FLOWSERVE

SIL SAFETY GUIDE

Valtek Mark Series Control Valves

High Performance Globe and Angle Valves

FCD VLENIM0001-01 07.07
FCD FCAIM0100-01
FCD VLAIM003-03
FCD VLAIM006
FCD VLENIM0036-04

Experience In Motion

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1. Introduction

This Safety Manual provides information necessary to design, install, verify and maintain a Safety Instrumented Function (SIF) utilizing a Flowserve Valtek Mark Series Valve and Cylinder Actuator. This manual provides necessary requirements for meeting the IEC 61508 or IEC 61511 functional safety standards.

1.1 Terms and Abbreviations

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:

State where solenoid valve is de-energized and spring is extended

Fail Safe:

Failure that causes the valve to go to the defined fail-safe 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 Acronyms

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

Please refer to the back cover for your regional Flowserve contact details.

1.4 Related Literature

Hardware Documents:

Valtek Mark Series Control Valve Installation, Operation, and Maintenance Instructions

Valtek Mark Series Control Valve Brochures and Technical Bulletins

Guidelines/References:

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. Mark Series Device Description

The Valtek Mark Series control valve offers superior performance in liquid and gaseous services, while also permitting easy, fast and inexpensive maintenance.

The spring-cylinder actuated Mark Series valve provides stiffness and maintains high positioning accuracy, repeatability, controlled high speed, and faithful response. The Mark Series valve actuator handles up to 150 psig (10.3 barg) supply air and has the thrust to shut off against much higher fluid pressures.

The Mark Series valve is designed so the spring, supply air pressure and fluid pressure itself combine to produce exceptionally tight shutoff. A self-aligning seat ring further enhances the shutoff capability of the Mark Series valve. Additionally, the Mark Series valve's high degree of parts interchangeability, fewer inventory parts are required. In addition, the actuator is lighter, smaller and easier to handle than comparable diaphragm actuators.

The Mark Series of valves can be categorized into the following segments:

Mark One (FCD VLENIM0001-01 07.07; FCD FCAIM0100-01): globe and angle design managing a pressure drop between upstream and downstream pressure changes.

Mark One 3-Way (FCD VLAIM003-03): globe and angle design designed for applications requiring the combining or diverting of fluids by way of an added 3-way adaptor.

Mark Six (FCD VLAIM006): globe and angle design specifically for cryogenic applications requiring a cold box extension.

Survivor (FCD VLENIM0036-04): a sweep angle type control valve uniquely designed for use in erosive, corrosive, and flashing applications.

3. Designing a Safety Instrumented Function using a Flowserve Valtek Mark Series Valve

3.1 Safety Function

When de-energized, the Mark Series valve moves to its fail-safe position. Depending on the version specified Fail – Closed or Fail - Open, the Mark Series will extend the valve plug to close off the flow path through the valve body or open the flow path through the valve body.

The Mark Series valves are 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. For SIL rated valves the minimum operating temperature is -40°F/-40°C , for other environmental limits refer to the various Valtek Mark Series valve Technical Bulletins.

3.3 Application limits

The materials of construction of a Mark Series valve are specified in various Valtek Mark Series valve Technical Bulletins. It is especially important that the designer check for material compatibility considering on-site chemical contaminants, temperature/pressure limitations, and air supply conditions. If the Mark Series valve 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 Flowserve. This report details all failure rates and failure modes.

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. The exida exSILentia® tool is recommended for this purpose as it contains accurate models for the Mark Series valve and its failure rates.

When using a Mark Series valve in a redundant configuration, a common cause factor of 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 Mark Series valve. 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 Systematic Integrity

The product has met manufacturer design process requirements of Safety Integrity Level (SIL) 3. These are intended to achieve sufficient integrity against systematic errors of design by the manufacturer. A Safety Instrumented Function (SIF) designed with this product must not be used at a SIL level higher than the statement without “prior use” justification by end user or diverse technology redundancy in the design.

3.5.2 Random Integrity

The Mark Series valve is a Type A Device. Therefore based on the SFF between 60% and 90%, when the Mark Series valve 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 (Mark Series valve, 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.

3.5.3 Safety Parameters

For detailed failure rate information refer to the Failure Modes, Effects and Diagnostic Analysis Report for the Mark Series valve.

3.6 Connection of the Mark Series valve to the SIS Logic-solver

The Mark Series valve is connected to the safety rated logic solver which is actively performing the safety function as well as automatic diagnostics designed to diagnose potentially dangerous failures within the Mark Series valve, (i.e. partial valve stroke test).

3.7 General Requirements

The system's response time shall be less than process safety time. To find the maximum necessary time for the Mark Series valve to move to its safe state position please refer to Table 1.

All SIS components including the Mark Series valve must be operational before process start-up.

User shall verify that the Mark Series valve is suitable for use in safety applications by confirming the Mark Series valve's nameplate is properly marked.

Personnel performing maintenance and testing on the Mark Series valve shall be competent to do so.

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

The useful life of the Mark Series valve is discussed in the Failure Modes, Effects and Diagnostic Analysis Report for the Mark Series valve.

