bürkert
FLUID CONTROL SYSTEMS

Safety Manual

Valves, Positioner

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Operating Instructions 2104/00_EUen_00815378 / Original EN

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1 INTRODUCTION

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

You can find this manual on the Internet at country.burkert.com

1.1 Terms and Abbreviations

Process Valve	Any valve that is used to control the flow of media being used in a process. For the purpose of this document, this is usually a 2-way valve whose movement is being controlled by an actuator and pilot valve.
Pilot Valve	A 3-way or 4-way valve is used to send or remove pressurized media to and from an actuator for the opening and closing of a process valve.
Direct Acting	Refers to a solenoid valves main orifice that is opened and closed as a direct result of the solenoid valves electromagnetic movement when the coil is energized and de-energized.
Indirect Acting	Refers to a solenoid valves main orifice that is opened and closed as a direct result of fluid flow directed from the electromagnetic 3-way solenoid pilot.
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.

Table 1: Terms and Abbreviations

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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).
Full stroke	State where the valve is closed.
Tight Shut-Off	State where the valve is closed and sealed with leackage no greater than the defi nedleak rate. Tight Shut-Off requirements shall be specifi ed according to the application. If Shut-Off requirements allow fl ow greater than ANSI class V, respectively ANSI class IV, then Full Stroke numbers may used.
Open on Trip	State where the valve is open.
Partial Valve Stroke Test	It is assumed that the Partial Stroke Testing, when performed, is performed at least an order of magnitude more frequent than the proof test, therefore the test can be assumed an automatic diagnostic. Because of the automatic diagnostic assumption the Partial Stroke Testing also has an impact on the Safe Failure Fracture.
Type A element	“Non-complex” element (all failure modes are well defi ned); for details see 7.4.4.1.2 of IEC

Table 2: Acronyms

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1.3 Product Support

Product support can be obtained from:

Germany

Bürkert Fluid Control Systems
Sales Center
Christian-Bürkert-Strasse 13–17
D-74653 Ingelfingen
Tel. +49 (0) 7940 - 10 91 111
Fax +49 (0) 7940 - 10 91 448
Email: info@burkert.com

International

The contact addresses can be found on the last pages of the printed Quickstart.
And also on the Internet at country.burkert.com

1.4 Related Literature

Hardware Documents:

- *Valves Installation, Operation and Maintenance Instructions*

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: *2010 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*

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1.6 Assumptions

- Failure rates are constant, wear out mechanisms are not included.
- Propagation of failures is not relevant.
- The devices are installed per the manufacturer's instructions.
- Sufficient tests are performed prior to shipment to verify the absence of vendor and/or manufacturing defects that prevent proper operation of specified functionality to product specifications or cause operation different from the design analyzed.
- Materials are compatible with process conditions and process fluids.
- The mean time to restoration (MTTR) after a safe failure is 24 hours.
- Only the described variants are used for safety applications.
- All components that are not part of the safety function and cannot influence the safety function (feedback immune) are excluded.
- Clean and dry operating air is used per ISO 8573-1:2010 7.4.4 Quality Standard for Instrument Air.
- All devices are operated in the low demand mode of operation.
- Full valve stroke testing is performed at a rate at least ten times more often than the expected demand rate.
- For SIL x safety functions the partial valve stroke test is at least SIL (x-1) compliant. If for example the safety needs to fulfill SIL 3 then the partial valve stroke test should be at least SIL 2 compliant.
- Valves are installed such that the controlled substance will flow through the valve in the direction indicated by the flow arrow, located on the valve body.
- Failures caused by maintanance capability are site specific and therefore cannot be included.
- FVST and proof testing include a valve signature.

1.7 Air quality failures

The product failure rates that are displayed in this section are failure rates that reflect the situation where the device is used with clean filtered air. Additionally, contamination from poor control air quality may affect the function or air flow in the device. For applications where these assumptions do not apply, the user must estimate the failure rates due to contaminated air and add this failure rate to the product failure rates.

