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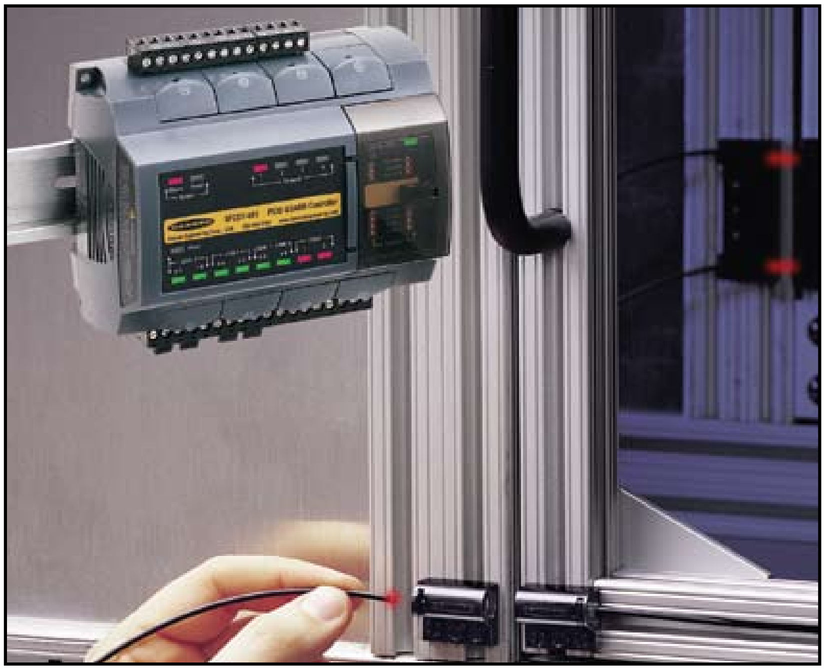
PICO-GUARD™ Application and Design Guide



Section Contents

This manual contains numerous WARNING and CAUTION statements. WARNINGS refer to situations that could lead to significant or serious personal injury or death. CAUTIONS refer to situations that could lead to slight personal injury or potential damage to equipment.

Table of Contents

Important ...
read this page before proceeding!

In the United States, the functions that PICO-GUARD Systems are intended to perform are regulated by the Occupational Safety and Health Administration (OSHA). Outside of the United States, these functions are regulated by other agencies, organizations, and governments. Whether or not any particular PICO-GUARD System installation meets all applicable requirements depends upon factors that are beyond the control of Banner Engineering Corp. These factors include the details of how the PICO-GUARD System is applied, installed, wired, operated, and maintained. **It is the responsibility of the purchaser and user to apply this PICO-GUARD System in full compliance with all relevant applicable regulations and standards.**

PICO-GUARD Systems can guard against accidents only when they are properly installed and integrated into the machine, properly operated, and properly maintained. Banner Engineering Corp. has attempted to provide complete application, installation, operation, and maintenance instructions. In addition, we suggest that any questions regarding application or use of PICO-GUARD Systems be directed to the factory applications department at the telephone number or addresses shown on the back cover.

In addition to OSHA regulations, several other organizations provide information about the use of safeguarding devices. Refer to the American National Standards Institute (ANSI), the Robotics Industries Association (RIA), the Association for Manufacturing Technology (AMT), and others. Banner Engineering Corp. makes no claim regarding a specific recommendation of any organization, the accuracy or effectiveness of any information provided, or the appropriateness of the provided information for a specific application. See Inside Back Cover for information pertaining to applicable U.S., European, and International standards and where to acquire copies.

The user has the responsibility to ensure that all local, state, and national laws, rules, codes, and regulations relating to the use of this safeguarding system in any particular application are satisfied. Extreme care is urged to ensure that all legal requirements have been met and that all installation and maintenance instructions contained in this manual are followed.

U.S. Standards Applicable to Use of PICO-GUARD Systems

ANSI B11 Standards	***Safeguarding of Machine Tools***
ANSI/RIA R15.06	***Safety Requirements for Robot Systems***
ANSI NFPA 79	***Electrical Standard for Industrial Machinery***

See Inside Back Cover for information on these and other applicable standards, and where to acquire copies.

1. PICO-GUARD System Overview

Foreword

The PICO-GUARD Application and Design Guide, in combination with the controller manual and the optical element data sheets, is intended to provide complete application, installation, operation, and maintenance instructions.

The format of this guide is to provide a quick reference to sections that apply to a particular application. The user must review and be familiar with all sections that may apply to their particular situation.

The application examples contained in Appendix A are general in nature. Every guarding application has a unique set of requirements. Extreme care is urged to ensure that all legal requirements are met and that all installation instructions are followed. In addition, any questions regarding application or use of PICO-GUARD Systems should be directed to the factory applications department at the telephone number or addresses shown on the back cover.

This manual contains numerous WARNING and CAUTION statements. WARNINGS refer to situations that could lead to significant or serious personal injury or death. CAUTIONS refer to situations that could lead to slight personal injury or potential damage to equipment.

1.1 Description

The Banner PICO-GUARD fiber optic safety system is a patented* diverse-redundant microprocessor-controlled optoelectronic guarding system. This system consists of a controller, flexible optical fiber, protective sheathing, and optical elements (fiber optic interlock switches, beams, and grids). The system can be used with various combinations of optical elements using the independent optical channels.

The controller also has electrically-based Universal Safety Stop Interface inputs that can connect to other safeguards, process controls, or actuators. Regardless of the combination of optical elements and external safeguards used, when the system detects an interruption of an optical path or receives a safety stop request, it will provide a stop signal to the machine control circuit. The machine control circuit then reacts to protect personnel from hazards, or to protect equipment, critical tooling, or critical materials in process.

* U.S. Patent No. 20030215172

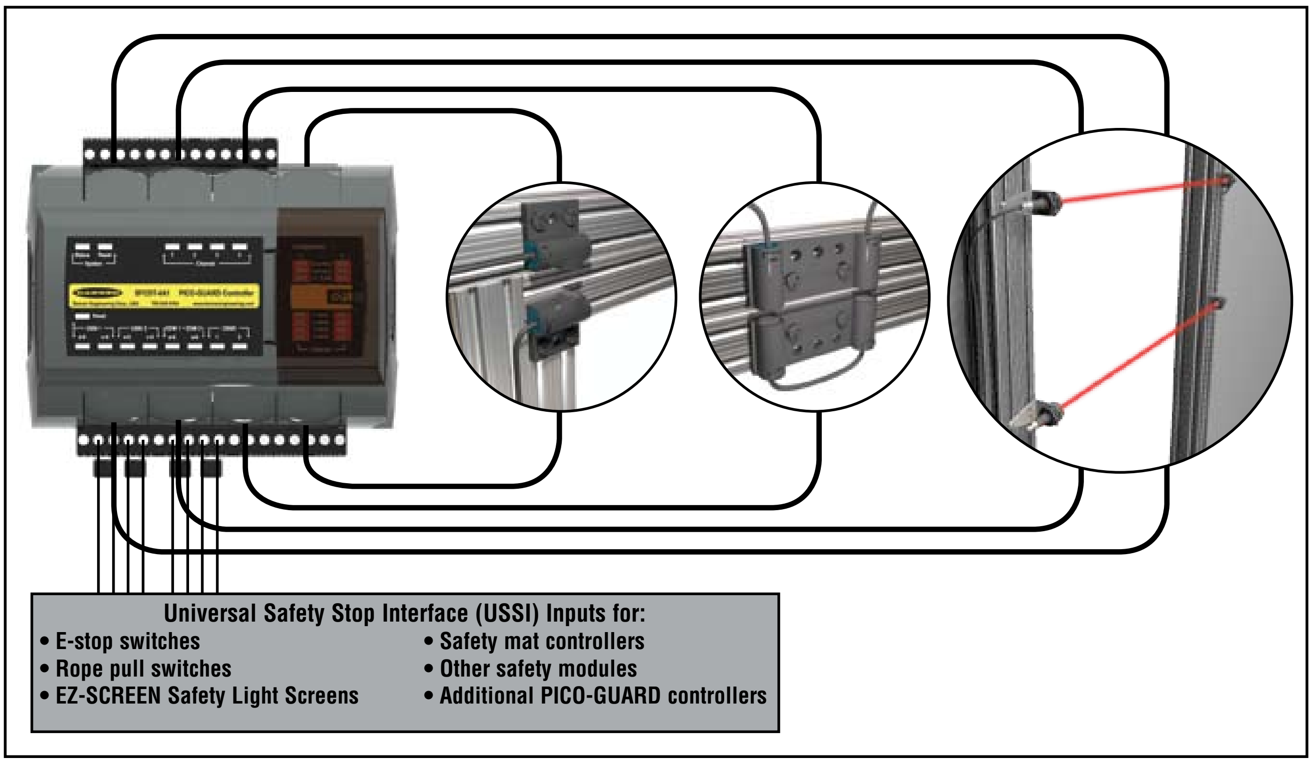


Figure 1-1. PICO-GUARD System Overview

The controller has two solid-state diverse-redundant safety outputs (OSSDs) to control 24V dc loads. If an ac-powered MPCE or other load is required, an accessory interface module may be used to convert the PICO-GUARD outputs to isolated, forced-guided relay contacts (e.g., model IM-T-9A or IM-T-11A; see Section 1.3.3 for more information).

The optical elements (such as fiber optic safety interlock switches or fiber optic safety points) are available in a variety of configurations to allow easy installation and proper operation on a variety of doors and other hard guarding applications.

Each optical element can be used as either an emitter or a receiver; optical elements have no electrical connection. This can greatly reduce the required inventory and simplifies installation.

Plastic fibers are available in three versions: solid-core fiber, solid-core fiber with integral fluoropolymer sheathing and solid-core fiber with integral PVC sheathing (see Section 1.3.2).

Removable terminals simplify the wiring process. See Section 2 and the controller manual for electrical connection instructions.

1.1.1 Applications and Limitations

The Banner PICO-GUARD fiber optic safety system is intended to be used in a variety of safeguarding applications.

For appropriate applications and complete installation information, please refer to the individual sections contained within this Guide, the PICO-GUARD Controller Manual, the data sheets of the individual PICO-GUARD optical elements and manuals regarding any external safeguarding device interfaced with the PICO-GUARD system. The user must determine whether the use of a particular safeguard or the Banner PICO-GUARD fiber optic safety system is allowed.

Generally, use of the Banner PICO-GUARD System is not allowed:

- On machinery that has inadequate or inconsistent machine response time and stopping performance, or
- On machinery with long or excessive stopping times without monitored guard-locking mechanism, or
- To guard any machine that ejects materials or component parts in such a manner that the material or component parts are not contained and are considered to be a hazard, or
- In any environment that is likely to adversely affect photoelectric sensing system efficiency. For example, corrosive chemicals or fluids or unusually severe levels of smoke or dust, if not controlled, may degrade the efficiency or effectiveness of the safeguarding function.

1.2 PICO-GUARD Controller Operating Features

The Banner PICO-GUARD Model SFCDT-4A1.. Controller features several selectable functions: manual or auto power-up, trip or latch output, external device monitoring (EDM), and optical channel controls. In addition, the controller's status indicators provide quick, clear, ongoing indication of system status and operation. Please refer to the PICO-GUARD Controller manual for complete information.

Auto/Manual Power-Up
The setting for Auto or Manual power-up determines whether the System will require a manual reset to proceed to normal operation when power is applied to the system.

Selectable Trip/Latch Output
The setting for Trip or Latch output determines whether the System will require a manual reset to turn the OSSD outputs on after a blocked optical channel condition has occurred. If the system is set for trip output, other measures must be taken to prevent a pass-through hazard.

External Device Monitoring (EDM)
This feature allows the System to monitor the status of external devices, such as MPCEs. The choices are One- or Two-Channel Monitoring, or No Monitoring. EDM is used when the System OSSD outputs directly control the energizing and de-energizing of the MPCEs or other external devices.

Optical Channel Controls
DIP switches for two optical channels can be set for Enable or Disable for system operation in applications that require less than four operating optical channels.

Controller model SFCDT-4A1C has four non-safety channel outputs – one for each optical channel.

Status Indicators
Status indicators on the front of the controller continuously show the status and operating conditions of the system. Indicators are provided for System Status, System Reset, Optical Channels 1 and 3, Mute Enable, Muting Sensor inputs, EDM inputs, and OSSD 1 and OSSD 2 outputs. There is also a configuration indicator to indicate a valid system configuration setting.

In addition to the controller status indicators, an optional remote display unit is available to provide the same ongoing status information at additional locations. (See Accessories, Section 1.3.3.)

1.3 PICO-GUARD System Components

Each PICO-GUARD Fiber Optic Safety System requires a controller, optical fiber, and one or more pairs of optical elements. Controllers include the controller instruction manual, the application and design guide (this document), and controller mounting hardware. See the Banner Engineering Machine Safety Catalog or www.bannerengineering.com for available optical elements.

See Section 6 for information about Fiber Optic Safety Interlock Switches.

See Section 7 for information about Fiber Optic Safety Point and Grid elements.

See Section 8 for information about Fiber Optic Emergency Stop Button elements.

1.3.1 Controller

4-channel PICO-GUARD controller	**SFCDT-4A1**
4-channel PICO-GUARD controller with optical channel outputs	**SFCDT-4A1C**
4-channel PICO-GUARD controller with muting function	**SFCDT-4A1CM1**

All controller models have four discrete optical channels. Model SFCDT-4A1C features a dedicated non-safety output for each optical channel, to simplify use and troubleshooting. Model SFCDT-4A1CM1 features an integral muting function; refer to data sheet p/n 122801 for more information.

1.3.2 Plastic Optical Fiber

Plastic optical fiber for use with Banner PICO-GUARD optical elements is available in bulk form (to be cut to length in the field) or precut lengths with polished ends for maximum excess gain. Both are available in three styles: standard polyethylene jacketed solid-core plastic fiber for most applications; polyethylene jacketed solid-core plastic fiber with a PVC sheath to withstand mechanical abrasion or harsh duty; and polyethylene jacketed solid-core plastic fiber with fluoropolymer sheathing to withstand harsh chemicals or gases. Accessory sheathing is also available to provide additional protection for any of these fibers. A fiber cutter (for bulk fiber) is shipped with each PICO-GUARD controller.

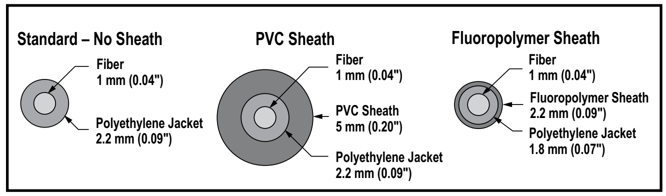


Figure 1-2. Plastic optical fiber cross-section dimensions

Length		Standard Polyethylene Jacket	PVC Sheath	Fluoropolymer Sheath
Bulk Fiber				
9 m	(30')	**PIU430U**	**PIU430UXP**	**PIU430UXT**
18 m	(60')	**PIU460U**	**PIU460UXP**	**PIU460UXT**
30.5 m	(100')	**PIU4100U**	**PIU4100UXP**	**PIU4100UXT**
61 m	(200')	**PIU4200U**	**PIU4200UXP**	**PIU4200UXT**
100.5 m	(330')	**PIU4330U**	**PIU4330UXP**	**PIU4330UXT**
152.5 m	(500')	**PIU4500U**	**PIU4500UXP**	**PIU4500UXT**
488 m	(1600')	**PIU41600U**	**PIU41600UXP**	**PIU41600UXT**
Cut Lengths With Polished Ends				
0.3 m	(1')	**PWS43P**	**PWXP43P**	**PWXT43P**
0.5 m	(1.6')	**PWS45P**	**PWXP45P**	**PWXT45P**
0.7 m	(2.3')	**PWS47P**	**PWXP47P**	**PWXT47P**
1 m	(3.3')	**PWS410P**	**PWXP410P**	**PWXT410P**
1.5 m	(4.9')	**PWS415P**	**PWXP415P**	**PWXT415P**
2 m	(6.5')	**PWS420P**	**PWXP420P**	**PWXT420P**
2.5 m	(8.2')	**PWS425P**	**PWXP425P**	**PWXT425P**
3 m	(9.8')	**PWS430P**	**PWXP430P**	**PWXT430P**
3.5 m	(11.5')	**PWS435P**	**PWXP435P**	**PWXT435P**
4 m	(13.1')	**PWS440P**	**PWXP440P**	**PWXT440P**
4.5 m	(14.7')	**PWS445P**	**PWXP445P**	**PWXT445P**
5 m	(16.4')	**PWS450P**	**PWXP450P**	**PWXT450P**
6 m	(19.7')	**PWS460P**	**PWXP460P**	**PWXT460P**
7 m	(23.0')	**PWS470P**	**PWXP470P**	**PWXT470P**
8 m	(26.2')	**PWS480P**	**PWXP480P**	**PWXT480P**
9 m	(29.5')	**PWS490P**	**PWXP490P**	**PWXT490P**
10 m	(32.8')	**PWS4100P**	**PWXP4100P**	**PWXT4100P**
11 m	(36')	**PWS4110P**	**PWXP4110P**	**PWXT4110P**
12 m	(39.4')	**PWS4120P**	**PWXP4120P**	**PWXT4120P**
13 m	(42.6')	**PWS4130P**	**PWXP4130P**	**PWXT4130P**
14 m	(46')	**PWS4140P**	**PWXP4140P**	**PWXT4140P**
15 m	(49.2')	**PWS4150P**	**PWXP4150P**	**PWXT4150P**
20 m	(65.6')	**PWS4200P**	**PWXP4200P**	**PWXT4200P**
25 m	(82')	**PWS4250P**	**PWXT4250P**	**PWXT4250P**
30 m	(98.4')	**PWS4300P**	**PWXP4300P**	**PWXT4300P**

1.3.3 Accessories

See Sections 6 and 7 for information about available optical element models and accessories.

SFA-FA	In-line signal attenuator
SFA-FS	Fiber splice
SFA-RD	Remote display
PFC-2-25	Bag of 25 PFC-2 plastic optical fiber cutters
FS64P100	Black PVC sheathing, 100'
MGA-KSO-1	SPST keyed reset switch
IM-T-9A	Interface module (3 N/O redundant-output contacts)
IM-T-11A	Interface module (2 N/O redundant-output contacts plus 1 N/C auxiliary contact)
11-BG00-31-D-024 (see Note below)	10 amp positive-guided contactor 3 N/O, 1 N/C*
11-BF16C01-024 (see Note below)	16 amp positive-guided contactor 3 N/O, 1 N/C*
SFA-FFP	Field Fiber Polishing Kit; see data sheet p/n 128868 for information

*** NOTE: If used, two contactors are required per controller. See Controller manual, Figures 3-7 and 3-10.**

1.3.4 Replacement Parts

SFA-CTB1	PICO-GUARD Controller 4-position terminal block
SFA-CTB2	PICO-GUARD Controller 9-position terminal block
SFA-CTB3	PICO-GUARD Controller 18-position terminal block
SFA-CTB4	PICO-GUARD Controller 5-position terminal block
SFA-CMH	PICO-GUARD Controller mounting hardware
SFA-IAG	Interlock switch alignment guide

1.3.5 Literature

69761	PICO-GUARD Controller Manual
69765	Daily Checkout Card
69766	Semi-Annual Checkout Card
69763	PICO-GUARD Application and Design Guide
109963	PICO-GUARD CD with Software Programs

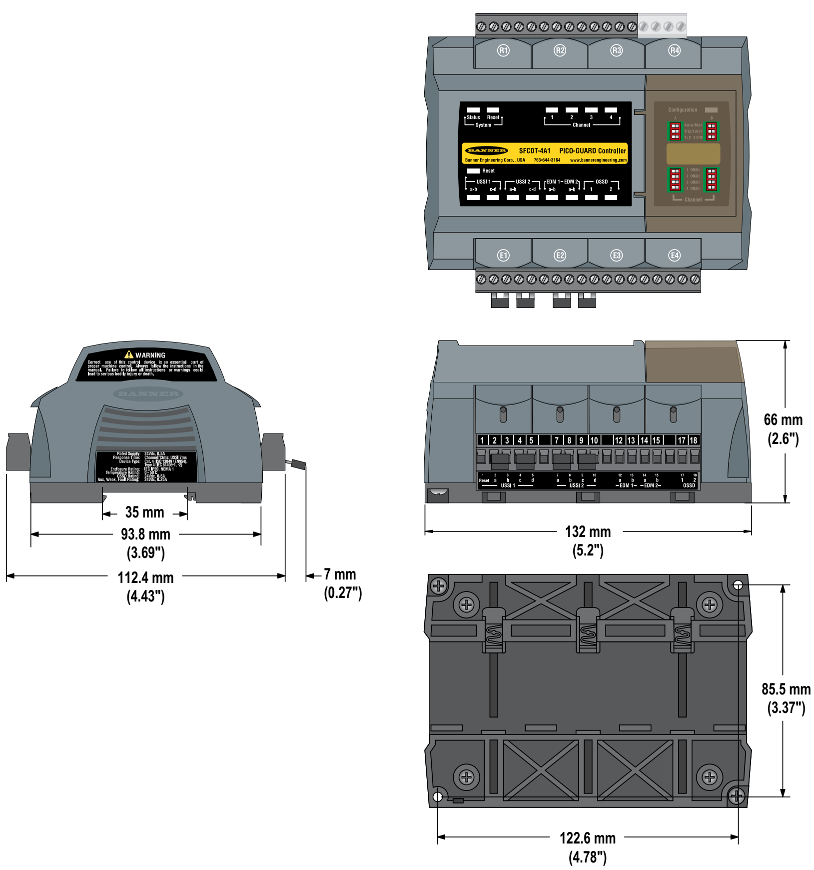


Figure 1-3. Model SFCDT-4A1.. controller dimensions

2. Universal Safety Stop Interface (USSI)

2.1 USSI Description

The PICO-GUARD SFCDT-4A1(C) controller has two USSI inputs: one with a latch function that requires a manual reset after it is cycled, and one with a trip function which automatically resets when the inputs close, satisfying the simultaneity requirement (see Figure 2-1).

