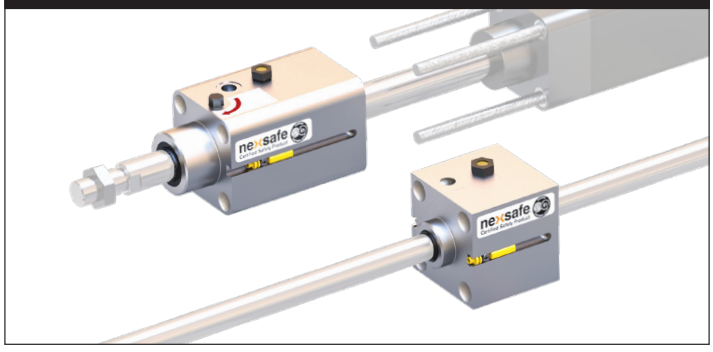
nexen®

# Certified Safety Products

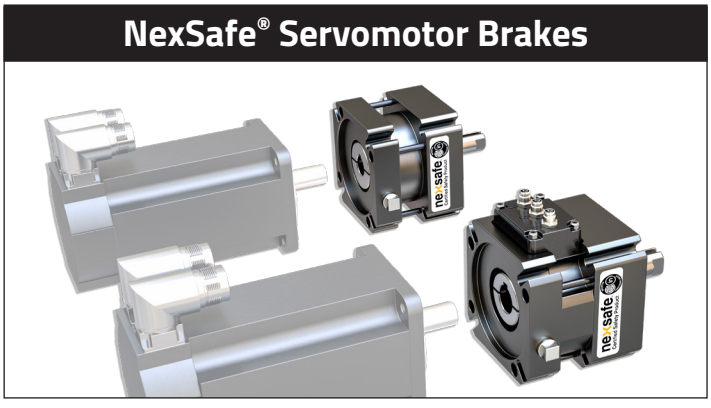
## Safety Application Guide

### NexSafe® Rod Locks



### NexSafe® Rail Brakes

### NexSafe® Servomotor Brakes



nexsafe®
Certified Safety Products

INTERTEK FS FUNCTIONAL SAFETY

# The NexSafe® Advantage

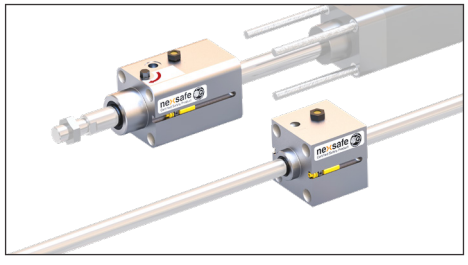
NexSafe® Functional Safety certified Rod Locks, Rail Brakes and Servomotor Brakes provide a verified, reliable solution that machine builders can depend on. With ISO 13849-1 Functional Safety Certification by Intertek©, these products can be used on a machine for operations such as holding, emergency stopping or positioning. NexSafe products are an ideal fit for applications where safety is a priority.

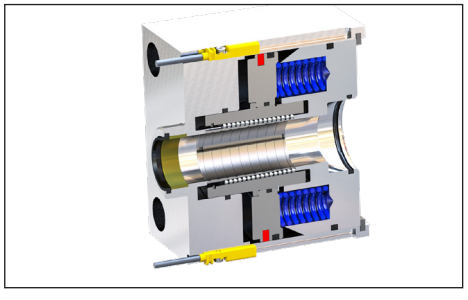
With spring-engaged, air-released functionality, these products are default to lock, ideal for emergency stopping and holding applications. Optional operating mode sensors further ensure NexSafe products are an ideal fit for safety channels designed for ISO 13849-1 Categories B through 4 and Performance Levels PLa through PLe.

ISO 13849-1 is a safety of machinery standard that assists in the design and integration of safety related parts of control systems or machines. This safety standard includes a system of categorizing the risk a machine poses, and the safety functions to mitigate that risk. By selecting NexSafe certified safety components, machine builders can rely on the provided reliability data while achieving a safety performance level.

## Safety Rated Rod Lock

Precision holding with guide rod systems and NFPA or ISO cylinders.



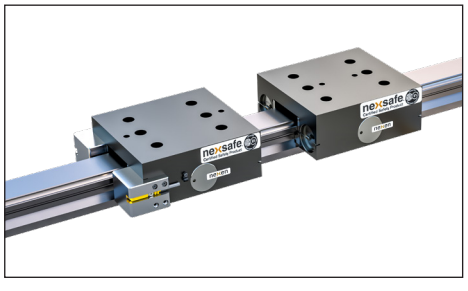


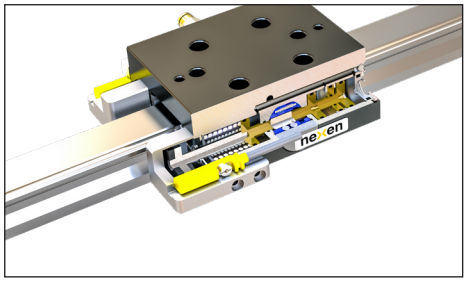
**Safety Features**
- Spring-engaged, air-released
- Multiple springs
- Engagement and Disengagement sensors available
- $B_{10D}$ of 2 million cycles

**Features**
- Low backlash
- Can be used in all orientations
- Cylinder mount or stand alone
- No rod wear due to the large clamping area
- Can be stacked for additional force
- Meets IP67 standards
- Emergency stopping and holding

## Safety Rated Rail Brake

Compact and powerful brakes compatible with most profile guide rails and carriages.

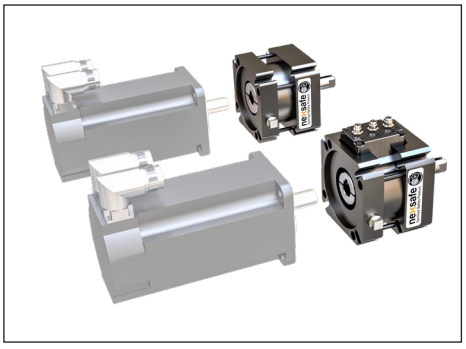


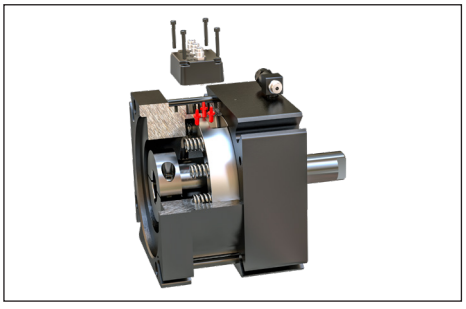


**Safety Features**
- Spring-engaged, air-released
- Multiple springs
- Multiple actuators
- Engagement and Disengagement sensors available
- $B_{10D}$ of 4 million cycles

**Features**
- High clamping force
- Low backlash
- Holds in all orientations
- Emergency stopping and holding
- Brake geometry matches rail system

## Safety Rated Servomotor Brake





Powerful, high-torque brake installed between the servomotor and gearhead/load.

**Safety Features:**

- Spring-engaged, air-released
- Multiple springs
- Integral clamp collar with backup keyway
- Engagement, Disengagement and Wear sensors available
- $B_{10D}$ of 2 million cycles

**Features:**

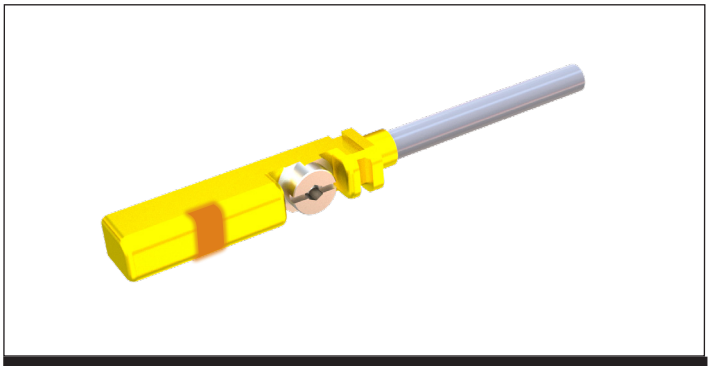
- Zero backlash
- Long facing life
- Can be used in all orientations
- Low inertia
- Sizes to fit most servomotors
- Meets IP67 standards, when used without optional sensors
- Emergency stopping and holding
- Enough torque to stall servomotors

# Operating Feedback

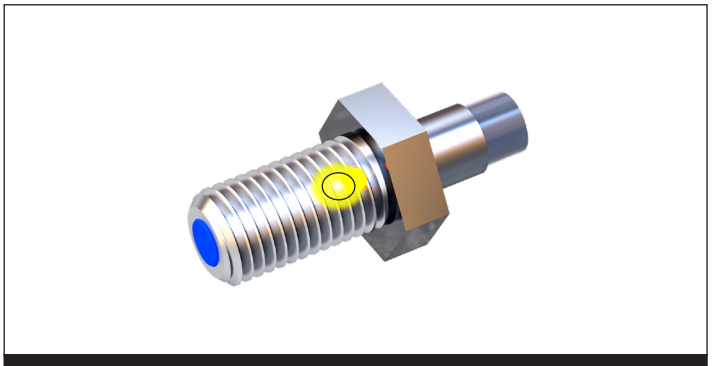
Optional Operating Mode Sensors

Optional operating mode sensor(s) are available for all three Nexsafe product lines and can be used to signal Engagement, Disengagement or Wear. By using the Operating Mode Sensors, system manufacturer's are able to gain higher safety category ratings per ISO 13849-1.

