SAFETY MANUAL
SOLENOID VALVES
STEEL LINE SERIES

INDEX

1. INTRODUCTION

1.1. Scope

The purpose of this Safety Manual is to document all the information specifically related to the safety aspect of the following products:

STEEL LINE SERIES SOLENOID VALVES 1/4 NPT & 1/2 NPT:

- **DOUBLE SOLENOID VALVES**
- **SOLENOID - SPRING VALVES**
- **SOLENOID VALVES WITH SELF-LOCKING MANUAL RESET**
- **SOLENOID VALVES WITH INVERTED SELF-LOCKING MANUAL RESET**
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These solenoid valves are certified for use as component in Safety Instrumented Systems (SIS). This Safety Manual is required in order to enable the integration of the solenoid valves into a Safety Instrumented System with the objective to be in compliance with the requirements of IEC 61508-2, Annex D.

The information contained in this Safety Manual is valid for the models/series indicated in section 2.1 of this Safety Manual.

This Safety Manual defines, in particular:

- Environmental conditions in which the solenoid valves can operate,
- Parameters related to Functional Safety,
- Tests, checks, and periodic maintenance.

For the purpose of its correct use, this Safety Manual shall be consulted in conjunction with:

- TF231011-IST (Installation, use and maintenance instructions for valves and solenoid valves)
- CAT16 (Process Automation Technology Catalogue)

CAUTION: A copy of this Safety Manual must be stored by the User and used in conjunction with the product for all useful life of the product itself.

1.2. Disclaimer and warning

By using these solenoid valves, it hereby signifies that the User has read this disclaimer and warning carefully, and that understands and agrees to abide by the terms and conditions herein.
Integrating these solenoid valves into a Safety Instrumented System (SIS), the User agrees that is solely responsible for their own conduct while using these solenoid valves, and for any consequences thereof.
The User agrees to use these solenoid valves only for purposes that are proper and in accordance with all applicable laws, rules, and regulations, and all terms, safety prescriptions and precautions, practices, policies and all additional revisions or guidelines that PNEUMAX has made and may make available.

IMPORTANT: PNEUMAX won't be held liable for severe personal injuries, damage to property or environment caused by any of the followings:

- Unqualified personnel working on the solenoid valves,
- Override or bypassing of the Safety Function,
- Non-compliance with the instructions detailed in this Safety Manual.

1.3. Skill level required

This manual is addressed to qualified personnel authorized for installation, operation, and maintenance of solenoid valves series Steel Line. As required by IEC 61508-1 standard, an appropriate level of competence shall be taken into account considering all relevant factors including safety engineering knowledge appropriate to the technology, knowledge of safety regulatory framework and previous experience.

1.4. Product Support and Service

Please refer to Pneumax Quality, Technical and Customer Claim Offices.

1.5. Related Documents

Id.	Code	Title
[D1]	TF231011-IST	Installation, use and maintenance instructions for valves and solenoid valves series SS11, SS12, SS14, SS18, SS34 and SS38
[D2]	CAT16	Process Automation Technology Catalogue

Related document D1 is available only for products compliant to Directive 2014/34/EU.

1.6. Reference Standards

Id.	Code	Title
[S1]	IEC 61508:2010 Parts 1-2 and 4-7	Functional safety of electrical/electronic/programmable electronic safety-related systems
[S2]	IEC 654-1:1993	Industrial-process measurements and control equipment – Operating conditions - Part 1: Climatic conditions
[S3]	IEC 61511:2016 Part 1–3 + Part 1-A1:2017	Functional Safety – Safety Instrumented Systems for the process industry sector

1.7. Terms and abbreviations

For terms and definitions, reference is made to IEC 61508-4.

1.8. Acronyms

BPCS	Basic Process Control System
CCF	Common Cause Failure
DC	Diagnostic Coverage
DETT	De-energise to trip
EMC	Electromagnetic Compatibility
ETT	Energise to trip
FMEDA	Failure Modes, Effects and Diagnostics Analysis
HFT	Hardware Fault Tolerance
IOM	Installation, Operation, and Maintenance
MOC	Management Of Change
MRT	Mean Repair Time
PFD_{AVG}	Average Probability of dangerous Failure on Demand
PVST	Partial Valve Stroke Test
SC	Systematic Capability
SFF	Safe Failure Fraction
SIF	Safety Instrumented Function
SIL	Safety Integrity Level
SIS	Safety Instrumented System
SRS	Safety Requirements Specification
STR	Spurious Trip Rate

2. PRODUCT DESCRIPTION

2.1. Detailed models

Product Code	Description
#SS1232C##01L# - #SS1432C##01L#	3/2 monostable solenoid valves
#SS12520##01L# - #SS14520##01L#	5/2 monostable solenoid valves
#SS1232C####L# - #SS1432C####L#	3/2 bistable solenoid valves
#SS12520####L# - #SS14520####L#	5/2 bistable solenoid valves
#SS1232C##14L# - #SS1432C##14L#	3/2 monostable manual reset solenoid valves
#SS12520##14L# - #SS14520##14L#	5/2 monostable manual reset solenoid valves
#SS1232C##15L# - #SS1432C##15L#	3/2 monostable inverse manual reset solenoid valves
#SS12520##15L# - #SS14520##15L#	5/2 monostable inverse manual reset solenoid valves

2.2. Main Technical Data

Feature	Description
Size	1/4" – 1/2"
Body Material	AISI 316L
Spool	AISI 316L
Spring	AISI 316
Operator	AISI 316L
Seals	NBR for low temperatures

2.3. Service condition limitations (Environmental limits)

Please refer to the information indicated on the product label and product documentation regarding pressure, temperature and other conditions of use. It is important to not use the product outside the indicated operating limits.

