Solenoid valves for safety-instrumented systems: functional principle and typical applications
Competence in Functional Safety
Solenoid valves for safety-instrumented systems

SAMSON GROUP

SAMSON MESS- UND REGELTECHNIK

Pfeiffer Chemie-Anlagentechnik GmbH

AIR TORQUE

RINGO VALVULAS

Cera System®

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SAMSONIC SAMSOMATIC GMBH

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KT Elektronik

VETEC Ventiltchnik GmbH
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1 Scope

In safety-instrumented systems, pneumatic valves are used to shut off or open pipelines. Solenoid valves are the interface between the electric control level and the pneumatic actuator. SAMSOMATIC has been active in developing and manufacturing solenoid valves with a high reliability at a low power consumption for many years. The solenoid valves meet the highest quality requirements and are suitable for use in safety-instrumented systems up to SIL 3 according to IEC 61511, up to SIL 4 according to IEC 61508 as well as PL e according to ISO 13849.

2 What makes SAMSOMATIC solenoid valves superior?

1. Solenoid valves with diaphragms are preferably used in safety-instrumented systems. The decisive advantage provided by diaphragms is that the solenoid valves operate reliably on demand and move the valve to the fail-safe position even after the solenoid valves have remained static for long periods of time or when the booster valves are slightly clogged with dirt.

2. An electropneumatic binary converter, which has proven reliable in service a million times over, working together with a flapper/nozzle system, guarantees reliable switching even after it has remained static for long periods of time.

3. By constantly purging the electronics compartment with instrument air, the solenoid valves are protected against corrosion even when installed in damp or aggressive environments.

4. All solenoid valves are subjected to function and leak tests, minimizing the probability of failure on demand due to defective components or leaks.
3 Functional principle of the electropneumatic binary converter

The electropneumatic binary converter is supplied with a constant supply pressure of 1.4 bar. In the idle position, the flapper (2) is lifted off the outlet nozzle (3) by the spring (4), allowing a small rate of air to flow through the outlet nozzle into the electronics compartment. This causes the pressure in the system to drop to a level at which the downstream booster valve is not activated (refer to section 4).

When the solenoid coil (1) is energized by an electric binary signal, the magnetic field causes the flapper (2) to be pushed downwards against the force of the spring (4) and the outlet nozzle (3) to be closed. As a result, the pressure in the system rises and the booster valve is switched to the operating position.

When the electric binary signal is deactivated, the booster valve is switched to the idle position again by the spring (4).

Advantages of the flapper/nozzle system
- Reliable switching even after remaining static for long periods of time
- No memory effect, as occurs in piezo elements for example
- Switching behavior independent of the mounting position
- Long service life (over 20 million switching cycles)
- Low power consumption thanks to frictionless bearing of the flapper
4 Functional principle of solenoid valves with diaphragms

The solenoid valves consist of an electropneumatic binary converter (refer to section 3) and a booster valve with return spring. The supply pressure is applied to connection 4. Connection 3 is routed to the actuator. The actuator is vented over connection 5.

The air supply for the electropneumatic binary converter is routed internally through connection 4 at the booster valve. Connection 9 is sealed by a blanking plug. The pressure reducer (5) reduces the supply air pressure to 1.4 bar.

In the idle position, the flapper (2) is lifted off the outlet nozzle (3) by the spring (4). This causes a pressure lower than the switch-on pressure of the booster valve to build up in the pressure divider, which consists of the restrictor (6) and outlet nozzle (3).

When the solenoid coil (1) is energized by an electric binary signal, the outlet nozzle (3) is closed by the flapper (2) against the force of the spring (4). This causes the pressure in the pressure divider to rise above the switch-on pressure of the booster valve, switching it to the operating position.