The USSI provides for easy integration of safeguards, E-stop buttons, process control, etc. Each interface consists of input channels A and B (terminals a/b and c/d respectively), which are compatible with Banner Engineering safety devices that have solid-state safety OSSD outputs (with "handshake" verification), such as the EZ-SCREEN systems. The USSIs are also compatible with devices that have normally open hard-contacts or relay outputs (voltage-free).

For each USSI, the two input channels (A and B) must meet a simultaneity requirement of 3.0 seconds when closing and opening. A mismatch of greater than 3.0 seconds will result in a lockout. A lockout that is due to a failure to meet simultaneity requirements can be cleared by cycling the USSI inputs (with simultaneity being met) and then performing a manual reset (USSI 1).

The USSI is a redundant two-channel input and can not operate or be interfaced in a one-channel method.

To ensure Safety Category 4 (per ISO 13849-1), the USSI provides a "handshake" with Banner Engineering safety devices with OSSD solid-state safety outputs. This handshake verifies that the interface of the two devices is capable of detecting certain failures that may occur, such as a short-circuit to a secondary source of power or to the other channel, high input resistance, or the loss of signal ground (see Figure 2-2).

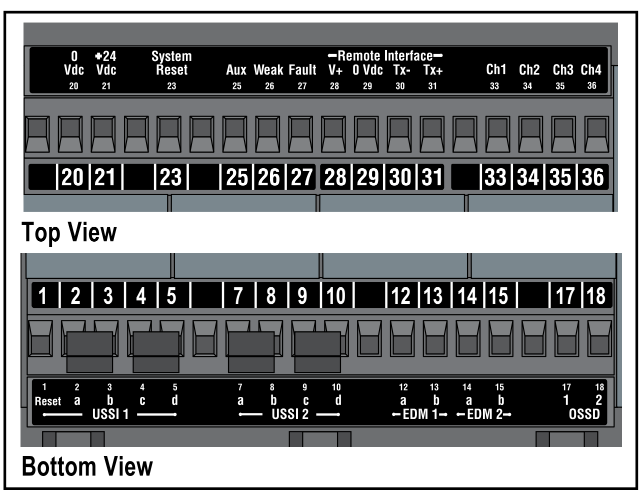


Figure 2-1. Model SFCDT-4A1(C) controller terminal locations

If OSSDs without this handshake capability (i.e., non-Banner Safety devices) are used, either interposing safety relays or interfacing modules must also be used to provide hard contacts and must be wired as shown in Figure 2-3.

To properly interface dry-contacts or relay outputs, each input channel has a corresponding handshake signal. Thus, the USSI uses a four-wire interface to ensure the detection of failures mentioned above. These contacts may come from any of a variety of devices, including process control, emergency stop switches, positive-opening safety switches, safety modules, and safety light screens (see Figure 2-3).

NOTE: If an USSI is not to be used, USSIa must be jumpered to USSIb, and USSIc must be jumpered to USSId (factory default). Do not short Channel A to Channel B of the USSI, or a lockout will occur. See the PICO-GUARD controller manual for further information.

2.2 USSI Supplemental Safeguarding Systems

A variety of safety systems can be interfaced with the USSIs. Each safety application has its own unique combination of application requirements, and the user is responsible to ensure proper installation and use, and that the application complies with all relevant standards and regulations. The following and Appendix A.1 provide generic examples of the flexibility of the USSI.

WARNING . . . Generalized Instructions

The application examples described in Section 2.2 and in Appendix A.1 depict generalized guarding situations. **Each guarding application has its own unique set of application requirements. Use extreme care to meet all legal requirements and follow all installation instructions.**

Please direct any questions to the factory applications department at the telephone number or addresses listed on the front cover.

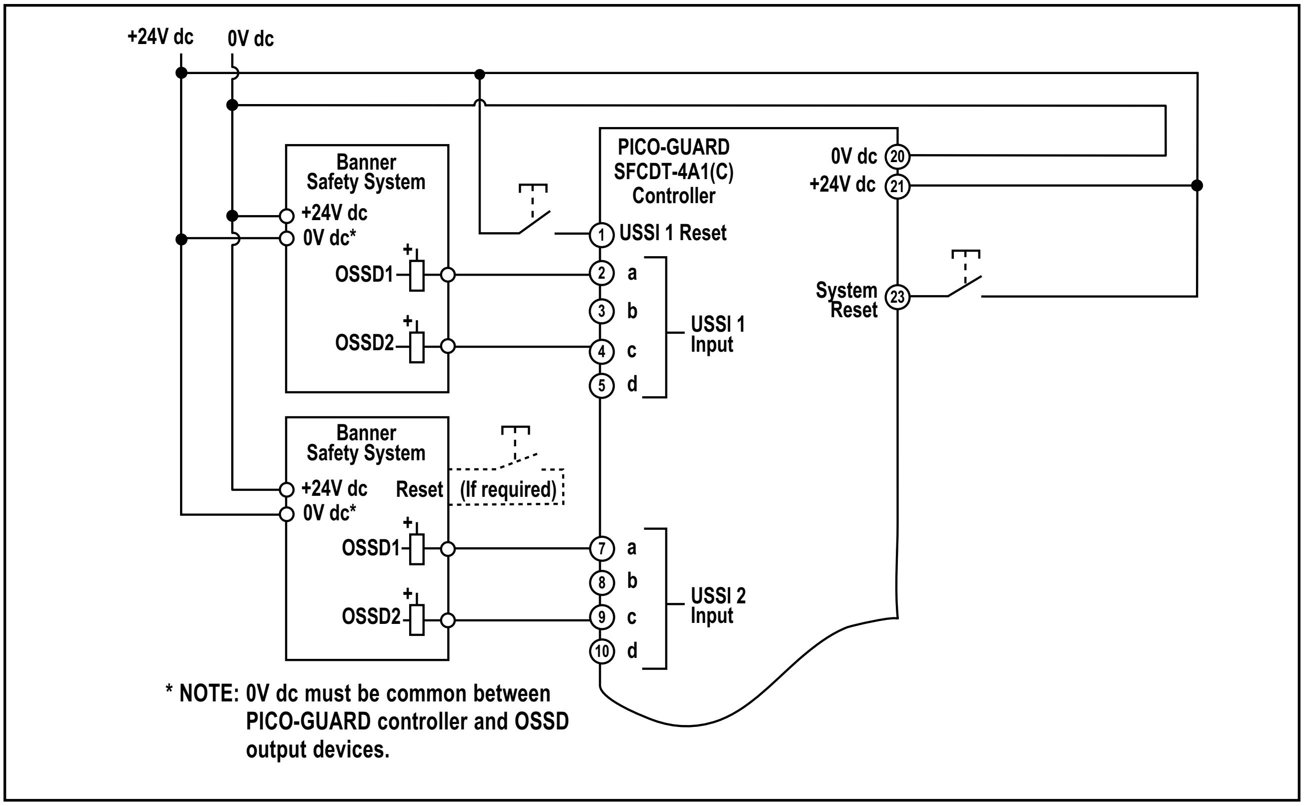


Figure 2-2. USSI hookup of PICO-GUARD model SFCDT-4A1(C) controller (safeguards with handshake-compliant OSSDs)

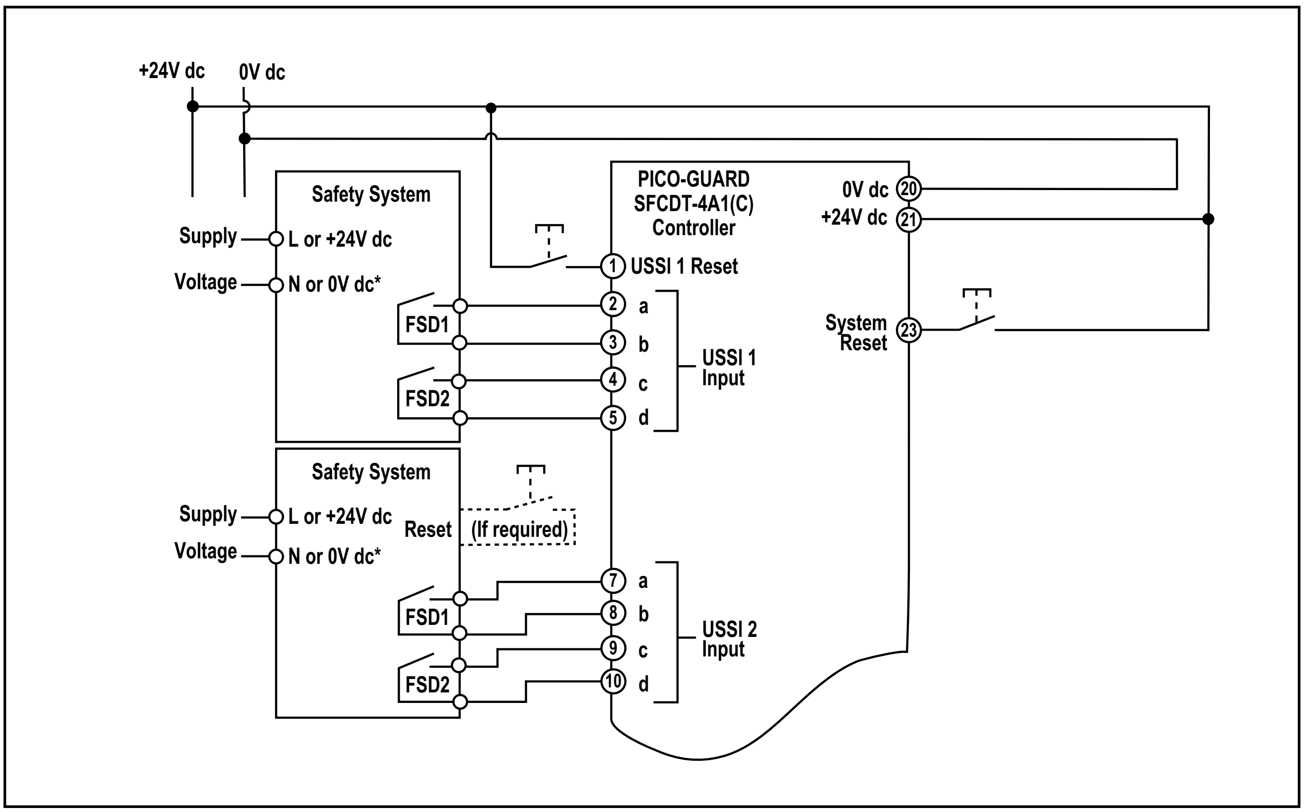


Figure 2-3. USSI hookup of PICO-GUARD model SFCDT-4A1(C) controller (safeguarding device with relay output) with 4-wire interface

2.2.1 Emergency Stop Buttons and Rope/Cable Pulls

E-Stop Switch Requirements (Positive-Opening)
As shown in Figure 2-4, the E-stop switch must provide two contact pairs, which are closed when the switch is in the "armed" position. Once activated, the E-stop switch must open its contacts and return to the closed-contact position only after deliberate action (such as twisting, pulling, or unlocking). The switch should be a "positive-opening type," as described by IEC947-5-1. A mechanical force applied to such a button (or switch) is transmitted directly to the contacts, forcing them open. This ensures that the switch contacts will open whenever the switch is activated. ANSI/NFPA 79 specifies the following additional requirements:

- Emergency Stop push buttons shall be located at each operator control station and at other operating stations where emergency shutdown shall be required.
- Stop and Emergency Stop push buttons shall be continuously operable from all control and operating stations where located.
- Actuators of Emergency Stop devices shall be colored Red. The background immediately around the device actuator shall be colored Yellow. The actuator of a push-button-operated device shall be of the palm or mushroom-head type.
- The Emergency Stop actuator shall be a self-latching type.

NOTE: Some applications may have additional requirements. **The user must comply with all relevant regulations.**

WARNING . . . Reset Routine Required

U.S. and international standards require that a reset routine be performed after returning the E-stop switch to its closed-contact position (when arming the E-stop switch). When automatic reset is used, an alternate means must be established to require a reset routine, after the E-stop switch is armed. **Allowing the machine to restart as soon as the E-stop switch is armed creates an unsafe condition which could result in serious injury or death.**

WARNING . . . Multiple E-Stop Switches

Whenever two or more E-stop switches are connected to the same USSI input:

- **The contacts of both switches must be connected together in series.** This series combination is then wired to the respective USSI input. Never connect the contacts of multiple E-stop switches in parallel to the USSI inputs; this defeats the switch contact monitoring ability of the USSI, and creates an unsafe condition that could result in serious injury or death.
- **During checkout, each switch must be individually actuated (engaged), then re-armed, and the controller must be reset** (if using manual reset mode). This allows the monitoring circuits to check each switch and its wiring to detect faults. Failure to test each switch individually in this manner could result in undetected faults and create an unsafe condition that could result in serious injury or death.

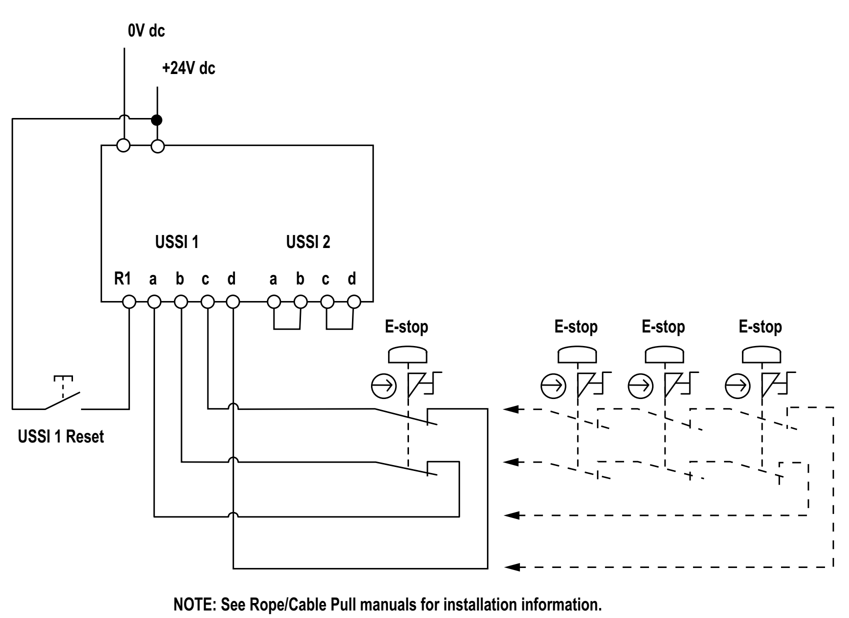


Figure 2-4. E-stop buttons (and rope/cable pulls) interfaced with the Latch USSI

WARNING . . . Emergency Stop Functions

If USSI Input is used for an Emergency Stop function, do not mute or bypass the safety outputs (OSSDs) of the PICO-GUARD controller. NFPA79 requires that the Emergency Stop function remain active at all times. **Muting or bypassing the safety outputs will render the Emergency Stop function ineffective.**

2.2.2 Positive-Opening Safety Interlock Switches

The USSI may be used to monitor interlock safety gates or guards. Requirements vary widely for the level of control reliability or safety category (per ISO 13849-1) in the application of interlocked guards. While Banner Engineering recommends the highest level of safety in any application, it is the responsibility of the user to safely install, operate, and maintain each safety system and comply with all relevant laws and regulations. Of the following applications, Figure 2-5 meets or exceeds the requirements for OSHA control reliability and Safety Category 4, per ISO 13849-1.

> **WARNING . . . Unguarded Moving Parts**
>
> **It must not be possible for personnel to reach any hazard point through an opened guard (or any opening) before hazardous machine motion has completely stopped.**
>
> Please reference OSHA CFR1910.217, ANSI B11 standards, or other appropriate standards for information on determining safety distances and safe opening sizes for your application (see Inside back cover).

Interlock Guarding Requirements

The following general requirements and considerations apply to the installation of interlocked gates and guards for the purpose of safeguarding. In addition, the user must refer to the relevant regulations to be sure to comply with all necessary requirements.

Hazards guarded by the interlocked guard must be prevented from operating until the guard is closed; a Stop command must be issued to the guarded machine if the guard opens while the hazard is present. Closing the guard must not, by itself, initiate hazardous motion; a separate procedure must be required to initiate the motion. The safety switches must not be used as a mechanical or end-of-travel stop.

The guard must be located an adequate distance from the danger zone (so the hazard has time to stop before the guard is opened sufficiently to provide access to the hazard), and it must open either laterally or away from the hazard, not into the safeguarded area. Depending on the application, an interlocked gate or door should not be able to close by itself and activate the interlocking circuitry (ANSI/RIA R15.06). In addition, the installation must prevent personnel from reaching over, under, around, or through the guard to the hazard. Any openings in the guard must not allow access to the hazard (see OSHA 29CFR1910.217 Table O-10 or the appropriate standard). The guard must be strong enough and designed to protect personnel and contain hazards within the guarded area, which may be ejected, dropped, or emitted by the machine.

The safety switches and actuators used with the USSI must be designed and installed so that they cannot be easily defeated. They must be mounted securely, so that their physical position can not shift, using reliable fasteners that require a tool to remove. Mounting slots in the housings are for initial adjustment only; final mounting holes must be used for permanent location.

Safety Interlock Switch Requirements

Two individually mounted safety interlock switches are recommended for each guard to meet safety category 4, per ISO 13849-1, and must satisfy several requirements. Each switch must provide at minimum, one normally closed (N/C) electrically isolated contact to interface with the USSI (see Figure 2-5).

The contacts must be of "positive-opening" design, with one or more normally closed contacts rated for safety. Positive-opening operation causes the switch to be forced open, without the use of springs, when the switch actuator is disengaged or moved from its home position (see the Banner Safety Catalog for examples). In addition, the switches must be mounted in a "positive mode" to move/disengage the actuator from its home position and open the normally closed contact when the guard opens.

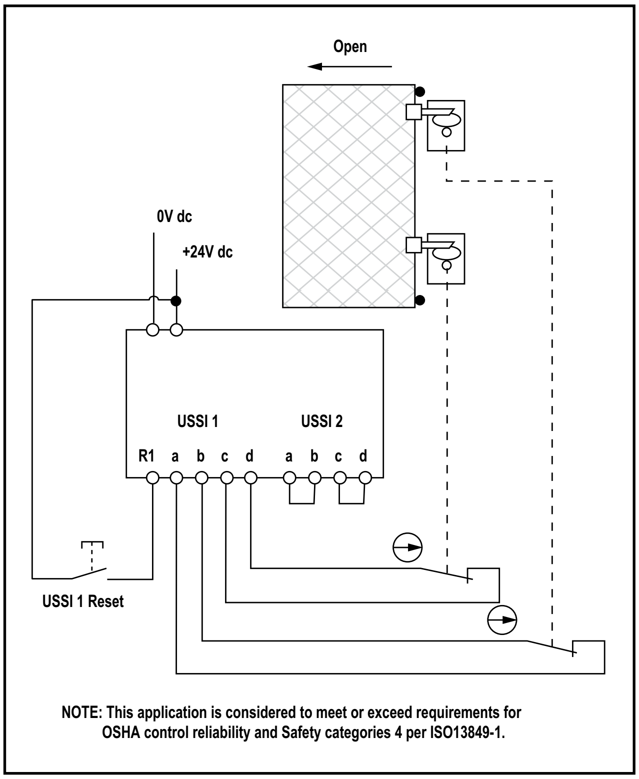


Figure 2-5. USSI monitoring two positive-opening safety switches

Monitoring Series-Connected, Positive-Opening Safety Switches

When monitoring two individually mounted safety switches (as shown in Figure 2-5), a faulty switch will be detected if it fails to switch as the guard opens. In this case, the controller will de-energize its OSSD output and disable its reset function until the input requirements are met (i.e., the faulty switch is replaced). However, when a series of interlocking safety switches is monitored by a single USSI, the failure of one switch in the system may be masked or not detected at all (see Figure 2-6).

Series-connected, positive-opening interlock switch circuits do not meet ISO 13849-1 Safety Category 4 and may not meet Control Reliability requirements because of the potential of an inappropriate reset or a potential loss of the safety stop signal. A multiple connection of this type should not be used in applications where loss of the safety stop signal or an inappropriate reset could lead to serious injury or death.

The following two scenarios assume two positive-opening safety switches on each guard:

1. **Masking of a failure.** If a guard is opened but a switch fails to open, the redundant safety switch will open and cause the PICO-GUARD controller to de-energize its outputs. If the faulty guard is then closed, both USSI input channels also close, but because one channel did not open, the controller will not reset.

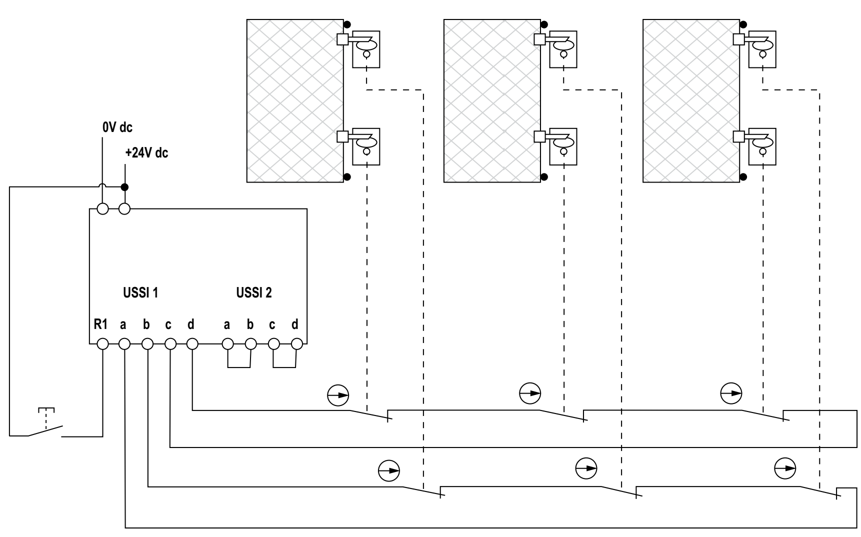
   However, if the faulty switch is not replaced and a second "good" guard is cycled (opening and then closing both of the USSI input channels), the controller considers the failure to be corrected. With the input requirements apparently satisfied, the controller allows a reset. *This system is no longer redundant and, if the second switch fails, may result in an unsafe condition* (i.e., the accumulation of faults results in the loss of the safety function).

