Safety Manual for
Series H & Series MH
Hydraulic Cylinders

Milwaukee Cylinder

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Revision	Date	Author	Comment
1	1/22/15	PMF	Initial Release

1 Introduction

This Safety Manual provides information necessary to design, install, verify and maintain a Safety Instrumented Function (SIF) utilizing the Series H & Series MH hydraulic cylinders ordered with the SIL option and it includes all mounting styles except for pivot mounts. It also pertains to SIL designated custom cylinders that are based on Series H or Series MH designs. This manual provides necessary requirements for meeting the IEC 61508 or IEC 61511 functional safety standards.

1.1 Terms

Safety	Freedom from unacceptable risk of harm
Functional Safety	The ability of a system to carry out the actions necessary to achieve or to maintain a defined safe state for the equipment / machinery / plant / apparatus under control of the system
Basic Safety	The equipment must be designed and manufactured such that it protects against risk of damage to persons by electrical shock and other hazards and against resulting fire and explosion. The protection must be effective under all conditions of the nominal operation and under single fault condition
Safety Assessment	The investigation to arrive at a judgment - based on evidence - of the safety achieved by safety-related systems
Fail-Safe State	Applies to SIL optioned Series H or Series MH cylinders and SIL designated custom cylinders. For spring return cylinders, this is the state where the cylinder is de-pressurized and an internal spring retracts the piston rod. For dual acting cylinders, this is the state where the piston rod is used to move the equipment to the safe state within the specified safety time.
Fail Safe safe	Failure that causes the equipment to go to the defined fail-state without a demand from the process.
Fail Dangerous	Failure that does not respond to a demand from the process (i.e. being unable to go to the defined fail-safe state).
Fail Dangerous Undetected	Failure that is dangerous and that is not being diagnosed by automatic stroke testing.
Fail Dangerous Detected	Failure that is dangerous but is detected by automatic stroke testing.
Fail Annunciation Undetected	Failure that does not cause a false trip or prevent the safety function but does cause loss of an automatic diagnostic and is not detected by another diagnostic.

Fail Annunciation Detected	Failure that does not cause a false trip or prevent the safety function but does cause loss of an automatic diagnostic or false diagnostic indication.
Fail No Effect	Failure of a component that is part of the safety function but that has no effect on the safety function.
Low demand mode	Mode, where the frequency of demands for operation made on a safety-related system is no greater than twice the proof test frequency.

1.2 Abbreviations

FMEDA	Failure Modes, Effects and Diagnostic Analysis
HFT	Hardware Fault Tolerance
MOC	Management of Change. These are specific procedures often done when performing any work activities in compliance with government regulatory authorities.
PFDavg	Average Probability of Failure on Demand
SFF	Safe Failure Fraction, the fraction of the overall failure rate of a device that results in either a safe fault or a diagnosed unsafe fault.
SIF	Safety Instrumented Function, a set of equipment intended to reduce the risk due to a specific hazard (a safety loop).
SIL	Safety Integrity Level, discrete level (one out of a possible four) for specifying the safety integrity requirements of the safety functions to be allocated to the E/E/PE safety-related systems where Safety Integrity Level 4 has the highest level of safety integrity and Safety Integrity Level 1 has the lowest.
SIS	Safety Instrumented System – Implementation of one or more Safety Instrumented Functions. A SIS is composed of any combination of sensor(s), logic solver(s), and final element(s).

1.3 Product Support

Product support can be obtained from:

Milwaukee Cylinder Customer Service Department

Phone 414-769-9700

www.milwaukeecylinder.com *sales@milwaukeecylinder.com*

1.4 Related Literature

Hardware Documents:

- Series H & Series MH Catalogs
- Safety Integrity Level Selection – Systematic Methods Including Layer of Protection Analysis, ISBN 1-55617-777-1, ISA
- Control System Safety Evaluation and Reliability, 2nd Edition, ISBN 1-55617-638-8, ISA
- Safety Instrumented Systems Verification, Practical Probabilistic Calculations, ISBN 1-55617-909-9, ISA

1.5 Reference Standards

Functional Safety

- IEC 61508: 2000 Functional safety of electrical/electronic/ programmable electronic safety-related systems
- ANSI/ISA 84.00.01-2004 (IEC 61511 Mod.) Functional Safety – Safety Instrumented Systems for the Process Industry Sector

2 Device Description

The components of the Safety Instrumented Function are described in this section.

The dual acting version of this device advances or retracts the piston rod using hydraulic fluids. The spring return version advances the piston rod using hydraulic fluids and retracts the piston rod through the use of an internal spring. The cylinders are available from 1 1/2” to 12” or 25mm to 200mm bore sizes, with a variety of rod sizes and mounting styles and are designed to meet NFPA (National Fluid Power Association) or ISO dimensional standards. NOTE: Pivot mounts such as clevis mounts and trunnion mounts have not been evaluated for a SIL rating and are not applicable to this document.

3 Designing a SIF Using a Customer Product

3.1 Safety Function

Dual acting cylinder

When the blind end (or cap end) port of the cylinder is energized with hydraulic fluid, the cylinder piston rod extends out. When the rod end (or head end) port of the cylinder is energized with hydraulic fluid the piston rod retracts. The piston rod is used to move the equipment to the safe state within the specified safety time.

Spring return cylinder

The cylinder operates in the same manner as the dual acting cylinder, except utilizes the force of an internal spring to accomplish the retraction of the piston rod.