Check the following image for an example of a product label:

IMPORTANT: The designer of the SIF must check that the product is rated for use within the expected environmental limits, maximum working pressure and temperature.

IMPORTANT: The materials of construction of the devices are specified on the dedicated products catalogue (document [D2]). It is especially important that the designer of the SIF check for material compatibility considering on-site chemical contaminants and air (as appropriate) supply conditions. If the solenoid valves are used outside the application limits or with incompatible materials, the reliability data and predicted SIL capability becomes invalid.

3. RELIABILITY AND SAFETY CHARACTERISTICS

3.1. Safety Function(s)

The reliability parameters have been obtained with reference to the following Safety Function(s).

Id.	Safety Function	Safety Function Description
[SF1]	de-energised to trip (DETT)	The valve moves to the predefined safe state when de-energised.
[SF2]	energised to trip (ETT)	The valve moves to the predefined safe state when energised.

The following table summarizes the applicable safety function(s) for available solenoid valve versions.

Valve version	[SF1] (DETT)	[SF2] (ETT)
Spring / solenoid	YES (fail safe)	YES
Solenoid / Solenoid	/	YES
Spring + manual reset / solenoid	YES (fail safe)	/
Spring + inverse manual reset / solenoid	/	YES

3.2. Demand mode

Low Demand mode, as per IEC 61508 [S1], part 4, subclause 3.5.16 (i.e., the Safety Function is only performed on demand, with a frequency of demands no greater than once per year).

3.3. Product Classification

Solenoid valves Steel Line series are classified as Type A equipment, as per IEC 61508 [S1], part 2.

3.4. Useful Time

Based on general field failure data and a low demand mode of operation, for standard service conditions the expected useful life of the solenoid valves can be considered 5 years to 10 years.

WARNING: The above value is valid only if prescriptions of this Safety Manual are fully respected.

3.5. Mean Repair Time (MRT)

The Mean Repair Time (MRT) is 2 hours.
This is an estimation for the solenoid valves replacement considering skilled personnel for maintenance, availability of spare parts and adequate tools on site. Contact the manufacturer for maintenance and repair of internal parts. Pneumax may not be hold accountable for any malfunctions related to reparations done by the end-user.

3.6. Failure Rates

With reference to the Safety Function(s) previously specified, a FMEDA has been carried out.
The following failure rates have been obtained.

Models	Description	Operating Mode	λ_S	λ_{DU}	λ_{DD}
#SS1232C##01L# #SS1432C##01L#	3/2 monostabile	DETT	158	167	-
		ETT	-	327	-
#SS12520##01L# #SS14520##01L#	5/2 monostabile	DETT	192	270	-
		ETT	120	336	-
#SS1232C####L# #SS1432C####L#	3/2 bistable	ETT	-	371	-
#SS12520####L# #SS14520####L#	5/2 bistable	ETT	120	380	-

Models	Description	Operating Mode	λ_S	λ_{DU}	λ_{DD}
#SS1232C##14L# #SS1432C##14L#	3/2 monostable manual reset	DETT	158	180	-
#SS12520##14L# #SS14520##14L#	5/2 monostable manual reset	DETT	192	282	
#SS1232C##15L# #SS1432C##15L#	3/2 monostable inverse manual reset	ETT	-	328	
#SS12520##15L# #SS14520##15L#	5/2 monostable inverse manual reset	ETT	120	336	

All failure rates are in FIT (Failure In Time 1 FIT = 1 failure/10^9 hours).
The dangerous undetected failure rate λ_{DU} is due to faults that cause the failure of the Safety Function(s) and that are not detected by the diagnostic tests.
The dangerous detected failure rate λ_{DD} is due to faults causing the failure of the Safety Function(s) but that are detected by diagnostic tests.
The safe failure rate λ_S is due to faults that result in the spurious operation of the Safety Function or in the increase of the probability of spurious operation of the Safety Function.

The failure rates shall be used for PFD_{AVG} estimation, taking into consideration parameters such as redundancy, diagnostic capability (provided by external devices such as Partial Stroke Test devices, if any, or introduced by the whole Safety Instrumented System), Proof Test and its effectiveness, Mean Repair Time (MRT), up to the maintenance capability and its minimum characteristics.