After the solenoid coil is de-energized, the booster valve is switched to the idle position again by the return spring (7). The solenoid valve can be converted to accept an external air supply at connection 9 by turning a flat gasket on the enclosure. This is necessary when the solenoid valve is mounted onto an actuator for modulating service and a constant control pressure of at least 1.4 bar must be guaranteed at the electropneumatic binary converter.
5 Applications

5.1 Air purging of the actuator spring chamber to protect the actuator springs against corrosion

Task
In safety-instrumented systems, valves often remain static in one position for long periods of time. During this time, the actuator springs are at risk of corroding if moisture enters the actuator.

Solution using a Type 3967 Solenoid Valve
The electronics compartment of the solenoid valve is constantly purged with instrument air through the flapper/nozzle system (refer to section 3). This air purging is also guaranteed when the solenoid valve is energized. The electronics compartment is directly connected to the actuator’s spring chamber over the NAMUR interface. The solenoid valve is vented at the enclosure cover by a filter check valve (with IP 65 degree of protection), which opens at a defined excess pressure. As a result, a minimal level of positive pressure constantly exists in the electronics compartment and the actuator spring chamber, preventing moisture from entering the spring chamber and inhibiting corrosion.
5.2 Emergency venting of an actuator

Task
In the event of failure, an actuator is to be vented independent of the control signal.

Solution
The actuator is often controlled by a positioner (A) and a solenoid valve (C) in a process control system. When the solenoid valve (C) is energized, the output of the pneumatic booster (B) is connected to the actuator. The pneumatic booster (B) supplies the actuator with an air flow output whose pressure corresponds exactly to the signal pressure, except that it has a much higher volume. This increases the positioning speed even of large pneumatic actuators. In the event of failure, the electric power supply is cut off by the process control system and the solenoid valve (C) is switched to the fail-safe position. The actuator is vented independent of the output of the positioner (A) and pneumatic booster (B). This solution can also be implemented for small actuators without a pneumatic booster (B).

A – SAMSON Type 3730-3 Positioner
B – SAMSON Type 3755 Pneumatic Booster
C – SAMSOMATIC solenoid valve (e.g. Type 3963-1310014211101000)
5.3 Venting an actuator when the supply pressure falls below a minimum pressure

Task
If the supply pressure level falls below a certain pressure, the actuator is to be vented and the valve moved to its fail-safe position.

Solution using a solenoid valve and an electric pressure monitor or pressure limiter
In normal operation, the actuator is controlled by a positioner together with a solenoid valve (A). The supply pressure is constantly monitored by an electric pressure monitor (B). When the supply pressure falls below a certain minimum pressure, the electric power supply is automatically cut off and the solenoid valve (A) is switched to fail-safe position. The actuator is vented as a result. The electric signal is not reactivated immediately after the supply pressure increases again due to the hysteresis of the pressure monitor (B).
An electric pressure limiter with internal interlock can also be used instead of the electric pressure monitor. In this case, the electric signal must be reactivated manually.
This solution can also be implemented for rotary actuators and on/off valves.

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A – SAMSOMATIC solenoid valve (e.g. Type 3963-13100220111100000)
B – SAMSOMATIC Type 3994-0370-DWR-6 Electric Pressure Monitor, or alternatively
Type 3994-0370-DWR-6.206 Electric Pressure Limiter with internal interlock
(adjustment range between 0.5 and 6 bar)
5.4 Switching to a backup buffer tank when the air supply fails

Task
After a supply air failure, the position of an on/off valve is to be maintained for a certain period of time.

Solution using a buffer tank for instrument air
In normal operation, the actuator is filled with air or vented by a solenoid valve (A) according to the process requirements. The required instrument air is supplied by a main supply air station. In the event that this air station fails, the air supply is maintained by a backup buffer tank (B), which provides the solenoid valve (A) with instrument air. The continued operation of an on/off valve over a certain period can be guaranteed in this way. This allows repairs to be performed on the supply air station while the process is running or the plant to be shut down safely. The supply pressure can be monitored by an electric pressure monitor (e.g. Type 3994-0370-DWR-6, not shown in the diagram) to signal when the pressure falls below a certain limit.