The hydraulic cylinder is intended to be part of final element subsystem as defined per IEC 61508 and the achieved SIL level of the designed function must be verified by the designer.

3.2 Environmental limits

The designer of a SIF must check that the product is rated for use within the expected environmental limits. Refer to the Milwaukee Cylinder Series H & Series MH catalogs for environmental limits.

3.3 Application limits

The materials of construction of these hydraulic cylinders are specified in the Milwaukee Cylinder Series H & Series MH catalogs. It is especially important that the designer check for material compatibility considering on-site chemical contaminants and oil supply conditions. If the hydraulic cylinder is used outside of the application limits or with incompatible materials, the reliability data provided becomes invalid.

3.4 Design Verification

A detailed Failure Mode, Effects, and Diagnostics Analysis (FMEDA) report is available from Milwaukee Cylinder. This report details all failure rates and failure modes as well as the expected lifetime.

The achieved Safety Integrity Level (SIL) of an entire Safety Instrumented Function (SIF) design must be verified by the designer via a calculation of PFDAVG considering architecture, proof test interval, proof test effectiveness, any automatic diagnostics, average repair time and the specific failure rates of all products included in the SIF. Each subsystem must be checked to assure compliance with minimum hardware fault tolerance (HFT) requirements.

Note: The exida exSILentia® tool is recommended for this purpose as it contains accurate models for the components and their failure rates.

When using a hydraulic cylinder in a redundant configuration, a common cause factor of at least 5% should be included in safety integrity calculations.

The failure rate data listed the FMEDA report is only valid for the useful life time of a hydraulic cylinder. The failure rates will increase sometime after this time period. Reliability calculations based on the data listed in the FMEDA report for mission times beyond the lifetime may yield results that are too optimistic, i.e. the calculated Safety Integrity Level will not be achieved.

3.5 SIL Capability

3.5.1 Random Integrity

The product is a Type A Device. Therefore based on the SFF between 60% and 90%, when it is used as the only component in a final element subassembly, a design can meet SIL 2 @ HFT=0.

When the final element assembly consists of many components (this device, actuator, solenoid, quick exhaust valve, etc.) the SIL must be verified for the entire assembly using failure rates from all components. This analysis must account for any hardware fault tolerance and architecture constraints.

3.5.2 Safety Parameters

For detailed failure rate information, refer to the FMEDA (Failure Modes, Effects and Diagnostic Analysis) Report for the Milwaukee Cylinder Series H & Series MH Cylinder report no. MIL 14-02-039 R001.

3.6 General Requirements

The system's response time shall be less than process safety time. The final system that the hydraulic cylinder is installed on must meet the requirements base on the cylinder specifications

All SIS components including the hydraulic cylinder must be operational before process start-up.

User shall verify that the hydraulic cylinder is suitable for use in safety applications by confirming the cylinder been properly identified.

Personnel performing maintenance and testing on the hydraulic cylinder shall be competent to do so.

Results from the proof tests shall be recorded and reviewed periodically.

The useful life of the cylinder is discussed in the FMEDA (Failure Modes, Effects and Diagnostic Analysis Report).

4 Installation and Commissioning

4.1 Installation

Refer to the Milwaukee Cylinder Series H & Series MH catalogs.

4.2 Physical Location and Placement

The cylinder shall be accessible with sufficient room for hydraulic connections and shall allow manual proof testing.

Hydraulic piping to the cylinder shall be kept as short and straight as possible to minimize the oil flow restrictions and potential clogging. Long or kinked hydraulic tubes may also increase the valve closure time.

The cylinder shall be mounted in a low vibration environment. If excessive vibration can be expected special precautions shall be taken to ensure the integrity of hydraulic connectors or the vibration should be reduced using appropriate damping mounts.

5 Operations and Maintenance

5.1 Proof test without automatic testing

Reference Milwaukee Cylinder Series H & Series MH Cylinders FMEDA report no. MIL 14-02-039 R001 for a proof test procedure and other related information.

The objective of proof testing is to detect failures within the hydraulic cylinder that are not detected by any automatic diagnostics of the system. The primary concern is undetected failures that prevent the safety instrumented function from performing its intended function.

The frequency of proof testing, or the proof test interval, is to be determined in reliability calculations for the safety instrumented functions for which a hydraulic cylinder is applied. The proof tests must be performed more frequently than or as frequently as specified in the calculation in order to maintain the required safety integrity of the safety instrumented function.

The results of the proof test should be recorded and any failures that are detected and that compromise functional safety should be reported to Milwaukee Cylinder Customer Service Department.

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The person(s) performing the proof test of a hydraulic cylinder should be trained in SIS operations, including bypass procedures, valve maintenance and company MOC (Management of Change) procedures. No special tools are required.

5.2 Repair and replacement

Repair procedures in the Milwaukee Cylinder Series H & Series MH catalogs must be followed.

5.3 Useful Life

Reference: Milwaukee Cylinder Series H & Series MH Cylinder FMEDA report no. MIL 14-02-039

5.4 Manufacture Notification

Any failures that are detected and that compromise functional safety should be reported to Milwaukee Cylinder Customer Service Department.

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6 Status of the Document

6.1 Releases

Revision: 1
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Author: Peter Frymark
Review: R1: *Reviewer; Douglas Lacina, February 11, 2015*
Release status: Released

6.2 Future Enhancements

Based on future project requests.

6.3 Release Signatures

/s/ Peter Frymark, Product Engineer

Name, Title

/s/ Douglas Lacina, Marketing & Engineer Leader

Name, Title

Name, Title