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2 DEVICE DESCRIPTION

You can find these Failure Modes, Effects and Diagnostic Analysis Reports on the Internet at country.burkert.com

Please refer to the respective Installation Manual for the device description and report no. *Buerkert 12/10-097-C R001* for the results of the hardware assessment carried out on the solenoid valves 6013-*-***, 6014-*-***, 6518-*-***, 6519-*-***, 5470-*-***, 0290-*-***, 5404-*-*** and 6027-*-***.

Please refer to the respective Installation Manual for the device description and report no. *Buerkert 12/10-97-C R003* for the results of the hardware assessment carried out on the direct-acting solenoid valves 2/2 or 3/2-way 330-*-***, 331-*-*** and 6144-*-*** and the pilot-operated solenoid valves 2/2-way 5282-*-*** with pilot control type 331-*-***, 3/2-way 6524-*-*** with pilot control type 6144-*-*** and 5/2-way 6525-*-*** with pilot control type 6144-*-*** and 3/2-way 6526-*-*** and 5/2-way 6527-*-*** with pilot control type 6106 and 3/2-way 6534-C-***.

Please refer to the respective Installation Manual for the device description and report no. *Buerkert 18/11-116 R004* for the results of the hardware and mechanical assessment carried out on the pneumatic controller/ positioner types 8690 – 8697.

Please refer to the respective Installation Manual for the device description and report no. *Buerkert 19/02-177 R005* for the results of the hardware assessment carried out on the Seated Valves types 2000, 2012, AP2000, AP2012, 2100, 2101, AP07 and AP08.

Please refer to the respective Installation Manual for the device description and report no. *Buerkert 19/02-177 R006* for the results of the hardware assessment carried out on the Diaphragm Valves types 2030, 2031, 2032, 2033, AP2030, 2103, 2104, 2105 and AP09.

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3 DESIGNING A SIF USING BÜRKERT WERKE GMBH & CO. KG VALVES

3.1 Safety Function

When de-energized, the actuator moves the Valves to their fail-safe position. Depending on the version specified Fail – Closed or Fail - Open, the Valves will move the valve plug to close off the flow path through the valve body or open the flow path through the valve body.

The Valve 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 environmental limits of each Bürkert product are specified in the products respective catalog and Installation and Maintenance Instructions. The designer of a SIF must check that the product is rated for use within the expected environmental limits. Information on the environmental limit values can be found in the *data sheets* of *Bürkert Werke GmbH & Co. KG*.

3.3 Application limits

The application limits of each Bürkert product are specified in the products respective catalog and Installation and Maintenance Instructions. The materials of construction of a Valve are specified in the *Bürkert Werke GmbH data sheets*. It is especially important that the designer check for material compatibility considering on-site chemical contaminants and air supply conditions. If the Valves are 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 Bürkert Werke GmbH & Co. KG. This report details all failure rates and failure modes as well as the expected lifetime.

Please refer to report no. *Buerkert 12/10-097-C R001* for the results of the hardware assessment carried out on the solenoid valves 6013-*-***, 6014-*-***, 6518-*-***, 6519-*-***, 5470-*-***, 0290-*-***, 5404-*-*** and 6027-*-***.

Please refer to report no. *Buerkert 12/10-97-C R003* for the results of the hardware assessment carried out on the direct-acting solenoid valves 2/2 or 3/2-way 330-*-***, 331-*-*** and 6144-*-*** and the pilot-operated solenoid valves 2/2-way 5282-*-*** with pilot control type 331-*-***, 3/2-way 6524-*-*** with pilot control type 6144-*-*** and 5/2-way 6525-*-*** with pilot control type 6144-*-*** and 3/2-way 6526-*-*** and 5/2-way 6527-*-*** with pilot control type 6106 and 3/2-way 6534-C-***.

Please refer to report no. *Buerkert 18/11-116 R004* for the results of the hardware and mechanical assessment carried out on the pneumatic controller/ positioner types 8690 – 8697.

Please refer to report no. *Buerkert 19/02-177 R005* for the results of the hardware assessment carried out on the Seated Valves types 2000, 2012, AP2000, AP2012, 2100, 2101, AP07 and AP08.