A – SAMSOMATIC solenoid valve (e.g. Type 3963-13100120011100000)
B – Buffer tank (sized according to customer requirements)
C – Check valve
D – Safety valve
5.5 Reliable fail-safe action of actuators

Task
To achieve better reliability and possibly also a higher level of safety (SIL or PL) in safety-instrumented systems, the solenoid valves must be designed in a redundant configuration. In this way, if one solenoid valve fails, the fail-safe action of the actuator is still guaranteed by a second solenoid valve. A hook-up of the solenoid valves in series or in parallel is used depending on the safety requirements. This usually involves complex hook-ups.

Solution using a redundancy plate
A redundancy plate allows two solenoid valves to be connected in series or in parallel without any additional hook-up. The solenoid valves are mounted either on the left or right side to the NAMUR interfaces of the redundancy plate. The redundancy plate can be directly attached to rotary actuators over a third NAMUR interface. An additional adapter plate also allows a hook-up using threaded connections or the attachment of the solenoid valves to linear actuators with a NAMUR rib.

Advantages of the redundancy plate
- Easy and quick mounting
- Compact design
- Captive fastening screws
- Body made of powder-coated aluminum or stainless steel
- G or NPT threaded connections
- Attachment to rotary actuators with NAMUR interface according to VDI/VDE 3845
- Attachment to linear actuators with NAMUR rib according to IEC 60534-6-1

Reliable fail-safe action to vent the actuator

Reliable fail-safe action to fill the actuator with air
5.6 Reliable fail-safe action of actuators with pressure monitoring

Task
To achieve better reliability and possibly also a higher level of safety (SIL or PL) in safety-instrumented systems, the solenoid valves must be designed in a redundant configuration. In this way, if one solenoid valve fails, the fail-safe action of the actuator is still guaranteed by a second solenoid valve. However, it is not possible to identify which solenoid valve has failed without pressure monitoring.

Solution using integrated pressure switches
The output pressure of the solenoid valves is constantly monitored by two integrated pressure switches. If an energized solenoid valve does not produce the minimum output pressure, an electric contact indicates this failure, for example to the process control system. This not only allows the detection of a faulty solenoid valve, but enables the switching functions to be tested while the process is running, without changing the position of the process valve.
6 Appendix: Certificates

Certificate no. V 60 2012 C8 Rev. 01
Type 3963 Solenoid Valve with safety function
Suitable for use in safety-instrumented systems up to SIL 3 according to IEC 61511 or SIL 4 according to IEC 61508

Certificate no. V 177 2009 C2 Rev. 01
Type 3967 Solenoid Valve with safety function
Suitable for use in safety-instrumented systems up to SIL 3 according to IEC 61508

Certificate no. V 177 2010 C6
Type 3967 Solenoid Valve with safety function
Suitable for use in safety-instrumented systems in high demand mode up to SIL 3 according to IEC 61508

Certificate no. V 177 2010 C4
Type 3967 Solenoid Valve with safety function
Suitable for use in safety-instrumented systems up to PL e according to ISO 13849
Certification:

Nr. V80 2012 C8 Rev.01

Manufacturer:
SAMSONATIC GMBH
Weismüllerstraße 20-22
60314 Frankfurt / Main

Product/Test Item:
Solenoid valves with safety function
Type series:
3701, 3963, 3968, 3776, 3730, 3731, 3756

Application/Safety Function:
Control valves for compressed air to close on demand of a safety function

Test results:
Given the required hardware fault tolerances (HFT = 0 for SIL 2 and HFT = 1 for SIL 3), the above mentioned components are suitable for use in safety related systems up to and including SIL 3 according to DIN EN 61511 / DIN EN 61508. Under consideration of the requirements of DIN EN 61508 the systematic suitability of the control valves for use as a component in systems with SIL 4 according to DIN EN 61508 is given. The suitability for certain applications can only be evaluated by examination of the complete safety-related system with considering requirements of IEC 61508 / 61511.

For detailed results see test report No. V83 2012 D7 Rev. 01 dated 2012-12-07. A short summary of test results is filed up on the backside of this certificate.

