High Pressure Fire Loop Analysis

IE5332 Experimental Investigation in Advanced Industrial Engineering Topics

MS System Engineering and Management

Capstone Project (Fall 2017)

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Background

Pantex is the nation's primary site for assembly and disassembly of nuclear weapons. (CNS, 2017) The mission of nuclear deterrence is crucial to our national defense. Because of this mission that doing business within Pantex always has additional requirements and a higher level of outside observation.

Operations at Pantex are primarily conducted on 2,000 acres of the 18,000-acre site. Pantex has approximately 650 buildings, including specialized facilities in which maintenance, modification, disassembly, and assembly operations are conducted. (CNS, 2017)

Much like a small city, Pantex has a tremendous challenge in providing fire protection to all of these buildings. Pantex uses a sizeable underground piping system to supply water to each of these buildings. This underground piping system is called the High Pressure Fire Loop (HPFL). A majority of the HPFL system was installed during the early 80's. During this period ductile iron was the material of choice. The problem with ductile iron is that over time it rusts. A project was started in the early 2010s to replace the ductile iron with a new product. This product is High-Density Polyethylene (HDPE). This product is a hard plastic able to withstand pressure, temperature, and slight movement. HDPE piping comes in multiple widths and lengths. Because HDPE is a type of plastic, it can be joined in two different ways. It can be joined using a process called butt fusion welding, or it can be joined using a coupling. Butt fusion welding is performed by heating up the end of both pieces of pipe and then smooshing them together. This cause the melted plastics of both pieces of pipe to mix. Similar to welding two pieces of metal together, the butt fusion weld is stronger than the surrounding areas of the pipe. The other method to join these pipes together is a coupling. The coupling is called an Electrofusion Coupling (EFC). The coupling is placed over one end of the pipe, and then the other pipe is inserted. The two pipes meet in the middle of the coupling. The coupling is made of HDPE with a wire that is embedded into the plastic. An electric current runs through the wire. The current causes the wire to heat up melting the plastic coupling and plastic pipe to together. Melting the coupling and pipe together forms a solid bond. There is a multitude of instances where an Electrofusion coupling needs to be used. However, the preferred method is to butt weld these two pieces of pipe together due to the strength of the bond.

Problem Statement

As stated in the background above during the early 2010s a project was started to begin replacing a portion of the HPFL system with HDPE piping. An outside contractor performed the work. There was a multitude of assumptions that were made about the work quality that was performed. Since 2012 there have been three failures of these EFCs. These failures have been cut out and sent back to the manufacturer. The manufacturer performed a series of test. The test results show that the failed couplings were not installed correctly. This paper will not get into the details of what went wrong but will focus on the path forward for these improperly installed couplings. This concept paper will lay out the framework to analyze the functionality, operability, reliability, and probability of future failures.

Objectives and Scope

Objective

As stated in the problem statement above the objective of this analysis is to determine the functionality, operability, reliability, and probability of future failures within the HPFL system.

Scope

The scope will be limited to analyzing the effect of the EFC within the system and how one improperly installed coupling affects the rest of the HPFL system. The discussion will include normal operations, impaired flow, and service interruptions. Normal operations are defined as two-way flow to buildings. Impaired operations are defined as a building that only has one-way flow being provided to the building. Service interruptions will be when a building does not have water available to it.

The project will look at the following aspects of the reliability of the HPFL system: mean time to failure (MTTF) of EFCs, mean time between failures (MTBF), series system models, and parallel system models. These calculations will then be used to discuss the reliability of the system when one of the couplings fails. Compare the reliability of two-way feeds versus one-way feeds.

Applied Classes

The graduate courses for the CNS cohort are listed below:

1. IE 5320 Systems Theory
2. IE 5324 Advanced Economics of Systems
3. IE 5331 Supply Chain Management and Logistics
4. IE 5329 Project Management
5. IE 5345 Reliability Theory
6. IE 5311 Principles of Optimization
7. IE 5346 Total Quality Systems
8. IE 5331 System Engineering Process
9. IE 5342 Design of Experiments
10. IE 5332 Capstone

The basis for any study within a System Engineering program would be incomplete without including a section dedicated to Systems Theory. The theory presented during this class directly applies to the program statement written above. The HPFL system would be incomplete without the piping that connects all areas. Discussions will include the importance of not just focusing on the EFCs but the operability of the system as a whole. The analysis will include studying why looking at the system is more important than looking at the individual failure rates of individual components.

The study of the system will then be carried over into the System Engineering Process of how the system was designed. The design process of the HPFL system will be studied to include any potentially missed opportunities for improvement.

The primary focus of this Capstone project is to analyze the operability of the HPFL system as a whole. A significant portion of the analysis will include the methods and theories learned in IE 5345 Reliability Theory. The calculations learned in Dr. Du class will be applied to determine component failure rates, MTTF, the probability of multiple failures, and one-way versus two-way flows.

References

CNS. (2017, 10 13). *About*. Retrieved from Pantex: http://www.pantex.com/about/