

Pneumatic Safety Valves Safety Function

Products: E-stop Button, Guardmaster® Compatibility Input Safety Relay, DM² Safety Valve

Safety Rating: CAT. 4, PL_e to ISO 13849-1: 2015



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Important User Information

Read this document and the documents listed in the additional resources section about installation, configuration, and operation of this equipment before you install, configure, operate, or maintain this product. Users are required to familiarize themselves with installation and wiring instructions in addition to requirements of all applicable codes, laws, and standards.

Activities including installation, adjustments, putting into service, use, assembly, disassembly, and maintenance are required to be carried out by suitably trained personnel in accordance with applicable code of practice.

If this equipment is used in a manner not specified by the manufacturer, the protection provided by the equipment may be impaired.

In no event will Rockwell Automation, Inc. be responsible or liable for indirect or consequential damages resulting from the use or application of this equipment.

The examples and diagrams in this manual are included solely for illustrative purposes. Because of the many variables and requirements associated with any particular installation, Rockwell Automation, Inc. cannot assume responsibility or liability for actual use based on the examples and diagrams.

No patent liability is assumed by Rockwell Automation, Inc. with respect to use of information, circuits, equipment, or software described in this manual.

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Throughout this manual, when necessary, we use notes to make you aware of safety considerations.



WARNING: Identifies information about practices or circumstances that can cause an explosion in a hazardous environment, which may lead to personal injury or death, property damage, or economic loss.



ATTENTION: Identifies information about practices or circumstances that can lead to personal injury or death, property damage, or economic loss. Attentions help you identify a hazard, avoid a hazard, and recognize the consequence.

IMPORTANT

Identifies information that is critical for successful application and understanding of the product.

Labels may also be on or inside the equipment to provide specific precautions.



SHOCK HAZARD: Labels may be on or inside the equipment, for example, a drive or motor, to alert people that dangerous voltage may be present.



BURN HAZARD: Labels may be on or inside the equipment, for example, a drive or motor, to alert people that surfaces may reach dangerous temperatures.



ARC FLASH HAZARD: Labels may be on or inside the equipment, for example, a motor control center, to alert people to potential Arc Flash. Arc Flash will cause severe injury or death. Wear proper Personal Protective Equipment (PPE). Follow ALL Regulatory requirements for safe work practices and for Personal Protective Equipment (PPE).

General Safety Information

Contact Rockwell Automation to learn more about our safety risk assessment services.

IMPORTANT This application example is for advanced users and assumes that you are trained and experienced in safety system requirements.



ATTENTION: Perform a risk assessment to make sure that all task and hazard combinations have been identified and addressed. The risk assessment can require additional circuitry to reduce the risk to a tolerable level. Safety circuits must consider safety distance calculations, which are not part of the scope of this document.

Safety Distance Calculations



ATTENTION: While safety distance or access time calculations are beyond the scope of this document, compliant safety circuits must often consider a safety distance or access time calculation.

Non-separating safeguards provide no physical barrier to prevent access to a hazard. Publications that offer guidance for calculating compliant safety distances for safety systems that use non-separating safeguards, such as light curtains, scanners, two-hand controls, or safety mats, include the following:

EN ISO 13855:2010 (Safety of Machinery – Positioning of safeguards with respect to the approach speeds of parts of the human body)

EN ISO 13857:2008 (Safety of Machinery – Safety distances to prevent hazardous zones being reached by upper and lower limbs)

ANSI B11:19 2010 (Machines – Performance Criteria for Safeguarding)

Separating safeguards monitor a moveable, physical barrier that guards access to a hazard. Publications that offer guidance for calculating compliant access times for safety systems that use separating safeguards, such as gates with limit switches or interlocks (including SensaGuard™ switches), include the following:

EN ISO 14119:2013 (Safety of Machinery – Interlocking devices associated with guards - Principles for design and selection)

EN ISO 13855:2010 (Safety of Machinery – Positioning of safeguards with respect to the approach speeds of parts of the human body)

