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Functional Safety manual
Vanessa Series 30,000

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Content

1 Introduction

1.1 Scope

This manual provides necessary information for meeting the IEC 61508 or IEC 61511 functional safety standards and to design, install, verify and maintain a Safety Instrumented Function using Emerson Vanessa valves Series 30,000.

1.2 Terms and Abbreviations

Table 1: Terms and Abbreviations

FMEDA	*Failure Modes, Effects and Diagnostic Analysis*
HFT	*Hardware Fault Tolerance*
PFD_{AVG}	*Average Probability of Failure on Demand*
SFF	*Safe Failure Fraction*
SIL	*Safety Integrity Level*
SIF	*Safety Instrumented Function*
SIS	*Safety Instrumented System*
DC	*Diagnostic Coverage Factor*
IOM	*Installation, Operation and Maintenance manual*

1.3 Reference Documents

- *Installation, Operation & Maintenance manual for Series 30,000*
- *Series 30,000 Product data sheet*
- *Series 30,000 Product brochure*
- *TÜV RH Certificate 968/V_1107.00/19*

1.4 Related Standards

- *IEC 61508 Parts 1-2 and 4-7:2010 Functional safety of electrical/electronic/ programmable electronic safety-related systems*
- *IEC 61511 Parts 1-3:2004 Functional safety - Safety instrumented systems for the process industry sector*

1.5 *Responsibilities for safety*

The system integrator is responsible to implement the choice of the safety function and to verify the achieved SIL of the safety related system, which the valve is part of.

The safety of design and operation of the safety-related system, in which the product is integrated, must be ensured by manufacturer and by operator.

1.5.1 *Responsibility of manufacturer*

A detailed FMEDA and inspection of the Functional safety management were carried out to assess the safe design of the product. Review of qualification tests and evaluation of field feedback were used to confirm functional safety of the product.

All safety-related information of the overall system to the operator are provided in the present document.

Guidelines that allow a safe commissioning of the product, instructions for installation, operation and maintenance are provided in IOM (Installation, Operation & Maintenance manual) for Series 30,000.

1.5.2 *Responsibility of operator*

Personnel working on the overall system shall be instructed and trained to maintain the safe operation of the overall system. Periodic test of the overall system shall be carried out by qualified employees. Results from tests shall be recorded, stored and periodically reviewed.

2 *Device Description*

The Series 30,000 product is a triple-offset, torque seated valve with metal-to-metal sealing, operated by quarter-turn rotation.

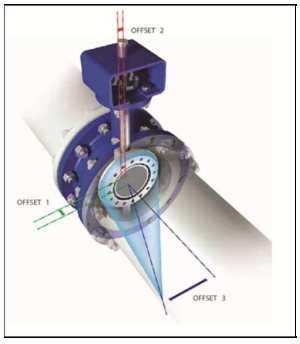

Figure 1

The product is extensively used in critical protective service applications (i.e. turbine/expander emergency shut-down, backflow pump protection, compressor blow-off, turbine by-pass, vent emergency open, etc.) with forty years of proven use and constant feedback from the field.

It is a purely mechanical device which shall be operated by an actuator and a control system to perform the specified safety function. It is intended to become part of the final element of the safety related system.

The valve does not perform any automatic diagnostic function by itself, however automatic diagnostic of the final element may be performed by the valve through the actuator control system.

The valve is classified as "Type A" device, having an HFT = 0. The operation mode of the valve is classified as "Low Demand".

3 *Functional Safety relevant specifications*

3.1 *Safety Function*

Safety function mode 1: Deliver on demand a full open or close stroke and external tightness

The valve performs the safety function on demand if it delivers a full stroke driven by the actuator, moving to the safe position, either close or open depending on the specified fail-safe action, within the specified time, when the system is de-energized.

Safety function mode 2: Deliver on demand a full close stroke within specified tightness and external tightness

The valve performs the safety function on demand if it delivers a full stroke driven by the actuator, moving to the safe closed position, within the specified time, when the system is de-energized AND performs the seat tightness rate which does not affect the process safety function (typically a leakage rate higher than ANSI/FCI 70-2 Class IV rate may be considered a Dangerous failure for the process safety function).

3.2 *Application and Environmental Limits*

The designer of a SIF must verify that the device is rated for use within the expected application pressure and temperature limits. For usage in safety-related applications, the compatibility of the operating medium with the valve materials of construction must be verified to be in compliance with the service and the environment. Reference shall be made to the valve nameplate, the valve technical manual and the IOM.

When solid particles are present in the fluid Vanessa recommends the valve installation with the shaft in the horizontal plane or, at least, with the shaft at an angle that minimizes any deposit in the bottom bearing area.