Table 1

Estimated Stroking Speeds[(1)]

Actuator Size (sq. in.)	Stroke (inches)	Without Boosters		With Boosters	
		Total Time To Open	Total Time To Close	Total Time To Open	Total Time To Close
25 (1/4-inch tubing)	0.75	1	0.5	-	-
	1	1.2	0.7	-	-
	1.5	1.4	0.9	-	-
50 (1/4-inch tubing)	1	2.7	1.5	0.3	0.1
	2	3.7	2.6	0.3	0.2
	3	4.6	3.6	0.4	0.3
100 (1/4-inch tubing)	2	9.2	5.6	0.6	0.4
	3	11.1	7.7	0.8	0.5
	4	12.8	9.6	1	0.7
	6	15.8	13	1.2	0.9
	8	18.6	16.2	1.4	1.1
	10	21.2	19.5	1.5	1.4
	12	23.6	22.8	1.7	1.6
	18	29.2	28.9	2.1	2.1
	24	32.3	32.1	2.4	2.3
200 (3/8-inch tubing)	2	15.2	11.2	1	0.8
	3	18.9	15.2	1.4	1.1
	4	22.3	18.8	1.7	1.3
	6	28.5	25.1	2.1	1.8
	8	34.3	30.9	2.6	2.3
	10	39.9	36.8	3	2.7
	12	45.1	42.6	3.4	3.2
	18	60	58.4	4.6	4.5
	24	68.9	68.1	5.3	5.2
300 (3/8-inch tubing)	3	26.9	22.9	2.1	1.8
	4	31.9	28.3	2.5	2.3
	6	41.3	37.6	3.3	3
	8	50.1	46.1	4.1	3.7
	10	58.5	54.4	4.8	4.4
	12	66.6	62.8	5.6	5.2
	18	89.3	85.9	7.7	7.2
	24	103.1	99.9	9.1	8.6

NOTE: Data is based on tests with boosters connected to the top and bottom ports of a spring cylinder actuator with a fail-close, standard spring and Beta positioner with I/P module, calibrated at 4-20 mA; 80 psi supply air to positioner and boosters.

NOTE: Divide stroking times by two when using two boosters on each cylinder port and ¾-inch NPT supply air pipes.

(1) Times are in seconds, are estimated and will vary slightly with different packing sets, plugs, seals, failure modes, etc.

(2) Listed tubing size is from positioner to actuator on systems without boosters, or to booster input signal on systems with boosters. All supply air tubing to boosters is ¾-inch.

4. Installation and Commissioning

4.1 Installation

The Mark Series valve must be installed per standard practices outlined in the Installation Manuals. The environment must be checked to verify that environmental conditions do not exceed the ratings. The Mark Series valve must be accessible for physical inspection.

4.2 Physical Location and Placement

The Mark Series valve shall be accessible with sufficient room for pneumatic connections and shall allow manual proof testing.

Pneumatic piping to the valve shall be kept as short and straight as possible to minimize the airflow restrictions and potential clogging. Long or kinked pneumatic tubing may also increase the valve closure time.

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

4.3 Pneumatic Connections

Recommended piping for the inlet and outlet pneumatic connections to the Mark Series valves is ¼" to ½" stainless steel tubing. The length of tubing between the Mark Series valve and the control device, such as a solenoid valve, shall be kept as short as possible and free of kinks.

Only dry instrument air filtered to 50 micron level or better shall be used. The process air pressure shall meet the requirements set forth in the installation manual. The process air capacity shall be sufficient to move the valve within the required time.

5. Operation and Maintenance

5.1 Proof test without automatic testing

Refer to applicable FMEDA for proof testing information.

FMEDA	Report Number
Mark One Control Valve	FLO 10-01-53 R001
Mark Six Control Valve	FLO 10-01-53 R002
Survivor Control Valve	FLO 10-01-53 R003
Mark One Three-way	FLO 10-01-53 R004
Valtek Spring Cylinder Linear Actuator	FLO 10-01-53 R005

5.2 Proof test with automatic partial valve stroke testing

An automatic partial valve stroke testing scheme that performs a full stroke of the isolation valves in the Mark Series valve and measures valve movement timing will detect most potentially dangerous failure modes. It is recommended that a physical inspection (Step 2 from Table 1) be performed on a periodic basis with the time interval determined by plant conditions. A maximum inspection interval of five years is recommended.

5.3 Repair and replacement

Repair procedures in the various Mark Series valve Installation, Operation and Maintenance manuals must be followed.

The SIL rating of the valve will be voided if the repair is not performed with Flowserve OEM parts and serviced by a competent person.

5.4 Useful Life for Mark Series Safety Valve

The useful life of the Mark Series valve is 10,000 cycles

5.5 Flowserve Notification

Any failures that are detected and that compromise functional safety should be reported to Flowserve. In case of failure please refer to the back cover and contact your regional Flowserve customer service.

Appendix A – SIS Checklist

The following checklist may be used as a guide to employ the Mark Series valve device in a safety critical SIF compliant to IEC61508.

#	Activity	Result	Verified	
			By	Date
	Design			
	Target Safety Integrity Level and PFDavg determined			
	Correct valve mode chosen (Fail-closed, Fail-open)			
	Design decision documented			
	Pneumatic compatibility and suitability verified			
	SIS logic solver requirements for valve tests defined and documented			
	Routing of pneumatic connections determined			
	SIS logic solver requirements for partial stroke tests defined and documented			
	Design formally reviewed and suitability formally assessed			
	Implementation			
	Physical location appropriate			
	Pneumatic connections appropriate and according to applicable codes			
	SIS logic solver valve actuation test implemented			
	Maintenance instructions for proof test released			
	Verification and test plan released			
	Implementation formally reviewed and suitability formally assessed			
	Verification and Testing			
	Electrical connections verified and tested			
	Pneumatic connection verified and tested			
	SIS logic solver valve actuation test verified			
	Safety loop function verified			
	Safety loop timing measured			
	Bypass function tested			
	Verification and test results formally reviewed and suitability formally assessed			
	Maintenance			
	Tubing blockage / partial blockage tested			
	Safety loop function tested			

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