EN ISO 13857:2008 (Safety of Machinery – Safety distances to prevent hazardous zones being reached by upper and lower limbs)

ANSI B11:19 2010 (Machines – Performance Criteria for Safeguarding)

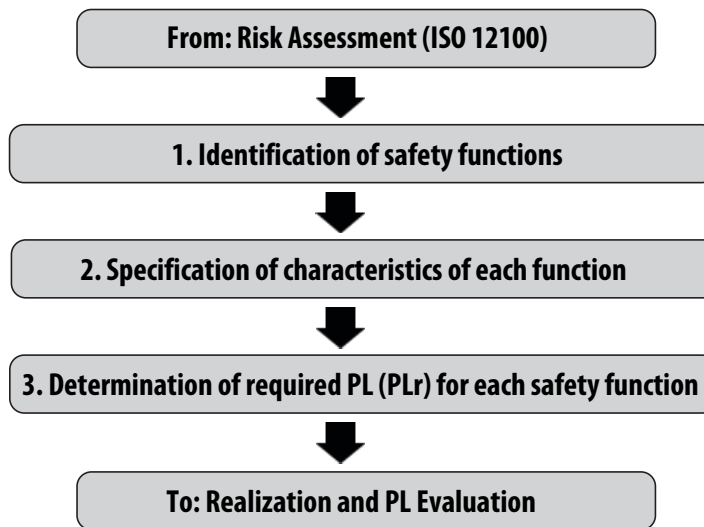
In addition, consult relevant national or local safety standards to assure compliance.

Introduction

This safety function application technique explains how to wire and configure an E-stop as an input device, a Guardmaster® compatibility input (GSR CI) safety relay as the logic/control device, and a pneumatic safety valve as the output device to create an integrated safety system.

Safety Function Realization: Risk Assessment

The required performance level is the result of a risk assessment and refers to the amount of the risk reduction to be conducted by the safety-related parts of the control system. Part of the risk reduction process is to determine the safety functions of the machine. In this application, the performance level required (PLr) by the risk assessment is Category 3, Performance Level d (CAT. 3, PLd), for each safety function. A safety system that achieves CAT. 3, PLd, or higher, can be considered control reliable. Each safety product has its own rating and can be combined to create a safety function that meets or exceeds the PLr.



Pneumatic Safety Valves Safety Function

This application technique includes one safety function: an E-stop function that results in the removal of air pressure from the pneumatic system when the safety system detects that the E-stop has been actuated.

Safety Function Requirements

Pressing the E-stop button stops and prevents hazardous motion by removing power to the coils of the safety valves. The pneumatic valves isolate air pressure and result in a Stop Category 0. When the E-stop is released, the power to the contacts of the valves does not restore pneumatic pressure until a secondary action occurs (the Reset button of the GSR CI is pressed and released). Faults at the wiring terminals or safety relay are detected before the next safety demand. The DM² safety valve from ROSS Controls is PLe-rated with self-monitoring.

The safety function in this application technique meets or exceeds the requirements for Category 3, Performance Level d (CAT. 3, PLd), per ISO 13849-1 and control reliable operation per ANSI B11.19.

Functional Safety Description

The pulsed-test output signals of the Guardmaster safety relay (terminals S11 and S21) are run separately through the two E-stop contacts to the input terminals S12 and S22, respectively. When the E-stop is pressed, these two circuits are interrupted. The GSR CI responds to this circuit interruption by opening its safety output contacts (13...14, 23...24, and 33...34), which de-energizes pilot solenoids A and B of the valve. The auxiliary contacts (41...42) close. The removal of power from the solenoids of the pneumatic valves results in the isolation of air pressure, which creates a stop (Stop Category 0). Hazardous motion cannot be started until the E-stop is released and the Reset button is pressed and released.

Bill of Material

This application technique uses these products.