2. **Non-detection of a failure.** If a good guard is opened, the controller de-energizes its outputs (a normal response). But if a faulty guard is then opened and closed before the good guard is re-closed, the failure on the faulty guard is not detected. *This system also is no longer redundant and may result in a loss of safety if the second safety switch fails to switch when needed.*

The circuits in either scenario do not inherently comply with the safety standard requirements of detecting single faults and preventing the next cycle. In multiple-guard systems using series-connected positive-opening safety switches, it is important to periodically check the functional integrity of each interlocked guard individually. **Operators, maintenance personnel, and others associated with the operation of the machine must be trained to recognize such failures and be instructed to correct them immediately.**

Open and close each guard separately while verifying that the controller outputs operate correctly throughout the check procedure. Follow each gate closure with a manual reset, if needed. If a contact set fails, the controller will not enable its reset function. If the controller does not reset, a switch may have failed; that switch must be immediately replaced.

This check must be performed and all faults must be cleared, at a minimum, during periodic checkouts. **If the application can not exclude these types of failures and such a failure could result in serious injury or death, then the safety switches must not be connected in series.**



WARNING . . .
Not a Safety Category 4 Application

When monitoring multiple guards with a series connection of multiple safety interlock switches, a single failure may be masked or not detected at all.

When such a configuration is used, procedures must be performed regularly to verify proper operation of each switch. See "Monitoring Series-Connected Positive-Opening Safety Switches" (above) for more information. **Failure to do so could result in serious injury or death.**

Figure 2-6. USSI monitoring positive-opening safety switches on multiple gates

3. Fiber Optic Cable and Excess Gain

3.1 Introduction to Banner Plastic Fiber Optics

Fiber optics contain no electrical circuitry and have no moving parts, so they can safely be used to “pipe” light into and out of hazardous or potentially explosive sensing locations and, with appropriate optical elements, withstand hostile environmental conditions. Moreover, fiber optics are completely immune to all forms of electrical “noise,” and may be used to isolate the electronics of a sensing system from known sources of electrical interference.

Fiber optics work on the optical principle of total internal reflection. This principle states that any ray of light that hits the boundary between two materials with different densities (in this case, the core and the cladding) will be totally reflected, provided that the angle of incidence is less than a certain critical value.

The principle of total internal reflection is true for both straight or bent fibers (assuming bends are within a defined minimum bend radius). Most fiber optic assemblies are flexible and allow easy routing through tight areas to the sensing location. **Due to light transmission properties and quality of the fibers, only Banner plastic fiber optic cables are recommended for use with the PICO-GUARD.**

Fibers are offered in two general styles: individual and bifurcated. **Individual** fibers are used in pairs in the opposed sensing mode. One fiber transmits the light to the sensing location; the other fiber returns the received light to the controller. **Bifurcated** plastic fiber assemblies are “two-way” fibers with a single sensing end that both emits the sensing beam and receives reflected light, and dual ends that attach separately to the controller. Bifurcated fibers are used in the “reflective” sensing modes – most often the diffuse mode, but also retroreflective and convergent modes (see warning below and Section 5).

WARNING . . . Fiber Optics for Personnel Safety Applications

Use only Optical Elements described in Sections 6, 7, and 8 for personnel safeguarding applications. These Optical Elements have been tested and certified to meet all relevant safety requirements.

Do not use standard plastic fiber optic assemblies, such as those listed in the Banner Engineering Photoelectric Sensor catalog, in personnel safeguarding applications. Any questions should be directed to the factory applications department at the telephone number or addresses shown on the back cover.

Plastic fibers must be routed away from sources of excessive heat, and isolated from excessive abrasion due to vibration or movement of the guard. The acrylic core of the optical fiber will be damaged by contact with acids, strong bases (alkalis), and solvents. The standard polyethylene jacket will protect the fiber from most chemical environments; however, some materials may migrate through the jacket with long-term exposure. Fluoropolymer- and PVC-sheathed fibers are available to withstand harsh chemicals or gases (fluoropolymer) or mechanical abrasion/harsh duty (PVC). Accessory PVC sheathing is also available to provide additional protection for any of these fibers.

Do not crush or otherwise deform the fiber optic cable. When using cable tie-straps (e.g., nylon cable ties), do not over- tighten such that the outer jacket is deformed or damaged. This will reduce excess gain, possibly allow the ingress of contamination, and may even sever the fiber optic cable.

3.2 Cutting Plastic Fiber Optic Cable

Unterminated plastic fibers are designed to be cut by the user to the length required for the application.

Do not cut the end of a **polished fiber** (PW.. series) unless the end has been damaged, contaminated, or must be cut to length.

NOTE: If a polished end is cut, the excess gain will be reduced and the advantage of the polished end will be lost. Do not cut polished fibers unless absolutely necessary.

To facilitate cutting, a Banner model PFC-2 cutting device is supplied with the PICO-GUARD controller. The cutting device is also available separately (see Section 1.3.3).

Cut the fiber as follows:

1. Locate the unfinished end of the fiber. Determine the length of fiber required for the application.
2. Lift the top (blade) of the cutter to open the cutting ports. Insert the fiber end through one of the cutting ports on the cutter so the excess fiber protrudes from the back of the cutter.
3. Double-check the fiber length, and close the cutter until the fiber is cut. Using a different cutting port, cut the second end to the required length. **To ensure a clean cut each time, do not use a cutting port more than once.**
4. Gently wipe the cut ends of the fiber with a soft, clean, dry cloth to remove any contamination. **Do not use solvents or abrasives on any exposed optical fiber.**

If using PVC sheathed fiber (XP models), sheathing must be removed without damaging the black jacket of the fiber; a 10 gauge or 3 mm (0.12") wire stripper is recommended. Remove 15 to 20 mm (0.6" to 0.75") of the PVC sheath from each end of the fiber to allow proper insertion into the optical elements and controller.

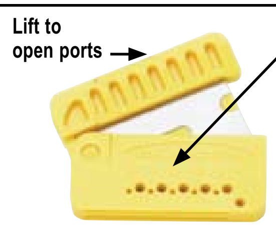


Figure 3-1. Trimming the fibers with the Model PFC-2 Fiber Cutter

Figure 3-2. Installing the prepared fiber ends into the controller

3.2.1 SFA-FFP Field Fiber Polisher

The model SFA-FFP Field Fiber Polisher kit is available for use with PICO-GUARD™ field-cut mono-core fibers. The kit provides the ability to polish field-cut fiber ends for minimum attenuation and maximum gain, up to 95% of the performance of a factory-polished fiber.

The kit is easy to use and will polish 13 to 40 fiber ends, depending on the quality of the original cut and need for polishing.

The kit includes:

- One 9" x 11" sheet 1500 sandpaper to remove imperfections in the fiber cut
- One 9" x 11" sheet 1 micron lapping film to fine-polish the fiber end
- One 1" dia. x ½" thick plastic fiber holder with 0.090" center hole to position fiber
- One model PFC-2 fiber cutter

3.3 Plastic Fiber Mechanical Specifications

Temperature Extremes	Temperatures below -30° C will cause embrittlement of the plastic materials but will not cause transmission loss. Temperatures above +70° C will cause both transmission loss and fiber shrinkage.
Repeat Bending/ Flexing	Life expectancy of plastic fiber optic cable is in excess of one million cycles at bend radii of no less than the minimum (stated below) and a bend of 90° or less. Avoid stress at the point where the cable enters the controller and the optical elements at the sensing end.
Operating Temperature	-30° to +70° C (-20° to +158° F) unless otherwise noted
Chemical Resistance	The PMMA core of the monofilament optical fiber will be damaged by contact with acids, strong bases (alkalis) and solvents. The polyethylene jacket will protect the fiber from most chemical environments. However, materials may migrate through the jacket with long-term exposure.
Minimum Bend Radius	25 mm (1.0") for 1 mm (0.04") core / 2.2 mm (0.09") outside diameter. NOTE: Loss of excess gain is minimized if the bend radius is greater than 100 mm (4.0").
Construction	**Optical Fiber:** PMMA – Polymethyl Methacrylate (Acrylic) **Standard Protective Jacket:** black polyethylene, with optional PVC or Fluoropolymer sheathing (depending on model; see Figure 1-3)

3.4 Excess Gain

Excess gain is a measurement of the amount of light falling on the receiver, over and above the minimum amount of light required just to operate the sensor's amplifier. Several factors impact excess gain, including operating distance, fiber loss, splice loss, and optical element loss. Excess gain values are used to predict the reliability of an Optical Element operating in a known environment.

Verify adequate excess gain for all optical channels when specifying a PICO-GUARD System. Tables in Section 7.3, 7.5 and 8.4 give general guidelines for adequate excess gain.

The Excess Gain Estimator program (see below) and the SFI Interlock Switch Options in Section 6.2 are two methods to verify whether adequate excess gain is available for a given application, and are meant to be a guideline, not pass/fail.

Excess Gain Estimator Program
To access the Excess Gain Estimator program for SFI Interlock Switches either load the CD (included with the controller) onto your computer, or go on-line to www.bannerengineering.com and double-click on:

Literature/Resources, then

Software and Electronic Data Sheets, then

PICO-GUARD (in the Machine Safety Products pull-down menu), then

Excess Gain Estimator

The program is self-explanatory and also has a "Help" function. The minimum value must be no less than 50, and the maximum value must be no more than 2,500 for reliable operation.

3.5 Troubleshooting Weak Signal Conditions

A Weak Signal (Low Excess Gain) condition causes the optical channel status LEDs to flash and turns ON the Weak Signal output. To troubleshoot a weak signal or to maximize excess gain:

1. Check the number and configuration of the optical elements in the optical channel loop.
2. Inspect entire fiber run for:
   - Cut or pinched fiber or jacket. Do not crush or otherwise deform the sheathing.
   - Tight bend radius (e.g., loops with tight bends). Do not exceed 1" minimum bend radius and if possible, not less than 4". (See Section 3.)
   - Extra splices and/or attenuators.
3. Ensure optimum optical alignment and operating distances between optical elements. Keep the operating distance as short as possible.
4. Check all fiber ends for clean, smooth cuts. Recut as necessary per Section 3.1.1. Field polishing is possible with SPA-FFP kit. See Section 3.2.1. Replacing one or more bulk/cut fibers with polished fibers will increase excess gain (model PW...P fibers – see Section 1.3.2).
5. Check for obstructions (e.g., loose o-rings, sheathing debris, etc.) within optical elements at all connections.
6. Ensure proper seating of the fiber in each optical element.
7. Visually confirm light transmission at each switching point (emitter optical element). A red light should be present. If very dim, replace suspect element (emitter element or previous receiver element or splice in a fiber loop) to see if problem is resolved.
8. Ensure that the environment does not negatively affect the optical fiber or the optical elements.

3.6 Cleaning of Components

PICO-GUARD optical elements are constructed of various materials. Plastic components (including lens covers) usually are best cleaned using mild detergent or window cleaner and a soft cloth. Avoid cleaners containing alcohol, as they may damage some parts. See the literature packed with the specific optical element for cleaning instructions or contact the factory (see the back cover for numbers) for recommendations.

4. Explosive Environments and Atmospheres

PICO-GUARD optical elements can be used in environments that pose the possibility of explosion and do not require costly isolation barriers or explosion-proof housings. However, the PICO-GUARD controller must be placed either outside the potentially explosive environment, or within an explosion-proof enclosure.

NOTE: For the purposes of this document, the terms "hazardous area" and "hazardous location" refer to personnel safety applications. To minimize confusion, potentially explosive situations are termed the "explosive environment" or the "explosive atmosphere."

What is a potentially explosive environment?
Environments or atmospheres that have sufficient concentrations of fuel or flammable material plus an oxidizer (air or oxygen) that may produce an explosion or fire if combined with a source of ignition.

Flammable materials may take the form of gases, vapors, dusts, or fibers. Flammable gases are gaseous elements and compounds that are broken into groups according to their level of explosion hazard (see Section 4.1).

Vapors, classified with gases, are the result of flammable liquids at or above the flash point temperature. At the flash point, the liquid gives off a sufficient amount of fumes that ignition is possible.

Combustible dust is an airborne particulate that results from solid material, rather than gases or liquids. Combustible fibers are considered larger than dust (e.g. lint).

The source of ignition is always some form of energy. Generally, ignition is caused by thermal energy (spontaneous combustion) or spark (electrical or friction). Examples of these sources include, but are not limited to: hot surfaces, open flames, electrical arcing, electrostatic discharge, lighting, electromagnetic radiation, and chemical reactions.

4.1 The Classification of Explosive Environments

In the United States, Articles 500 and 505 of the National Electrical Code (NEC) cover the requirements for electrical equipment and wiring for all voltages in locations where fire or explosion hazards may exist due to flammable gases or vapors, flammable liquids, combustible dust, or ignitable fibers. Two styles of classifications are described by the NEC, one based on Class/Division/Group, and one that is similar to International standards based on Zones/Groups.

Class/Division/Group (NEC Article 500)

Type of fuel:

CLASS I: Gases or vapors

CLASS II: Dusts

CLASS III: Fibers or flyings

Possibility of ignitable concentrations of fuel being present:

DIVISION 1: Present or likely to be present in normal operation, during maintenance, or under fault conditions that may cause ignition

DIVISION 2: Contained or not present or in normal operation. Could be present due to rupture of containment, abnormal operation of equipment, failure of ventilation system, or close proximity of CLASS I /DIV I location

Specific type of fuel and ignition capabilities:

GROUP A: Acetylene

GROUP B: Hydrogen

GROUP C: Acetaldehyde, ethylene, methyl ether

GROUP D: Acetone, gasoline, methanol, propane

GROUP E: Metal dust

GROUP F: Carbon dust

GROUP G: Grain dust

Zones/Groups (NEC Article 505 and IEC 60079)

Possibility of ignitable concentrations of fuel being present:

ZONE 0: Present continuously, frequently, or for long periods of time

ZONE 1: Likely to be present for short periods of time, occasionally, or as a result of maintenance

ZONE 2: Not likely to be present under normal operation, but possible due to equipment failure or abnormal operation for a short time duration

Location and specific type of fuel/ignition capabilities:

GROUP I: Equipment in mining operations where methane might be present

GROUP IIC: All other explosive atmospheres where acetylene and hydrogen might be present

GROUP IIB: All other explosive atmospheres where acetaldehyde, ethylene, and methyl ether might be present

GROUP IIA: All other explosive atmospheres where acetone, gasoline, methanol, and propane might be present

4.2 Methods of Preventing Explosions

In an explosive atmosphere, any method to prevent or reduce the possibility of an explosion must control or eliminate one or more of the three components (fuel, oxidizer, and energy).

Typically, the oxidizer (air or oxygen) can not be removed from the environment. Flammable materials can be contained in such a manner that the fuel/air mixture is either lean enough or rich enough to prevent combustion from occurring. Unfortunately, "rich" concentrations (other than in storage applications) are generally not practicable or possible.

Sometimes, it is possible to remove flammable materials by venting or purging the area so that build-up of explosive gases can not occur. Again, this is not always practicable or possible.

Typically, the simplest way to ensure that ignition does not occur is by eliminating or containing the source of energy. Some methods include:

Explosion-Proof Enclosures – designed to *contain the force and energy* of an explosion

Purged and Pressurized Enclosures – designed to *prevent the build-up* of explosive gases

Intrinsically Safe Systems (IS) – designed to *limit the electrical energy* to prevent ignition

Fiber Optics – designed to *limit the energy* to prevent ignition

Nonincendiary equipment and circuits – designed to *limit the electrical energy* to prevent ignition

Pneumatic Systems – designed to *limit the energy* to prevent ignition

Encapsulation/Oil Immersion/Powder Filling – designed to *isolate to prevent ignition*

The PICO-GUARD uses the method of fiber optics to limit the energy such that ignition is not possible. See warning below.

WARNING . . . Explosive Environments

Only the PICO-GUARD optical elements and interconnecting optical fibers may be exposed to a potentially explosive environment. **The electrical inputs and outputs are not designed for Intrinsically Safe (IS) applications.** This includes: USSIs, Resets, OSSDs, RS232 and the Remote Display, AUX, Weak Signal, Fault, EDM and power connections.

The PICO-GUARD controller and any electrical device interfaced with the controller's inputs and outputs must be located outside the explosive environment or within an appropriate explosion-proof enclosure. See Hazardous Location diagram #117870.

4.3 Standards Dealing with Explosive Environments

NOTE: Explosives, such as gunpowder, dynamite and pyrophoric materials (e.g. pure sodium), may not be covered by the documents below. Refer to the appropriate standards to apply the PICO-GUARD System in full compliance with all relevant applicable regulations and standards.

For more information, refer to standards applicable to the use of PICO-GUARD in a potentially explosive environment or atmosphere. These standards include, but may not be limited to:

Articles 500 and 505 of the National Electrical Code (NEC), Requirements for electrical equipment and wiring for all voltages in locations where fire or explosion hazards may exist due to flammable gases or vapors, flammable liquids, combustible dust, or ignitable fibers or flyings.

EN1127-1, Explosive Atmospheres – Explosion Prevention and Protection – Part 1: Basic Concepts and Methodology

FMRC3600, Electrical Equipment for Use in Hazardous (Classified) Locations, General Requirements

IEC 60079, Electrical Apparatus for Explosive Gas Atmospheres

IEC 61241, Electrical Apparatus for Use in the Presence of Combustible Dust

ISA12.1, Definitions and Information Pertaining to Electrical Instruments in Hazardous (Classified) Locations

NFPA 497, Classification of Flammable Liquids, Gases, or Vapors and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas (supersedes ANSI B185.1)

NFPA 499, Recommended Practice for the Classification of Combustible Dusts and of Hazardous (Classified) Locations for Electrical Installations in Chemical Process Areas

UL913, Intrinsically Safe Apparatus and Associated Apparatus for Use in CLASS I, II, and III, DIVISION 1, Hazardous (Classified) Locations

Caution . . . Gas Migration

It is possible for gas to migrate through the fiber or fiber cable. Proper sealing may be required between explosive and non-explosive environments. Furthermore, to minimize the possibility of gas migration, do not expose cut or damaged cable to explosive gas.

5. Equipment Protection (Non-Safety Applications)

The PICO-GUARD System can provide highly reliable photoelectric sensing when used for equipment protection that does not impact personnel safety. Unlike standard limit switches, or photoelectric or inductive sensors, the PICO-GUARD controller and optical elements are designed to default into a "beam-break" condition. With standard switches and sensors that can fail in an ON or GO condition, the loss of a "stop" signal could result in costly equipment damage.

The principle of a known or predictable failure mode (OFF or STOP) can be incorporated into a machine design to minimize situations that could result in damage to equipment. The machine control can be designed to achieve a condition (e.g., a "halt") that protects equipment if a stop signal is issued erroneously or if the PICO-GUARD fails.

Fiber Optic Equipment Protection is not intended for personnel safety. The user must ensure that the fiber optic assembly is appropriate for the intended application (see Warning below).

WARNING . . . Personnel Safeguarding

Use only Optical Elements described in Sections 6, 7 and 8 for personnel safeguarding applications. These Optical Elements have been tested and are certified to meet all relevant safety requirements.

Do not use standard fiber optic assemblies, such as those listed in the Banner Engineering Photoelectric Sensor catalog, in personnel safeguarding applications.

5.1 Fiber Optic Assembly Considerations

In addition to PICO-GUARD optical elements, this functionality can be incorporated into some standard plastic fiber optic assemblies, such as those listed in the Banner Engineering Photoelectric Sensor catalog. If optical short circuits or self-reflection can occur (due to issues including, but not limited to, contamination or crushing of the bifurcated cable/assembly and false proxing/tripping), or if the loss of the switchings action can otherwise occur, the PICO-GUARD **must not** be used in such applications (see Caution below).

Optical short circuits can occur when the light is reflected around an object intended to interrupt the light path. When an optical short circuit occurs, it is most frequently in opposed-mode sensing, but it can also occur in other sensing modes.

Self-reflection generally occurs in bifurcated plastic fiber assemblies in diffuse or retroreflective sensing modes. It usually occurs when the sensing end of the fiber assembly becomes contaminated or damaged, resulting in a latched ON condition.

CAUTION . . . Fiber Choice

Standard plastic fiber optic assemblies are available in a variety of sensing end styles and are listed in the Banner Engineering Photoelectric Sensor catalog. The machine designer should call the applications group at Banner Engineering for assistance in choosing an appropriate plastic fiber(s) for equipment protection (non-safety) applications.

5.2 Application Considerations

The optical and USSI inputs of the PICO-GUARD can be thought of as an AND-gate; all inputs must be true (active) for a reset to occur, *and* any one input will issue a Stop command.

The PICO-GUARD OSSD outputs are interfaced to enable or disable a motion or action. This motion or action is dependent on the occurrence of an initial event. This initial event is independent from the control of the PICO-GUARD, such that the action to cause the event can occur even if the PICO-GUARD is in a STOP condition.

An example would be a material feed mechanism that is not interfaced with the PICO-GUARD outputs so as to allow the automatic feeding of strip stock into a stamping power press. The power press clutch/brake is interfaced with the PICO-GUARD to prevent a stroke before the material has fully advanced (see Appendix A.2.4). Thus, the application is set up for Light Operate operation (light = Go, dark = Stop).

Generally, opposed-mode sensing (using individual fiber assemblies) is the best choice for reducing the failure modes that must be accounted for. It also tends to be the most effective means to provide the best excess gain factors with the least amount of loss. In addition, the small effective beam pattern makes it easy to control the sensing characteristics and parameters.

Bifurcated plastic fiber assemblies are “two-way” fibers with a single sensing end that both emits the sensing beam and receives reflected light, and dual ends that attach separately to the controller. Bifurcated fibers are used in the “reflective” or “proximity” sensing modes (most often, diffuse mode or retroreflective mode). If bifurcated plastic fiber assemblies are used, the installation **must exclude or eliminate** the possibility of the loss of the switching function as described in Section 5.1. Crushing of the fiber assembly and contamination due to materials such as liquids, metal shavings, or airborne contamination must be prevented.