Rating of the overall safety channel is the responsibility of the system manufacturer. Nexen's sensors are also Industry 4.0 compatible and can provide information to maximize machine efficiency.



| Disengagement and Engagement Sensors on Rod Lock and Rail Brake Product Lines | |
|---|---|
| **Operating Principal** | Magneto-Resistive |
| **Sensor Output** | Normally Open |
| | Normally Closed |



| Disengagement, Engagement and Wear Sensors on Servomotor Brake Product Line | |
|---|---|
| **Operating Principal** | Inductive Proximity Sensor |
| **Sensor Output** | Normally Open, or normally closed |
| **Fieldbus Connectivity** | IO-Link v1.0 (See Tech Data Sheet) |

## Safety Design Considerations

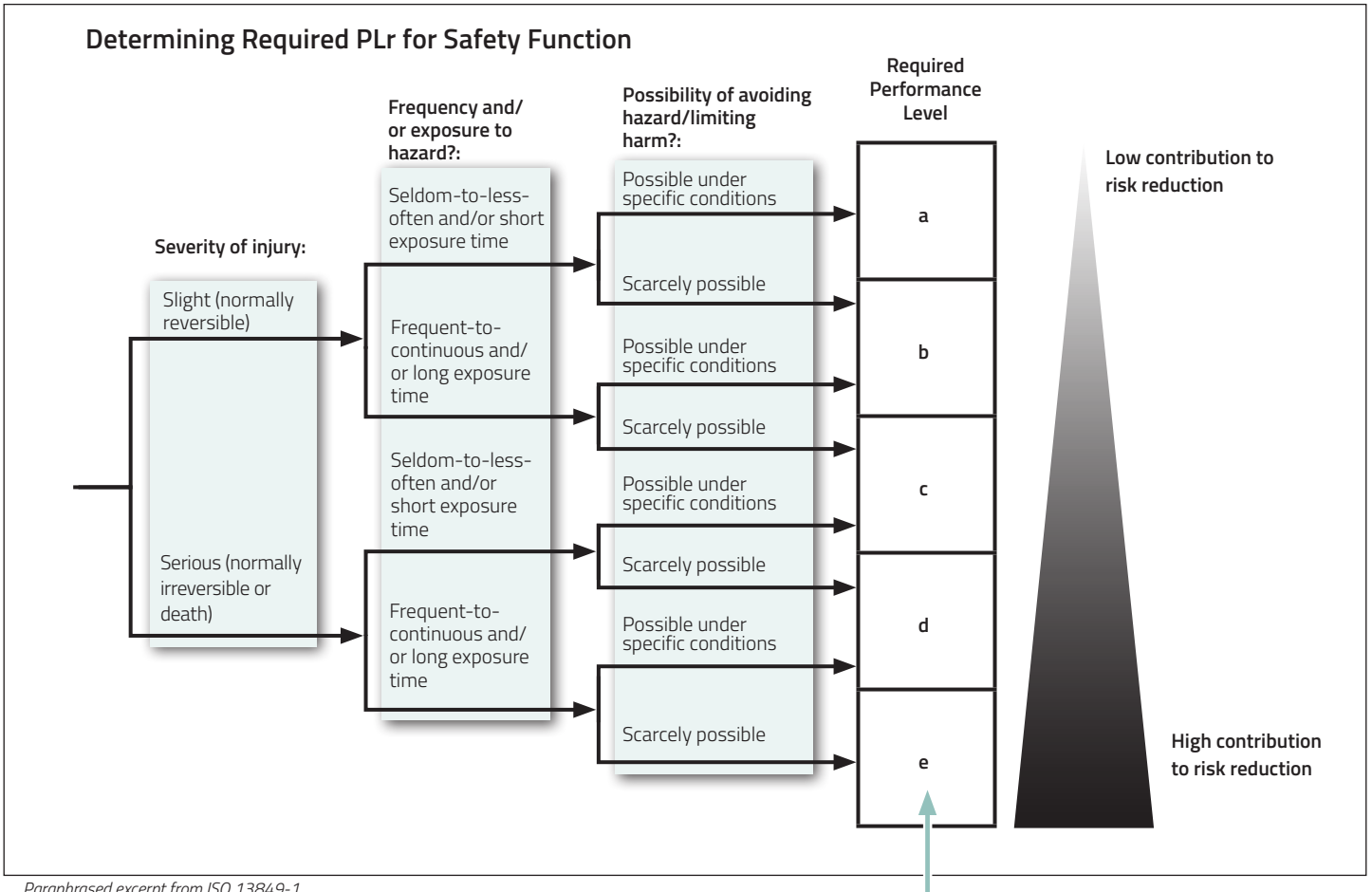
ISO 13849-1 "Safety of Machinery – Safety-Related Parts of Control Systems, Part 1: General Principles for Design" is an international standard intended to help incorporate safety systems into machinery with sufficient reliability. If initial machinery risk assessments identify a risk to safety, then a proper safety function per ISO 13849-1 is required to mitigate the risk. The standard specifies a Performance Level based on reliability data that is required for carrying out safety functions. Each Performance Level is defined by four specific requirements: Category, Mean Time to Dangerous Failure ($MTTF_D$), Diagnostic Coverage (DC) and Common Cause Failure (CCF). The Performance Level can then be used in risk assessments to ensure the proper safety devices have been implemented and the risk is reduced.

The following safety design steps are from ISO 13849-1 safety standard. It is the manufacturer's responsibility to follow the applicable standards to ensure machine safety.

### Specify Required Performance Level (PLr) Based on Risk Estimation

**Performance Level (PL)** is the value used to specify the ability of safety-related parts of a control system to perform a safety function.

**Required Performance Level (PLr)** is the required Performance Level (PL) to achieve the required risk reduction for each safety function.
The Performance Level (PL) of safety related parts of a control system must be equal to or higher than the Required Performance Level (PLr).




*Paraphrased excerpt from ISO 13849-1*

NexSafe products are capable of achieving all Performance Levels (PL a through PL e).

## Safety Design Considerations

**Select System Category Level Requirements.**
**Category Level** is the structure of the safety related parts of the control system and how their behavior in a fault condition affects the safety performance of the safety control system.

### Category Level Definitions

| Category | Summary of Requirements | System Behavior | Principal Used to Achieve Safety |
|---|---|---|---|
| B | Safety Related Parts of Controls Systems and/or their protective equipment, as well as their components, shall be designed, constructed, selected, assembled and combined in accordance with relevant standards so that they can withstand the expected influence. Basic safety principals shall be used. | The occurrence of a fault can lead to the loss of the safety function | Mainly characterized by selection of components |
| 1 | Requirements of Category B shall apply. Well-tried components and well-tried safety principles shall be used. | The occurrence of a fault can lead to the loss of the safety function but the probability of occurrence is lower than for category B. | Mainly characterized by selection of components |
| 2 | Requirements of Category B and the use of well-tried safety principles shall apply. Safety function shall be checked at suitable intervals by the machine control system. | The occurrence of a fault can lead to the loss of the safety function between the checks. The loss of safety function is detected by the check. | Mainly characterized by structure, generally a single channel with monitoring. |
| 3 | Requirements of Category B and the use of well-tried safety principles shall apply. Safety-related parts shall be designed, so that:<br>▪ A single fault in any of these parts does not lead to the loss of the safety function, and<br>▪ Whenever reasonably practicable, the single fault is detected. | When a single fault occurs, the safety function is always performed. Some, but not all, faults will be detected. Accumulation of undetected faults can lead to the loss of the safety function. | Mainly characterized by structure, generally a dual channel with monitoring. |
| 4 | Requirements of Category B and the use of well-tried safety principles shall apply. Safety-related parts shall be designed, so that:<br>▪ A single fault in any of these parts does not lead to the loss of the safety function<br>▪ The single fault is detected at or before the next demand upon the safety function, but that if this detection is not possible, an accumulation of undetected faults shall not lead to the loss of the safety function. | When a single fault occurs, the safety function is always performed. Detection of accumulated faults reduces the probability of the loss of the safety function (high DC). The faults will be detected in time to prevent the loss of the safety function. | Mainly characterized by structure, generally dual channel with dual monitoring. |

*Paraphrased excerpt from ISO 13849-1*

NexSafe products are capable of achieving all Category Levels (Cat B through Cat 4).

# Safety Design Considerations

## Specify Mean Time to Dangerous Failure ($MTTF_D$)

$B_{10D}$ is the mean number of cycles until 10% of the components fail dangerously.
NexSafe B10D: Refer to product specifications.

Mean Time to Dangerous Failure ($MTTF_D$) is given in three levels (see Table) and shall be taken into account for each channel individually. NexSafe $MTTF_D$: Perform calculation using intended application cycle rate, operating usage and Nexen supplied $B_{10D}$ cycle life specification.

| Denotation of each channel | Range of each channel |
|---|---|
| **Low** | 3 years ≤ $MTTF_D$ < 10 years |
| **Medium** | 10 years ≤ $MTTF_D$ < 30 years |
| **High** | 30 years ≤ $MTTF_D$ ≤ 100 years |

$$MTTF_D = \frac{(10 \cdot B_{10D} \cdot t_{cycle(sec)})}{(\text{Days per Year} \cdot \text{Hours per Day} \cdot 3600 \text{ Seconds per Hour})}$$

*Paraphrased excerpt from ISO 13849-1*

Useful Life ($T_{10D}$) is the mean time until 10% of the components fail dangerously. $B_{10D}$ can be converted to $T_{10D}$ by using the mean number of annual operations.
NexSafe $T_{10D}$: Perform calculation using $MTTF_D$ calculated on previous step.

$$T_{10D} = \frac{MTTF_D}{10}$$

## Specify Diagnostic Coverage

Diagnostic Coverage (DC) is the ratio between the failure rate of detected dangerous failures and the failure rate of total dangerous failures. Diagnostic coverage can exist for the whole or parts of a safety-related system.
NexSafe Diagnostic Coverage (DC): Dependent on brake redundancy and sensor setup, refer to product safety ratings.