Cat. No.	Description	Quantity
800FM-G611MX10	800F reset push button, metal, guarded, blue, R, metal latch mount, one normally-open contact, standard	1
800FM-MT44MX02	800F non-illuminated mushroom operators, twist-to-release, 40 mm (1.58 in.), round metal (type 4/13, IP66), red, metal latch mount, no normally-open contacts, two normally-closed contacts, standard, standard pack	1
800F-15YSE112	800F legend plate, 60 mm (2.36 in.) round, universal, E-stop, yellow with black legend text, 22.5 mm (. 89 in.) opening	1
440R-S13R2	Guardmaster safety relay, one dual-channel universal input, one normally-closed auxiliary output	1
DM2CNAxxA21	DM2 series pneumatic safety valve – Contact ROSS Controls for proper valve sizing and a specific part number	1

Setup and Wiring

For detailed information on how to install and wire, refer to the publications listed in the [Additional Resources](#).

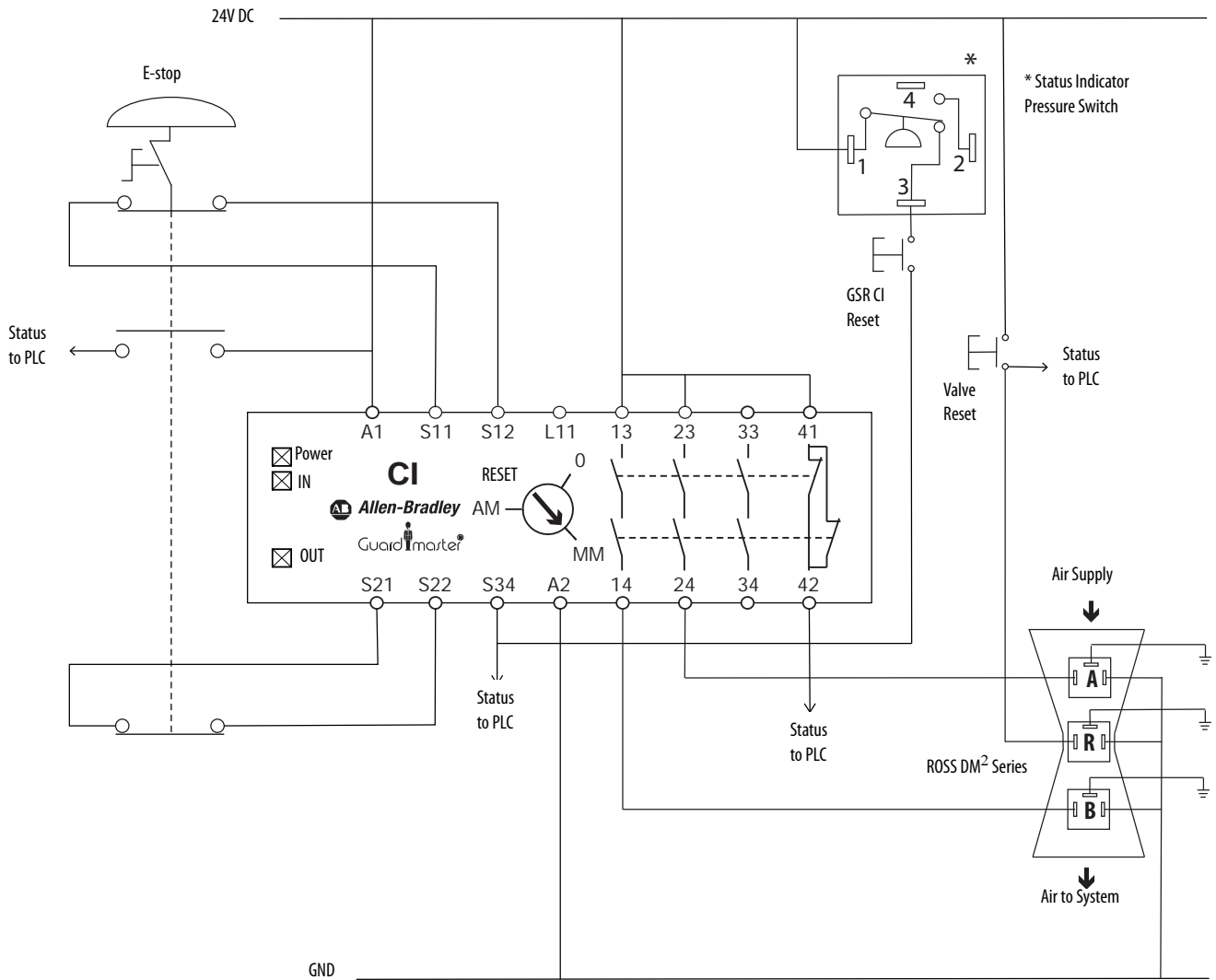
System Overview

The pulsed-test signals of the GSR CI (terminals S11 and S21) are run separately through the two E-stop contacts to the input terminals S12 and S22, respectively. This configuration enables the GSR CI to detect loose wire, contact failed closed, short to 24V, short to ground, and cross-channel faults. The GSR CI responds to faults by opening its safety contacts (13...14, 23...24, and 33...34), which de-energizes pilot solenoids A and B. The GSR CI cannot be reset until the fault is corrected. After a loose wire or contact failed closed fault, the GSR CI can be reset once the E-stop has been pressed and released. After a short to 24V, short to ground, or cross-channel fault, the GSR CI must be power-cycled before it can be reset.

