the different companies can be grouped together. In the first group, dataset obtained from company C, D, E and F are similar and in the second group company A, B provided similar data. There is very little similarity between the two groups as indicated by the low p-values for A-C, A-F, B-C, B-F, A-E, A-D, B-E and B-D.

This analysis supports the hypothesis derived from a visual inspection of the company MTBCM results depicted in Figure 3. The company pressure transmitter MTBCM performance falls into two distinct groups. The y-axis of Figure 3 shows the relative number of observed transmitters contributed by each company out of the total of 1421 monitored pressure transmitters.

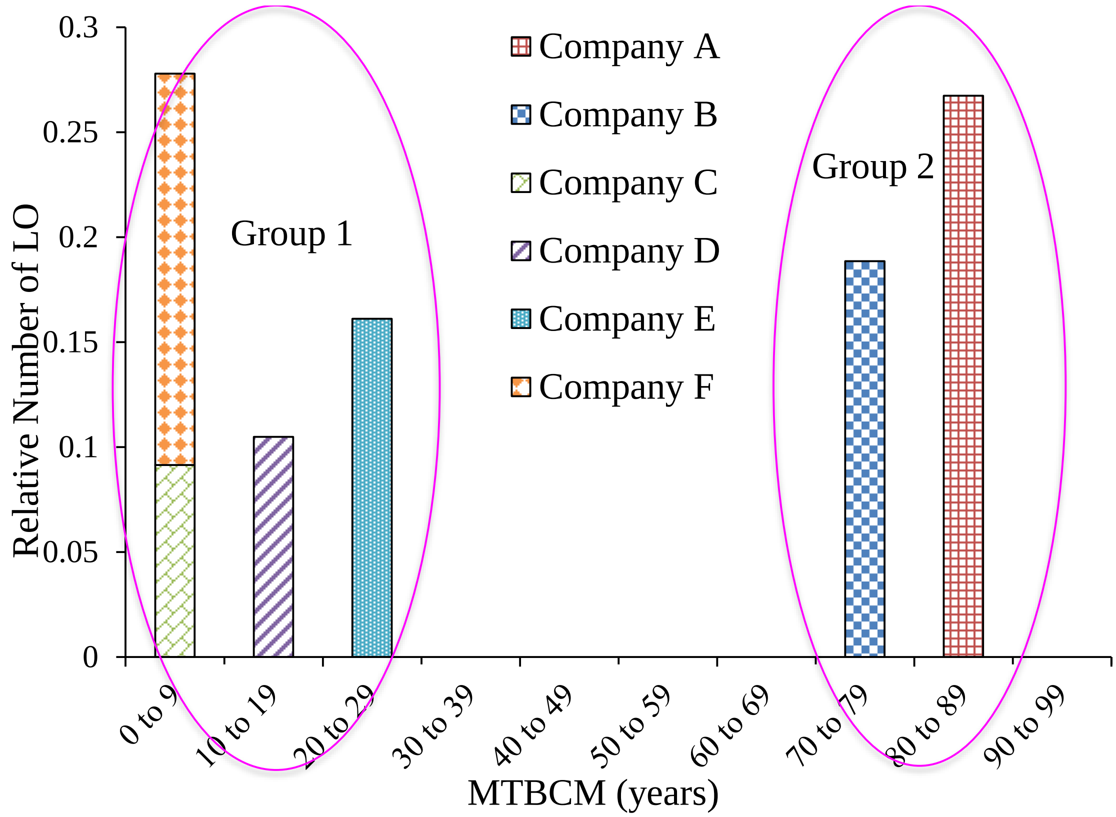


Figure 3: Summary of MTBCM Results

The first group consists of companies C, D, E, and F. A simple average of the MTBCM of these companies, assuming that the MTBCM of each company is representative of that company's performance, is 11.0. The second group consists of companies A and B. A simple average of the MTBCM of group 2 is 78.5. The weighted averages were approximately the same as the simple averages.

Methodology Challenges and Solutions

In this first phase of IRN studies, it is important to note which aspects of the IRN methodology can be improved. In general, the management of datasets and communication between industry and IRN is challenging. For this study, acknowledgement of datasets from submitting partners was simply by open communication, making it cumbersome to acknowledge and obtain feedback on datasets. In the future, datasets will have a two-step acknowledgement by MKOPSC, involving first the Associate Director's confirmation of data submittal with student workers directly involved in the respective IRN project, followed by a secondary redundant check to confirm that data has been properly recorded. This system is simple, making it flexible and versatile when it needs to be, while maintaining data quality and reducing burden to data submission partners.

For data collection purposes, the definition of component failure can be ambiguous. In this study, the mean time between corrective maintenance was studied. During IRN review of the results of this project, it was hypothesized that possible ambiguity in the definition of corrective maintenance might have contributed to the bimodality of the results. Fortunately, the inclusion of higher-tier information in future works will help to eliminate these discrepancies. Still, the importance of careful project initiation and charter formulation is emphasized. Furthermore, assuring IRN members fully understand exactly what information is required for submittal is crucial in obtaining consistent data, especially in future studies when more detailed information is required.

Conclusions

In this study, the mean time between corrective maintenance (MTBCM) for single and dual sensing pressure transmitters was calculated using data submitted by six different companies, totaling sixteen individual datasets, with 1421 monitored devices. The data were first screened for quality and then analyzed to provide MTBCM values. This study shows that the IRN methodology operates effectively to collect, screen, and analyze data from IRN members to provide valuable reliability information. Several challenges were encountered, including management of datasets and the importance of failure definitions. Methodology improvements were developed to improve the IRN process, making it more flexible and robust, while reducing barriers to involvement in IRN.

The analysis result of the first phase of the pressure transmitter project also showed a significant difference in MTBCM performance between companies. This performance fell into two distinct groups. It may be inferred from the difference between the average MTBCMs of the two groups that some companies were having to perform corrective maintenance on their pressure transmitters 4-7 times more often than the companies in the higher MTBCM group. Addressing the root causes of this difference in performance could assist the participating companies in optimizing their maintenance resource program as well as potentially improving the performance control and safety functions utilizing these devices. As a result, expansions of the data collection taxonomy have been proposed for the second phase of the pressure transmitter project, which will analyze hypothesized contributions of these addition taxonomic elements to the differences in MTBCM performance between companies.

Future Studies

The MKOPSC IRN is committed to working to collect and improve data acquisition techniques associated with instrument reliability. Having completed this first study, a second study charter is under development addressing the same measurement (MTBCM). However, additional data will be collected to determine if the following variables contribute to differences in performance. These variables are:

• Process Fluid • Process Severity • External Environmental Severity	• Functional Use Classification • Technology • Support System

An additional study is planned on the complementary measurement Mean Time Between Test Failure (MTBTF) for pressure transmitter. Subsequent studies will begin to treat data into much larger groups such as input devices, final element and logic solvers.

References

1. Instrument Reliability Network (IRN):Irn.tamu.edu
2. Center for Chemical Process Safety (CCPS), VISION 20/20, Process Safety: The Journey Continues.
3. Freeman, Raymond. 2011. “What to Do When Nothing Has Happened.” Process Safety Progress, September, Vol. 30, No. 3: 204-11.