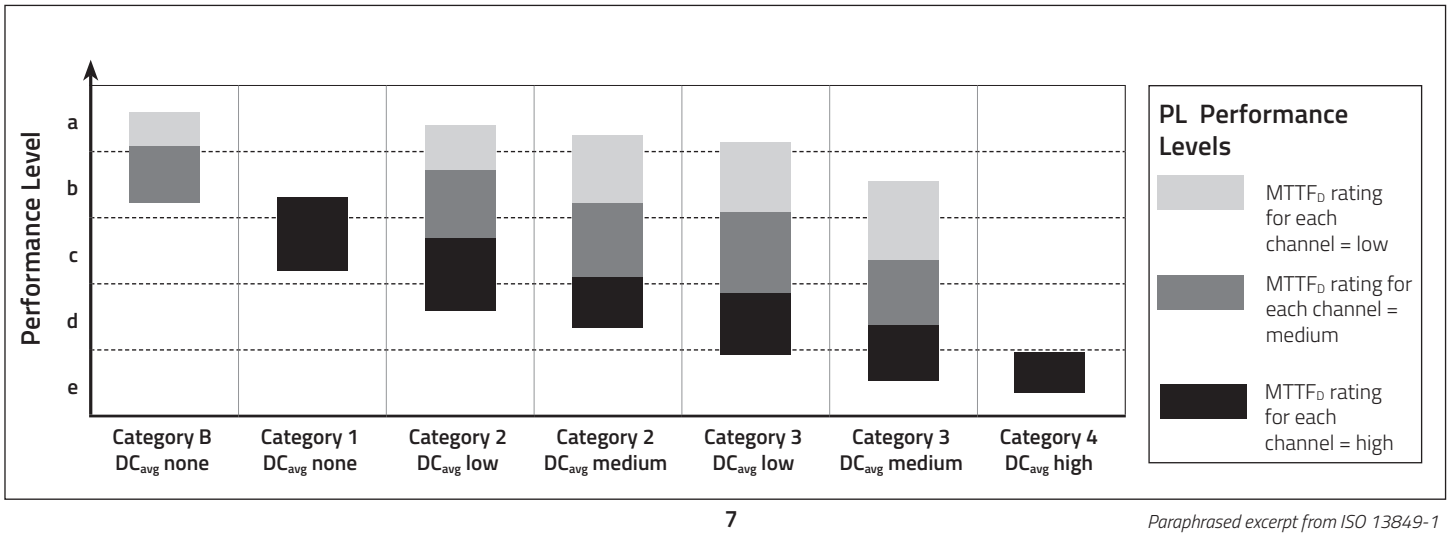
| None<br>If DC is < 60% | Low<br>If DC is 60 to 90 | Medium<br>If DC is 90 to 99% | High<br>If DC is ≥ 99% |
|---|---|---|---|
| No sensor feedback necessary. | Feedback sensor shall be used to monitor the operating mode of brake. | Feedback sensor shall be used to monitor the operating mode of brake. The brake must be cycled engaged and disengaged at least this often to check for brake functionality: | |
| | | every 3 months | once every day |

## Specify Common Cause Failure

Common Cause Failure (CCF) is the failure of different items, resulting from a single event, where these failures are not consequences of each other. CCF is to be considered at the system level, not the component level.
NexSafe Common Cause Failure (CCF): 75% assuming similar technology used in safety channel. Value may be higher if diversity of technology is used. Refer to product safety ratings.

## Reliability Data Relationships

The following graph shows the relationship between Category, Diagnostic Coverage, and $MTTF_D$ to the Performance Level. Use this graph to determine if the capabilities of the safety related parts of the control system can achieve a given Performance Level.





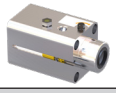
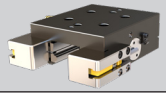

*Paraphrased excerpt from ISO 13849-1*

## NexSafe Compliance Capabilities

### Choose Required Performance Level (PLr) and Safety Category

ISO 13849-1 steps through to determine the Performance Level and Category required. Use the following table to identify the Performance Level and Category that are possible for a given NexSafe product's technology. The Category structure is further defined by any redundancies that are required with the number of sensors and products.

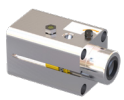
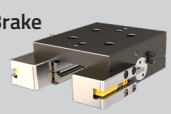
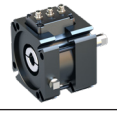
### NexSafe Product Capabilities

| | 1 Safety Product Required | | | 2 Safety Products Required* | | |
|---|---|---|---|---|---|---|
| | No Sensors Required | 1 Sensor Required | 2 Sensors Required | No Sensors Required | 1 Sensor Required | 2 Sensors Required |
| **Rod Lock**  | Category B (PLa, PLb)<br>Category 1 (PLb, PLc) | Category 2 (PLa, PLb, PLc, PLd) | | | Category 3 (PLa, PLb, PLc, PLd) | Category 4 (PLe) |
| **Rail Brake**  | Category B (PLa, PLb)<br>Category 1 (PLb, PLc) | | Category 2 (PLa, PLb, PLc, PLd) | | | Category 3 (PLa, PLb, PLc, PLd)<br>Category 4 (PLe) |
| **Servomotor Brake**  | Category B (PLa, PLb)<br>Category 1 (PLb, PLc) | Category 2 (PLa, PLb, PLc, PLd) | | | Category 3 (PLa, PLb, PLc, PLd) | Category 4 (PLe) |

**Products may differ in technology.*

### Example: Finding a NexSafe Product Configuration Capable of Meeting an Application's Safety Needs

**Safety Function:** Holding or emergency stopping a potentially hazardous movement.
**Proposed Product:** Nexen Servomotor Brake.
**System Structure:** Category 3.
**Possible Performance Levels:** Capable of PL a, PL b, PL c and PL d. (NexSafe Category 3 systems cannot achieve PL e.)
**Sensor Requirement:** One sensor required.
**Product Requirements:** Redundancy with two safety products required. Both products do not have to be NexSafe Servomotor Brakes, but must perform intended risk reduction on the safety function.

| | 1 Safety Product Required | | | 2 Safety Products Required* | | |
|---|---|---|---|---|---|---|
| | No Sensors Required | 1 Sensor Required | 2 Sensors Required | No Sensors Required | 1 Sensor Required | 2 Sensors Required |
| **Rod Lock**  | Category B (PLa, PLb)<br>Category 1 (PLb, PLc) | Category 2 (PLa, PLb, PLc, PLd) | | | Category 3 (PLa, PLb, PLc, PLd) | Category 4 (PLe) |
| **Rail Brake**  | Category B (PLa, PLb)<br>Category 1 (PLb, PLc) | | Category 2 (PLa, PLb, PLc, PLd) | | | Category 3 (PLa, PLb, PLc, PLd)<br>Category 4 (PLe) |
| **Servomotor Brake**  | Category B (PLa, PLb)<br>Category 1 (PLb, PLc) | Category 2 (PLa, PLb, PLc, PLd) | | | **Category 3 (PLa, PLb, PLc, PLd)** | Category 4 (PLe) |

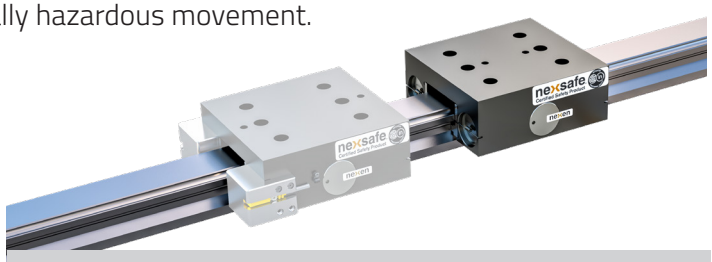
**Products may differ in technology.*



**Products may differ in technology.*

## Safety Example: Category B

**Safety Function:** Holding or emergency stopping a potentially hazardous movement.
**Required Performance Level (PLr):** b
**System Structure:** Category B
**Proposed Product:** Nexen NexSafe Rail Brake
**Calculate Mean Time to Dangerous Failure ($MTTF_D$):**




| Inputs | |
|---|---|
| Average Cycle Time | 5 seconds per cycle |
| Operating Hours per Day | 16 hours per day |
| Operating Days per Year | 260 days per year |
| Nexen Rail Brake $B_{10D}$ | 4 million cycles |

$$MTTF_D = \frac{(10 \cdot B_{10D} \cdot t_{cycle(sec)})}{(\text{Days per Year} \cdot \text{Hours per Day} \cdot 3600 \text{ Seconds per Hour})}$$

| Denotation of each channel | Range of each channel |
|---|---|
| Low | 3 years ≤ $MTTF_D$ < 10 years |
| Medium | 10 years ≤ $MTTF_D$ < 30 years |
| High | 30 years ≤ $MTTF_D$ ≤ 100 years |

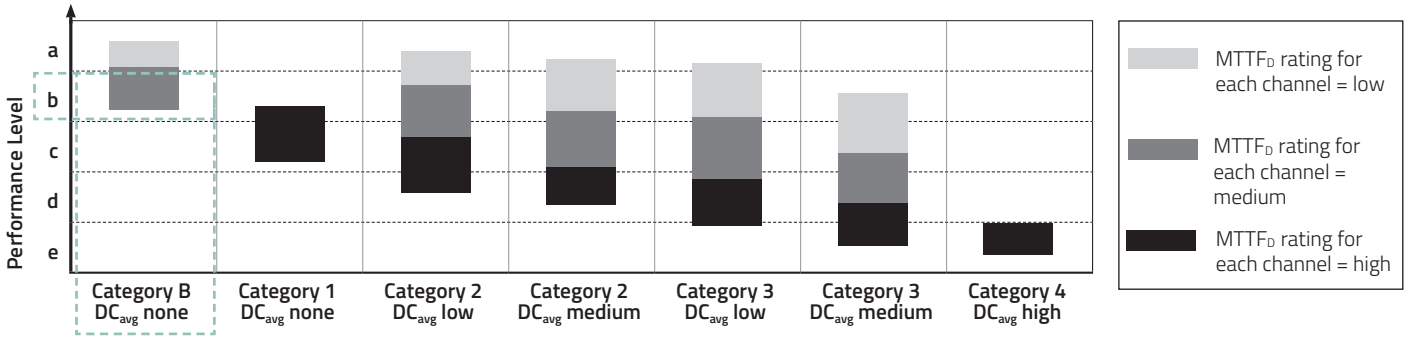
$$MTTF_D \text{ 13 years, "medium"} = \frac{(10 \cdot 4{,}000{,}000 \text{ cycles} \cdot 5 \text{ sec per cycle})}{(260 \text{ Days per Year} \cdot 16 \text{ Hours per Day} \cdot 3600 \text{ Seconds per Hour})}$$

**Calculate Useful Life ($T_{10D}$)** $T_{10D} = \frac{MTTF_D}{10}$ $1.3 \text{ years} = \frac{13 \text{ years}}{10}$

In this example the brake must be replaced after usage reaches $B_{10D}$ life of 4,000,000 cycles or 1.3 years.