The GSR CI monitors itself for any internal faults. When a fault is detected, the GSR CI responds by opening its safety contacts (13...14, 23...24, and 33...34), which de-energizes pilot solenoids A and B. Some internal faults can be cleared by power-cycling the GSR CI. In other cases, the GSR CI must be replaced.

The safety valve is a self-monitoring device rated up to Performance Level e. It has two pilot solenoid channels (A and B) and a manual reset function. It need not be monitored by the GSR CI.

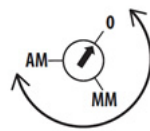
Electrical Schematic



Configuration

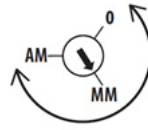
The following procedure sets the function of the device.

1. To start the configuration and overwrite, with power off, turn the rotary switch to position 0.



The unit powers up. After the power-up test, the PWR status indicator flashes red.

- To set the configuration, turn the rotary switch to the desired position.

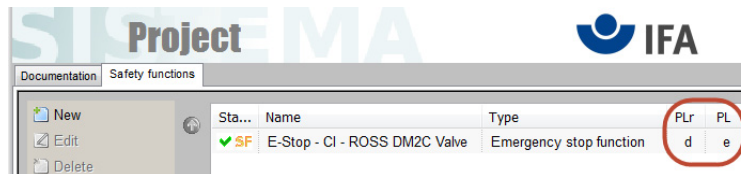


The IN1 status indicator blinks the new setting. The position is set when the PWR status indicator is solid green.

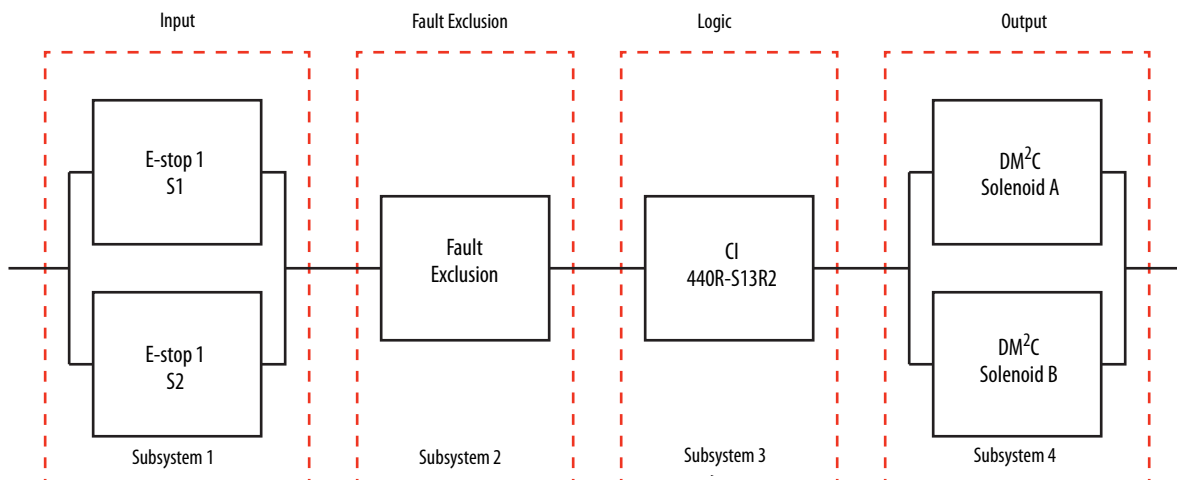
- Lock-in the configuration by cycling power to the unit.
- Confirm the configuration before operation.
- Record the unit setting in the white space on the face of the device.