This certificate remains valid until 12/2017

Cologne 2012-12-03
Inspector
Dipl.-Ing. Th. Küppers

Test Centre for Energy Appliances
Head of Test Centre
Dipl.-Ing. W. Rückwart

TÜV Rheinland Energie und Umwelt GmbH, Am Grauen Stein, D-51105 Köln, Germany

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Competence in Functional Safety
Solenoid valves for safety-instrumented systems

Certificate No.: V80 2012 CA Rev 01
Company: SAMSOMATIC GMBH
Weismüllerstraße 20-22
60314 Frankfurt/Main
Type series: 3701, 3963, 3968, 3776, 3730, 3731, 3756

<table>
<thead>
<tr>
<th>Failure probability</th>
<th>PFD</th>
<th>2.7E-07</th>
<th>8.37E-07</th>
</tr>
</thead>
<tbody>
<tr>
<td>Confidence level</td>
<td>1-e</td>
<td>95</td>
<td>95</td>
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<tr>
<td>Safe failure fraction</td>
<td>SFF</td>
<td>90</td>
<td>90</td>
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<tr>
<td>Hardware fault tolerance</td>
<td>HFT</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Diagnostic coverage</td>
<td>DC</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Type of subsystem acc. to IEC 61508-2:7.4.4.1.2</td>
<td>Type A</td>
<td>Type A</td>
<td></td>
</tr>
<tr>
<td>Assumed demands per year</td>
<td>demand</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Dangerous failure rate</td>
<td>λd</td>
<td>3.06E-10</td>
<td>9.55E-10</td>
</tr>
<tr>
<td>MTBF dangerous failure</td>
<td>MTBF D1</td>
<td>3.24E+09</td>
<td>1.05E+09</td>
</tr>
<tr>
<td>Safe failure rate</td>
<td>λs</td>
<td>2.77E-09</td>
<td>8.65E-09</td>
</tr>
<tr>
<td>Total failure rate</td>
<td>λs + λd</td>
<td>3.08E-09</td>
<td>2.55E-09</td>
</tr>
<tr>
<td>MTBF total</td>
<td>Y</td>
<td>37037</td>
<td>11947</td>
</tr>
<tr>
<td>Dangerous undetected</td>
<td>λDU</td>
<td>3.05E-10</td>
<td>9.55E-10</td>
</tr>
<tr>
<td>Safe undetected</td>
<td>λSU</td>
<td>2.77E-09</td>
<td>8.60E-09</td>
</tr>
<tr>
<td>Test interval</td>
<td>T</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>Average failure probability</td>
<td>PFDtest</td>
<td>1.35E-06</td>
<td>4.19E-06</td>
</tr>
</tbody>
</table>

Test result

With utilisation of the solenoid valves and LP-transmitter with safety function of the type series 3701, 3963, 3968, 3776, 3730, 3731, 3756 a safety-related system can be established for the process industry according DIN EN 61511 in single channel architecture up to SIL 2 if the valve is used as a single safety related system (hardware fault tolerance HFT=0).

With a structure establishing a HFT of at least 1 the valves are usable including SIL 3.

Under consideration of the requirements of DIN EN 61508, the control valves can be used as a component of safety related systems with SIL 4. In systems with SIL 4 the functional safety of the safety related system must not be based solely upon the function of the examined control valves.

For operation the "Manual on Functional Safety for Solenoid Valves" HB 3963 EN has to be observed.

Useful lifetime

The test result applies to new appliances and for deployment thereof for a period of time of maximum 5 years plus a maximum of 1.5 years storage time before being used for the first time. These periods of time may be extended if the technical parameters of the solenoid valves are verified according to the instructions of the manufacturer before set into operation: storage time max. 3, after that 3 years of operation time and again 3 years after check of operation parameters.

The operation time can only be extended under the responsibility of the plant operator considering the special operation conditions and suitable test intervals and maintenance procedures.

