

Jamesbury™ Quadra-Powr™ spring diaphragm quarter-turn actuators Series QPX Rev. 4.0 Safety manual



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1. Introduction

This safety manual provides the functional safety related information required to integrate and use *Quadra-Powr* spring diaphragm actuators in safety systems in compliance with the IEC 61508 standard. This safety manual shall be used together with the Installation, Maintenance, and Operation manual for *Jamesbury™ Quadra-Powr™* actuators.

The *Quadra-Powr* is a quarter turn rotary diaphragm actuator, which is used in automated on/off and control process applications. These units can be operated by air, water, oil, or other compatible supply media. Suitability of accessories with the operating media must be confirmed. In on/off service, the actuator is either fully closed or fully open. The *Quadra-Powr* actuator is commonly part of an automated on/off (block) valve assembly, which consists of a valve, actuator, accessories, and linkage parts. Only the actuator component of the automated on/off valve assembly is considered in this document. The valve part of the assembly can be a quarter turn valve such as a ball or disc type. Accessory parts of the automated on/off valve assembly may include a partial stroke test device, such as a pneumatic Neles ValvGuard or solenoid valves. Instruments such as quick exhaust valves, boosters and/or limit switches may be present.

In safety applications, the automated on/off valve assembly is part of safety instrumented function (SIF). The SIF purpose is to protect plant, environment and personnel against a hazard. In safety systems, the valve assembly is commonly called a final element subsystem. The primary function of the final element is to either isolate (block) the process, or to release or vent (blowdown) energy such as pressure, from the vessel.

2. Structure of the spring diaphragm actuator

2.1 Components and description of use

See IMO-215 or the documentation available for the actuator for a detailed technical description of the actuator.

2.2 Permitted actuator types

The information in this manual pertaining to functional safety applies to all *Quadra-Powr* actuator sizes and variants mentioned in the actuator type coding in the IMO's. This actuator is used as a spring return (SR) type only. The actuator can be used for either valve fail-open or valve fail-closed actions, depending on actuator installation (See IMO).

2.3 Supplementary actuator documentation

1. Installation, Maintenance and Operating Instruction IMO-215
2. Technical Bulletin A110-4

These are available from a Valmet contact, or for download from www.neles.com/valves.

Note that the IMO is not always shipped with the product.

3. Using the spring diaphragm actuator in safety systems

3.1 Safety function

When de-energised, the complete valve assembly goes to its fail safe position. The safety position of the bare shaft actuator can correspond to either valve fully closed or fully open. The safety action within the assembly is normally initiated by a solenoid valve or intelligent partial stroke device. This releases the actuator power fluid, causing the actuator to reach its safety position. Hence, the safety function of bare shaft actuator is a quarter turn rotation. The spring in the single acting actuator forces the actuator to reach its safety position.

3.2 Environmental and application restrictions

Ensure that the actuator is selected and specified correctly for the application and that the process conditions and atmospheric conditions are taken into account. Environmental limits for which the product is designed, and general instructions for applications, are given in the product IMO and technical bulletin. Please contact Valmet in case more details are needed. Proper specification of application, process and environmental conditions is the user responsibility.

The reliability values given in Paragraph 3.5 assume the actuator is selected correctly for the service and that all the environmental and application restrictions are considered. If the actuator is used outside of its application or environmental limits, or with incompatible materials, the reliability information shown in Paragraph 3.5 may not be valid.

3.3 Useful lifetime

The useful lifetime needed for functional safety reliability estimations is typically 10 – 15 years for the *Quadra-Powr* actuator, if Proof test (5.1), Partial stroke test (5.2), Maintenance (5.3), have been considered accordingly. The “useful lifetime” is the time period after burn-in and before wear-out, when the failure rate of a simple item is more or less constant. Note that the design life of the actuator is higher, and should not be confused with “useful lifetime” used in these reliability evaluations.

3.4 Connecting the spring diaphragm actuator to a safety system

The complete final element (which includes the valve, actuator, and accessories) is connected to the safety system through an electrical connection, which commonly operates an intelligent partial stroke device or a solenoid valve, which in turn, operates the actuator by supplying or exhausting the actuator’s fluid (see Fig 1).