Calculation of the Performance Level

When properly implemented, the safety function of this safety system provides a method of isolation of hazardous energy in the guarded area, when the emergency stop is actuated, by de-energizing the two solenoids of the DM² safety valve. The safety system can achieve a safety rating of Category 4, Performance Level e (CAT. 4, PL_e), according to ISO 13849-1: 2015, as calculated by using the Safety Integrity Software Tool for the Evaluation of Machine Applications (SISTEMA). SISTEMA is a software tool that is used to validate that the safety functions in a project can, when properly installed, implemented, and operated, achieve the Performance Level required; the PL_r.



The E-stop safety function can be modeled as shown in the diagram.



The SISTEMA results for the E-stop safety function are shown in the graphic.

Sta...	Name	PL	PFH [1/h]	CCF score	DCavg [%]	MTTFd [a]	Category	Requirements of the category
✓ SB	E-Stop	e	2.47E-8	65 (fulfilled)	99 (High)	100 (High)	4	fulfilled
✓ SB	Fault Exclusion	e	0	not relevant	not relevant	not relevant	4	fulfilled
✓ SB	Monitoring Safety Relay: GSR-CI	e	6.75E-9	not relevant	not relevant	not relevant	4	fulfilled
✓ SB	ROSS DM2C Valve	e	7.7E-9	not relevant	not relevant	not relevant	4	fulfilled

Because the E-stop is an electromechanical device, certain data must be considered, including the following:

- Mean Time to Failure, dangerous (MTTFd)
- Diagnostic Coverage (DCavg)
- Common Cause Failure (CCF)

The functional safety evaluations of electromechanical devices include the following:

- How frequently they are operated (MTTFd)
- Whether they are effectively monitored for faults (DCavg)
- Whether they are properly specified and installed (CCF)

Additionally, because the E-stop is an electromechanical device where one mechanical actuator controls two channels, a fault exclusion must be considered when calculating the safety ratings. A fault exclusion subsystem is added to SISTEMA to reflect this arrangement.

EN-ISO 13849-2:2012, Annex D, allows a fault exclusion for mechanical aspects (in this case one actuator operating two channels) of emergency stop devices in accordance with IEC 60947-5-5. The estimated maximum number of E-stop operations (8760 per year) is frequent, but not excessive. Thus, the fault exclusion itself has no effect on the category or performance level that is achieved by the E-stop safety function, yet it must be included. To achieve these values in the SISTEMA project, the category and performance level of the fault exclusion subsystem were manually entered as Category 4 and Performance Level e, the highest levels of the other subsystems in the safety function.

SISTEMA calculates the MTTFd by using B10d data provided in the Rockwell Automation SISTEMA library for the E-stops, along with the estimated frequency of use, entered during the creation of the SISTEMA project. This example presumes that the E-stop is operated or tested once an hour, 365 days a year, for a total of 8760 times a year.

The GSR CI provides the diagnostic coverage for the two E-stop channels.

The DCavg (99%) is taken from ISO 13849-1:2006, Table E.1. "Cross monitoring of input signals and intermediate results within the logic..." and from the installation instructions of the safety relay.