### Reliability Data Relationships

Compare Category, Diagnostic Coverage, and $MTTF_D$ to the Performance Level. Use this graph to determine if the capabilities of the safety related parts of the control system can achieve a given Performance Level.

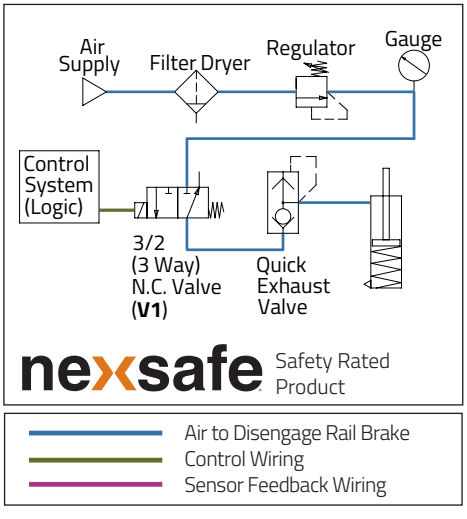



Performance Level (PL) is b, | Category is B | $TTF_D$ is 13 years, "medium" | Diagnostic Coverage (DC) is None, (0 to 60%)

### Category B Control Circuit Example: One Brake, No Sensors Required

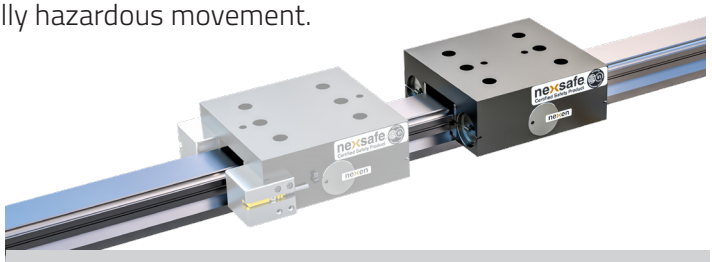
| | 1 Safety Product Required | | | 2 Safety Products Required* | | |
|---|---|---|---|---|---|---|
| | No Sensors Required | 1 Sensor Required | 2 Sensors Required | No Sensors Required | 1 Sensor Required | 2 Sensors Required |
| Rod Lock  | Category B (PLa, PLb)<br>Category 1 (PLb, PLc) | Category 2 (PLa, PLb, PLc, PLd) | | | Category 3 (PLa, PLb, PLc, PLd) | Category 4 (PLe) |
| Rail Brake  | **Category B (PLa, PLb)**<br>**Category 1 (P Lb, PLc)** | | Category 2 (PLa, PLb, PLc, PLd) | | | Category 3 (PLa, PLb, PLc, PLd)<br>Category 4 (PLe) |
| Servomotor Brake  | Category B (PLa, PLb)<br>Category 1 (PLb, PLc) | Category 2 (PLa, PLb, PLc, PLd) | | | Category 3 (PLa, PLb, PLc, PLd) | Category 4 (PLe) |

*Products may differ in technology.



## Safety Example: Category 1

**Safety Function:** Holding or emergency stopping a potentially hazardous movement.
**Required Performance Level (PLr):** c
**System Structure:** Category 1
**Proposed Product:** Nexen NexSafe Rail Brake
**Calculate Mean Time to Dangerous Failure ($MTTF_D$):**




| Inputs | |
|---|---|
| Average Cycle Time | 15 seconds per cycle |
| Operating Hours per Day | 16 hours per day |
| Operating Days per Year | 260 days per year |
| Nexen Rail Brake $B_{10D}$ | 4 million cycles |

$$MTTF_D = \frac{(10 \cdot B_{10D} \cdot t_{cycle(sec)})}{(\text{Days per Year} \cdot \text{Hours per Day} \cdot 3600 \text{ Seconds per Hour})}$$

| Denotation of each channel | Range of each channel |
|---|---|
| Low | 3 years ≤ $MTTF_D$ < 10 years |
| Medium | 10 years ≤ $MTTF_D$ < 30 years |
| High | 30 years ≤ $MTTF_D$ ≤ 100 years |

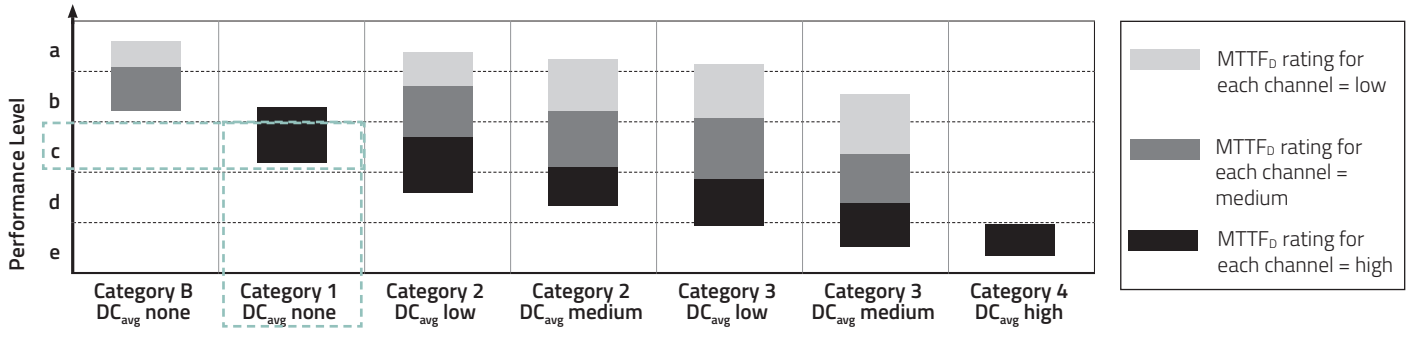
$$MTTF_D \text{ 40 years, "high"} = \frac{(10 \cdot 4{,}000{,}000 \text{ cycles} \cdot 15 \text{ sec per cycle})}{(260 \text{ Days per Year} \cdot 16 \text{ Hours per Day} \cdot 3600 \text{ Seconds per Hour})}$$

**Calculate Useful Life ($T_{10D}$)** $T_{10D} = \frac{MTTF_D}{10}$ 4 years $= \frac{40 \text{ years}}{10}$

In this example the brake must be replaced after usage reaches $B_{10D}$ life of 4,000,000 cycles or 4 years.

### Reliability Data Relationships

Compare Category, Diagnostic Coverage, and $MTTF_D$ to the Performance Level. Use this graph to determine if the capabilities of the safety related parts of the control system can achieve a given Performance Level.

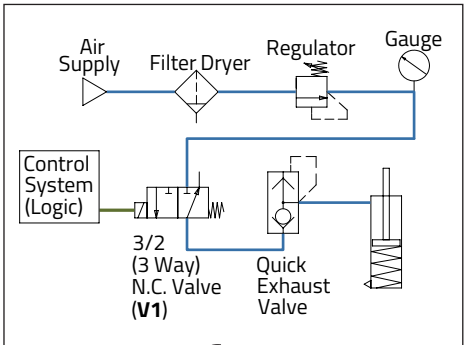



Performance Level (PL) is b, | Category is B | $TTF_D$ is 40 years, "high" | Diagnostic Coverage (DC) is None, (0 to 60%)

### Category 1 Control Circuit Example: One Brake, No Sensors Required

| | 1 Safety Product Required | | | 2 Safety Products Required* | | |
|---|---|---|---|---|---|---|
| | No Sensors Required | 1 Sensor Required | 2 Sensors Required | No Sensors Required | 1 Sensor Required | 2 Sensors Required |
| Rod Lock | Category B (PLa, PLb) / Category 1 (PLb, PLc) | Category 2 (PLa, PLb, PLc, PLd) | | | Category 3 (PLa, PLb, PLc, PLd) | Category 4 (PLe) |
| Rail Brake | **Category B (PLa, PLb)** / **Category 1 (P Lb, PLc)** | | Category 2 (PLa, PLb, PLc, PLd) | | | Category 3 (PLa, PLb, PLc, PLd) / Category 4 (PLe) |
| Servomotor Brake | Category B (PLa, PLb) / Category 1 (PLb, PLc) | Category 2 (PLa, PLb, PLc, PLd) | | | Category 3 (PLa, PLb, PLc, PLd) | Category 4 (PLe) |

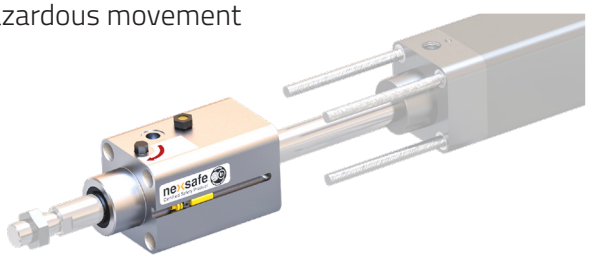
*Products may differ in technology.