A single final element installation provides hardware fault tolerance (HFT) equal to 0. If HFT equal to one is required, then two final elements installed in series (block) or parallel (vent) must be used.

Note that the single final element may contain internal redundancy of some accessories, e.g. where 1oo2 or 2oo2 solenoid valves are required.

Note that the bare shaft actuator cannot be connected to the safety system directly.

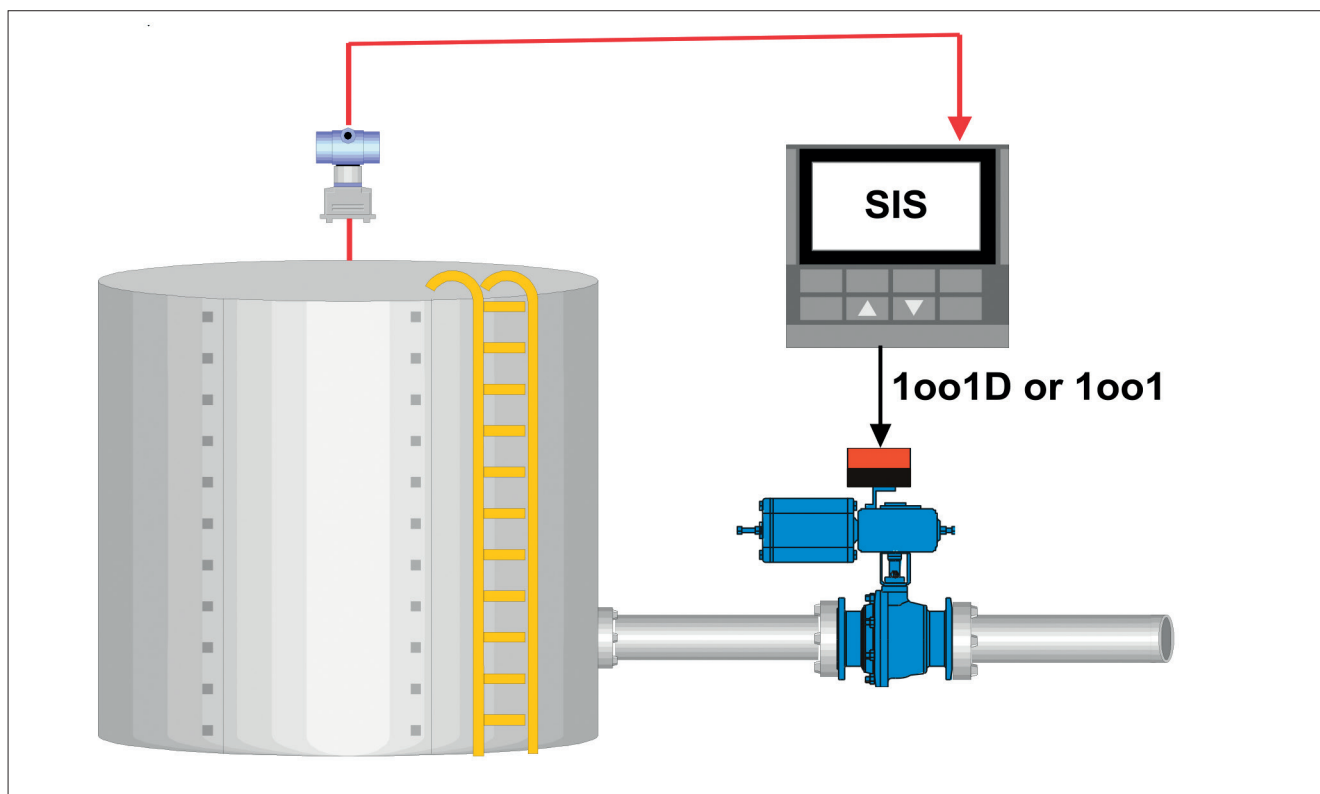


Fig. 1. Schematic picture of a safety loop. The final element with spring return actuator is connected to the Safety Instrumented System (SIS) via a solenoid or safety valve controller (partial stroke device). This shows a single channel final element subsystem architecture, either 1oo1D (with diagnostics) or 1oo1 (without diagnostics).