A 2.2 mm O.D. fiber with a 1 mm core is recommended, but smaller diameter fiber can be used with the UPFA-1 Adapter. However, a reduction in excess gain will result due to the smaller fiber core.

It should be noted that there is no gain adjustment other than adding SFA-FA attenuators to the fiber optic loop to reduce excess gain (see Sections 1.3.3 and 3.4).

Most Banner standard plastic fiber optic assemblies are unterminated on the controller end. These assemblies are approximately 2 m (6') long. They may be used as-is, they may be cut to a shorter length, or the length may be extended using additional plastic fiber and model SFA-FS Fiber Splices (see Section 1.3.3).

See Appendix A.2 for examples of Equipment Protection applications using highly reliable sensing. Further information on fiber optics and photoelectric sensing can be found in the Banner Photoelectric Sensors catalog (see “Introduction to Sensing Concepts and Terminology”) and the tutorials in the iKnow™ Photoelectrics section of the Banner website at www.bannerengineering.com.

6. Fiber Optic Safety Interlock Switches

General Requirements for Interlocked Guards

The following general requirements and considerations apply to the installation of interlocked gates and guards for the purpose of safeguarding. In addition, the user must refer to the relevant regulations and comply with all necessary requirements.

Hazards guarded by the interlocked guard must be prevented until the guard is closed; a Stop command must be issued to the guarded machine if the guard opens while the hazard is present. Closing the guard must not, by itself, initiate the hazardous motion; a separate procedure must be required to initiate the motion. The safety switches must not be used as a mechanical or end-of-travel stop.

The guard must be located an adequate distance from the danger zone (providing time to stop the hazard before the guard is opened enough to provide access to the hazard). It also must open either laterally or away from the hazard, and not into the safeguarded area. Dependent on the application, an interlocked gate or door should not be able to close by itself and activate the interlocking circuitry (ANSI/RIA R15.06). In addition, the installation must prevent personnel from reaching over, under, around, or through the guard to the hazard. Any openings in the guard must not allow access to the hazard (see ANSI B11.19 or the appropriate standard). The guard must be strong enough and be designed to protect personnel and contain hazards within the guarded area that may be ejected, dropped, or emitted by the machine.

The Fiber Optic Safety Interlock Switches must be designed and installed so they cannot be easily defeated. They must be mounted securely, using reliable fasteners that require a tool to remove, so that their physical position can not shift.

CAUTION . . . Appropriate Applications

In addition to the limitations listed on page 2 and in the PICO-GUARD controller manual, **use of the Banner PICO-GUARD Fiber Optic Safety Interlock Switches are generally not allowed:**

- For individual beams in an optical grid for presence sensing safeguarding (e.g., perimeter guarding). See Section 7.
- For linear (parallel) movement along the optical axis (see Section 6.3).
- On machinery with long or excessive stopping times and no monitored guard locking mechanism.

Direct any questions regarding the use or installation to the Factory Applications Department at the telephone numbers or addresses on the back cover.

WARNING . . . Unguarded Moving Parts

It must not be possible for personnel to reach any hazard point through an opened guard (or any opening) before hazardous machine motion has completely stopped.

Please reference OSHA CFR1910.217, ANSI B11 standards, or other appropriate standards for information on determining safety distances and safe opening sizes for your application (see inside back cover).

6.1 Fiber Optic Safety Interlock Switch Description

When the PICO-GUARD controller is used with Fiber Optic Safety Interlock Switches, the system can detect the opening or removal of a guard, panel, door, or other hard guarding and issue a Stop signal to the machine.

Fiber Optic Safety Interlock Switches are designed for non-locking guarding applications, unless another means of locking is provided.

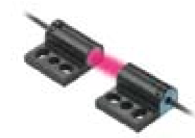
Unlike positive-opening mechanical interlocks, a single SFI series optical element pair per guard can, when used with the controller, obtain Safety Category 4 (per ISO13849-1). A series connection of multiple optical element pairs on multiple guards in a single fiber channel can also provide this same high level of safety, reducing the installation and maintenance cost of machine safety systems.

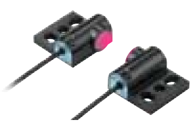
PICO-GUARD Fiber Optic Safety Interlock Switches are rated at IEC IP67. The polycarbonate housing materials of the switch sensors make them robust enough for most industrial environments. They are available in straight, right-angle and dual-lens/actuator models.

PICO-GUARD Extreme-Duty Fiber Optic Safety Interlock Switches, rated IEC IP67, are constructed of 316 stainless steel with PTFE-coated (Teflon™) fibers and glass windows for maximum resistance to chemical reactivity.

PICO-GUARD Heavy-Duty Fiber Optic Safety Interlock Switches are also rated IEC IP67. Their impact- and chemical-resistant zinc and glass construction (with PTFE-coated fibers) are designed for use in paint booth applications and other hostile environments. Models with PE (polyethylene) fibers provide increased ruggedness (compared with plastic models), at a lower cost for environments not using harsh chemicals.

6.2 Fiber Optic Safety Interlock Switch Models

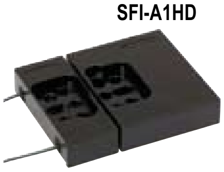




SFA-FA

SFA-FS

SFI-A1HD



SFI-D1HDP..

Model			Housing Description	Fiber Length
Standard PE Fiber, Polyethylene Jacket, No Sheath	PE Fiber, Polyethylene Jacket, PVC Sheath	PE Fiber, Polyethylene Jacket, Fluoropolymer Sheath		
Standard Plastic Housing Models				
SFI-S1R			Straight, right mounting	Bulk or Precut fiber, sold separately (see Section 1.3.2)
SFI-S1L			Straight, left mounting	
SFI-R1R			Right-angle, right mounting	
SFI-R1L			Right-angle, left mounting	
SFI-D1			Dual-lens, center mounting	
SFI-A1	SFI-A1XP	SFI-A1XT	Actuator, center mounting	Attached fiber loop
SFA-FA			Attenuator	Bulk or Precut fiber, sold separately (see Section 1.3.2)
SFA-FS			Fiber Splice	
Heavy-Duty Zinc Housing Models				
SFI-D1HDPS6	–	SFI-D1HDPXT6	Dual-lens, center mounting	1.8 m (6')
SFI-D1HDPS15	–	SFI-D1HDPXT15		4.5 m (15')
SFI-D1HDPS30	–	SFI-D1HDPXT30		9.0 m (30')
SFI-D1HDPS50	–	SFI-D1HDPXT50		15.3 m (50')
SFI-A1HD			Actuator, center mounting	Self-contained fiber loop
SFA-FGD1HD			Fiber guide for use with SFI-D1HDP.. Dual-lens switches above	–
Extreme-Duty Stainless Steel Housing Models				
–	–	SFI-M12SS06UXT	Threaded-barrel style, straight	1.8 m (6')
–	–	SFI-M12SS15UXT		4.5 m (15')
–	–	SFI-M12SS30UXT		9.0 m (30')
–	–	SFI-D1EDPXT6	Dual-lens, center mounting	1.8 m (6')
–	–	SFI-D1EDPXT15		4.5 m (15')
–	–	SFI-D1EDPXT30		9.0 m (30')
–	–	SFI-D1EDPXT50		15.3 m (50')
SFI-A1ED			Actuator, center mounting	Self-contained fiber loop

6.2.1 Fiber Optic Safety Interlock Switch Accessories

See Section 1.3.3 for additional accessories.

SFA-IAG	SFI Series Interlock Alignment Guide (see Figure 6-10)
SFA-IMB1	Retrofit bracket (to replace model SI-MAG1SM)
SFA-IMB2	Retrofit bracket (to replace model SI-MAG2SM)
SFA-FFP	Field Fiber Polishing Kit; see data sheet p/n 128868 for information

6.3 Fiber Optic Safety Interlock Switch Specifications

	SFI-..1..	**SFI-M12SS..**	**SFI-A1ED, SFI-D1EDPXT..**	**SFI-A1HD, SFI-D1HDPS.., and SFI-D1HDPXT..**
Operating Distance	1 mm to 50 mm (0.04" to 2") Also see Figure 6-8.			
Mounting	Holes for M4 (#10) screw (see Figures 6-1 – 6-4)	Mount to M12 clearance holes using supplied mounting nuts. See Figure 6-5.	Holes for M6 screw (see Figures 6-6 and 6-7).	
Operating Conditions	**Temperature range:** 0° to +70°C (+32° to 158°F) **Max. relative humidity:** 95% (non-condensing)			
Environmental Rating	IEC IP67			
Construction	**Housing:** Polycarbonate **Window:** Polycarbonate **Fibers:** PE, PVC, and PTFE-coated. See Section 1.3.2.	**Housing:** 316 stainless steel **Window:** glass **Fibers:** PTFE-coated		**Housing:** zinc with black zinc coating **Window:** glass **Fibers:** PXT models – PTFE coated PS models – PE polyethylene coated
Dimensions	See Section 6.3.1			

6.3.1 Fiber Optic Interlock Dimensions

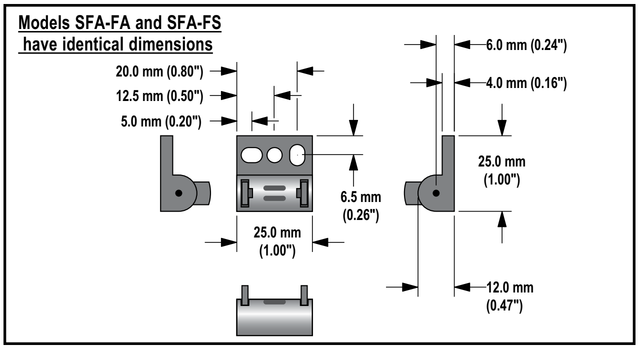


Figure 6-1. Model SFA-F.. splice and attenuator

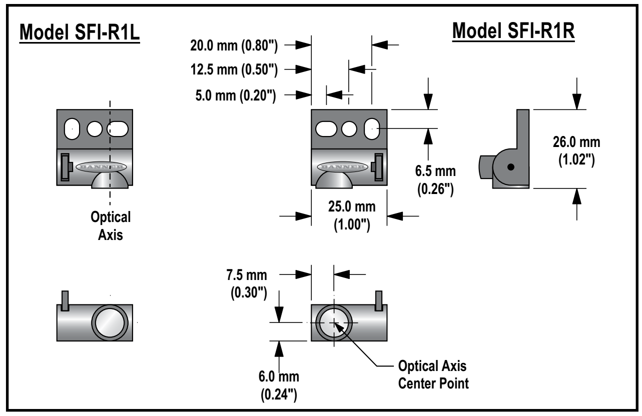


Figure 6-3. Model SFI-RA.. (right-angle housing) switch

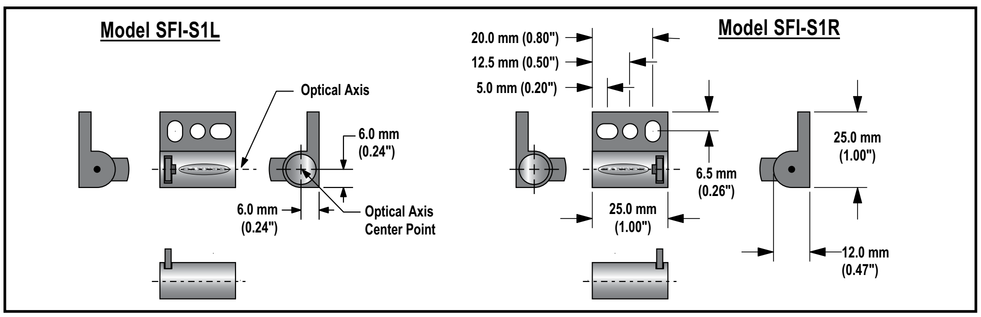


Figure 6-2. Model SFI-S1.. (straight housing) switch

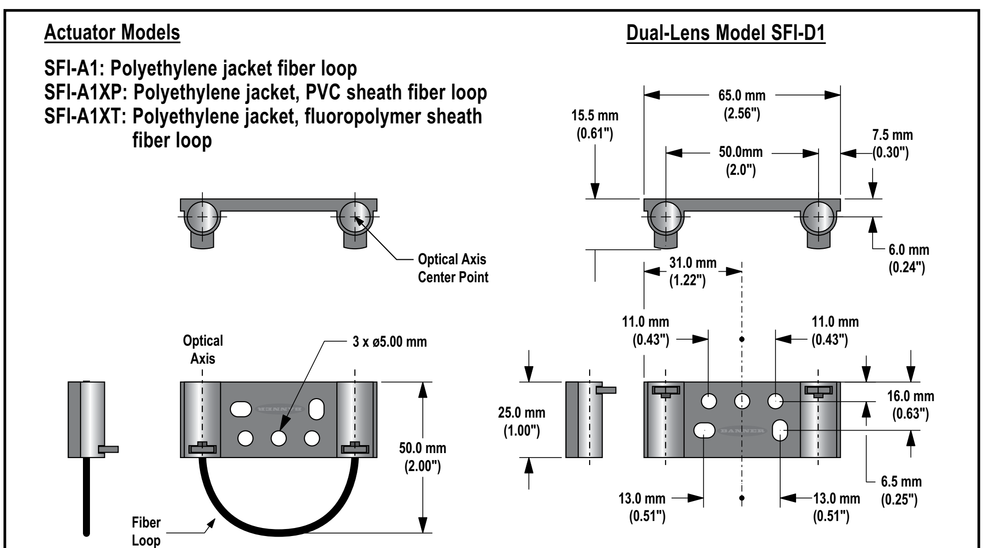


Figure 6-4. Model SFI-A1.. and S19-D1.. (dual-lens and actuator) switch

6.3.1 Fiber Optic Interlock Dimensions, continued

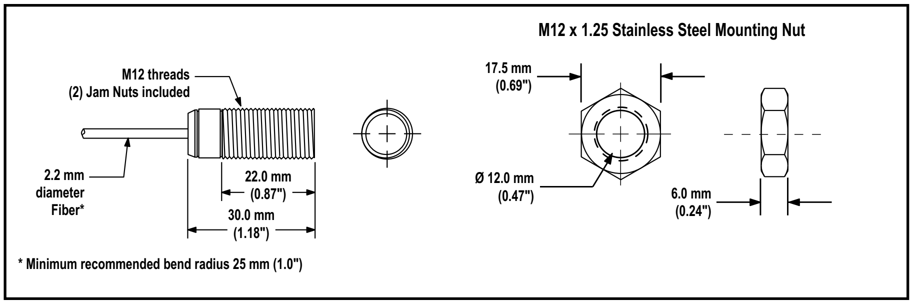


Figure 6-5. Model SFI-M12SS.. (barrel housing) switch

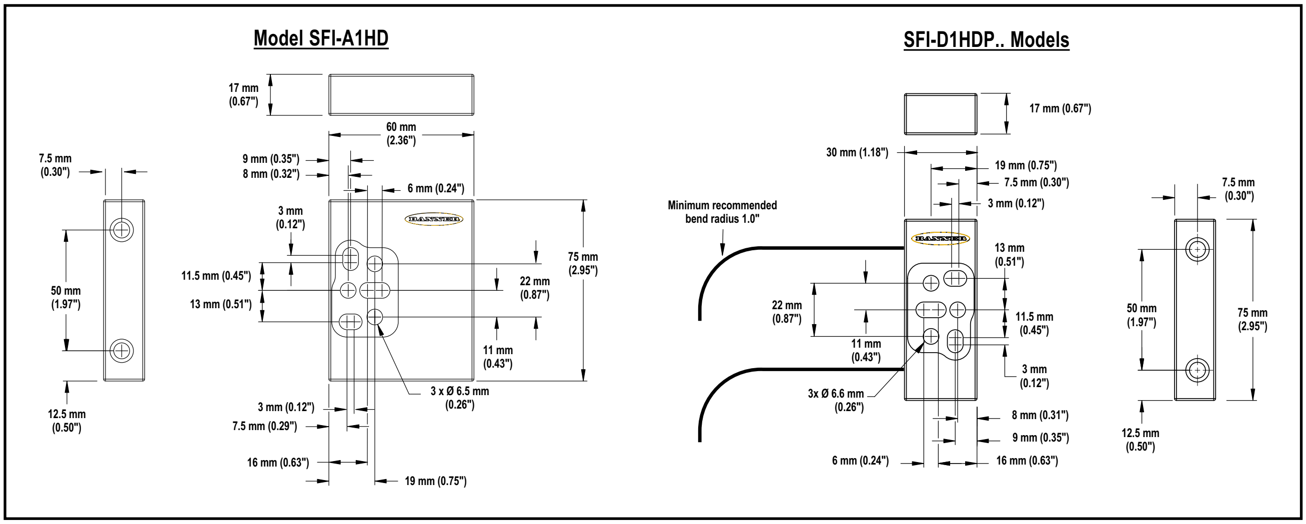


Figure 6-6. Models SFI-A1HD and SFI-D1HDP.. heavy-duty switch

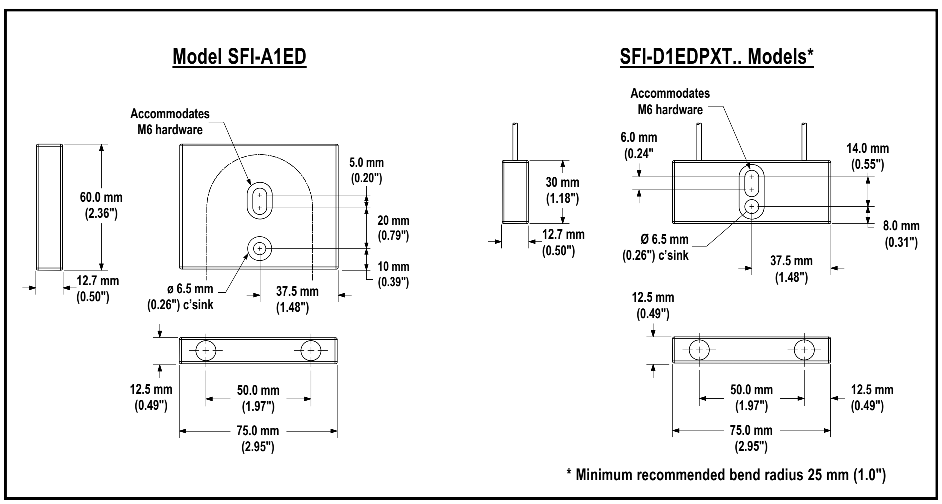


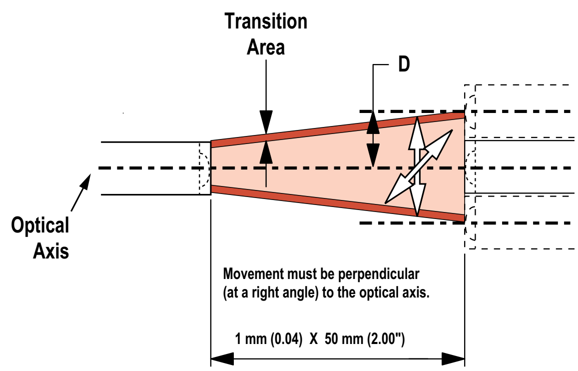
Figure 6-7. Models SFI-A1ED and SFI-D1EDPXT.. extreme-duty switch

6.4 Switch Mounting and Alignment Considerations

6.4.1 Switching Distance

The switching distance (D) is given as a "±" value and is dependent on the excess gain, the distance between the optical switches (X), and their alignment along the optical centerline (i.e., parallel to the dash/dotted centerline). Perpendicular displacement greater than "D" will result in a stop condition (see Figure 6-8).

Depending on alignment, fiber length, and other loss factors, the excess gain may fall below the threshold level before the switching distance and cause a weak signal or beam break condition before distance "D." This region is called the "Transitional Area."



SFI Fiber Optic Interlock Switch Models/ Model Combinations	Separation X		
	1 mm (0.04")	25 mm (1.0")	50 mm (2.0")
	Maximum Switching Distance D		
Two Straight	± 10 mm (0.39")	± 11 mm (0.43")	± 12 mm (0.47")
Straight + Right-Angle	± 10 mm (0.39")	± 23 mm (0.91")	± 35 mm (1.38")
Two Right-Angle	± 11 mm (0.43")	± 21 mm (0.83")	± 33 mm (1.30")
Two Right-Angle + Actuator	± 7 mm (0.28")	± 8 mm (0.31")	± 10 mm (0.39")
Dual-Lens + Actuator	± 7 mm (0.28")	± 8 mm (0.31")	± 9 mm (0.35")

Values are typical

Figure 6-8. Switching distance

6.4.2 Determining Interlock Switch Optical Channel Configuration

SFI Interlock Switch Options – PIU... Series Cut Fibers				
SFI Fiber Optic Interlock Switch Combinations	**Number of Interlock Switch Pairs on Circuit**			
	1	**2**	**3**	**4**
Straight & Straight (Total fiber length accurate for SFI-M12SS.., with one SFA-FS fiber splice between optical elements).				
Maximum total length of fiber, 50 mm (2") operating distance between each switch pair	110 m (361')	65 m (213')	30 m (98')	
Maximum total length of fiber, 1 mm (0.04") operating distance between each switch pair	120 m (394')	90 m (295')	50 m (164')	25 m (82')
Total length of fiber (or less) in which an SFA-FA Attenuator is required to prevent gain lockout; 1 mm (0.04") operating distance between each switch pair	35 m (115')	No Attenuator needed	No Attenuator needed	No Attenuator needed
Straight & Right-Angle				
Maximum total length of fiber, 50 mm (2") operating distance between each switch pair	105 m (344')	50 m (164')	10 m (33')	
Maximum total length of fiber, 1 mm (0.04") operating distance between each switch pair	115 m (377')	75 m (246')	35 m (115')	10 m (33')
Total length of fiber (or less) in which an SFA-FA Attenuator is required to prevent gain lockout; 1 mm (0.04") operating distance between each switch pair	30 m (98')	No Attenuator needed	No Attenuator needed	No Attenuator needed
Right-Angle & Right-Angle				
Maximum total length of fiber, 50 mm (2") operating distance between each switch pair	90 m (295')	35 m (115')		
Maximum total length of fiber, 1 mm (0.04") operating distance between each switch pair	95 m (312')	50 m (164')		
Total length of fiber (or less) in which an SFA-FA Attenuator is required to prevent gain lockout; 1 mm (0.04") operating distance between each switch pair	20 m (66')	No Attenuator needed		
Two Right-Angles & Actuator				
Maximum total length of fiber, 50 mm (2") operating distance between each switch pair	60 m (197')			
Maximum total length of fiber, 1 mm (0.04") operating distance between each switch pair	70 m (230')	10 m (33')		
Total length of fiber (or less) in which an SFA-FA Attenuator is required to prevent gain lockout; 1 mm (0.04") operating distance between each switch pair	No Attenuator needed	No Attenuator needed		
Dual-Lens & Actuator (Total fiber length accurate for SFI-D1HD.. and SFI-D1ED.., with one SFA-FS fiber splice between optical elements).				
Maximum total length of fiber, 50 mm (2") operating distance between each switch pair	70 m (230')	10 m (33')		
Maximum total length of fiber, 1 mm (0.04") operating distance between each switch pair	95 m (312')	30 m (98')		
Total length of fiber (or less) in which an SFA-FA Attenuator is required to prevent gain lockout; 1 mm (0.04") operating distance between each switch pair	10 m (33')	No Attenuator needed		

NOTE: The information in the table above is provided as a guide for installation of the PICO-GUARD Fiber Optic Safety Interlock Switches using 1 mm core plastic fiber. The total length of installed fiber may be affected by certain variables, such as alignment of the switches, bend radii of the fiber, environmental conditions, etc. Contact the factory applications department for additional information.