Please refer to report no. *Buerkert 19/02-177 R006* for the results of the hardware assessment carried out on the Diaphragm Valves types 2030, 2031, 2032, 2033, AP2030, 2103, 2104, 2105 and AP09.

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.

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When using Bürkert Valves/Positioners 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 Bürkert Valve/Positioner. 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 Valves/Positioners are Type A Devices. Therefore when used as the only component in a final element subassembly, a design can meet SIL 3 @ HFT=1 and SIL2 @ HFT=0. When the final element assembly consists of many components (Valves, 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.

3.5.3 Safety Parameters

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

Please refer to report no. *Buerkert 12/10-097-C R001* for the results of the hardware assessment carried out on the solenoid valves 6013-*-***, 6014-*-***, 6518-*-***, 6519-*-***, 5470-*-***, 0290-*-***, 5404-*-*** and 6027-*-***.

Please refer to report no. *Buerkert 12/10-97-C R003* for the results of the hardware assessment carried out on the direct-acting solenoid valves 2/2 or 3/2-way 330-*-***, 331-*-*** and 6144-*-*** and the pilot-operated solenoid valves 2/2-way 5282-*-*** with pilot control type 331-*-***, 3/2-way 6524-*-*** with pilot control type 6144-*-*** and 5/2-way 6525-*-*** with pilot control type 6144-*-*** and 3/2-way 6526-*-*** and 5/2-way 6527-*-*** with pilot control type 6106 and 3/2-way 6534-C-***.

Please refer to report no. *Buerkert 18/11-116 R004* for the results of the hardware and mechanical assessment carried out on the pneumatic controller/ positioner types 8690 – 8697.

Please refer to report no. *Buerkert 19/02-177 R005* for the results of the hardware assessment carried out on the Seated Valves types 2000, 2012, AP2000, AP2012, 2100, 2101, AP07 and AP08.

Please refer to report no. *Buerkert 19/02-177 R006* for the results of the hardware assessment carried out on the Diaphragm Valves types 2030, 2031, 2032, 2033, AP2030, 2103, 2104, 2105 and AP09.

3.6 Connection of the Valves to the SIS Logic-solver

The Valves are 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 Valves , (i.e. partial valve stroke test).

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3.7 General Requirements

The system's response time shall be less than process safety time. The Valves/Positioners will move to its safe state in less than 3 S under specified conditions.

All SIS components including the Valves/Positioners must be operational before process start-up.

User shall verify that the Valves are suitable for use in safety applications by confirming the Valves/Positioners nameplates are properly marked.

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

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

The useful life of the Valves is discussed in the Failure Modes, Effects and Diagnostic Analysis Report for the Valves/Positioners.

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4 INSTALLATION AND COMMISSIONING

4.1 Installation

- The Bürkert Valves/Positioners valve must be installed per standard installation practices outlined in the Installation Manual.
- The environment must be checked to verify that environmental conditions do not exceed the ratings.
- The Bürkert Valves/Positioners must be accessible for physical inspection.
- Instrument Air Filtration: These solenoids are intended for use on clean, dry air or inert gas filtered to 50 microns or better. To prevent freezing, the dew point of the media should be at least 10 °C (18 °F) below the minimum temperature to which any portion of the clean air or gas system could be exposed. Instrument air in compliance ISO 8573-1:2010 7.4.4 exceeds the above requirements and is, therefore, an acceptable medium for these Valves/ Positioners.
- It is the operator's responsibility to only use design options such as latches, when it is safe to do so.
- Recommended piping for the inlet and outlet pneumatic connections to the Valves is 1/2" stainless steel or PVC tubing. The length of tubing between the Valves and the control device, such as a solenoid valve, shall be kept as short as possible and free of kinks.
- 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.

4.2 Physical Location and Placement

The Valves/Positioners shall be accessible with sufficient room for pneumatic connections and shall allow manual proof testing.

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

The Valves/Positioners 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.