3.5 Random hardware integrity

The tables below show the “full” reliability numbers based on the Safety Certification for *Quadra-Powr* actuator. The data represent the bare shaft actuator, which is one part of the final element.

Note that all the other safety related components of the final element should be included when the reliability of the final element subsystem is estimated. The analysis must also account for the hardware fault tolerance and architecture constraints for the complete final element subsystem.

Table 1 QPX Failure rate data with automatic partial stroke test.

Sub system type		A
Diagnostic coverage, DC [%] *	DC[%]	77
Safe Failure Fraction	SFF	N/A**
Dangerous failures	λ_D [failures / hour]	1.65E-7
Dangerous undetected failures*	λ_{DU} [failures / hour]	1.27E-7
Dangerous detected failures, PST*	λ_{DD} [failures / hour]	0.38E-7
Safe failures	λ_S [failures / hour]	0
Safe undetected failures	λ_{SU} [failures / hour]	0
Safe detected failures	λ_{SD} [failures / hour]	0

Table 2 QPX Failure rate data without partial stroke test.

Sub system type		A
Diagnostic coverage, DC [%]*	DC[%]	0
Safe Failure Fraction	SFF	N/A*
Dangerous failures	λ_D [failures / hour]	1.65E-7
Dangerous undetected failures*	λ_{DU} [failures / hour]	1.65E-7
Dangerous detected failures, PST*	λ_{DD} [failures / hour]	0
Safe failures	λ_S [failures / hour]	0
Safe undetected failures	λ_{SU} [failures / hour]	0
Safe detected failures	λ_{SD} [failures / hour]	0

* Diagnostic coverage represents common valve and actuator assemblies, equipped with an intelligent part stroke device such as the pneumatic Neles ValvGuard. The DC value has been used to calculate λ_{DU} and λ_{DD} .

**Safe failure fraction must be assessed for the complete final element assembly, and therefore, are not included in this table.

3.6 Systematic integrity

Systematic integrity requirements according IEC 61508 up to and including Safety Integrity level (SIL) 3 are fulfilled with the required fault tolerance. These requirements include adequate integrity against systematic errors in the product design, and controlling systematic failures in the selection and manufacturing process. *Quadra-Powr* actuators must not be used in safety integrity functions with higher than the stated SIL level without a proven in use statement or, in some cases, redundant designs.

3.7 Additional information

Personnel doing the maintenance and testing must be competent to perform the required actions.

All final element components and components shall be operational before startup.

Proof testing should be recorded and documented according to IEC 61508 and maintenance actions done according to Part 5.

Unless the procedures above are properly followed, the reliability data shown in Paragraph 3.5 might not be valid.

4. Installation

The *Jamesbury Quadra-Powr* actuator must be installed on the valve according to Valmet instructions given in the Installation, Maintenance and Operation manual. Possible standards relevant to applications, local requirements, etc should be also considered. Installation must be done by competent persons. In case a bare shaft actuator (not supplied as an assembly by Valmet) is to be installed in a valve assembly, the installer is responsible to verify the suitability of all linkage parts (see more details in IMO). It is particularly important to confirm that all components are working properly together.

Incorrect installation may jeopardize the validity of the reliability data given in Paragraph 3.5.

In cases where the complete valve assembly is supplied and shipped by Valmet, the complete valve assembly is tested and configured according to Valmet internal procedures, except where project specific procedures are used.

5. Operation

5.1 Recommended proof test

The purpose of proof testing is to detect failures of the complete final element subsystem. Valmet recommends the following proof test procedure to achieve a proof test coverage factor of 99%:

- Conduct an initial visual inspection. Check that there are no unauthorized modifications to the SIS valve assembly. Verify that there is no observable deterioration in the SIS valve such as leaks, visible damage, or impurities on the SIS valve.
- Bypass the SIS valve if full stroke could cause an unnecessary process shutdown.
- Perform the safety action (full stroke), preferably using the system. Verify that the SIS valve achieves safe position within the required time specified by the application. Verify also the shutoff tightness for tightness critical applications. Note, that a tightness measurement might require removing the valve from the pipeline. If the valve must be removed from the pipeline, verify proper full stroke operation after re-installation.
- Restore the SIS valve to its normal position.
- Conduct a final visual inspection. Check that the SIS valve is in the normal position, and verify that all accessories are operating according to the specification for the SIS valve normal operation. Inspect visually that there is no observable deterioration of the SIS valve.
- Record all results and observations into the corresponding database with necessary audit trail information.
- Remove the SIS valve bypassing, if used.