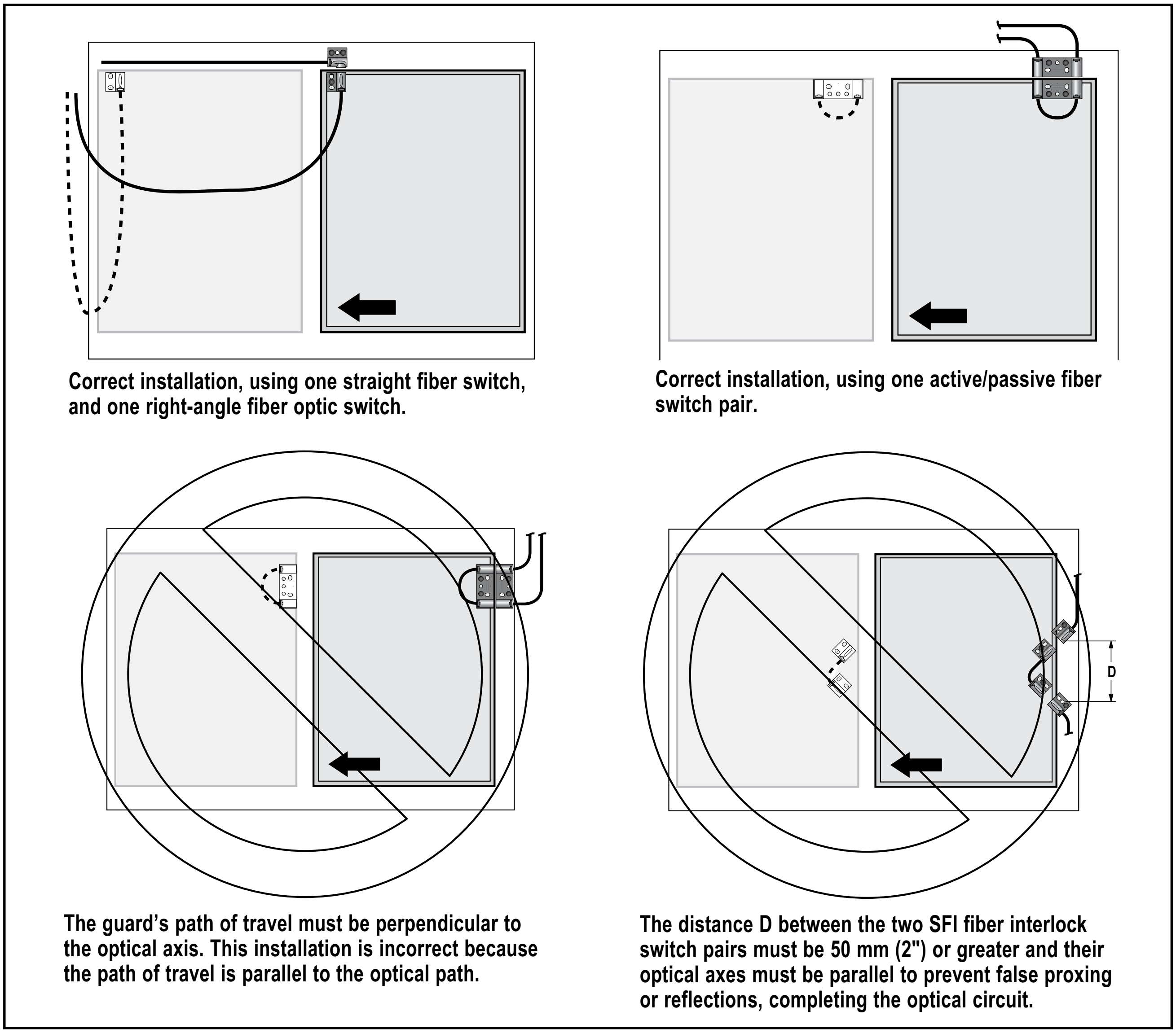
6.4.2 Determining Interlock Switch Optical Channel Configuration, continued

SFI Interlock Switch Options – PW... Series Polished Fibers				
SFI Fiber Optic Interlock Switch Combinations	**Number of Interlock Switch Pairs on Circuit**			
	1	**2**	**3**	**4**
Straight & Straight (Total fiber length accurate for SFI-M12SS.., with one SFA-FS fiber splice between optical elements).				
Maximum total length of fiber, 50 mm (2") operating distance between each switch pair	130 m (426')	75 m (246')	60 m (197')	35 m (115')
Maximum total length of fiber, 1 mm (0.04") operating distance between each switch pair	145 m (476')	110 m (361')	85 m (279')	70 m (230')
Total length of fiber (or less) in which an SFA-FA Attenuator is required to prevent gain lockout; 1 mm (0.04") operating distance between each switch pair	40 m (131')	25 m (82')	No Attenuator needed	No Attenuator needed
Straight & Right-Angle				
Maximum total length of fiber, 50 mm (2") operating distance between each switch pair	120 m (394')	55 m (180')	40 m (131')	
Maximum total length of fiber, 1 mm (0.04") operating distance between each switch pair	135 m (443')	90 m (295')	60 m (197')	
Total length of fiber (or less) in which an SFA-FA Attenuator is required to prevent gain lockout; 1 mm (0.04") operating distance between each switch pair	30 m (98')	No Attenuator needed	No Attenuator needed	
Right-Angle & Right-Angle				
Maximum total length of fiber, 50 mm (2") operating distance between each switch pair	115 m (377')	45 m (148')	15 m (49')	
Maximum total length of fiber, 1 mm (0.04") operating distance between each switch pair	125 m (410')	55 m (180')	25 m (82')	
Total length of fiber (or less) in which an SFA-FA Attenuator is required to prevent gain lockout; 1 mm (0.04") operating distance between each switch pair	25 m (82')	No Attenuator needed	No Attenuator needed	
Two Right-Angles & Actuator				
Maximum total length of fiber, 50 mm (2") operating distance between each switch pair	70 m (230')	8 m (26')		
Maximum total length of fiber, 1 mm (0.04") operating distance between each switch pair	90 m (295')	25 m (82')		
Total length of fiber (or less) in which an SFA-FA Attenuator is required to prevent gain lockout; 1 mm (0.04") operating distance between each switch pair	No Attenuator needed	No Attenuator needed		
Dual-Lens & Actuator (Total fiber length accurate for SFI-D1HD.. and SFI-D1ED.., with one SFA-FS fiber splice between optical elements).				
Maximum total length of fiber, 50 mm (2") operating distance between each switch pair	75 m (246')	25 m (82')		
Maximum total length of fiber, 1 mm (0.04") operating distance between each switch pair	100 m (328')	60 m (197')		
Total length of fiber (or less) in which an SFA-FA Attenuator is required to prevent gain lockout; 1 mm (0.04") operating distance between each switch pair	15 m (49')	No Attenuator needed		

NOTE: The information in the table above is provided as a guide for installation of the PICO-GUARD Fiber Optic Safety Interlock Switches using polished, 1 mm core plastic fiber. The total length of installed fiber may be affected by certain variables, such as alignment of the switches, bend radii of the fiber, environmental conditions, etc. Contact the factory applications department for additional information.

6.4.3 Path of Travel and Alignment

The path of travel (movement) of the Fiber Optic Safety Interlock Switch must always be perpendicular (at a right angle) to the optical axis to ensure proper switching action (see Figure 6-9). Perpendicular displacement along the optical centerline greater than the switching distance (see Figure 6-8) will result in a beam break and a Stop condition.



Correct installation, using one straight fiber switch, and one right-angle fiber optic switch.

Correct installation, using one active/passive fiber switch pair.

The guard's path of travel must be perpendicular to the optical axis. This installation is incorrect because the path of travel is parallel to the optical path.

The distance D between the two SFI fiber interlock switch pairs must be 50 mm (2") or greater and their optical axes must be parallel to prevent false proxing or reflections, completing the optical circuit.

Figure 6-9. Sliding gates: correct and incorrect installation of switches

In a guard-closed position, the maximum distance from lens face to lens face is 50 mm (2"). **Ensure that there is a minimum 1 mm (0.04") of separation between switches, and do not use the switches as an end-of-travel or mechanical stop.** The PICO-GUARD model SFI-IAG Interlock Alignment Guide can be used as a straight edge and a guide to ensure the separation between optical elements does not exceed 50 mm (2.0"). See Figure 6-10.

The SFI-IAG Interlock Alignment Guide can also assist in verifying the surface of the guard is physically even with the surface of the frame to ensure that the optical axis of each element is centered with the other (see Figure 6-11). This is important in maximizing excess gain, which impacts tolerance to vibration, door sag, and contamination. See “Switching Distance” in Section 6.4.

The use of tamper-resistant fasteners, such as one-way screws, is recommended. Do not over-tighten or mount the fiber switch on an uneven surface such that the switch is deformed or bows, because that will affect the optical performance.

Fiber Optic Safety Interlock Switches must be installed in a manner that discourages tampering or defeat. They must never be used as mechanical stops; over-travel may cause damage to the Fiber Optic Safety Interlock Switches.

NOTE: All mounting hardware is user-supplied. Fasteners should be of sufficient strength to guard against accidental breakage. Permanent fasteners or locking hardware are recommended to prevent loosening or displacement of the switch.

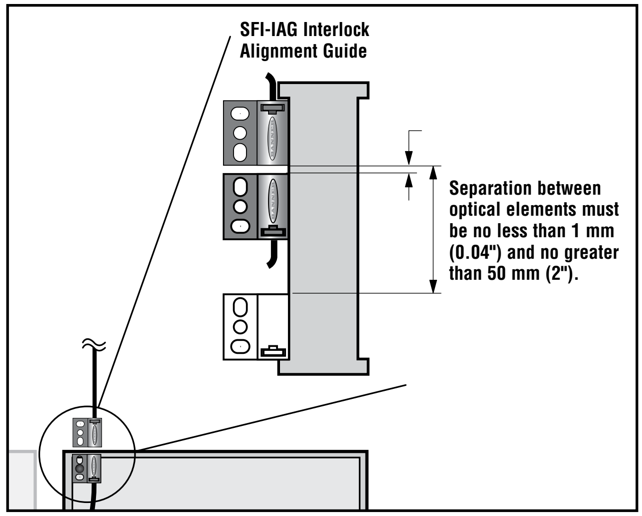


Figure 6-10. Distance between lenses must be between 1 and 50 mm (0.04" and 2")

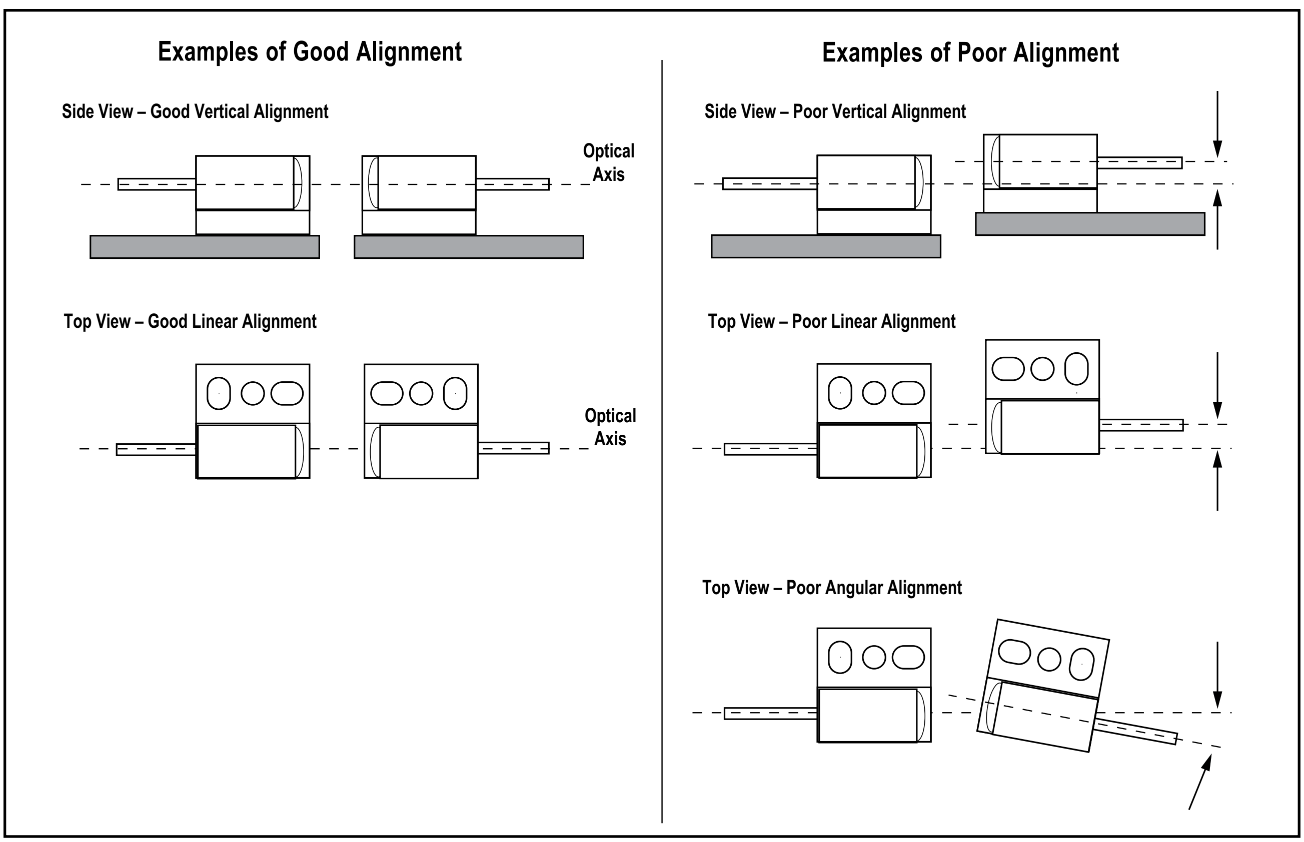


Figure 6-11. Examples of good and bad alignment

6.5 Fiber Connection / Routing to Interlock Switches

NOTE: Review Section 3 for complete recommendations for installing, cutting, and routing fiber optic cable.

To connect an SFI switch to a fiber with **unpolished ends** (PIU4 series), properly prepare the optical fiber by cutting a short length off the end (approximately 0.25"), or cut the optical fiber to length (see section 3.2 for fiber cutting procedure). A new cut ensures a flat termination of the fiber for good optical coupling. **Do not cut the polished end of the fiber** (PW.. series) unless the end has been damaged or contaminated or if it must be cut to length.

NOTE: If a polished end is cut, the excess gain will be reduced and the advantage of polishing will be lost. Do not cut polished fibers unless absolutely necessary.

If the fiber gripper is closed (flush with the body of the interlock switch), use a small flat screwdriver to carefully pry up the gripper until the fiber can be inserted into the body (see Figure 6-12).

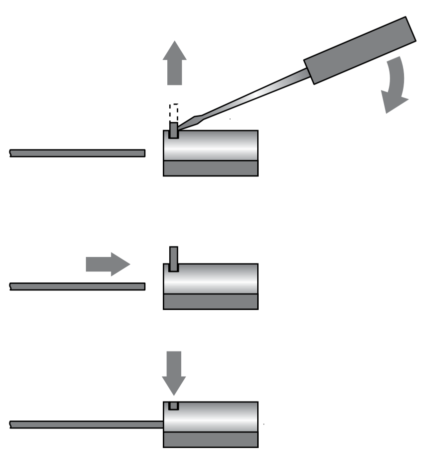


Figure 6-12. Installing fibers into an SFI series interlock switch

For SFI series interlock switches and the SFA-FA attenuator, insert the end of the fiber(s) into the body until it bottoms out. Then carefully push the tab(s) for the fiber gripper until flush with the body of the interlock switch.

For the SFA-FS splice, ensure both fiber grippers are open. Use the depth guide on the side of the mounting flange to gauge the proper amount of fiber to be inserted first. Carefully insert the fiber, and push the fiber gripper tab until it is flush with the body of the switch; this will secure the fiber. Insert the second fiber into the opposite side of the splice, until it bottoms out. Then carefully push the fiber gripper tab until it is flush with the body of the splice (see Figure 6-13).

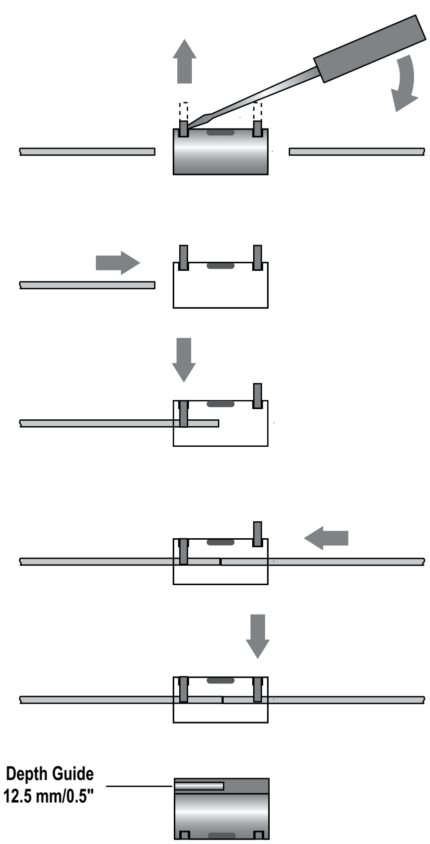


Figure 6-13. Installing fibers into an SFA-FS splice

Routing Fiber Optic Cable

Do not exceed the minimum bend radius for the fiber optic cable (see Section 3.3). The excess gain is dependent on switch pair alignment, fiber length, fiber bend radius, and other loss factors, which may result in a weak signal or beam break condition (i.e., increased transitional area, see Figure 6-8). For more information, go to www.bannerengineering.com (select PICO-GUARD and then software) for an online gain estimator or see Section 4.

Plastic fibers must be routed away from sources of excessive heat, and isolated from excessive abrasion resulting from vibration or movement of the guard. Accessory sheathing is available to protect the fiber optic cable from damage (see Section 1.3.3).

Do not crush or otherwise deform the fiber optic cable. When using cable tie-straps (e.g. nylon cable ties), do not over-tighten such that the outer jacket is deformed or damaged. This will reduce excess gain and may allow the ingress of contamination or sever the fiber optic cable.

It may be necessary to route the fiber optic cable in conduit or otherwise protect the fiber from damage and contamination.

6.6 Fiber Optic Interlocking

6.6.1 Multiple Guards Individually Monitored

One properly installed SFI Fiber Optic Safety Interlock Switch per interlocked guard is designed to meet the requirements of Control Reliability and Safety Category 4 per ISO13849-1 (EN954-1). See Figure 6-14.

Guards can be individually monitored and their status identified via the indicators on the controller, the SFA-RD Remote Display, the RS 232 port, or individual optical channel outputs (controller model SFCDT-4A1C only).

6.6.2 Zone Monitoring of Multiple Guards

Multiple guards on one optical channel can be interfaced to set up monitoring of multiple strings, cells, or areas. In such applications, the user must verify excess gain (see Section 4). As in Section 6.6.1, the fiber loop consisting of multiple SFI Fiber Optic Safety Interlock Switches is designed to meet the requirements of Control Reliability and Safety Category 4 per ISO 13849-1 (EN954-1). See Figure 6-15.

As with individual fiber switches, individual zones, sides, or cells can be monitored and their status identified via the indicators on the controller, the SFA-RD Remote Display, the RS 232 port, or individual optical channel outputs (controller model SFCDT-4A1C only).