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5 OPERATION AND MAINTENANCE

5.1 Proof test without automatic testing

The objective of proof testing is to detect failures within a Bürkert Werke GmbH & Co. KG Valve/Positioner that are not detected by any automatic diagnostics of the system. Of main concern are 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 an Bürkert Werke GmbH & Co. KG Valve/Positioner 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 following proof test is recommended:

5.1.1 Partial Valve Stroke Testing (PVST)

PVST is the operation of the actuator/valve through a portion of its total stroke range. This short stroke of operation checks that the actuator/valve is not seized in the running position. The limited stroke of the actuator/valve is intended to be short enough so as not to interfere with the operating flow of the system. The purpose of PVST is to provide a diagnostic check of the SIF function. Partial valve stroke testing is performed at a rate at least ten times more often than the expected demand rate. For SIL 2 safety functions the partial valve stroke test is at least SIL 1 compliant.

5.1.2 Full Valve Stroke Testing (FVST)

Full Valve Strike Testing (FVST) is similar in concept to a PVST, with the variation that the actuator/valve is moved through its full operation stroke during the test. This provides greater diagnostic coverage but typically cannot be performed while the process is running. It is a very effective test that can be automatically executed on batch processes and equipment that periodically shuts down.

The results of the proof test should be recorded and any failures that are detected and that compromise functional safety should be reported to Bürkert Werke GmbH & Co. KG.

For detailed information for proof tests refer to the Failure Modes, Effects and Diagnostic Analysis Report of the Valves/ Positioners.

Please refer to report no. *Buerkert 12/10-097-C R001* for detailed information for proof tests for the solenoid valves 6013-*-***, 6014-*-***, 6518-*-***, 6519-*-***, 5470-*-***, 0290-*-***, 5404-*-*** and 6027-*-***.

Please refer to report no. *Buerkert 12/10-97-C R003* for detailed information for proof tests for direct-acting solenoid valves 2/2 or 3/2-way 330-*-***, 331-*-*** and 6144-*-*** and the pilot-op- erated solenoid valves 2/2-way 5282-*-*** with pilot control type 331-*-***, 3/2-way 6524-*-*** with pilot control type 6144-*-*** and 5/2-way 6525-*-*** with pilot control type 6144-*-*** and 3/2-way 6526-*-*** and 5/2-way 6527-*-*** with pilot control type 6106 and 3/2-way 6534-C-***.

Please refer to report no. *Buerkert 18/11-116 R004* for detailed information for proof tests for pneumatic controller/ positioner types 8690 – 8697.

Please refer to *report no. Buerkert 19/02-177 R005* for detailed information for proof tests for Seated Valves types 2000, 2012, AP2000, AP2012, 2100, 2101, AP07 and AP08.

Please refer to report no. *Buerkert 19/02-177 R006* for detailed information for proof tests for Diaphragm Valves types 2030, 2031, 2032, 2033, AP2030, 2103, 2104, 2105 and AP09.

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

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5.2 Repair and replacement

According to section 7.4.9.5 of IEC 61508-2 a useful lifetime based on experience, should be assumend. General field knowledge suggests that most Valves/Positioners have a useful life of 3 to 10 years, but may be longer depending on the series and other factors.

It is the responsibility of the end user to establish a preventative maintenance process to replace all devices before the end of useful life.

5.3 Bürkert Werke GmbH & Co. KG. Notification

Any failures that are detected and that compromise functional safety should be reported to Bürkert Werke GmbH & Co. KG. Please contact Bürkert customer service.

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6 BÜRKERT VALVES/ POSITIONERS COVERED

Select Bürkert devices from the following series have been evaluated per IEC 61508 parts 1 and 2 and are covered under this document:

Solenoid valves 6013, 6014, 6518, 6519, 5470, 0290, 5404 and 6027 direct-acting solenoid valves 330, 331 and 6144 and the pilot-operated solenoid valves 5282 with pilot control type 331, 6524 with pilot control type 6144 and 6525 with pilot control type 6144 and 6526 and 6527 with pilot control type 6106 and 6534.

Pneumatic controller/ positioner types 8690 – 8697.

Seated Valves types 2000, 2012, AP2000, AP2012, 2100, 2101, AP07 and AP08.

Diaphragm Valves types 2030, 2031, 2032, 2033, AP2030, 2103, 2104, 2105 and AP09

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7 STATUS OF THE DOCUMENT

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