5.2 Recommended partial stroke test

A partial stroke test is a verified movement of an emergency valve from the normal operating position toward the safe state. Partial stroke testing can be done in most cases while the process is on-stream without disturbing the process. The purpose is to provide early detection of automated block / vent valve failure modes, and to reduce the probability of failure on demand. A partial stroke coverage factor of 77% is assumed.

Valmet recommends using the testing capability available with intelligent partial stroke devices such as the pneumatic Neles ValvGuard. In order to obtain the full benefit of diagnostics provided by partial stroke devices, ensure first that the device is calibrated and configured correctly according to the manufacturer's guidelines.

Before initiating the partial stroke, ensure that the partial stroke will not cause a process hazard. If needed, the possible pressure disturbance can be further estimated by using Neles Nelprof valve sizing software.

The required partial stroke test interval may depend on application and targeted SIL level, but test intervals from 1 month to 6 month are generally recommended. Partial stroke size is typically from 10 to 20% of full travel starting from fully open in shutdown service and from 3 to 5 % starting from fully closed in blowdown (vent) service.

Note, that in some valve types such as butterfly valves which have small valve dead angle values, a small amount of flow might occur during a partial stroke in blowdown service. In typical ball valves, the partial stroke test can be done within the valve's dead angle value, thus maintaining tightness in blowdown service.

A partial stroke test can be initiated either manually or automatically. The test interval is set by the user. The user can be reminded by a partial stroke scheduler system in manual mode, and the test interval is controlled by the intelligent partial stroke test device in the automatic mode. Contact the partial stroke test device manufacturer for more details on how to select and set parameters to control the partial stroke size and frequency.

5.3 Maintenance

Any repair of the *Jamesbury Quadra-Powr* actuator must be carried out by Valmet or competent personnel. Maintenance procedures are given in the IMO. Generally a maintenance interval of 5 years is recommended. With proper maintenance, a maintenance coverage factor of > 99% can be achieved.

After the maintenance is completed, verify the functionality of the actuator including the assembly regarding the safety function in question. Note that all maintenance actions should be recorded.

Valmet Service provides the recommended spare part kits defined in the Bills of Material contained in every Instructions, Maintenance and Operation (IMO) manual. The need for parts replacement increases with the number of valve operations done during its lifetime and with the severity of service. Only authorized Valmet replacement parts should be used.

Soft sealing materials especially are affected by aging, and useful lifetime depends strongly on the application. Therefore, the condition of those components should be checked carefully during proof testing. In optimum operating conditions, the maintenance interval may be extended up to 10 years. The estimated typical time for spare parts change is 0 to 2 times during the valve useful lifetime. Possible problems must be resolved in any case of failure, or doubt observed in proof testing.

6. References

- [1] IMO-215
- [2] Technical bulletin A110-4
- [3] SIL certificate TUV 968/V 1119.00/19
- [4] SIL report TUV 968/V 1119.00/19
- [5] IEC 61508 – Parts 1-2 and 4-7:2010
- [6] Neles ValvGuard IMO 7 VG9H 70 en
- [7] Neles ValvGuard IMO 7 VG9F 70 en
- [8] Neles ValvGuard Local Control Panel IMO 7 LCP 9H 70 en

Appendix 1. Examples of reliability (PFD) calculations for complete final elements

QPX series actuator and 7000 series valve, equipped with Neles ValvGuard for partial stroke testing and to perform the safety action. A diagnostic coverage factor of 77% is used for the complete valve assembly.