TÜV Rheinland Energie und Umwelt GmbH, Am Grauen Spei, D-51105 Köln, Germany
Competence in Functional Safety
Solenoid valves for safety-instrumented systems

Certificate
No. V 177 2009 C2 (Rev 01)

Manufacturer: Samsomatic GmbH
Weismüllerstraße 20-22
60314 Frankfurt

Product: Solenoid valve with safety function

Type: type series 3967
Use: moving into safe position on demand of a safety function by internal energy

Test results: The devices of the above mentioned series are suitable for use in safety related systems in low demand mode of operation as a single safety related subsystem according to IEC 61508 up to and including SIL 3.

For detailed results see test report
No. V 177 2009 T1 dated 2010-01-27
A short summary of test results is filed up on the backside of this certificate.

The suitability for certain fields of application can only be assessed by the evaluation of the complete safety related system in regard to the requirements of the IEC 61508.

This certificate remains valid until 01/2015

Cologne 2013-04-10

Test Centre for Energy Appliances
Head of Laboratory
Dipl.-Ing. W. Rückwart

TÜVRheinland Energie und Umwelt GmbH, Am Grauen Stein, D-51165 Köln, Germany

www.tuv.com
## Certificate

**Certificate No.** V 177 2009 C2 (Rev 01)

**Manufacturer:** Samsomatic GmbH
Weilemüllerstraße 20-22
60314 Frankfurt

**Type series** 3567, Solenoid Valve with safety function

### Appliance-specific values determined:

<table>
<thead>
<tr>
<th>Parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Probability of Failure on Demand (PFD)</td>
</tr>
<tr>
<td>Safety integrity level (SIL)</td>
</tr>
<tr>
<td>Safe failure fraction (SFF)</td>
</tr>
<tr>
<td>Hardware fault tolerance</td>
</tr>
<tr>
<td>Diagnostic coverage</td>
</tr>
<tr>
<td>Type of sub system</td>
</tr>
</tbody>
</table>

### Derived values

<table>
<thead>
<tr>
<th>Demand/hour</th>
<th>Freq demand/h</th>
<th>1.14E-03</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maintenance between demands (MTBF)</td>
<td>h</td>
<td>8750</td>
</tr>
<tr>
<td>Safe failure rate</td>
<td>αs</td>
<td>2.43E-10</td>
</tr>
<tr>
<td>MTBF dangerous failures</td>
<td>FIT</td>
<td>3.9E-09</td>
</tr>
<tr>
<td>Safe undetected</td>
<td>α0</td>
<td>3.9E-09</td>
</tr>
<tr>
<td>MTBF total</td>
<td>h</td>
<td>3.28E4433</td>
</tr>
<tr>
<td>Time to failure (MTBF)</td>
<td>y</td>
<td>3753</td>
</tr>
<tr>
<td>T1</td>
<td>h</td>
<td>4380</td>
</tr>
<tr>
<td>T2</td>
<td>h</td>
<td>4380</td>
</tr>
<tr>
<td>Probability of failure on demand (PFD) avg</td>
<td>5.33E-05</td>
<td></td>
</tr>
</tbody>
</table>

### Test results

In the opinion of the Test Laboratory, the devices are suitable for use in safety related systems in low demand mode of operation as a single safety related subsystem according to IEC 61508 up to and including SIL 3. (Hardware Fault Tolerance HFT=0).

Useful life time under operation conditions

This statement applies to new appliances and for deployment thereof for a period of time of maximum 5 years plus a maximum of 1.5 years storage time before being used for the first time. These periods of time may be extended, if the technical parameters of the solenoid valves are verified according to the instructions of the manufacturer before set into operation. Storage time max. 3, after that 3 years after check of operation parameters.

Alternatively: based on documented field experience under defined conditions, the maximum useful lifetime according IEC 61508 cl. 7.4.7.4 can be extended up to 8 - 12 years.

After expiry of the above mentioned periods of time the valves may not be used in safety related applications.

### Quality management

These statements are bound to the proven and verified deployment of safety-related quality management of the manufacturer.