## Safety Example: Category 2

**Safety Function:** Holding or emergency stopping a potentially hazardous movement
**Required Performance Level (PLr):** d
**System Structure:** Category 2
**Proposed Product:** Nexen NexSafe Rod Lock

**Example is for Functional channel only.**
**Test channel $MTTF_D$ is 100 years**



| Inputs | |
|---|---|
| Average Cycle Time | 48 seconds per cycle |
| Operating Hours per Day | 16 hours per day |
| Operating Days per Year | 260 days per year |
| Nexen Rod Lock $B_{10D}$ | 2 million cycles |

$$MTTF_D = \frac{(10 \cdot B_{10D} \cdot t_{cycle(sec)})}{(\text{Days per Year} \cdot \text{Hours per Day} \cdot 3600 \text{ Seconds per Hour})}$$

| Denotation of each channel | Range of each channel |
|---|---|
| Low | 3 years ≤ $MTTF_D$ < 10 years |
| Medium | 10 years ≤ $MTTF_D$ < 30 years |
| High | 30 years ≤ $MTTF_D$ ≤ 100 years |

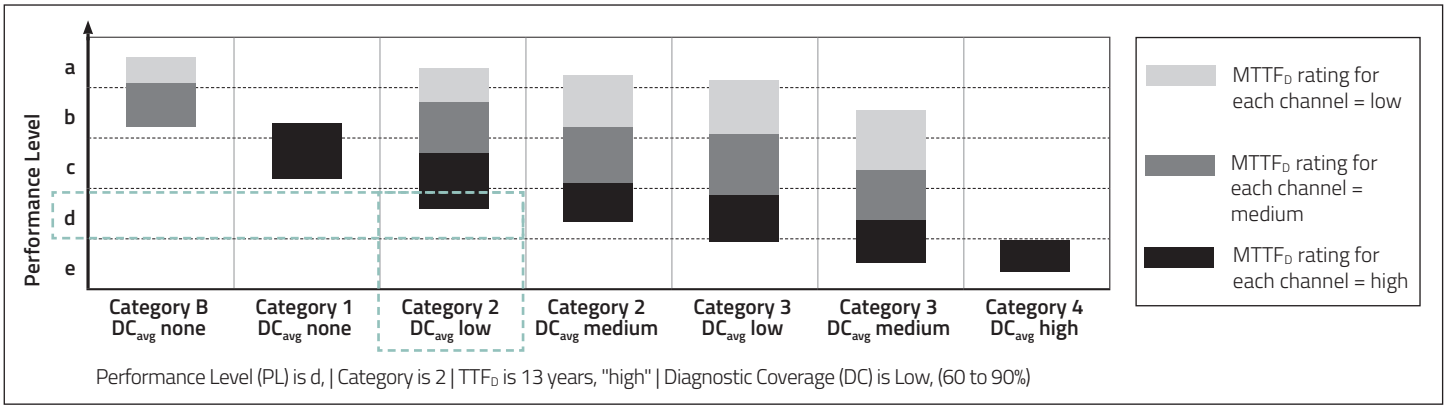
$$MTTF_D \text{ 64 years, "high"} = \frac{(10 \cdot 2{,}000{,}000 \text{ cycles} \cdot 48 \text{ sec per cycle})}{(260 \text{ Days per Year} \cdot 16 \text{ Hours per Day} \cdot 3600 \text{ Seconds per Hour})}$$

**Calculate Useful Life ($T_{10D}$)** $T_{10D} = \frac{MTTF_D}{10}$ $6.4 \text{ years} = \frac{64 \text{ years}}{10}$

In this example the brake must be replaced after usage reaches $B_{10D}$ life of 2,000,000 cycles or 6.4 years.

### Reliability Data Relationships

Compare Category, Diagnostic Coverage, and $MTTF_D$ to the Performance Level. Use this graph to determine if the capabilities of the safety related parts of the control system can achieve a given Performance Level.

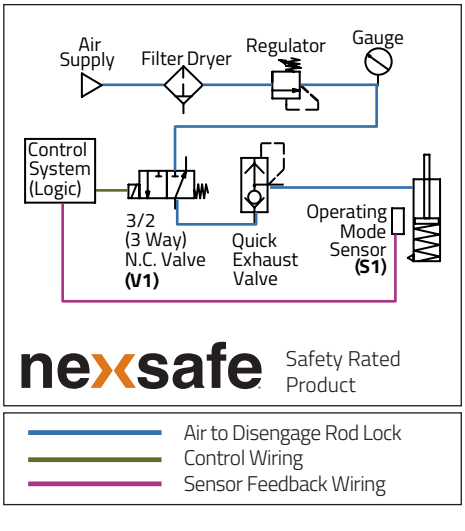



Performance Level (PL) is d, | Category is 2 | $TTF_D$ is 13 years, "high" | Diagnostic Coverage (DC) is Low, (60 to 90%)

### Category 2 Control Circuit Example: One Brake, One Sensor Required

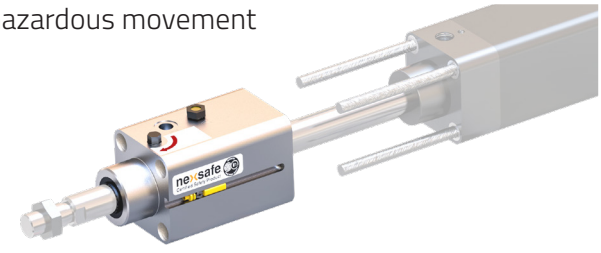
| | 1 Safety Product Required | | | 2 Safety Products Required* | | |
|---|---|---|---|---|---|---|
| | No Sensors Required | 1 Sensor Required | 2 Sensors Required | No Sensors Required | 1 Sensor Required | 2 Sensors Required |
| Rod Lock  | Category B (PLa, PLb)<br>Category 1 (PLb, PLc) | **Category 2 (PLa, PLb, PLc, PLd)** | | | Category 3 (PLa, PLb, PLc, PLd) | Category 4 (PLe) |
| Rail Brake  | Category B (PLa, PLb)<br>Category 1 (P Lb, PLc) | | Category 2 (PLa, PLb, PLc, PLd) | | | Category 3 (PLa, PLb, PLc, PLd)<br>Category 4 (PLe) |
| Servomotor Brake  | Category B (PLa, PLb)<br>Category 1 (PLb, PLc) | Category 2 (PLa, PLb, PLc, PLd) | | | Category 3 (PLa, PLb, PLc, PLd) | Category 4 (PLe) |

*Products may differ in technology.



## Safety Example: Category 3

**Safety Function:** Holding or emergency stopping a potentially hazardous movement
**Required Performance Level (PLr):** d
**System Structure:** Category 3
**Proposed Product:** Nexen NexSafe Rod Lock



### Calculate Mean Time to Dangerous Failure ($MTTF_D$):

| Inputs | |
|---|---|
| **Average Cycle Time** | 11 seconds per cycle |
| **Operating Hours per Day** | 16 hours per day |
| **Operating Days per Year** | 260 days per year |
| **Nexen Rod Lock $B_{10D}$** | 2 million cycles |

$$MTTF_D = \frac{(10 \cdot B_{10D} \cdot t_{cycle(sec)})}{(\text{Days per Year} \cdot \text{Hours per Day} \cdot 3600 \text{ Seconds per Hour})}$$

| Denotation of each channel | Range of each channel |
|---|---|
| Low | 3 years ≤ $MTTF_D$ < 10 years |
| Medium | 10 years ≤ $MTTF_D$ < 30 years |
| High | 30 years ≤ $MTTF_D$ ≤ 100 years |

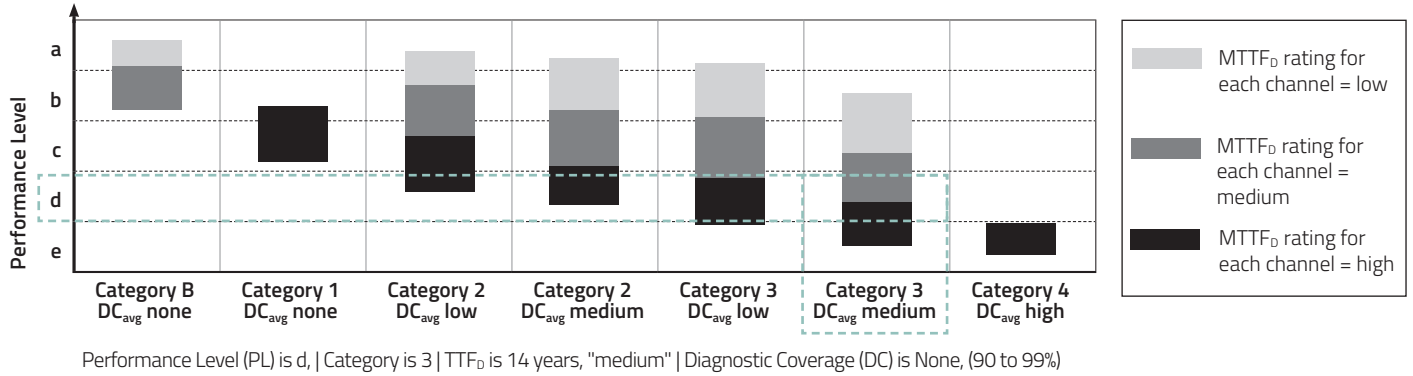
$$MTTF_D \text{ 14 years, "medium"} = \frac{(10 \cdot 2{,}000{,}000 \text{ cycles} \cdot 11 \text{ sec per cycle})}{(260 \text{ Days per Year} \cdot 16 \text{ Hours per Day} \cdot 3600 \text{ Seconds per Hour})}$$

**Calculate Useful Life ($T_{10D}$)** $T_{10D} = \frac{MTTF_D}{10}$ $1.4 \text{ years} = \frac{14 \text{ years}}{10}$

In this example the brake must be replaced after usage reaches $B_{10D}$ life of 2,000,000 cycles or 1.4 years.