The functional safety data for the DM²C safety solenoid valve is taken from the product literature and is entered directly into DM²C subsystem of the SISTEMA safety functions.

PL = PL_e

PFH = 7.7E-9

CAT. = CAT. 4

The measures against Common Cause Failure (CCF) are calculated by using the scoring process outlined in Annex F of ISO 13849-1. For the PL calculation, the required score of 65, required to fulfill the CCF requirement, is entered directly. The complete CCF scoring process must be done when implementing an actual safety system.

Verification and Validation Plan

Verification and validation play important roles in the avoidance of faults throughout the safety system design and development process. ISO 13849-2 sets the requirements for verification and validation. The standard calls for a documented plan to confirm that all safety functional requirements have been met.

Verification is an analysis of the resulting safety control system. The Performance Level (PL) of the safety control system is calculated to confirm that the system meets the required Performance Level (PL_r) specified. The SISTEMA software is typically used to perform the calculations and satisfy the requirements of ISO 13849-1.

Validation is a functional test of the safety control system to demonstrate that the system meets the specified requirements of the safety function. The safety control system is tested to confirm that all safety-related outputs respond appropriately to their corresponding safety-related inputs. The functional test includes normal operating conditions and potential fault injection of failure modes. A checklist is typically used to document the validation of the safety control system.

Before validating the system, confirm that the Guardmaster safety relay has been wired and configured in accordance with the installation instructions.

Verification and Validation Checklist

General Machinery Information			
Machine Name/Model Number			
Machine Serial Number			
Customer Name			
Test Date			
Tester Name			
Schematic Drawing Number			
E-stop	800FM-MT44MX02		
Safety Relay	440R-S13R2		
Pneumatic Safety Valve	DM ² Series		
Safety Wiring and Relay Configuration Verification			
Test Step	Verification	Pass/Fail	Changes/Modifications
1	Visually inspect the safety-relay circuit to verify that it is wired as documented in the schematics.		
2	Visually inspect the configuration switch of the safety relay to verify that the settings are correct as documented.		
Normal Operation Verification - The safety system responds properly to all normal E-stop and Reset inputs.			
Test Step	Verification	Pass/Fail	Changes/Modifications
1	Confirm that the safety system is not powered.		
2	Confirm that the E-stop button is released.		
3	Confirm that the air system is not pressurized.		
4	Apply power to the safety system.		

Verification and Validation Checklist

5	Confirm that the GSR CI does not reset when power is applied.		
6	Confirm that the air system does not pressurize when power is applied.		
7	Confirm that the PWR/Fault and IN status indicators of the GSR CI are green.		
8	Confirm that the OUT status indicator of the GSR CI blinks green.		
9	Press and release the Reset button of the GSR CI. The OUT status indicator of the GSR CI turns ON steady green. The air system pressurizes.		
10	Press the E-stop button. The safety system trips, and the air system de-pressurizes. The IN and OUT status indicators turn OFF.		
11	While the E-stop button is pressed, press and release the Reset button of the GSR CI. The IN and OUT status indicators of the GSR CI remain OFF. The air system remains de-pressurized.		
12	Release the E-stop button. The IN status indicator turns and remains ON. The OUT status indicator blinks green.		
13	Press and release the Reset button of the GSR CI. The OUT status indicator of the GSR CI turns ON steady green. The air system pressurizes.		

Validation of Safe Response to Abnormal Operation - The safety system responds properly to all foreseeable faults with corresponding diagnostics.