The valve body is more resistant than the pipe to which it is connected, being of simple cylindrical-shape with outward cylindrical branches and wall thickness much higher than the pipe itself. Therefore, the valve body and flanges cannot be taken as a limiting factor for the maximum allowable loads transmitted by the pipe.

The valve seating load is applied in the radial direction, hence the seating behaviour is not affected by piping stresses, unlike gate and wedge valves which are strongly affected by compressive and bending loads induced by the connected pipe.

For operating temperatures above 200°C (392°F) thermal insulation of the valve body is recommended to keep uniform thermal distribution.

When specified, environmental loads like wind, blast, earthquake are considered for the valve design.

3.2.1 Shaft side and Disc side: the valve installation direction

Vanessa valve is designed to withstand design differential pressure in both directions. However, the valve installation with respect to the fluid pressure direction1 may affect the valve functional safety performance and failure rates.

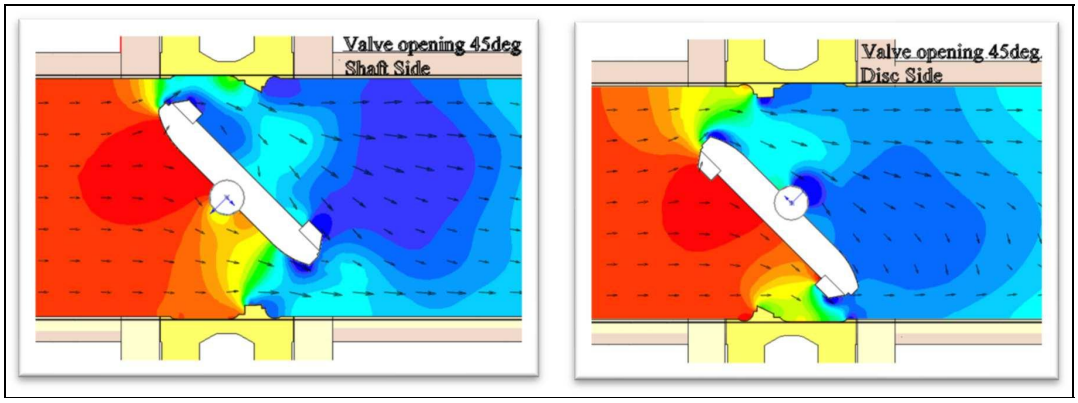

Figure 2

<u>Safety function to close</u>: the installation with the pressure acting on the shaft side of the trim is preferred in case of Safety function to close and Safety function to close with internal tightness. Disc side installation is not recommended for safety function to close.

<u>Safety function to open</u>: installation with the pressure acting on the disc side of the trim is preferred in case of Safety function to open. The risk related to the valve internal leakage needs to be evaluated against

[1] The fluid pressure direction shall not be confused with the direction of the flow, which may be opposite (example: pump protection from backflow)

the safety function of the process. Shaft side installation may be used in case of safety function to open whenever the maximum allowable leakage is more stringent than Class IV.

Vanessa attaches the indication plate "DP" on the valve flange as a reference for the direction of installation upon which the actuator selection is based.

3.3 *Design Verification*

A FMEDA was conducted to evaluate the fault avoidance and fault controlling measures in the relevant steps of the product life cycle. Possible failures in the design phase as well as during the manufacturing and assembling were contemplated. Failures that do not affect the safety function (no effect) were not considered. The requirements for fault avoidance and fault controlling measures are fulfilled.

Furthermore, the suitability of the design is proven by the positive result of a type examination as well as an endurance test and the adequate field feedback of the product.

The system integrator is responsible to implement the choice of the safety function and to verify the achieved SIL of the safety related system, of which the valve is part of, by the calculation of the PFD of the single components considering the system architecture, proof test interval time, average repair time and automatic diagnostic tests and ensuring compliance with the minimum HFT requirements.

3.4 *SIL Capability and Architectural Constraints*

The development and manufacturing process and the functional safety management applied by the manufacturer in the relevant lifecycle phases of the product has been inspected and assessed as suitable for the use in applications with a maximum Safety Integrity Level of 3 (SC 3).

Based on PFD values of Table 2 *the product may be suitable for use in a safety instrumented system up to SIL 3.*

Following route 2H, under consideration of the minimum required HFT = 1, the product may be used up to SIL 3, and up to SIL 2 considering HFT = 0.

For route 1H approach which provide guidelines for external automatic diagnostics, using SFF determination, the valve may be used up to SIL 3 according to the diagnostic coverage provided by external devices and measures as part of the safety-related overall system. SFF is an application-related value rather than a component-related value, therefore it is the responsibility of the end user to ensure a sufficient safe failure fraction by choosing the appropriate diagnostic measures and intrinsically safe design of the SIS.