### Reliability Data Relationships

Compare Category, Diagnostic Coverage, and $MTTF_D$ to the Performance Level. Use this graph to determine if the capabilities of the safety related parts of the control system can achieve a given Performance Level.

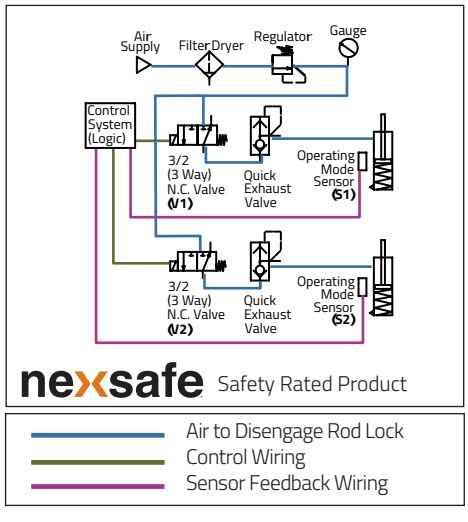



Performance Level (PL) is d, | Category is 3 | $TTF_D$ is 14 years, "medium" | Diagnostic Coverage (DC) is None, (90 to 99%)

### Category 3 Control Circuit Example: Two Redundant Brakes, One Sensor on Each

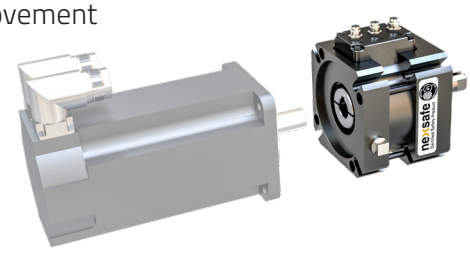
| | 1 Safety Product Required | | | 2 Safety Products Required* | | |
|---|---|---|---|---|---|---|
| | No Sensors Required | 1 Sensor Required | 2 Sensors Required | No Sensors Required | 1 Sensor Required | 2 Sensors Required |
| Rod Lock | Category B (PLa, PLb)<br>Category 1 (PLb, PLc) | Category 2 (PLb, PLc, PLd) | | | **Category 3 (PLa, PLb, PLc, PLd)** | Category 4 (PLe) |
| Rail Brake | Category B (PLa, PLb)<br>Category 1 (P Lb, PLc) | | Category 2 (PLa, PLb, PLc, PLd) | | | Category 3 (PLa, PLb, PLc, PLd)<br>Category 4 (PLe) |
| Servomotor Brake | Category B (PLa, PLb)<br>Category 1 (PLb, PLc) | Category 2 (PLa, PLb, PLc, PLd) | | | Category 3 (PLa, PLb, PLc, PLd) | Category 4 (PLe) |

*Products may differ in technology.



## Safety Example: Category 4

**Safety Function:** Holding or emergency stopping a potentially hazardous movement
**Required Performance Level (PLr):** e
**System Structure:** Category 4
**Proposed Product:** Nexen NexSafe Servomotor Brake



### Calculate Mean Time to Dangerous Failure ($MTTF_D$):

| Inputs | |
|---|---|
| Average Cycle Time | 24seconds per cycle |
| Operating Hours per Day | 16 hours per day |
| Operating Days per Year | 260 days per year |
| Nexen Servomotor Brake $B_{10D}$ | 2 million cycles |

$$MTTF_D = \frac{(10 \cdot B_{10D} \cdot t_{cycle(sec)})}{(\text{Days per Year} \cdot \text{Hours per Day} \cdot 3600 \text{ Seconds per Hour})}$$

| Denotation of each channel | Range of each channel |
|---|---|
| Low | 3 years ≤ $MTTF_D$ < 10 years |
| Medium | 10 years ≤ $MTTF_D$ < 30 years |
| High | 30 years ≤ $MTTF_D$ ≤ 100 years |

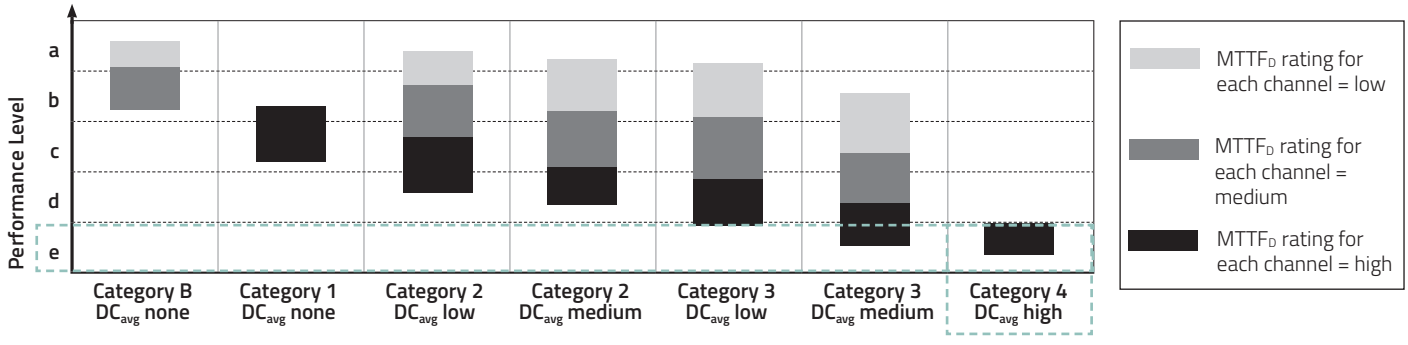
$$MTTF_D \text{ 32 years, "high"} = \frac{(10 \cdot 2{,}000{,}000 \text{ cycles} \cdot 24 \text{ sec per cycle})}{(260 \text{ Days per Year} \cdot 16 \text{ Hours per Day} \cdot 3600 \text{ Seconds per Hour})}$$

**Calculate Useful Life ($T_{10D}$)** $T_{10D} = \frac{MTTF_D}{10}$ 3.2 years $= \frac{32 \text{ years}}{10}$

In this example the brake must be replaced after usage reaches $B_{10D}$ life of 2,000,000 cycles or 3.2 years.

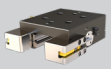
### Reliability Data Relationships

Compare Category, Diagnostic Coverage, and $MTTF_D$ to the Performance Level. Use this graph to determine if the capabilities of the safety related parts of the control system can achieve a given Performance Level.

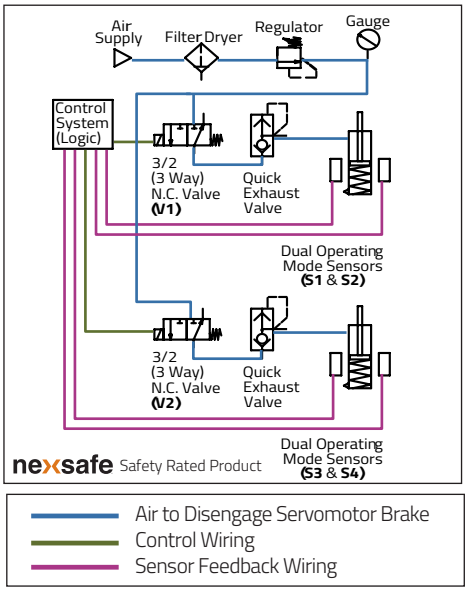



Performance Level (PL) is e, | Category is 4 | $TTF_D$ is 32 years, "high" | Diagnostic Coverage (DC) is High, (≥99%)

### Category 4 Control Circuit Example: Two Redundant Brakes, Two Sensors on Each

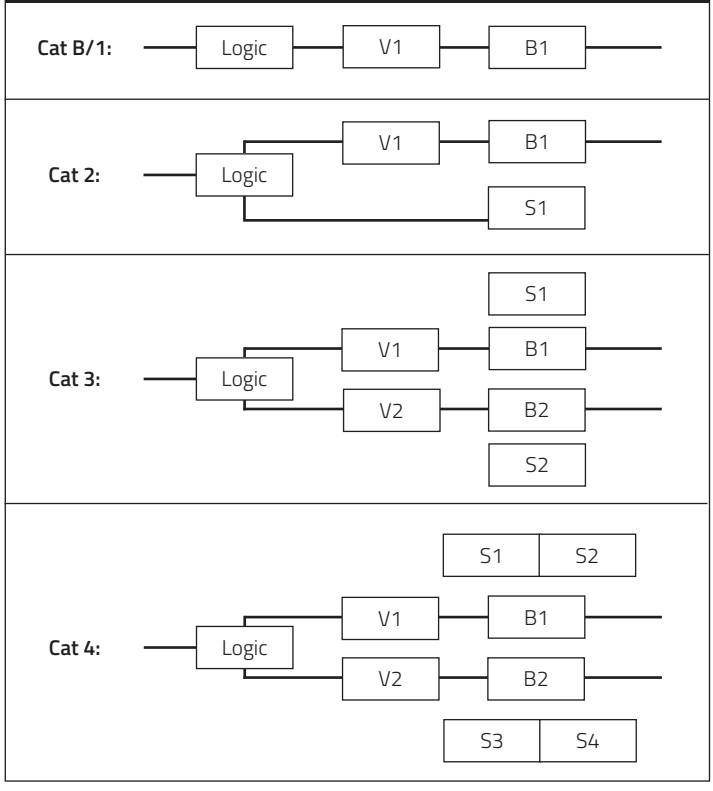
| | 1 Safety Product Required | | | 2 Safety Products Required* | | |
|---|---|---|---|---|---|---|
| | No Sensors Required | 1 Sensor Required | 2 Sensors Required | No Sensors Required | 1 Sensor Required | 2 Sensors Required |
| Rod Lock  | Category B (PLa, PLb)<br>Category 1 (PLb, PLc) | Category 2 (PLa, PLb, PLc, PLd) | | | Category 3 (PLa, PLb, PLc, PLd) | Category 4 (PLe) |
| Rail Brake  | Category B (PLa, PLb)<br>Category 1 (PLb, PLc) | | Category 2 (PLa, PLb, PLc, PLd) | | | Category 3 (PLa, PLb, PLc, PLd)<br>Category 4 (PLe) |
| Servomotor Brake  | Category B (PLa, PLb)<br>Category 1 (PLb, PLc) | Category 2 (PLa, PLb, PLc, PLd) | | | Category 3 (PLa, PLb, PLc, PLd) | **Category 4 (PLe)** |

*Products may differ in technology.