The assumptions associated with these failure rates are as follows:
- Failure rates are constant over the expected lifetime specified in section 3.4 of this Safety Manual,
- Wear-out or infant mortality contributions are not included.

The above failure rates are valid:
- For the service conditions listed in section 2.3 of this Safety Manual,
- If periodic test and maintenance are properly carried out.

3.7. Hardware safety integrity (Architectural constraints)

In compliance with Route 1_H (see IEC 61508 [S1], part 2, subclause 7.4.4.2), the solenoid valve can be used in a single channel configuration (i.e., HFT = 0) up to SIL 1 or SIL 2 depending on the valve models and safety functions, and in consideration of SFF values.

In compliance with Route 2_H (see IEC 61508 [S1], part 2, subclause 7.4.4.3), the solenoid valve can be used in a single channel configuration (i.e., HFT = 0) up to SIL 2.

Therefore, the solenoid valves can be used up to SIL 2 with HFT=0 and SIL 3 with HFT=1. Check the systematic capability SC=3 of section 3.8 of this safety manual.

3.8. Systematic safety integrity (Systematic Capability)

The solenoid valves have met manufacturer design process requirements of SIL 3 (evaluated according to Route 1S of IEC 61508-2 [S1]).

This Systematic Capability is guaranteed only if the User:
- Uses the product according to its instructions for use [D1] or [D2] and to this Safety Manual,
- Uses the product in the appropriate environment, as per section 2.3 of this Safety Manual.

WARNING: A Safety Instrumented Function (SIF) designed with this product must not be used at a SIL higher than that stated, unless diverse technology in the design of the SIF is used (see IEC 61508 [S1], part 2, subclause 7.4.3).

3.9. Common Cause Failures

The solenoid valve has a single channel configuration, i.e., HFT = 0.
When carrying out PFDAVG calculations for redundant architectures, the following Common Cause factors should be used:

- $\beta = \beta_D = 10\%$

The above values are referred to 1oo2 architecture.
The values for other architectures shall be calculated according to IEC 61508 [S1], part 6, table D.5.
The above values are calculated in the hypothesis of redundancy without diversity.

4. INSTALLATION & COMMISSIONING

4.1. Installation

The solenoid valves must be installed per the standard practices outlined in the manual [D1] and product documentation [D2].
The environment must be checked to verify that environmental conditions do not exceed the ratings (see also section 2.3 of this Safety Manual).
The solenoid valve must be accessible for physical inspection.

4.2. Physical location and placement

The solenoid valves shall be accessible with sufficient room for pneumatic connections.
The valves shall be mounted in a low vibration environment. If excessive vibration can be expected, then special precautions shall be taken to ensure the integrity of pneumatic connectors, or the vibration should be reduced using appropriate damping mounts.

5. OPERATION & MAINTENANCE

5.1. Proof test

5.1.1. General

Purpose of the Proof Test is to reveal (all, or as close as possible to all) the failures not detected by the diagnostic tests (if any).

5.1.2. Disclaimer

The content of this chapter is relevant for reliability tests only.
Refer to manual [D1] or product catalogue [D2] for further information about the product maintenance, handling and storage. In case of any doubt, contact Pneumax SpA offices.

5.1.3. Suggested Proof Test Interval

The suggested Proof Test interval is 1 year. The choice of the Proof Test interval, anyway, is under User's responsibility and should take in account (at least) the followings:

- PFD_{AVG} target,
- Safety Function,
- Service conditions.

5.1.4. Execution of the test

The test is considered passed if the following conditions are satisfied:

Safety Function	Description
[SF1] DETT	De-energise the coil and check that the valve changes completely its state / position within 1s or 2s.
[SF2] ETT	Energise the coil and check that the valve changes completely its state / position within 1s or 2s.

5.1.5. Test set-up and test facilities

The test shall be carried out on the solenoid valve as installed.
The test can be automated, if carried out by using a Logic Solver or a Partial Stroke Test device.
The procedure carried out without automated means might lead to a lower test coverage.

5.1.6. Proof Test Coverage

In case of Proof Test:

- automated, and
- supervised by trained and skilled operators, and
- carried out with calibrated measuring instruments,

the Proof Test Coverage (PTC) could be estimated in a value close to 100%.
Otherwise, the Proof Test Coverage (PTC) should be estimated by the User considering measurement inaccuracies as well as the reliability/competence of the operator.

5.1.7. Further Inspections

Proper inspection should be carried out on the solenoid valve to ensure that (as minimum):

- there are no external leakages,
- dust and dirt are removed from surfaces,
- the solenoid valve is exempted from damages, even accidental.

Furthermore, for solenoid valves compliant to Directive 2014/34/EU, check the indications reported on document [D1] TF231011-IST.

5.2. Notification of failures

In case of detection of a failure, it is under User's responsibility to take action according to IEC 61508 [S1] and IEC 61511 [S3], if applicable.
PNEUMAX must be informed when the solenoid valves are required to be replaced due to failure. The occurred failure shall be documented and reported to PNEUMAX Quality & Technical representatives.