The achieved SIL of an entire SIF design must be verified by the SIF designer via a calculation of PFDavg considering the system architecture, the proof test interval and, proof test effectiveness, any automatic diagnostics, average repair time and the specific failure rates of all components included in the SIF. Each subsystem must be checked to assure compliance with minimum hardware fault tolerance requirements.

Table 3: Product specific parameters

Route of Assessment	2_H / 1_S
Type of Sub-system	Type A
Mode of Operation	Low Demand Mode
Hardware Fault Tolerance (HFT)	0

Safety function	Valve installation	Internal Tightness	Valve configuration	Lambda Dangerous λ_D (FIT)	Average Probability of Failure on Demand 1oo1 $PFD_{avg}(T_1)$	SIL/ Budget	Average Probability of Failure on Demand 1oo2 $PFD_{avg}(T_1)$	SIL/ Budget
To close	Shaft side	No	Basic	177	7.79E-04	2 8%	7.86E-05	3 8%
			Cryo/HT	241	1.06E-03	2 11%	1.07E-04	3 11%
		Yes	Basic	354	1.55E-03	2 15%	1.58E-04	3 16%
			Cryo/HT	420	1.84E-03	2 18%	1.88E-04	3 19%
To open	Disc side	-	Basic	178	7.81E-04	2 8%	7.89E-05	3 8%
			Cryo/HT	256	1.12E-03	2 11%	1.14E-04	3 11%
	Shaft side	-	Basic	207	9.08E-04	2 9%	9.18E-05	3 9%
			Cryo/HT	285	1.25E-03	2 12%	1.25E-04	3 13%

Note 1: Assumed Proof Test Interval time T_1 = 1 year
Note 2: λ confidence level of calculation 1-α = 95 %
Note 3: assumed β_{1oo2} = 10 %
Note 4: Lambda Dangerous Detected λ_{DD} =0 assumed Diagnostic Coverage DC = 0 %

The valve failure data are valid within the useful lifetime of the product.

The valve average MRT is estimated considering that the required spare parts are available on site and that maintenance skilled and trained personnel operate with proper tools and equipment. Depending on the valve size and pressure class average MRT can be considered 24 h.

When the valve is used in redundant configuration, a common cause factor of at least 5% can be used.

In order to determine whether the tested device is suitable for use in a certain safety-related system, it is necessary to determine the PFDavg value of the overall system. Usually it is presumed that a final element (valve, actuator, solenoid valve, etc.) uses up to 50% of the total available PFDavg value. Vanessa product uses only from 10% to 20% of the system total available PFDavg (SIL Budget) depending on the safety function.

4 *Installation, commissioning, operation and maintenance*

Detailed description of installation and commissioning requirements are included in the valve IOM.

The device must be accessible for physical inspection and maintenance purposes.

Description of requirements and recommendations for connections and supply media are normally included in the actuator IOM manual.

Detailed description of operation and maintenance requirements is included in the valve IOM.

4.1 *Proof test*

The objective of proof testing is to detect failures within the device that are not detected by any automatic diagnostics of the system. Of main concern are undetected failures that prevent the SIF from performing its intended safety function.

The frequency of proof testing, or the proof test interval, is to be determined in reliability calculations for the SIF for which a device is applied. The proof tests must be performed at least as frequently as specified in the designer calculation in order to satisfy and maintain the required safety integrity of the SIF.

The suggested proof test consists of a full stroke of the device, as described in the table below. The proof test shall be carried out by competent and qualified personnel, trained to carry out operations on SIS. No special tools are required.

Table 4: Proof test procedure

Step	Action
1	Bypass the safety function and take appropriate action to avoid a false trip
2	Interrupt or change the signal/supply to the actuator to force the actuator and the valve to perform a full stroke to the Fail-Safe position and confirm that the Safe State is achieved and within the correct time. In case of safety function to close check for valve seat tightness to verify that the valve (and not only the actuator) has reached the closed position; additionally, if tightness is a safety-related performance it is necessary to measure the seat leakage rate. In case of safety function to open check that the process flow rate is compatible with the fully open position of the valve.
3	Restore the supply/signal to the actuator and confirm that the normal operating state is achieved.
4	Inspect the valve and the final element components for any leaks, visible damage or contamination.
5	Record the test results and any failures in your company's SIF inspection database
6	Remove the bypass and restore normal operation

The proof test procedure may be integrated by more specific instructions from the safety manuals of the actuator and/or positioner manufacturer.