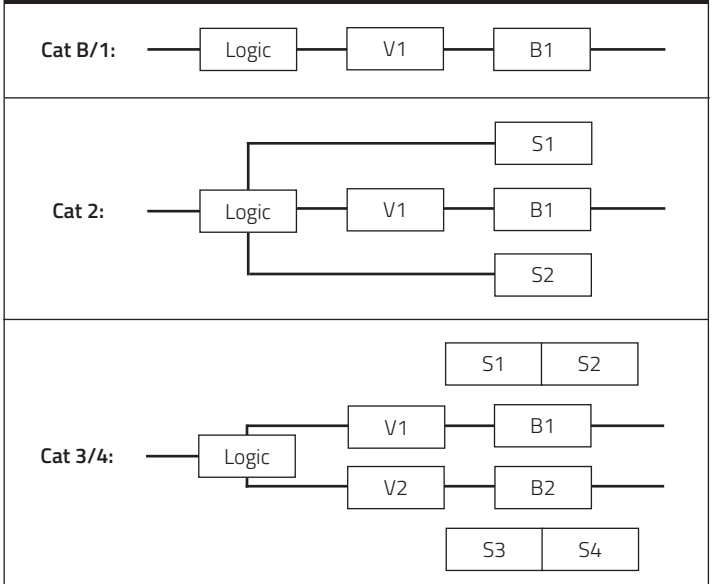


## Example Block Diagrams

### Rod Locks and Servomotor Brakes




### Rail Brakes




| Key | |
|---|---|
| **Logic=** | Customer Logic and Controls |
| **B=** | Rod Lock, Servomotor Brake, or Rail Brake |
| **V=** | Pneumatic Control Valve |
| **S=** | Operating Mode Sensor |

### Assumptions

- System can be reduced to a single channel with Logic, Valve, and Brake
- $MTTF_D$ is selected based on the category, performance level, and diagnostic coverage and $t_{cycle}$ is back figured to provide a maximum cycle rate (rounded up)
- $B_{10D}$ for a pneumatic valve is 20,000,000 per 13849-1:2015, Annex C, Table C.1
- PFH for logic is $1.5X10^{-8}$ based on common industry manufacturers
- 260 operational days per year (five days per week)
- 16 operation hours per day (two eight-hour shifts)

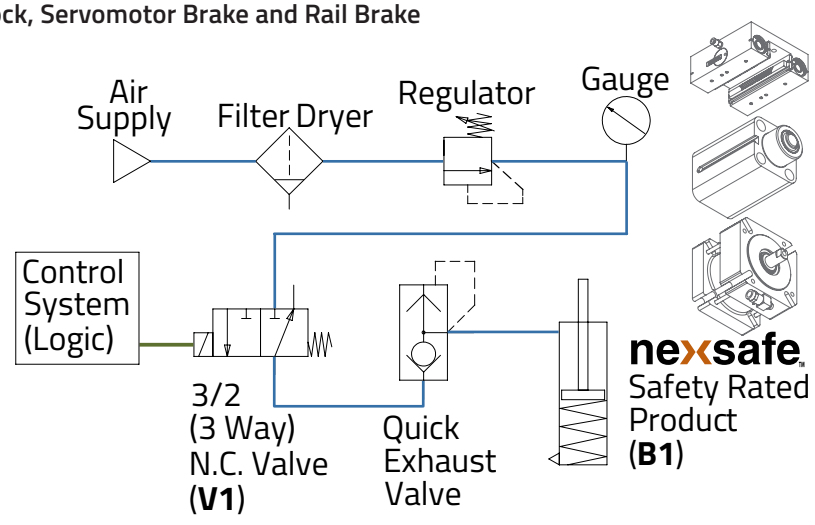
| Sample Tabulated Values | | Category B | | Category 1 | | Category 2** | | | | | | | | Category 3** | | | | | | | Cat 4 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | DC None | | DC None | | DC Low | | | | DC Medium | | | | DC Low | | | | DC Medium | | | DC High |
| | | PLa | PLb | PLb | PLc | Pla | PLb | PLc | PLd | PLa | PLb | PLc | PLd | PLa | PLb | PLc | PLd | PLb | PLc | PLd | PLe |
| Rod Lock | $MTTF_D$ (years) | 3.3 | 13 | 33 | 43 | 3.3 | 8.2 | 27 | 68 | 3.3 | 6.2 | 18 | 39 | 3.3 | 4.3 | 12 | 27 | 3.3 | 6.2 | 15 | 33 |
| | $t_{cycle}$* (s/cycle) | 2.8 | 10.8 | 27.3 | 35.7 | 2.8 | 6.8 | 22.4 | 56.6 | 2.8 | 5.2 | 14.9 | 32.3 | 2.8 | 3.6 | 9.9 | 22.4 | 2.8 | 5.2 | 12.4 | 27.3 |
| | $T_{10D}$ (years) | 0.3 | 1.3 | 3.3 | 4.3 | 0.3 | 0.8 | 2.7 | 6.8 | 0.3 | 0.6 | 1.8 | 3.9 | 0.3 | 0.4 | 1.2 | 2.7 | 0.3 | 0.6 | 1.5 | 3.3 |
| Servobrake | $MTTF_D$ (years) | 3.3 | 13 | 33 | 43 | 3.3 | 8.2 | 27 | 68 | 3.3 | 6.2 | 18 | 39 | 3.3 | 4.3 | 12 | 27 | 3.3 | 6.2 | 15 | 33 |
| | $t_{cycle}$* (s/cycle) | 2.8 | 10.8 | 27.3 | 35.7 | 2.8 | 6.8 | 22.4 | 56.6 | 2.8 | 5.2 | 14.9 | 32.3 | 2.8 | 3.6 | 9.9 | 22.4 | 2.8 | 5.2 | 12.4 | 27.3 |
| | $T_{10D}$ (years) | 0.3 | 1.3 | 3.3 | 4.3 | 0.3 | 0.8 | 2.7 | 6.8 | 0.3 | 0.6 | 1.8 | 3.9 | 0.3 | 0.4 | 1.2 | 2.7 | 0.3 | 0.6 | 1.5 | 3.3 |
| Rail Brake | $MTTF_D$ (years) | 3.3 | 13 | 33 | 43 | 3.3 | 8.2 | 27 | 68 | 3.3 | 6.2 | 18 | 39 | 3.3 | 4.3 | 12 | 27 | 3.3 | 6.2 | 15 | 33 |
| | $t_{cycle}$* (s/cycle) | 1.5 | 5.9 | 14.9 | 19.5 | 1.5 | 3.7 | 12.2 | 30.9 | 1.5 | 2.8 | 8.2 | 17.7 | 1.5 | 2.0 | 5.4 | 12.2 | 1.5 | 2.8 | 6.8 | 14.9 |
| | $T_{10D}$ (years) | 0.3 | 1.3 | 3.3 | 4.3 | 0.3 | 0.8 | 2.7 | 6.8 | 0.3 | 0.6 | 1.8 | 3.9 | 0.3 | 0.4 | 1.2 | 2.7 | 0.3 | 0.6 | 1.5 | 3.3 |

***NOTE:** $t_{cycle}$ is rounded up to the nearest tenth as a worst-case.

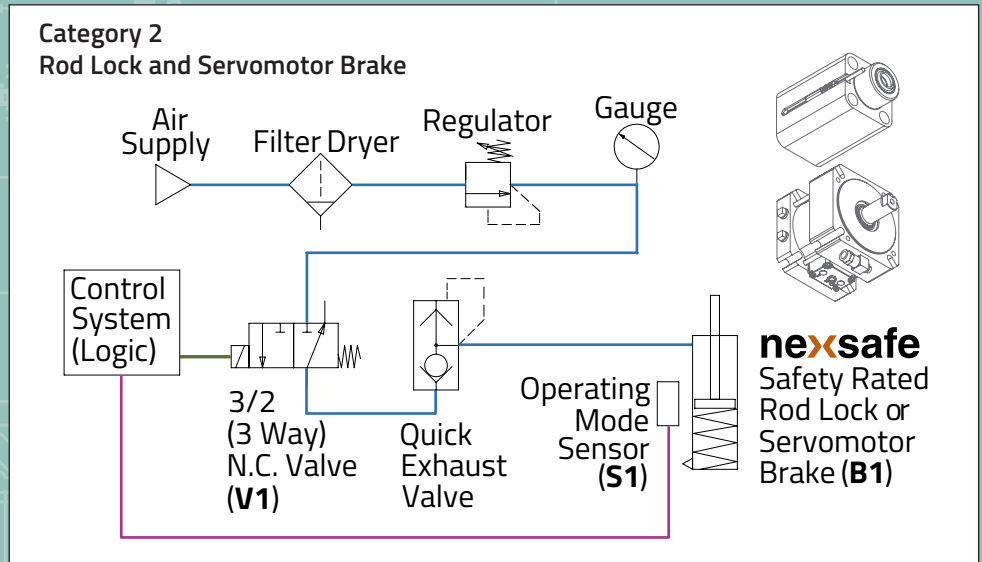
** NexSafe Cat 2 and Cat 3 systems must compare pneumatic valve power signal with Sensor output signal