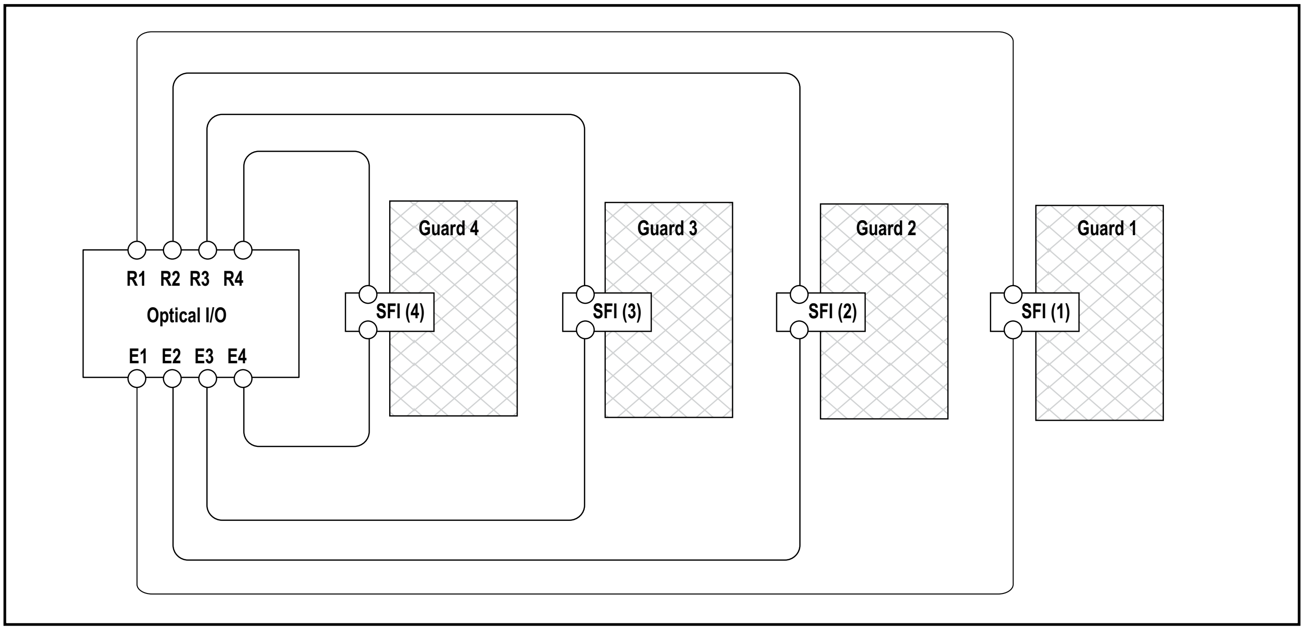


Figure 6-14. Monitoring multiple guards with one switch per guard

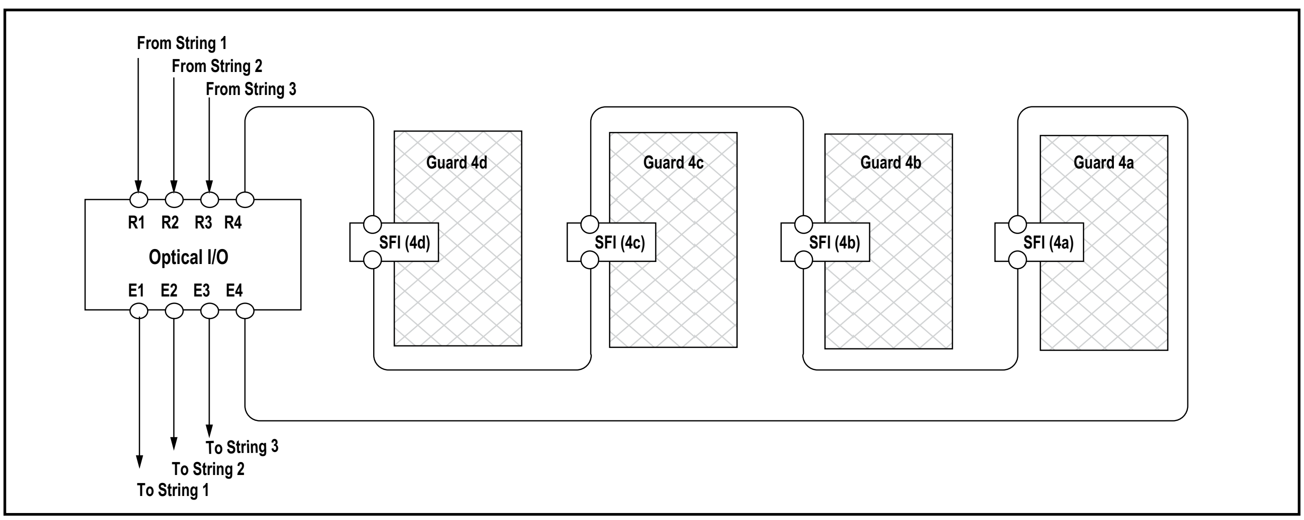


Figure 6-15. Monitoring multiple guards in a single zone (fiber optic loop)

6.6.3 Hinged Doors and Gates

SFI series interlock switches can be mounted inside or outside the hazardous area that the interlocked door is safeguarding (see Figure 6-16). Depending on the application and whether the enclosed process degrades the optical signal or negatively impacts the fiber or the switch, mounting within the frame of the machine can reduce the possibility of defeat, improve esthetics of the machine, and reduce the chance of damage to optical elements.

When interlocking a hinged guard, a strain-relief loop must be incorporated at the point of rotation. This loop must allow adequate range of motion without the fiber being stretched, crushed, pinched, or otherwise damaged when the guard is opened and closed. Routing of the fiber must not allow the minimum bend radius to be exceeded.

An SFI interlock switch pair mounted with a horizontal optical axis can reduce the amount of contamination (dust) that accumulates on the lens of a switch. Contamination of the lens decreases excess gain and can cause intermittent tripping due to a weak signal. Controller model SFCDT-4A1.. has a solid-state output and individual channel indictors to alert the user of such a condition.

A vertical optical axis may reduce the chance of optical cross talk, or it may be required by the layout of the machine. A vertical optical axis may also be more tolerant of door sag.

Over time, door sag can cause misalignment of the SFI interlock switches. This is a common issue with hinged guards (especially double doors) and must be addressed during periodic checks. To prevent problems resulting from door sag (e.g,. intermittent tripping), ensure that the hinge and latching mechanisms are of adequate strength to carry the weight and force of the door.

SFI interlock switches will allow approximately ±3 to 6 mm (0.125" to 0.25") of misalignment, depending on excess gain, to permit for some amount of door sag or vibration.

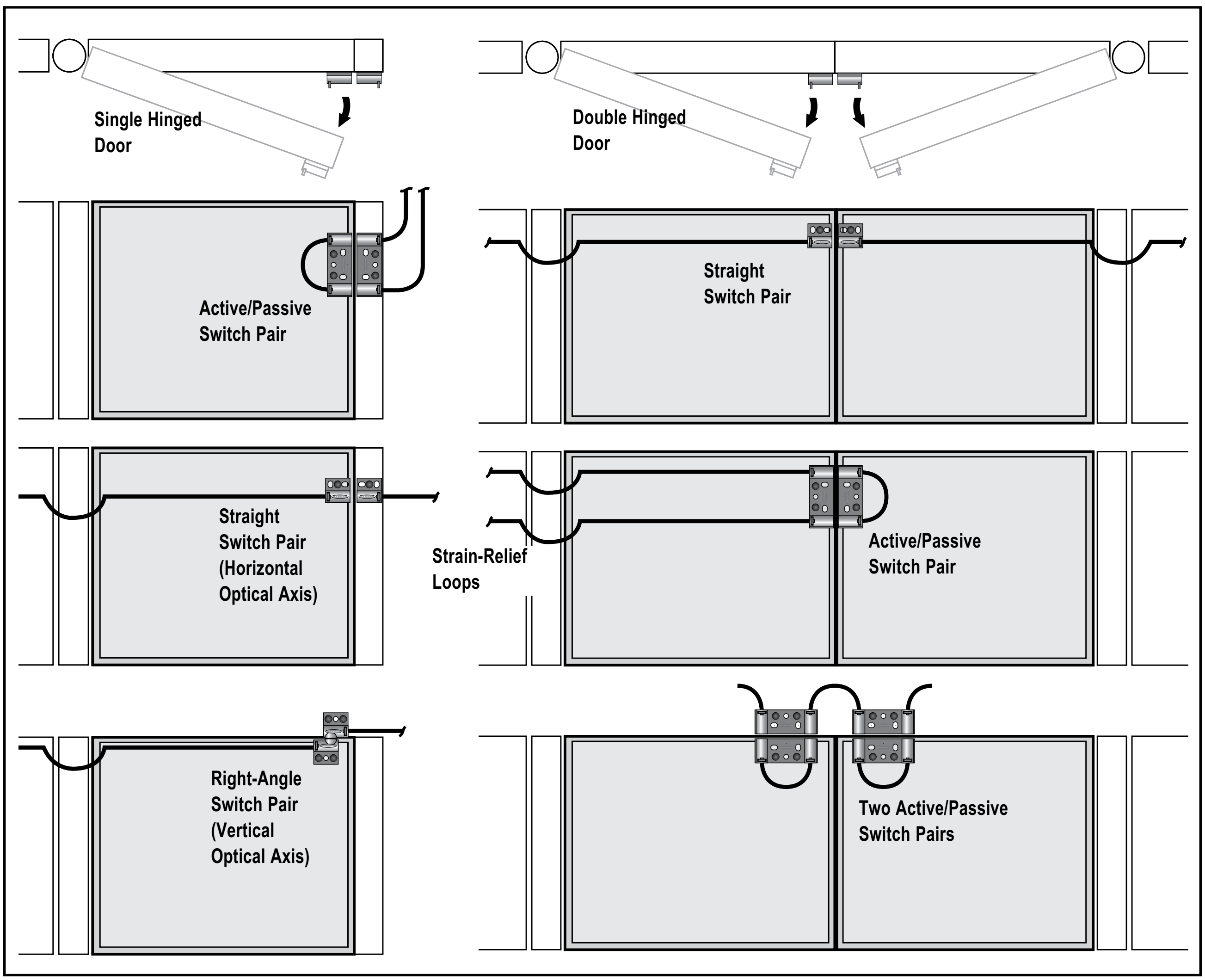


Figure 6-16. Aligning switches on hinged doors and gates

6.6.4 Covers and Removable Guards

Generally, an SFI-D1/-A1 active/passive switch pair is used when a cover or removable guard is to be interlocked (see Figure 6-17).

The disadvantage is that the SFI-D1/-A1 pair is optically considered to be two openings, resulting in twice the loss of optical signal than with straight and right-angle interlocking switches. However, the advantage of not having to route the optical fibers to the removable portion of the guard often outweighs the loss of excess gain.

In applications where guide pins or dowels are used, ensure that the linear motion (to the optical axis) required to remove the cover does not allow access to the hazard (see Figure 6-18). **See Warning on page 17.**

If using two individual fiber optic interlocks (straight or right-angle), the distance "D" must not be less than 50 mm (2") due to the possibility of false proxing (see Figures 6-9 and 6-19).

Do not mount individual optical elements (straight or right-angle SFI series) along the same optical axis in such a manner that the optical path can be completed when the guard is removed (see Figure 6-20).

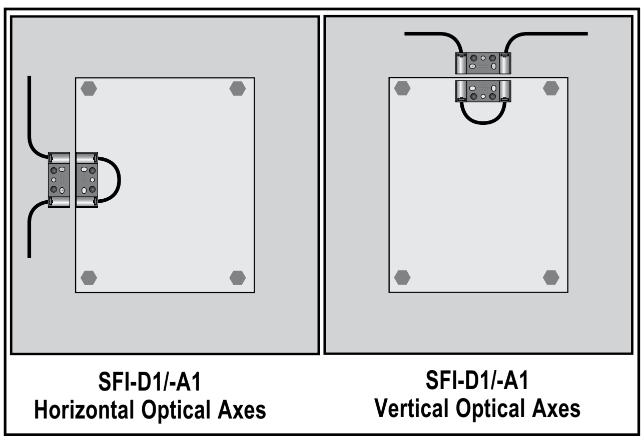


Figure 6-17. Active/passive pairs for covers and removable guards

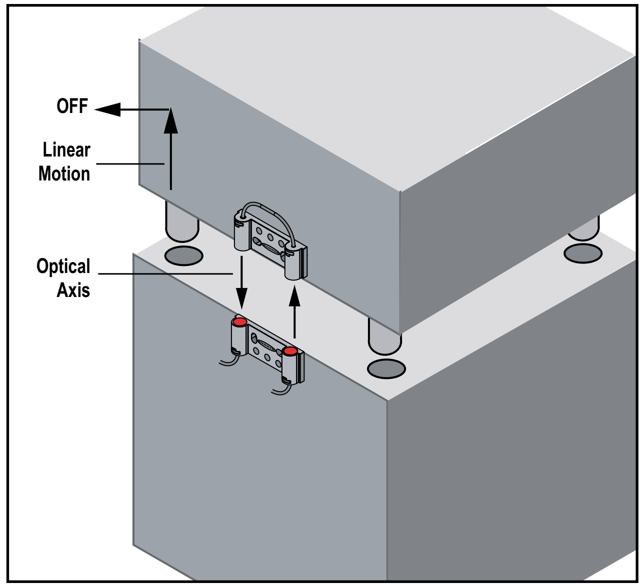


Figure 6-18. Pins or dowels on a removable cover

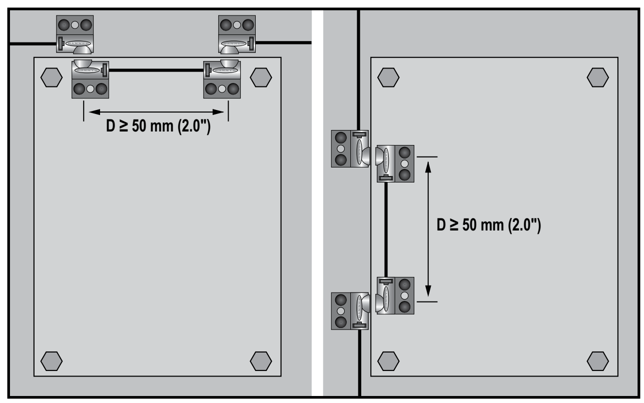


Figure 6-19. Use of individual switch pairs for covers and removable guards

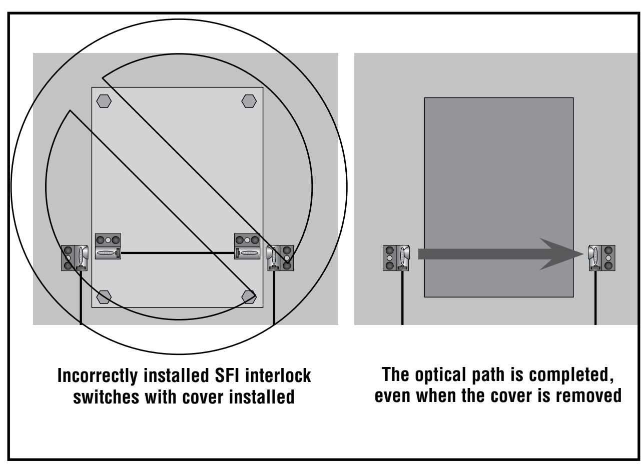


Figure 6-20. Switch pairs mounted along the same optical axis complete the optical circuit, even when the cover is removed

7. Fiber Optic Safety Point and Grid Optical Elements

PICO-GUARD Fiber Optic Safety Point and Grid optical elements are designed for use in access-guarding and perimeter-guarding applications (see 7.1 Pass-Through Applications). These devices create a vertical grid of multiple beams to detect a body or torso (rather than a hand or an arm) as a person enters a hazardous area. The grid is created either by the use of a single pair of Grid elements, or by the careful mounting of multiple pairs of Point elements. This arrangement is not intended nor designed for hand or finger detection in point-of-operation guarding applications.

In this manual, the area through which the beams travel is called the "light grid," regardless of whether Point or Grid optical elements are used.

CAUTION . . . Appropriate Applications

In addition to the limitations listed on page 2 and in the PICO-GUARD controller manual, **use of the Banner PICO-GUARD Fiber Optic Safety Points and Grids are generally not allowed:**

- For hand or finger detection in point-of-operation guarding (when used individually),
- For non-vertical area-guarding applications,
- To guard any machine with inadequate or inconsistent machine response time and stopping performance,
- As tripping devices to initiate machine motion (PSDI applications) on mechanical power presses, per OSHA regulation 29 CFR 1910.217,
- To guard any machine that cannot be stopped immediately after a stop signal is issued, such as single-stroke (or "full-revolution") clutched machinery
- To guard any machine that ejects materials or component parts through the sensing field, or
- In any environment that is likely to adversely affect photoelectric sensing system efficiency. For example, corrosive chemicals or fluids or unusually severe levels of smoke or dust, if not controlled, may degrade the efficiency of the safety point or grid optical elements.

Direct any questions regarding the use or installation to the Factory Applications Department at the telephone numbers or addresses on the back cover.

A recommended set of beam placement positions has become accepted in the United States and Europe. The standards (ANSI/RIA R15.06, ANSI B11 and EN 999) recommend safe beam placement, in order to hinder personnel from crawling over, under or through the light grid, and into the hazardous area, without detection. For more information, refer to Section 7.4.1.

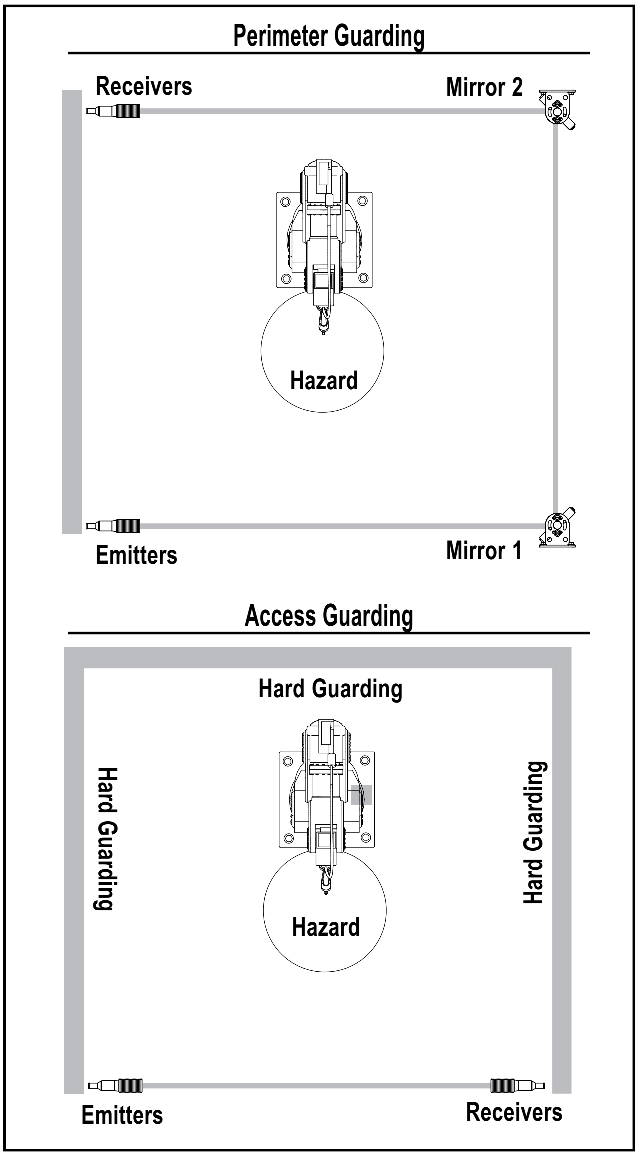


Figure 7-1. Perimeter-guarding and access-guarding applications for PICO-GUARD Point devices

7.1 Pass-Through Hazards

Perimeter- and access-guarding applications must be designed to prevent *pass-through hazards*. A pass-through hazard can occur after an individual is allowed to cross the safeguard (which issues a stop command to remove the hazard). The danger arises if the machine's dangerous motion may resume while the person remains – now undetected – within the hazardous (safeguarded) area. Measures to prevent a pass-through hazard, include, but are not limited to:

- **A latching output** on the safety system guarding the access or perimeter to the hazardous area, which requires a manual reset procedure before machine motion can be re-initiated. The reset switch has several requirements, including its placement outside of the guarded area, and out of reach of anyone inside the guarded area. It must also be guarded to prevent accidental or unintended actuation. In addition, the reset switch operator must have full view of the entire guarded area during the reset procedure.

  Because the PICO-GUARD controller has a selectable (latch or trip) output, it must be installed and configured to prevent hazardous motion from occurring while personnel are within the guarded area. See the PICO-GUARD controller manual for more information.

- **Supplemental safeguarding,** such as described by the ANSI B11 series of safety requirements or other appropriate standards, to:

  – prevent personnel from standing undetected within the guarded area, and

  – prevent personnel from entering the guarded area, undetected by the safety light grid, or other safeguarding means.

WARNING . . . Reset Switch Location

All reset switches must be:
- Mounted outside the hazardous area,
- a location that allows the switch operator full view of the entire guarded area,
- Out of reach from within the safeguarded space, and
- Protected against unauthorized or inadvertent operation.

If any areas within the guarded area are not visible from the Reset switch, **additional means of safeguarding must be provided,** as described by the ANSI B11 series or other appropriate standards. **Failure to do so could result in serious injury or death.**

WARNING . . . Use of Trip/Latch Output and Auto Power-up

Application of power to the PICO-GUARD System, the clearing of the light grid, or the reset of a latch condition MUST NOT initiate dangerous machine motion. Machine control circuitry must be designed so that one or more initiation devices must be engaged (i.e., a conscious act) to start the machine in addition to the **PICO-GUARD** System going into RUN mode. Failure to follow these instructions could result in serious bodily injury or death (see Section 1.2).

7.2 Fiber Optic Safety Point Models

Banner PICO-GUARD Point components are purchased individually, and include mounting hardware and a test piece. Two elements are needed for each emitter/receiver pair; optical elements may be used interchangeably as emitters or receivers.

12 mm Models	30 mm Models	Fiber Description	Fiber Length	Fiber* Diameter
SFP12PS8	**SFP30SS8**	Polished-End Integral Fiber, Polyethylene Coated	2.4 m (8')	2.2 mm (0.09")
SFP12PS15	**SFP30SS15**		4.5 m (15')	
SFP12PS25	**SFP30SS25**		7.5 m (25')	
SFP12PS50	**SFP30SS50**		15 m (50')	
--	**SFP30SS100**		30 m (100')	
SFP12PXP8	**SFP30SXP8**	Polished-End Integral Fiber, PVC Coated	2.4 m (8')	5 mm (0.2")
SFP12PXP15	**SFP30SXP15**		4.5 m (15')	
SFP12PXP25	**SFP30SXP25**		7.5 m (25')	
SFP12PXP50	**SFP30SXP50**		15 m (50')	
--	**SFP30SXP100**		30 m (100')	
SFP12PXT8	**SFP30SXT8**	Polished-End Integral Fiber, PTFE Coated	2.4 m (8')	2.2 mm (0.09")
SFP12PXT15	**SFP30SXT15**		4.5 m (15')	
SFP12PXT25	**SFP30SXT25**		7.5 m (25')	
SFP12PXT50	**SFP30SXT50**		15 m (50')	
--	**SFP30SXT100**		30 m (100')	

*See Figure 1-2.