TÜV Rheinland Energie und Umwelt GmbH, Am Grauen Stein, D-51105 Köln, Germany
Certificate
No. V177 2010 G6

Manufacturer: Samsomatic GmbH
Weismüllerstraße 20-22
60314 Frankfurt
Germany

Test item: Electromagnetic valves with safety function

Type: 3967

Use/Safety function: Move into design required position by means of an integrated energy storing mechanism

Test results: The devices of the above mentioned series are suitable for use in safety related systems in high demand mode of operation as a safety related subsystem according to IEC 61508 up to and including SIL 3.

For detailed results see test report No. V177 2010 E5 dated 2010-11-29
A short summary of test results is filed up on the backside of this certificate.

The suitability for certain fields of application can only be assessed by the evaluation of the complete safety related system incorporating the test item in regard to the requirements of the IEC 61508.

This certificate remains valid until November 2015

Cologne 2012-04-03
Test Laboratory
for Energy Appliances
Head of Laboratory
Dipl.-Ing. W. Rückwart

TÜV Rheinland Energie und Umwelt GmbH, Am Grauen Stein, D-51165 Köln, Germany

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### Appliance-specific values determined:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value (unit)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Probability of dangerous failure on demand</td>
<td>2.15E-27</td>
</tr>
<tr>
<td>Confidence level</td>
<td>1-α</td>
</tr>
<tr>
<td>Suitability SIL level</td>
<td>SIL 1-2-3</td>
</tr>
<tr>
<td>Common cause factor</td>
<td>β</td>
</tr>
<tr>
<td>Safe failure fraction</td>
<td>SFF %</td>
</tr>
<tr>
<td>Test interval repetitive test (T₁, T₂)</td>
<td>[h]</td>
</tr>
<tr>
<td>Hardware fault tolerance (1 valve, 1oo1)</td>
<td>HFT₁, HFT₂</td>
</tr>
<tr>
<td>Hardware fault tolerance (2 valves, 1oo2)</td>
<td></td>
</tr>
<tr>
<td>Probability of dangerous failure per hour</td>
<td>PFHₜ₀</td>
</tr>
<tr>
<td>Type of sub-system (IEC 61508-2, 6.4.4.1.2)</td>
<td>Type A</td>
</tr>
<tr>
<td>Mode of Operation (IEC 61508-4, 3.5.16)</td>
<td>high demand</td>
</tr>
<tr>
<td>Dangerous failure rate (λ₀)</td>
<td>see remark below</td>
</tr>
</tbody>
</table>

1. The value for β is to be approved as part of the evaluation of a complete system.

### Test results

It is the opinion of the test laboratory that the test item is suitable for use in safety related systems in high demand mode of operation as an element of a safety related subsystem according to IEC 61508 up to and including SIL 3. For a system SIL 2 and higher and operation in high demand mode a design with multi-channel and HFT x 1 or higher is recommended.

### Identification of probability of dangerous failure per hour

The value of PFHₜ₀ depends on the rate of operation (n₀) of the safety related system. For single and dual channel systems could be calculated by following equation:

\[
PFH_{(1,1oo)} = \lambda_{1,1oo} = n_0 \times \lambda_{1,1oo}, \quad PFH_{(2,1oo2)} = \lambda_{2,1oo2} = [(1 - \beta) \times \lambda_{2,1oo2}] \times T_1 + \beta \times \lambda_{1,1oo1}
\]

### Useful life time under operation conditions

The valves are to be operated as specified by the manufacturer. The correct operation shall be observed by continuous diagnostic according to the requirements of IEC 61508 or by adequate repetitive test with a maximum interval of one year.

For operation without continuous diagnostic the test laboratory is of the opinion that this test result is valid for a period of 5 years after first putting into operation. A storage under the conditions given by the manufacturer of 1.5 years after production and before taking into operation will not have a negative influence.

In addition the test result is valid up to a maximum of 600,000 cycles of operation.

### Quality management

These statements are bound to the proven and verified deployment of a safety-related quality management system by the manufacturer.