Safety Input E-stop Tests

Test Step	Verification and Validation	Pass/Fail	Changes/Modifications
1	While the air system is pressurized, remove the E-stop input wire at terminal S12 of the GSR CI. The GSR CI immediately trips and de-energizes the solenoids of the safety valve. The air system de-pressurizes. The IN and OUT status indicators are OFF.		
2	Reconnect the wire to S12. The GSR CI does not respond. Press and release the Reset button of the GSR CI. The GSR CI does not respond.		
3	Cycle the E-stop button. The IN status indicator is ON and the OUT status indicator is blinking. Press and release the Reset button of the GSR CI. The GSR CI resets. The safety valve energizes and the air system pressurizes. The OUT status indicator is ON steady.		
4	While the air system is pressurized, jump the E-stop input wire at terminal S11 to terminal S12 of the GSR CI. The GSR CI does not respond.		
5	Press the E-stop button. The GSR CI immediately trips. The air system de-pressurizes. The IN status indicator and OUT status indicators turn OFF.		
6	Release the E-stop button. Press and release the Reset button of the GSR CI. The GSR CI does not respond.		
7	Remove the jumper from S11 to S12. Cycle the E-stop button. The IN status indicator is ON and the OUT status indicator blinks. Press and release the Reset button of the GSR CI. The air system pressurizes. The OUT status indicator is ON steady.		
8	Repeat steps 1...7 to test E-stop channel 2. Use S21 in place of S11 and S22 in place of S12.		
9	Briefly short the E-stop input wire at terminal S12 of the GSR CI to 24V DC. The GSR CI immediately trips. The air system de-pressurizes. The PWR/Fault status indicator is steady red. All other status indicators are OFF.		
10	Press and release the Reset button of the GSR CI. The GSR CI does not respond.		
11	Cycle power to the GSR CI. Confirm that the PWR/Fault and IN status indicators of the GSR CI are green. Confirm that the OUT status indicator blinks green. Press and release the Reset button of the GSR CI. The air system pressurizes. The OUT status indicator turns steady green.		
12	Briefly short the E-stop input wire at terminal S12 of the GSR CI to 0V DC. The GSR CI immediately trips. The air system de-pressurizes. The PWR/Fault status indicator is steady red. All other status indicators are OFF.		
13	Press and release the Reset button of the GSR CI. The GSR CI does not respond.		

Verification and Validation Checklist

14	Cycle power to the GSR CI. Confirm that the PWR/Fault and IN status indicators of the GSR CI are green. Confirm that the OUT status indicator blinks green. Press and release the Reset button of the GSR CI. The air system pressurizes. The OUT status indicator turns steady green.		
15	Repeat steps 9... 14 to test E-stop channel 2. Use S21 in place of S11 and S22 in place of S12.		
16	Briefly short terminal S12 to terminal S22 of the GSR CI. The GSR CI immediately trips. The air system de-pressurizes. The PWR/Fault status indicator is steady red. All other status indicators are OFF.		
17	Press and release the Reset button of the GSR CI. The GSR CI does not respond.		
18	Cycle power to the GSR CI. Confirm that the PWR/Fault and IN status indicators of the GSR CI are green. Confirm that the OUT status indicator blinks green. Press and release the Reset button of the GSR CI. The air system pressurizes. The OUT status indicator turns steady green.		
Validation of Safe Response to Abnormal Operation - The safety system responds properly to all foreseeable faults with corresponding diagnostics.			
Safety Logic, GSR CI Tests			
Test Step	Validation	Pass/Fail	Changes/Modifications
1	While the air system is pressurized, turn the reset rotary switch on the safety relay from the proper MM to AM position. The air system remains pressurized. The PWR/Fault status indicator blinks red/green twice, then remains green and repeats.		
2	Press and release the E-stop button. The system trips and the air system de-pressurizes. The PWR/Fault status indicator blinks red/green twice, then remains green and repeats. The OUT status indicator blinks and requests a Reset.		
3	Press and release the Reset button of the GSR CI. The air system pressurizes. The OUT status indicator turns steady green, which indicates that the GSR CI has reset. The PWR/Fault status indicator continues to blink red/green twice, then remains green and repeats.		
4	Set the rotary switch back to MM. After a moment, the PWR/Fault status indicator turns steady green.		
Validation of Safe Response to Abnormal Operation - The safety system responds properly to all foreseeable faults with corresponding diagnostics.			
Safety Output, Safety Valve Tests			
Test Step	Verification and Validation	Pass/Fail	Changes/Modifications
1	Power up the safety system. Confirm that the E-stop button is released. Press and release the Reset button of the GSR CI to start/reset the GSR CI. The air system pressurizes.		
2	While the air system is pressurized, remove the wire from terminal 14 of the GSR CI. The GSR CI does not trip. The air system de-pressurizes.		
3	Reconnect the wire to terminal 14. The air system does not pressurize. Press and release the Reset button of the valve. The air system does not pressurize.		
4	Press the E-stop button. The GSR CI trips. The IN and OUT status indicators are OFF. Press and release the Reset button of the valve.		
5	Release the E-stop button. Press and release the Reset button of the GSR CI. The GSR CI resets. The air system pressurizes. The IN and OUT status indicators are ON.		
6	Repeat steps 2... 5 by using terminal 24 in place of terminal 14.		