7.3 Fiber Optic Safety Point Optical Element Specifications

7.3.1 SFP12.. Specifications

<table>
<tr><td>Operating Range</td><td>Range information is based on the use of integral polished fibers. The use of SFA-FS Fiber Splice or cutting the fiber will reduce range.

Do not cut polished fiber ends unless absolutely necessary – cut only if the end has been damaged or contaminated, or if it must be cut to length. Use only the Model PFC-2 Fiber Cutter to cut fibers, when necessary. If a polished end is cut, the excess gain will be reduced, the advantage of polishing will be lost, and the operating range will be reduced.

Minimum Operating Range: 150 mm (6")
Maximum Operating Range: see table below

<table>
<tr><th colspan="5">Maximum Operating Range*</th></tr>
<tr><th>Receiver / Emitter</th><th>SFP12..8</th><th>SFP12..15</th><th>SFP12..25</th><th>SFP12..50</th></tr>
<tr><td>SFP12..8</td><td>6.4 m (21')</td><td>5.5 m (18')</td><td>4.6 m (15')</td><td>3 m (10')</td></tr>
<tr><td>SFP12..15</td><td>5.5 m (18')</td><td>4.8 m (16')</td><td>4 m (13')</td><td>2.7 m (9')</td></tr>
<tr><td>SFP12..25</td><td>4.6 m (15')</td><td>4 m (13')</td><td>3.4 m (11')</td><td>2.1 m (7')</td></tr>
<tr><td>SFP12..50</td><td>3 m (10')</td><td>2.7 m (9')</td><td>2.1 m (7')</td><td>1.5 m (5')</td></tr>
<tr><td colspan="5">*In applications using SSM or MSM Series corner mirrors, range is reduced by approximately 8 percent for each mirror used. See Section 7.2.2.</td></tr>
</table>
</td></tr>
<tr><td>Beam Diameter</td><td>9 mm (0.35")</td></tr>
<tr><td>Effective Aperture Angle (EAA)</td><td>Meets Type 4 requirements per IEC 61496-2, Section 5.2.9; ± 2.5° at 3 m</td></tr>
<tr><td>Operating Conditions</td><td>Temperature range: 0° to +70° C (+32° to 158° F)
Max. relative humidity: 95% (non-condensing)</td></tr>
<tr><td>Environmental Rating</td><td>IEC IP67</td></tr>
<tr><td>Construction</td><td>Housing and Window: Polycarbonate</td></tr>
</table>

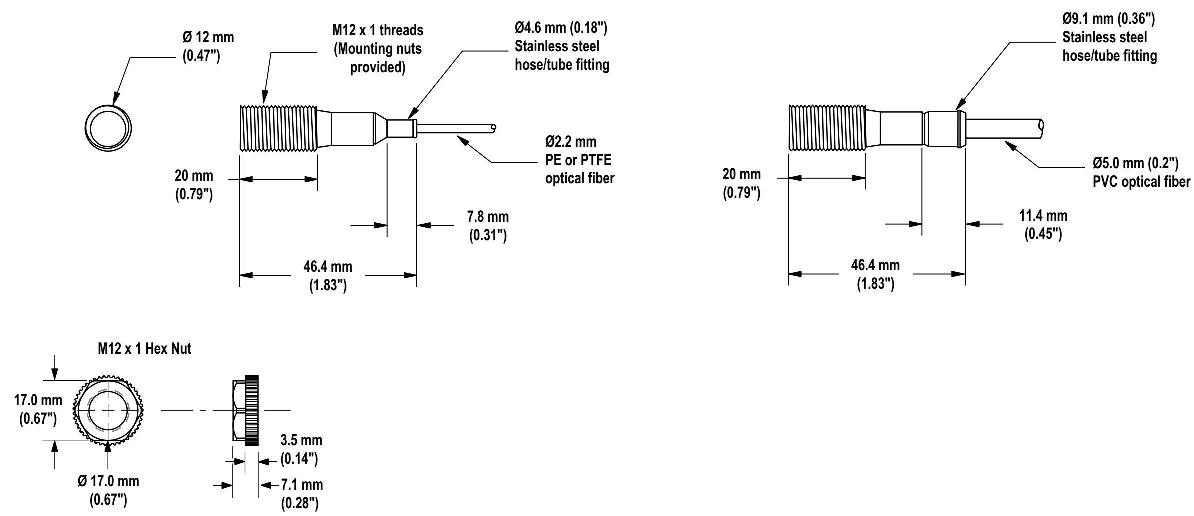


Figure 7-2. Model SFP12.. Fiber Optic Safety Point optical element dimensions

7.3.2 SFP30.. Specifications

Operating Range	Range information is based on the use of integral polished fibers. The use of SFA-FS Fiber Splice or cutting the fiber will reduce range. **Do not cut polished fiber ends unless absolutely necessary –** cut only if the end has been damaged or contaminated, or if it must be cut to length. Use only the Model PFC-2 Fiber Cutter to cut fibers, when necessary. If a polished end is cut, the excess gain will be reduced, the advantage of polishing will be lost, and the operating range will be reduced. **Minimum Operating Range:** 0.8 m (2.6') **Maximum Operating Range:** see table below

Maximum Operating Range*

Emitter \ Receiver	SFP30..8	SFP30..15	SFP30..25	SFP30..50	SFP30..100
SFP30..8	28.7 m (94.0')	25.9 m (85.0')	23.2 m (76.0')	20.1 m (66.0')	13.7 m (45.0')
SFP30..15	25.9 m (85.0')	24.4 m (80.0')	22.9 m (75.0')	19.5 m (64.0')	12.8 m (42.0')
SFP30..25	23.2 m (76.0')	22.9 m (75.0')	21.9 m (72.0')	17.1 m (56.0')	12.2 m (40.0')
SFP30..50	20.1 m (66.0')	19.5 m (64.0')	17.1 m (56.0')	14.0 m (46.0')	11.0 m (36.0')
SFP30..100	13.7 m (45.0')	12.8 m (42.0')	12.2 m (40.0')	11.0 m (36.0')	8.5 m (28.0')

*In applications using SSM or MSM Series corner mirrors, range is reduced by approximately 8 percent for each mirror used. See Section 7.2.2.

Beam Diameter	25 mm (0.98")
Effective Aperture Angle (EAA)	Meets Type 4 requirements per IEC 61496-2, Section 5.2.9; ± 2.5° at 3 m
Operating Conditions	**Temperature range:** 0° to +70° C (+32° to 158° F) **Max. relative humidity:** 95% (non-condensing)
Environmental Rating	IEC IP67
Construction	**Housing and Window:** 304 stainless steel housing, tempered glass window

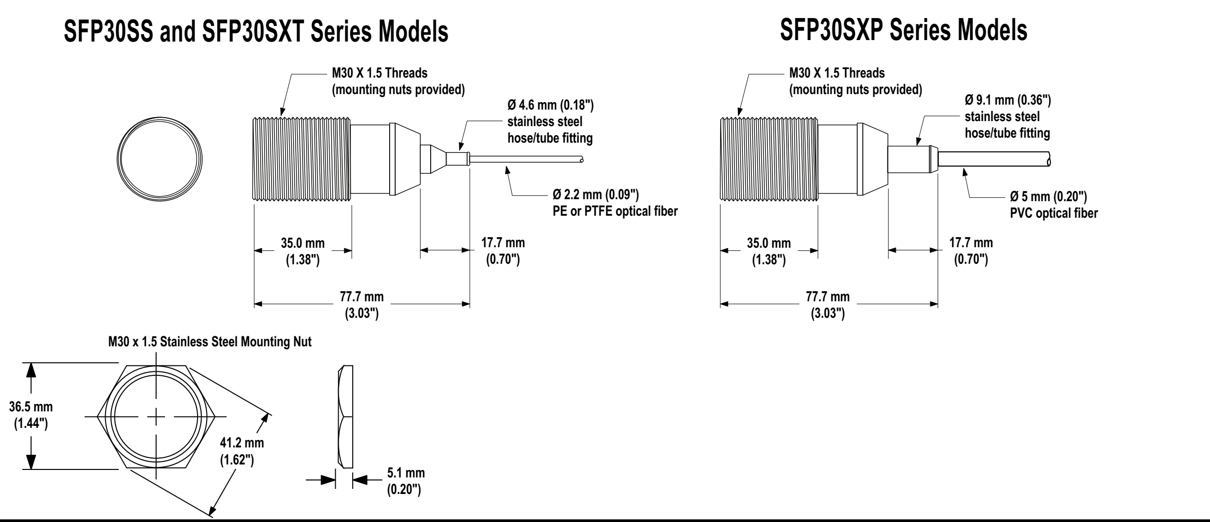
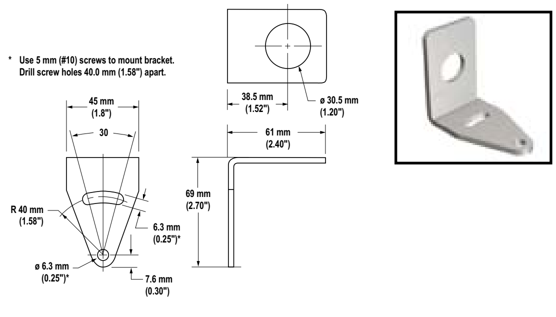
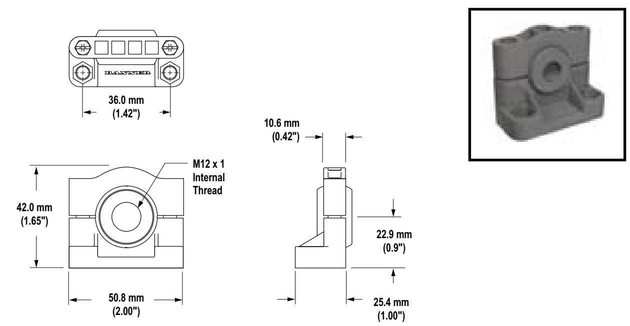


Figure 7-3. Model SFP30.. Fiber Optic Safety Point optical element dimensions

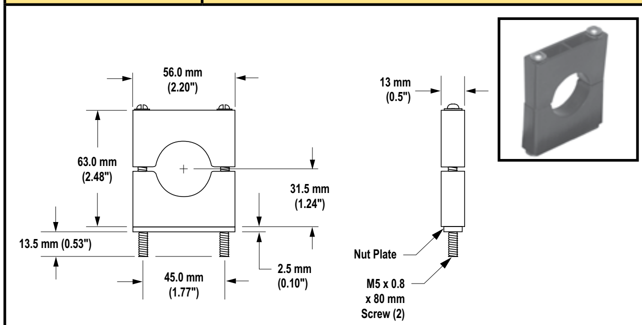
7.3.3 Accessory Mounting Brackets for Point Elements

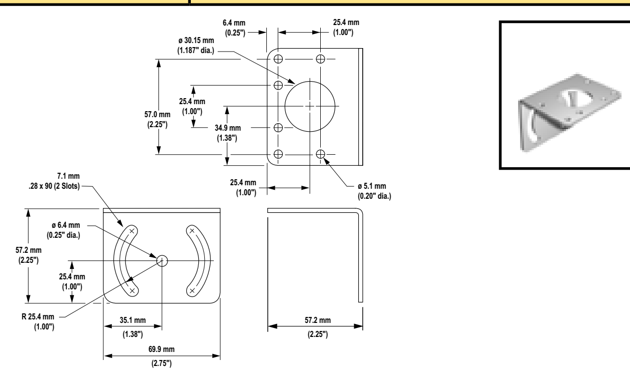
SMB12MM	• 12-gauge, 304 stainless steel, right-angle bracket for 12 mm barrel-style sensors • Curved mounting slot allows the bracket ± 10˚ of lateral movement • Clearance for M4 (#8) hardware	**SMB1812SF**	• 12 mm swivel • Black reinforced thermoplastic polyester • Includes stainless steel swivel locking hardware



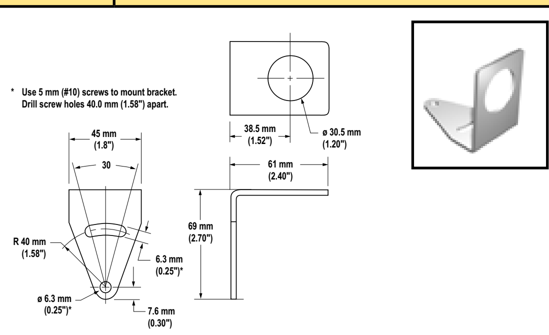


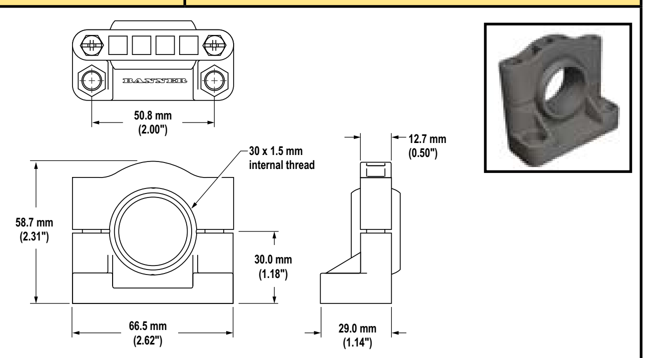
SMB30C	• 30 mm split clamp bracket • Black reinforced thermoplastic polyester • Includes stainless steel mounting hardware	**SMB30MM**	• 30 mm 12-gauge, 304 stainless steel bracket with curved mounting slots for versatile orientation • Clearance for M6 (1/4") hardware





SMB30A	• 30 mm 12-gauge, 304 stainless steel, right-angle mounting bracket with a curved mounting slot for versatile orientation • Clearance for M6 (1/4") hardware	**SMB30SC**	• 30 mm swivel bracket • Black reinforced thermoplastic polyester • Includes stainless steel mounting and swivel locking hardware





7.4 Fiber Optic Safety Grid Models

Each PICO-GUARD Grid element is individually packaged and includes mounting hardware, a test piece and data sheet. Two elements of equal beam number and spacing are needed for each emitter/receiver pair; optical elements may be used interchangeably as emitters or receivers.

Model	Protected Height	Number of Beams	Beam Spacing	Overall Housing Length (L1)*	Fiber Length	Application Standard
SFG2-584C8	584 mm (23.0")	2	584 mm (23.0")	768 mm (30.8")	2.4 m (8')	ANSI/RIA R15.06 ANSI B11
SFG2-584C15					4.5 m (15')	
SFG2-584C25					7.5 m (25')	
SFG2-584C50					15 m (50')	
SFG2-584C100					30 m (100')	
SFG3-533C8	1066 mm (42.0")	3	533 mm (21.0")	1251 mm (49.2")	2.4 m (8')	ANSI/RIA R15.06 ANSI B11
SFG3-533C15					4.5 m (15')	
SFG3-533C25					7.5 m (25')	
SFG3-533C50					15 m (50')	
SFG3-533C100					30 m (100')	
SFG2-500C8	500 mm (19.7")	2	500 mm (19.7")	684 mm (26.9")	2.4 m (8')	EN 999
SFG2-500C15					4.5 m (15')	
SFG2-500C25					7.5 m (25')	
SFG2-500C50					15 m (50')	
SFG2-500C100					30 m (100')	
SFG3-400C8	800 mm (31.4")	3	400 mm (15.7")	984 mm (38.7")	2.4 m (8')	EN 999
SFG3-400C15					4.5 m (15')	
SFG3-400C25					7.5 m (25')	
SFG3-400C50					15 m (50')	
SFG3-400C100					30 m (100')	
SFG4-300C8	900 mm (35.4")	4	300 mm (11.8")	1084 mm (42.7")	2.4 m (8')	ANSI/RIA R15.06 ANSI B11 EN 999
SFG4-300C15					4.5 m (15')	
SFG4-300C25					7.5 m (25')	
SFG4-300C50					15 m (50')	
SFG4-300C100					30 m (100')	

*** See Figure 7-4.**

7.5 Fiber Optic Safety Grid Specifications

Operating Range **NOTE: Do not cut polished fiber ends unless absolutely necessary – cut only if the end has been damaged or contaminated, or if it must be cut to length. Use only the Model PFC-2 Fiber Cutter to cut fibers, when necessary. If a polished end is cut, the excess gain will be reduced, the advantage of polishing will be lost, and the operating range will be reduced. See warning below.**	Range information is based on the use of integral polished fibers. The use of SFA-FS Fiber Splice or cutting the fiber will reduce range. In applications using SSM or MSM Series corner mirrors, range is reduced by approximately 8 percent for each mirror used. **Minimum Operating Range:** 800 mm (2.6') **Maximum Operating Range:** see table below

Maximum Operating Range (All Models)

Receiver / Emitter	SFG..8	SFG..15	SFG..25	SFG..50	SFG..100
SFG..8	31.1 m (102')	29.0 m (95')	26.5 m (87')	21.6 m (71')	14.9 m (49')
SFG..15	29.0 m (95')	27.1 m (89')	24.7 m (81')	20.1 m (66')	14.0 m (46')
SFG..25	26.5 m (87')	24.7 m (81')	22.6 m (74')	18.3 m (60')	12.8 m (42')
SFG..50	21.6 m (71')	20.1 m (66')	18.3 m (60')	14.9 m (49')	10.4 m (34')
SFG..100	14.9 m (49')	14.0 m (46')	12.8 m (42')	10.4 m (34')	7.0 m (23')

Beam Diameter	25 mm (0.98")
Effective Aperture Angle (EAA)	Meets Type 4 requirements per IEC 61406-2, Section 5.2.9; ± 2.5° at 3 m
Operating Conditions	**Temperature range:** 0° to +70° C (+32° to 158° F) **Max. relative humidity:** 95% (non-condensing)
Environmental Rating	IEC IP65
Construction	Black anodized aluminum housing and label; tempered glass window; zinc end caps (MEK resistant). Polyethylene-coated plastic fiber optic cable within PVC outer jacket (see SFA-FCC-.. flexible MEK-resistant conduit).

WARNING . . . Cutting Optical Fibers

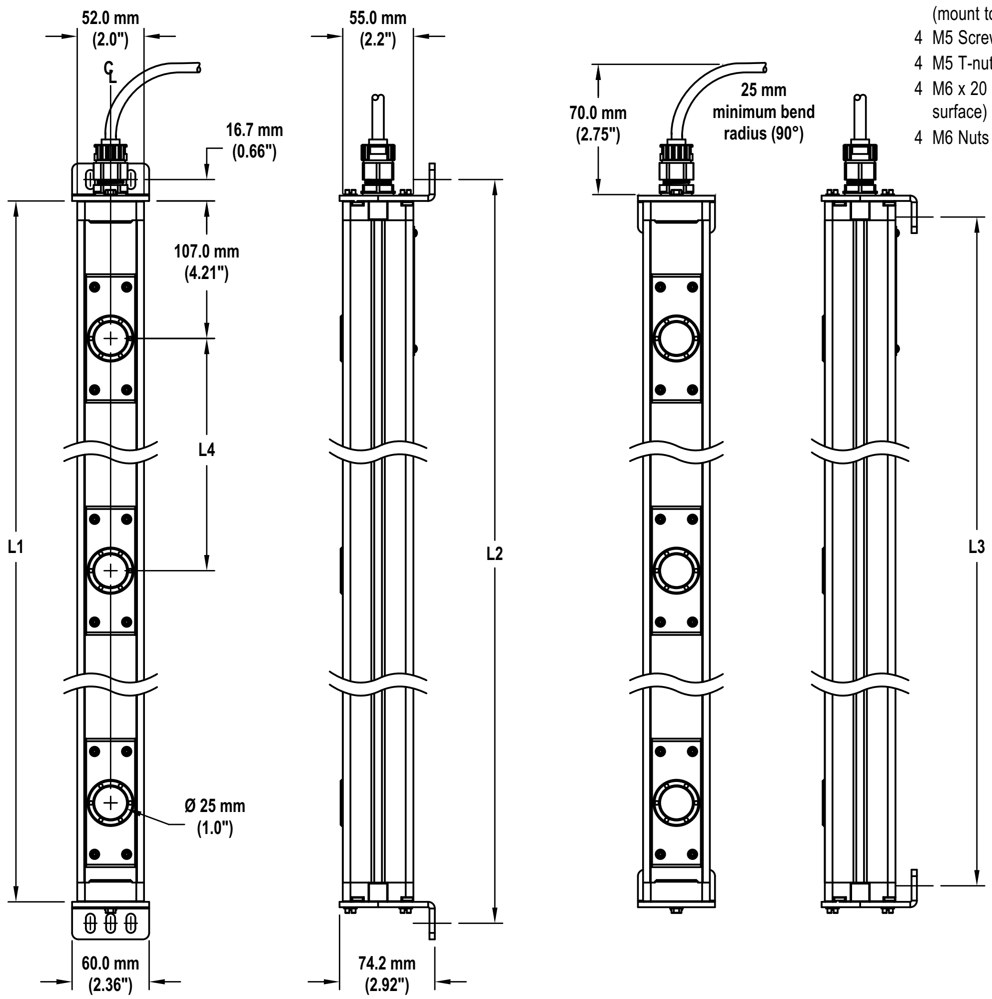
If the optical fibers are to be cut, the fibers must be correctly re-labeled with supplied labels before cutting to minimize the possibility of incorrect optical channel assignment.

Under no circumstances should the fibers be cut to less than 2.4 m (8') long, or the Effective Aperture Angle (EAA) may increase, resulting in a greater possibility of an optical short circuit and preventing detection of an individual. This could result in serious bodily injury or death.