Final element setup				
Safety position	Close			
Architecture	1oo1D			
Diagnostic coverage	Valve+Actuator (close)+VG			0.77

Test intervals			
Full stroke test	TIFST [months]		48
Partial stroke test	TIPST [months]		3
Pneumatic test	TIPNEUMATIC [days]		7

Valve and Actuator		$\lambda D[1/h]$	MTTR[Hours]	PFD
Valve	JB 7000/9000-SERIES	2.42E-8	24	1.185E-4
Actuator	QPX-SERIES	1.65E-7	24	8.08E-4

Accessories		$\lambda D[1/h]$	MTTR[Hours]	PFD
Intelligent PST	VG9000F/H	5.578E-8	4	5.646E-5
Instru 1 (1oo1)	RCI9H2	1.9E-9	4	3.33E-5
Instru 2 (None)				
Instru 3 (None)				
Instru 4 (None)				
Instru 5 (None)				

Calculate

Result:
PFD total

1.016E-3

Final element is suitable for use in safety systems up to and including

SIL 2

QPX series actuator and 7000 series valve, equipped with a solenoid valve to perform the safety action.

Final element setup				
Safety position	Close			
Architecture	1oo1			
Diagnostic coverage	No diagnostic test			0

Test intervals		
Full stroke test	TIFST [months]	48

Valve and Actuator		λ_D [1/h]	MTTR[Hours]	PFD
Valve	JB 7000/9000-SERIES	2.42E-8	24	4.246E-4
Actuator	QPX-SERIES	1.65E-7	24	2.895E-3

Accessories		λ_D [1/h]	MTTR[Hours]	PFD
Instru 1 (1oo1)	SOV GENERIC 3-WAY	5.85E-7	4	1.025E-2
Instru 2 (None)				
Instru 3 (None)				
Instru 4 (None)				
Instru 5 (None)				

Calculate

Result:

PFD total

1.357E-2

Final element is suitable for use in safety systems up to and including

SIL 1

Appendix 2. Equations to calculate PFD for 1oo1 and 1oo1D final elements.

These equations correspond to IEC 61508 and ISA TR-96.05.01.

An average value of probability of failure on demand for 1oo1D architecture with diagnostics is given by the equation

$$PFD_{AVG} = DC * \lambda_D * TI_{PST}/2 + (1-DC) * \lambda_D * TI_{FST}/2 + \lambda_D * MTTR$$

where, DC is diagnostic coverage (fraction), λ_D is dangerous failure rate (failures / hour), TI_{FST} is full stroke test interval (hours), TI_{PST} is partial stroke test interval (hours) and MTTR is mean time to repair (hours).

Diagnostic coverage provided by a typical partial stroke device is applicable to the valve, actuator, quick exhaust valves and volume boosters. Diagnostic coverage for a solenoid or air operated valve is not available.

The Neles ValvGuard pneumatic device itself uses diagnostic coverage provided by the internal pneumatic diagnostic test, and / or the partial stroke test.

The PFD equation for 1oo1 voting without diagnostic testing is similar to 1oo1D except that the diagnostic coverage is equal to 0. Thus the general equation becomes:

$$PFD_{AVG} = \lambda_D * TI_{FST}/2 + \lambda_D * MTTR$$

Appendix 3. SIL Certificate.

Certificate



SIL/PL Capability

www.tuv.com
ID 0600000000

No.: 968/V 1119.00/19

Product tested	Quarter turn actuators with spring return	Certificate holder	Metso Flow Control Oy Vanha Porvoontie 229 01301 Vantaa Finland
Type designation	Quadra-Powr X QPX1 – QPX5		
Codes and standards	IEC 61508 Parts 1-2 and 4-7:2010		
Intended application	Safety Function: Perform full stroke by the meaning of spring force The actuators are suitable for use in a safety instrumented system up to SIL 2 (low demand mode). Under consideration of the minimum required hardware fault tolerance HFT = 1 the test items may be used in a redundant architecture up to SIL 3.		
Specific requirements	The instructions of the associated Installation, Operating and Safety Manual shall be considered.		
Summary of test results see back side of this certificate.			
Valid until 2024-07-08			
The issue of this certificate is based upon an examination, whose results are documented in Report No. 968/V 1119.00/19 dated 2019-07-08. This certificate is valid only for products which are identical with the product tested.			
TÜV Rheinland Industrie Service GmbH Bereich Automation Funktionale Sicherheit Am Grauen Stein, 51105 Köln Köln, 2019-07-08		 Dipl.-Ing. Thomas Steffens	
Certification Body Safety & Security for Automation & Grid			

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