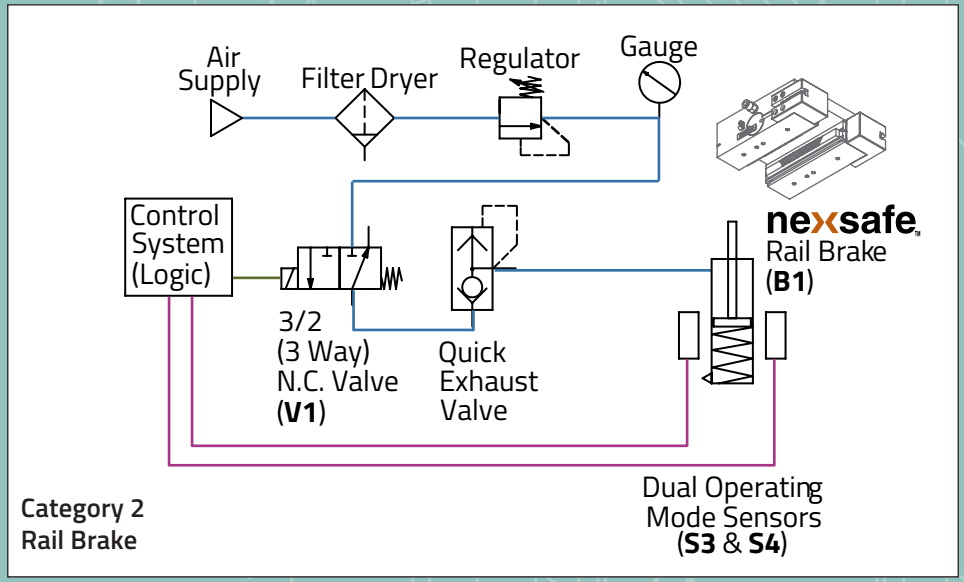
# Example Safety Rated Control Circuits

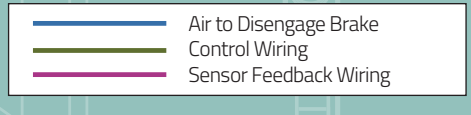
**Category B/1**
**Rod Lock, Servomotor Brake and Rail Brake**



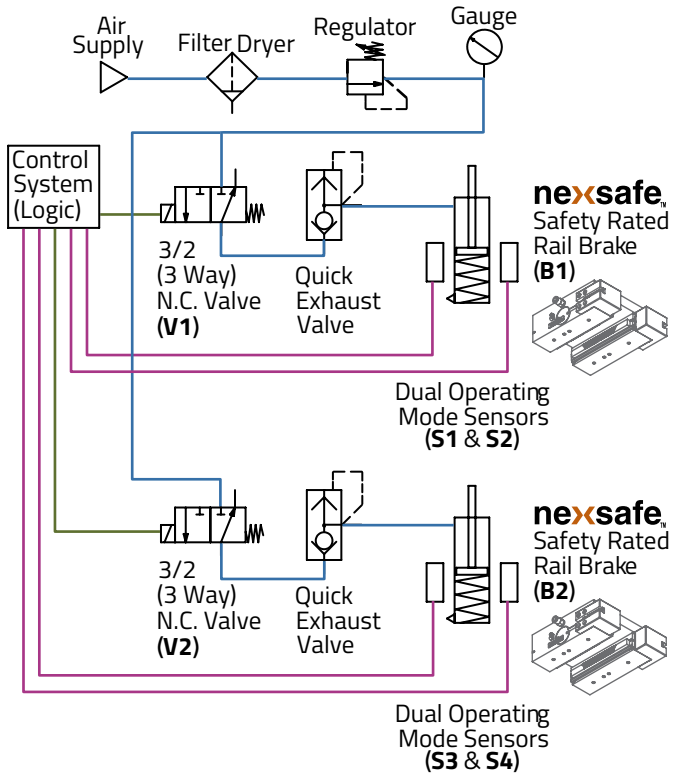

**Category 2**
**Rod Lock and Servomotor Brake**



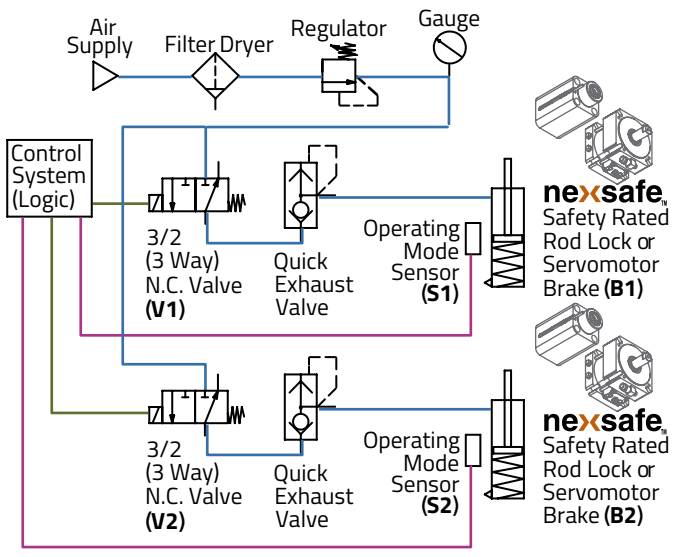



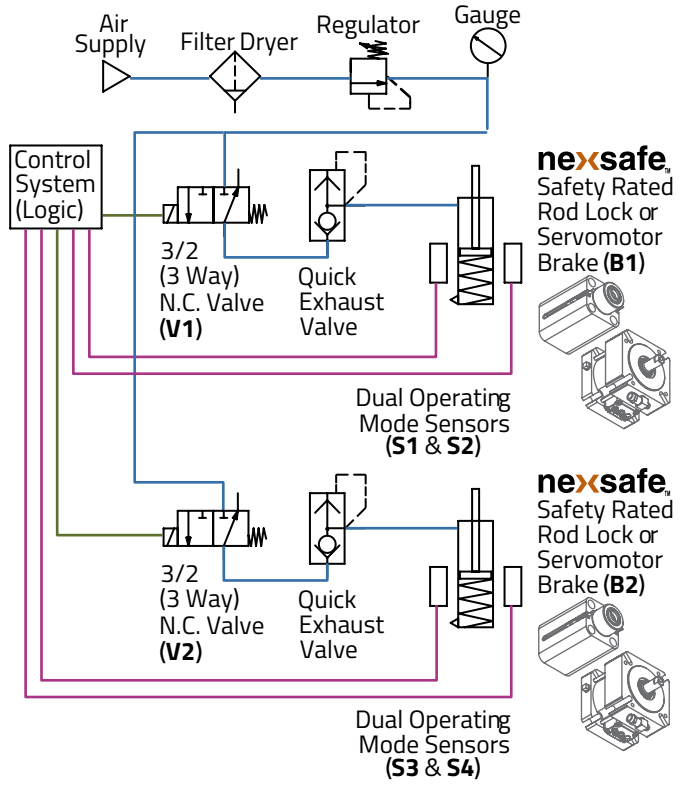
## Category 3/4
## Rail Brake




## Category 3
## Rod Lock and Servomotor Brake



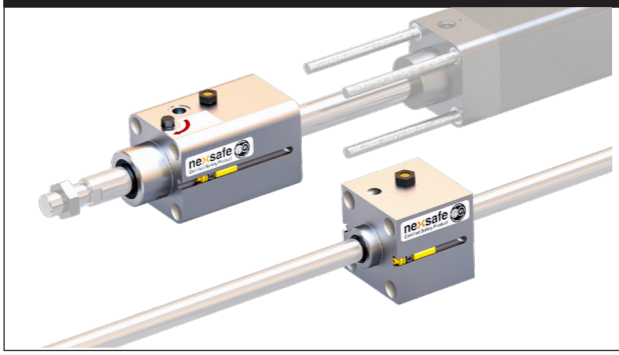

## Category 4
## Rod Lock and Servomotor Brake



# nexsafe®

Certified Safety Products

## NexSafe® Rod Locks



Precision holding with guide rod systems and NFPA or ISO cylinders.

- ✓ CAT 4 PL e
- ✓ SIL 3

Certificate NO. FS-CRT-0006
intertek.com/directories/

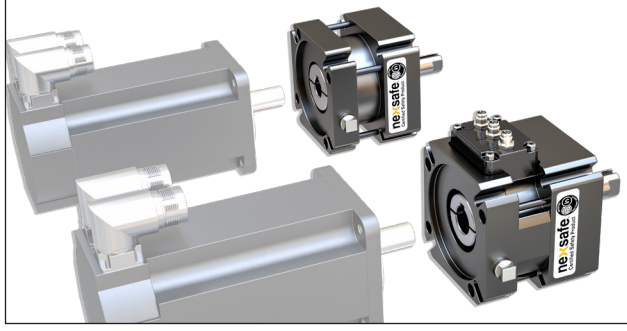
## NexSafe® Rail Brakes

Compact and powerful brakes compatible with most profile guide rails and carriages.

- ✓ CAT 4 PL e
- ✓ SIL 3

Certificate NO. FS-CRT-0007
intertek.com/directories/

## NexSafe® Servomotor Brakes



Powerful, high-torque brake installed between the servomotor and the gearbox.

- ✓ CAT 4 PL e
- ✓ SIL 3

Certificate NO. FS-CRT-0008
intertek.com/directories/

nexen

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