Additional Resources

These documents contain more information about related products from Rockwell Automation.

Resource	Description
Guardmaster Safety Relay CI Installation Instructions, publication 440R-IN046	Provides guidance on how to install, commission, operate, and maintain a Guardmaster Safety Relay CI.
SAFEBOOK 4: Safety related control systems for machinery, publication SAFEBK-RM002	Describes the principles and standards that are used to implement a safety control system for machinery.
Safety in numbers: A 7-step guide to functional safety, publication SAFETY-QR008	Provides information on how to implement functional safety in the process industry.
Safety in numbers: The 6 Essentials of Hazard and Operability Studies, publication SAFETY-QR009	Describes the importance of using Hazard and Operability (HAZOP) studies to achieve compliant levels of functional safety.
Industrial Automation Wiring and Grounding Guidelines, publication 1770-4.1	Provides general guidelines on how to install a Rockwell Automation® industrial system.
Safety Products Catalog, publication S117-CA001 Website http://www.rockwellautomation.com/rockwellautomation/catalogs/overview.page	Provides information about Rockwell Automation® safety products.
Safety Automation Builder website, http://www.marketing.rockwellautomation.com/safety-solutions/en/MachineSafety/ToolsAndDownloads/Safety_Automation_Builder?link=SubDownload&source=config	Provides tools that help users build a safety system that is based on a risk assessment and SISTEMA software.
Product Certifications website, http://www.rockwellautomation.com/global/certification/overview.page	Provides declarations of conformity, certificates, and other certification details.
ROSS Controls website, http://www.rosscontrols.com	Provides information about the products and services that are offered by ROSS Controls, along with details about the industries and applications in which the products are used. Also provides access to product support and literature.

You can view or download publications at <http://www.rockwellautomation.com/literature/>. To order paper copies of technical documentation, contact your local Allen-Bradley distributor or Rockwell Automation sales representative.

Notes:

Rockwell Automation Support

Use the following resources to access support information.

Technical Support Center	Knowledgebase Articles, How-to Videos, FAQs, Chat, User Forums, and Product Notification Updates.	www.rockwellautomation.com/knowledgebase
Local Technical Support Phone Numbers	Locate the phone number for your country.	www.rockwellautomation.com/global/support/get-support-now.page
Direct Dial Codes	Find the Direct Dial Code for your product. Use the code to route your call directly to a technical support engineer.	www.rockwellautomation.com/global/support/direct-dial.page
Literature Library	Installation Instructions, Manuals, Brochures, and Technical Data.	www.rockwellautomation.com/literature
Product Compatibility and Download Center (PCDC)	Get help determining how products interact, check features and capabilities, and find associated firmware.	www.rockwellautomation.com/global/support/pcdc.page

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Your comments will help us serve your documentation needs better. If you have any suggestions on how to improve this document, complete the How Are We Doing? form at http://literature.rockwellautomation.com/idc/groups/literature/documents/du/ra-du002_-en-e.pdf.

For more information on Safety Function Capabilities, visit:

http://marketing.rockwellautomation.com/safety/en/safety_functions

Rockwell Automation maintains current product environmental information on its website at <http://www.rockwellautomation.com/rockwellautomation/about-us/sustainability-ethics/product-environmental-compliance.page>.

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