According to the safety function and to the valve installation different diagnostic coverage factors can be accomplished with the tests described in Table 3 and Table 4:

Table 5: Diagnostic coverage

Safety function	Valve installation	Safety-related Tightness?	Procedure details, test instruments, equipment	DC
TO CLOSE	Shaft side	No	Check close angular position of limit switch box or position transmitter or logic solver For piston-type actuators check residual pressure in the actuator cylinder Measure closing time and compare it with stored SIS data Check seat tightness	90%
		Yes	In addition to the above measure seat tightness	90%
TO OPEN	Disc side	N/A	Check open angular position of limit switch box or position transmitter or logic solver For piston-type actuators check residual pressure in the actuator cylinder Measure opening time and compare it with stored SIS data Check process flow rate is compatible with the valve fully open position	90%
	Shaft side	N/A	As described above	90%

In case the on-line checks and inspections described above are not satisfactory, it is necessary to carry out a deeper analysis possibly removing the valve from the line and carefully assess the condition of the valve components, and replace some, if necessary. Maintenance procedures to refurbish the valve are fully described in the IOM.

4.2 *Partial stroke test*

The basic Partial Stroke test procedure in relationship with the recommended proof test coverage can be summarized as follows:

Table 6: Partial stroke test procedure

Step	Action
1	Bypass the safety function and take appropriate action to avoid a false trip
2	Interrupt or change the signal/supply to the actuator to force the actuator and the valve to perform a partial stroke (15-25 degrees) towards the Fail-Safe position and confirm that the expected position is achieved. In case of safety function to close with internal tightness it is not possible to verify the valve seat tightness.
3	Restore the supply/signal to the actuator and confirm that the normal operating state is achieved.
4	Inspect the valve and the final element components for any leaks, visible damage or contamination.
5	Record the test results and any failures in your company's SIF inspection database
6	Remove the bypass and restore normal operation

The partial stroke test procedure may be integrated by more specific instructions from the safety manuals of the actuator and/or positioner manufacturer.

According to the safety function and to the valve installation different diagnostic coverage factors can be accomplished with the tests described in Table 5.

Table 7: PST Diagnostic coverage

Safety function	Valve installation	Safety-related Tightness?	Procedure details, test instruments, equipment	DC
TO CLOSE	Shaft side	No	Check open-partial close-open by manual or automatic PST device, smart positioner or by logic solver (angular position vs. Time) For piston-type actuators measure pressure in the actuator cylinder Check process flow rate change Compare data with stored SIS data	90%
		Yes		70%
TO OPEN	Disc side	N/A	Check close-partial open-close by manual or automatic PST device, smart positioner or by logic solver (angular position vs. Time) For piston-type actuators measure pressure in the actuator cylinder Check process flow rate change Compare data with stored SIS data	90%
	Shaft side	N/A	As described above	90%

4.3 *Maintenance*

The product has been designed to require a minimum of maintenance. Maintenance activities can be carried out on the main valve seals (packing, seal ring, disc, bottom flange and bonnet gaskets) in order to restore the original external and/or internal tightness. The product must be maintained and refurbished in accordance with the Installation, Operation and Maintenance manual instructions.

After five years of operation at least it is required to perform a complete maintenance inspection and overhauling to carefully assess the condition of the valve components, and possibly replace worn components with original spare parts. Within normal duty and correct maintenance this time may be longer depending on the application.

Due to the intensive proof the Maintenance Coverage Factor can be set to MTC = 96%.

Consult factory in case valve repair, removal or replacement is necessary.

4.4 *Useful Lifetime*

Useful lifetime is a reliability engineering term that describes the operational time interval where the failure rate of a device is relatively constant. It is not a term which covers product obsolescence, warranty, or other commercial issues.

The valve is of fully metallic construction, therefore valve components are not subject to ageing effects to the same extent as a plastic, elastomeric or other non-metallic parts can be affected. The time-related factors alone are not significant, the valve reliability is strongly related to the specific application.

The valve lifetime may strongly vary on the type of fluid, clean/unclean duty, process pressure and temperature, other working conditions, and several other factors. Corrosion, erosion, wear etc. are considered age-related (late life) or systematic failures, provided that materials and technologies applied are indeed suitable for the application, in all modes of operation.

Based on general field failure data a useful life period of approximately 20 years is expected for the Vanessa Triple-offset Valve. When the specific plant experience indicates a shorter useful lifetime than indicated, the number based on plant experience should be used. If the use is within agreed process service duty, the average useful lifetime of the product can be estimated in more than 25 years.

Use, maintenance and inspection of the product shall be carried out as per instructions of IOM.

4.5 *Manufacturer Notification*

Any failure detected on site that impair the process functional safety should be reported to the factory. Defective products must be returned to the factory for investigation and rectification. Contact customer service of the Vanessa Manufacturing plant at the following address: via Piacenza, 29018 Lugagnano Val d'Arda, Italy) or local Emerson representative.