TÜV Rheinland Energie und Umwelt GmbH, Am Grauen Stein, D-51105 Köln, Germany
Certificate
No. V 177 2010 C4

Manufacturer: Samsomatic GmbH
Weismüllerstraße 20-22
60314 Frankfurt
Germany

Test item: Electromagnetic valves with safety function

Type: 3967

Use/Safety function: Move into design required position by means of an integrated energy storing mechanism

Test results: The devices of the above mentioned series are suitable for use in safety related systems according to DIN EN ISO 13849 up to and including PLe.

For detailed results see test report No. V177 2010 E3 dated 2010-11-18
A short summary of test results is filed up on the backside of this certificate.

The suitability for certain fields of application can only be assessed by the evaluation of the complete safety related system incorporating the test item in regard to the requirements of the DIN EN ISO 13849.

This certificate remains valid until November 2015

Cologne 2012-04-03

Test Laboratory for Energy Appliances
Head of Laboratory
Dipl.-Ing. W. Rückwart

TÜV Rheinland Energie und Umwelt GmbH, Am Grauen Stein, D-51105 Köln, Germany

www.tuv.com
Competence in Functional Safety
Solenoid valves for safety-instrumented systems

Certificate No. V177 2010 04
Manufacturer: Samsomatic GmbH
Type series 3997

Appliance-specific values determined:

<table>
<thead>
<tr>
<th>Expected life time</th>
<th>B10u [operations]</th>
<th>≥ 600,000</th>
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</thead>
<tbody>
<tr>
<td>Suitability Performance level</td>
<td>PL</td>
<td>a, b, c, d, e</td>
</tr>
<tr>
<td>Suitable Category</td>
<td>B</td>
<td>1, 2, 3, 4</td>
</tr>
<tr>
<td>Common cause factor</td>
<td>CCF</td>
<td>≥ 65</td>
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<tr>
<td>Safe failure fraction</td>
<td>SFF</td>
<td>≥ 2^{-1}</td>
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<tr>
<td>Use of basic safety requirements</td>
<td>fulfilled</td>
<td></td>
</tr>
<tr>
<td>Use of established safety requirements</td>
<td>fulfilled</td>
<td></td>
</tr>
<tr>
<td>Mean time to fail</td>
<td>MTTFu [hour]</td>
<td>See remark below</td>
</tr>
<tr>
<td>Dangerous failure rate</td>
<td>λd [1/hour]</td>
<td>see remark below</td>
</tr>
</tbody>
</table>

(1) The value for β is to be approved as part of the evaluation of a complete system.

Test results

It is the opinion of the test laboratory that the test item is suitable for use in safety related system according to DIN EN ISO 13849 up to and including PLd. Essential condition is that the entire system complies with the requirements of DIN EN ISO 13849. For PLc a system design suitable for Category 3 or higher is recommended. For PLd a system design suitable for Category 4 or higher is recommended.

For a renewal of the certificate after 5 years the test results must be revalidated in respect to the operation performance.

Identification of probability of dangerous failure per hour

The value of MTTFu and PFHd depend on the rate of operation (nop) of the safety related system. The values could be calculated by following equation:

\[
\lambda_d = \frac{1}{\text{MTTF}_u} = \frac{0.1}{B_{\text{stf}} \times n_{op}}
\]

Useful life time under operation conditions

The valves are to be operated as specified by the manufacturer.

The correct operation shall be observed by continuous diagnosis according to the requirements of DIN EN ISO 13849.

For operation without continuous diagnosis the test laboratory is of the opinion that this test result is valid for a period of 5 years after first putting into operation. Storage under the conditions given by the manufacturer of 1.5 years after production and before taking into operation will not have a negative influence.

In addition the test result is valid up to a maximum of operation cycles according to the given B10u.

Quality management

These statements are bound to the proven and verified deployment of a safety-related quality management system by the manufacturer.

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7 Notes
Local customer assistance across the world

Specifications subject to change without notice.