Hardware included with each Grid element:

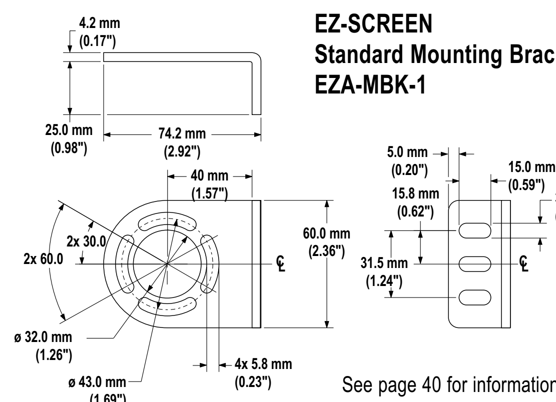
Qty.	Description
1	Test rod, model **STP-3**, 45 mm (1.75") dia.
1	Extra set of ID labels for individual fibers
1	**EZA-MBK-1** mounting bracket kit, includes the following: 2 Standard mounting brackets (mount to end caps or to housing sides) 4 M5 Screws (bracket to housing) 4 M5 T-nuts (for side-mount) 4 M6 x 20 mm Screws (bracket to mounting surface) 4 M6 Nuts with captive lock washers

Grid Elements
(standard end-cap brackets shown)



Model	Beam Spacing L4	Housing Length L1	Distance Between Brackets L2	Distance Between Brackets L3
SFG2-584..	584 mm (23.0")	768 mm (30.8")	802 mm (31.6")	743 mm (29.3")
SFG3-533..	533 mm (21.0")	1251 mm (49.2")	1284 mm (50.6")	1226 mm (48.3")
SFG2-500..	500 mm (19.7")	684 mm (26.9")	717 mm (28.2")	659 mm (25.9")
SFG3-400..	400 mm (15.7")	984 mm (38.7")	1017 mm (40.1")	959 mm (37.8")
SFG4-300..	300 mm (11.8")	1084 mm (42.7")	1117 mm (44.0")	1059 mm (41.7")

EZ-SCREEN
Standard Mounting Bracket
EZA-MBK-1

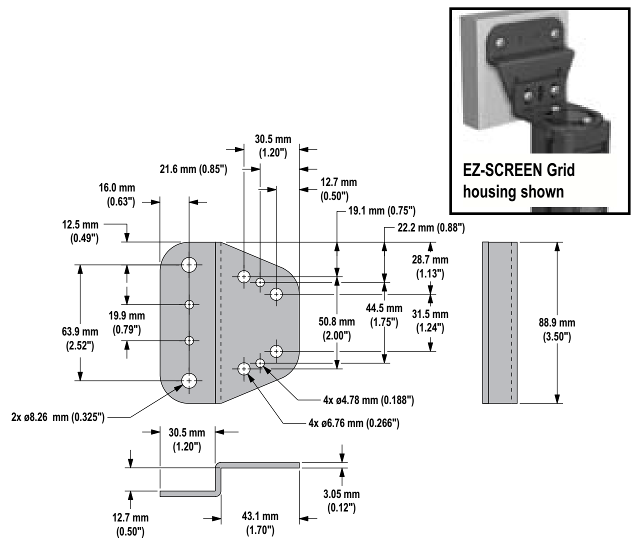


See page 40 for information about other accessory brackets.

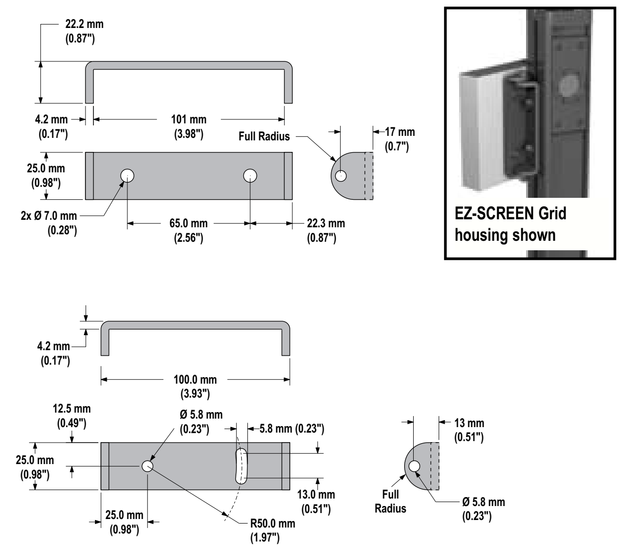
Figure 7-4. Fiber Optic Safety Grid optical element dimensions

7.5.1 Accessory Mounting Brackets for Grid Elements

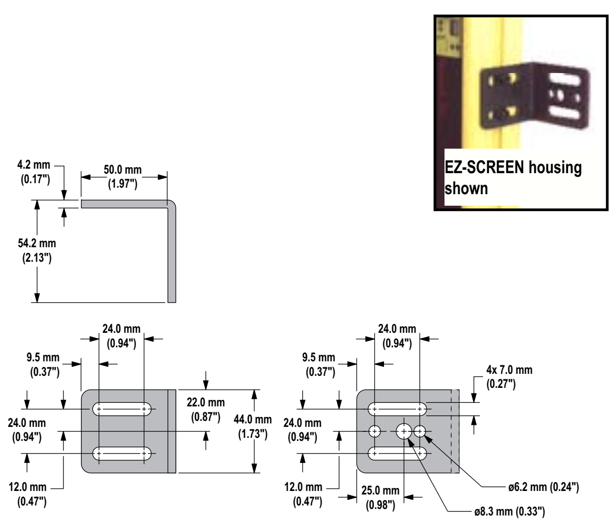
EZA-MBK-2
- Adapter Bracket Kit to attach to MSA Series Stands



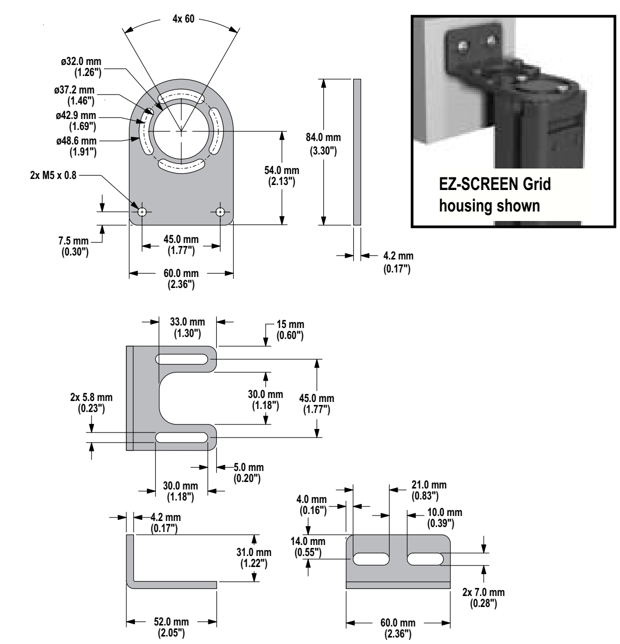
EZA-MBK-3
- Side-Swivel Bracket Kit



EZA-MBK-8
- Retrofit Bracket Kit (to replace SICK/Leuze Grid systems)



EZA-MBK-9
- Adjustable Bracket Kit
- 2-part bracket allows forward/backward and side-to-side tilt



7.5.2 Grid Element Replacement Parts

SFA-W-1	Field-replaceable tempered glass window with aluminum ring and o-ring
STP-3	Test piece, 1.75" diameter
EZA-MBK-1	Replacement standard bracket kit

7.6 Point and Grid Accessories

LAT-1

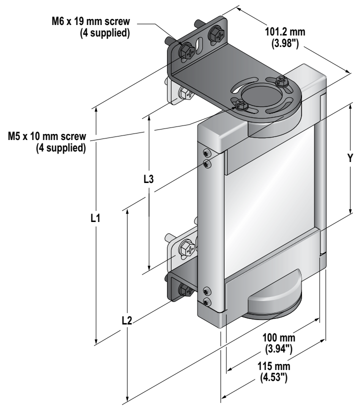
LAT-1-SFP12	For use with SFP12 Point	Laser alignment tool with adapter hardware. Includes retroreflective target material and mounting clip.
LAT-1-SFP30	For use with SFP30 Point	
LAT-1-SS	For use with PICO-GUARD Grid	
SFA-LAT-12	Replacement adaptor hardware for SFP12	
SFA-LAT-30	Replacement adaptor hardware for SFP30	
EZA-LAT-SS	Replacement adaptor (clip) hardware for Grid models	
EZA-LAT-2	Clip-on retroreflective LAT target for Grid models	
BRT-THG-2-100	50 mm (2") wide reflective tape, 2.5 m (100") long	
BT-1	Beam Tracker	
SFPA-AG12-1	ACCESS-GUARD™ kit for SPF12 models (see Figure 7-6)	
SFPA-AG30-1	ACCESS-GUARD™ kit for SPF30 models (see Figure 7-6)	
EZA-S500-M45	Enclosure with top and bottom 45° mirrors for 500 mm grid ACCESS-GUARD™ applications (see Figure 7-6)	
EZA-S584-M45	Enclosure with top and bottom 45° mirrors for 584 mm grid ACCESS-GUARD™ applications (see Figure 7-6)	
SFA-FCC-008	2.4 m (8')	Flexible nylon MEK-resistant conduit snaps into Grid housing strain relief fitting to provide protection to fibers. Cuts to length easily, using a box cutter or similar blade. Cable gland available below to provide MEK-resistant protection from Grid emitter/receiver housing to controller enclosure.
SFA-FCC-015	4.5 m (15')	
SFA-FCC-025	7.5 m (25')	
SFA-FCC-050	15 m (50')	
SFA-FCC-100	30 m (100')	
SFA-FCC-CGM20	Cable gland, M20 threads (for bulkhead pass-through)	
SFA-FFP	Field Fiber Polishing Kit; see data sheet p/n 128868 for information.	

7.6.1 Corner Mirrors

For Point and Grid Models

Other models and sizes are available; refer to the Banner Safety Products Catalog or the web site for more information.

NOTE: The total range decreases by approximately 8% per mirror.



Model	Length			
	Y	L1 (Brackets "outward")	L2	L3 (Brackets "inward")
SSM-100	100 mm (3.9")	211 mm (8.3")	178 mm (7.0")	153 mm (6.0")
SSM-550	550 mm (21.7")	661 mm (26.0")	628 mm (24.7")	603 mm (23.7")
SSM-675	675 mm (26.6")	786 mm (31.0")	753 mm (29.6")	728 mm (28.7")
SSM-975	975 mm (38.4")	1086 mm (42.8")	1053 mm (41.5")	1028 mm (40.5")
SSM-1175	1175 mm (46.3")	1286 mm (50.6")	1253 mm (49.3")	1228 mm (48.3")

7.7 Mechanical Installation Considerations

The three most important factors that influence the layout of PICO-GUARD Safety Point and Grid mechanical installation are:

- Beam configuration,
- Separation distance and
- Supplemental safeguarding and hard guarding.

Other considerations include optical element orientation, adjacent reflective surfaces, use of corner mirrors, and installation of multiple systems.

> **WARNING . . . Position Components Carefully**
> The optical elements must be positioned such that the hazard can not be accessed by reaching over, under, around or through the sensing field. Additional guarding may be required; see Separation Distance, Section 7.7.2, and Hard Guarding, Section 7.7.3.

7.7.1 Beam Configuration

When using one or more PICO-GUARD Safety Point optical elements to form a grid for access-guarding and perimeter-guarding applications, careful consideration must be given to the beam configuration in order to ensure proper operation. Configuration issues include:

- **Number of Beams and Beam Height from Floor.** Recommended beam configurations for access-guarding and perimeter-guarding applications are described in standards such as ANSI/RIA R15.06, ANSI B11 and ISO13855 (EN 999). See Figure 7-5.
- **Mounting Multiple Systems.** To prevent light from the emitter(s) of one PICO-GUARD light grid from affecting adjacent grids, the beams from the various grids must be isolated from one another through the use of physical, non-reflective barriers (see Figure 7-13). Mounting the emitter and receiver optical elements so that the beams travel in the opposite directions, as shown in Figure 7-13, also helps to isolate systems.
- **Opposed-Mode Configuration.** In opposed-mode configuration, the emitter and receiver are mounted opposite from each other to form a single beam (see Figure 7-6). Opposed-mode configuration can be combined with vertical corner mirrors for perimeter guarding applications, as shown in Figure 7-1 and described in Section 7.7.5.
- **ACCESS-GUARD Configuration.** In ACCESS-GUARD configuration, one optical channel of the PICO-GUARD System (one emitter/receiver element pair) is used with two angled mirrors to create multiple beams – in effect, forming a vertical light grid using one beam. The ACCESS-GUARD™ kit is available for constructing this configuration (see Figure 7-5 and Sections 7.6, 7.7.2 and 7.7.5).

The corresponding optical elements must be mounted across from one another (e.g., emitter channel #1 across from receiver channel #1). Otherwise, dangerous voids in the resulting light grid could allow objects or personnel to pass undetected through the grid (see Figure 7-6). **Verify that the fiber ends are connected such that fiber #1 is connected to optical channel #1, fiber #2 is connected to optical channel #2 and so on. (See 7.8.2 for fiber connection information.)**

per ANSI B11 and ANSI/RIA R15.06	Top Beam H1	Bottom Beam H2	Distance Between Beams* H3
Reach-Over Applications (bending at the waist)	0.9 m ≤ H1 < 1.2 m (36" ≤ H1 < 48")	H2 ≤ 0.3 m (H2 ≤ 12")	H3 ≤ 0.6 m (H3 ≤ 24") *Distance between beams + beam diameter must not exceed 24".
Reach-Through Applications	H1 ≥ 1.2 m (H1 ≥ 48")		
per ISO 13855 (EN999)	**Beam Heights Above Reference Plane** (e.g., Floor)		
2-Beam Application	0.4 m, 0.9 m (16", 36")		
3-Beam Application	0.3 m, 0.7 m, 1.1 m (12", 28", 44")		
4-Beam Application	0.3 m, 0.6 m, 0.9 m,1.2 m (12", 24", 36", 48")		

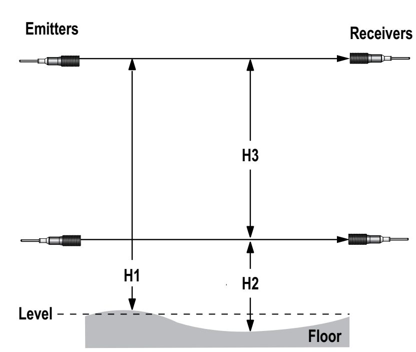


Figure 7-5. Verify required height between top and bottom beams and the floor, throughout the length of the beam path, per applicable standards.

WARNING . . . Proper Sensing Mode Configurations

Optical elements must be installed:

- with corresponding emitters and receivers across from one another,
- not in a retroreflective mode (see Section 7.7.5), and
- in such a way that allows no access under, through, or over the sensing field.

Failure to do so will impair the performance of the PICO-GUARD System and result in incomplete guarding; serious bodily injury or death could result.

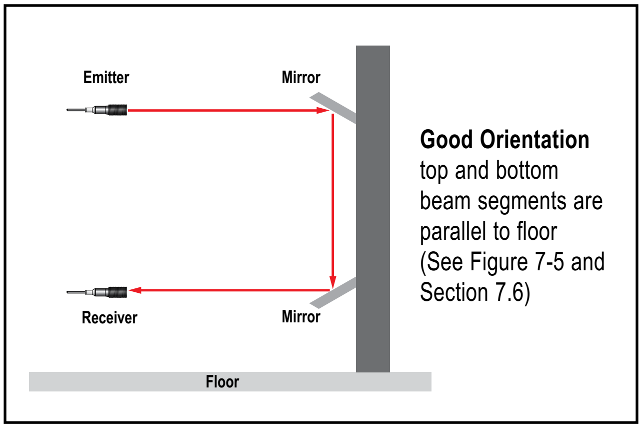


Figure 7-6. Acceptable ACCESS-GUARD configuration

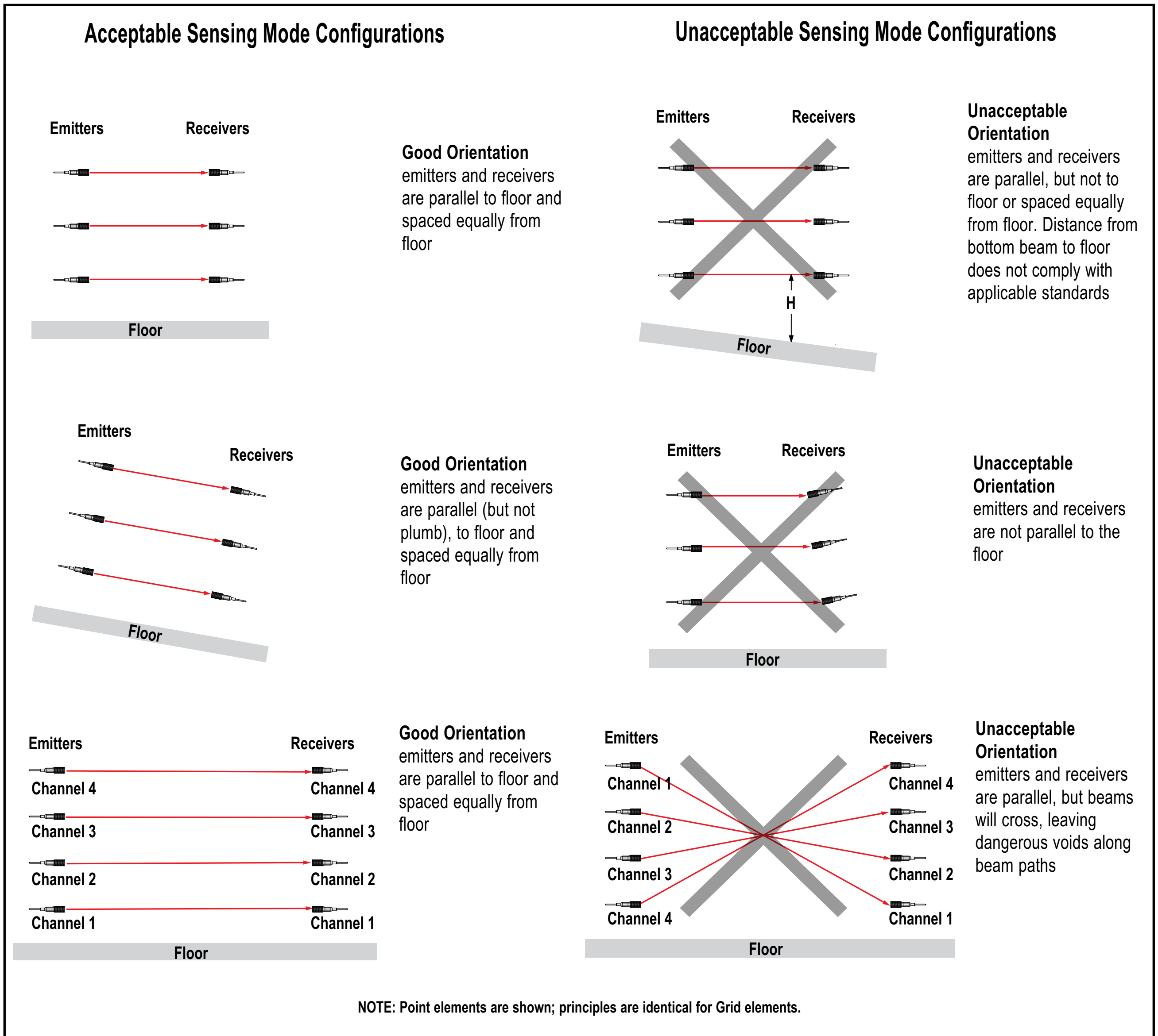


Figure 7-7. Acceptable and unacceptable sensing mode configurations

7.7.2 Minimum Separation Distance (Ds)

Minimum separation (safety) distance (Ds) is the minimum distance required between the light grid and the closest reachable hazard point. Separation distance is calculated so that the PICO-GUARD controller will send a stop signal to the machine when an object or a person is detected (by blocking a sensing beam), allowing the machine to come to a stop by the time the person can reach any machine hazard point.

After the Ds has been determined, record the calculated distance on the Daily Checkout Card for that installation.

Separation distance calculation takes into account several factors, including a calculated human speed, the total system stopping time (which itself has several components), and the depth penetration factor. The formula used to calculate separation distance is:

$$Ds = K \times (Ts + Tr) + Dpf$$

where:

Ds = the separation distance, in mm (inches);

K = 1600 mm per second (or 63" per second), the OSHA1910.217, ANSI B11, ANSI/RIA R15.06 recommended hand-speed constant (See Note 1);

Ts = the overall stop time of the machine (in seconds) from the initial “stop” signal to the final ceasing of all motion, including stop times of all relevant control elements (such as an IM-T-.. interfacing module), and measured at maximum machine velocity (See Note 2 and Warnings on page 45).

Tr = 0.013 seconds, the maximum response time of the PICO-GUARD SFCDT-4A1.. controller; and

Dpf = the added distance due to depth penetration factor (for U.S. applications, prescribed in ANSI/RIA R15.06 and ANSI B11). Assuming beam spacing larger than 2.5" but less than 24", Dpf is 36", 48" or 850 mm:

- Dpf is 36" if the top beam is 48" or higher and the bottom beam is 12" or less from the floor (a reach-through hazard; U.S. applications).
- Dpf is 48" if the top beam is 36" to 48" above the floor and the bottom beam is 12" or less from the floor (a reach-over hazard; U.S. applications).
- Dpf is 850 mm for European 2-beam applications, as prescribed in EN 999.

NOTES:

1. The OSHA-recommended hand speed constant K has been determined by various studies, and although these studies indicate speeds of 63"/second to more than 100"/second, they are not conclusive determinations. The user should consider all factors, including the physical ability of the operator, when determining the value of K to be used.
2. Ts is usually measured by a stop-time measuring device. If the machine manufacturer’s specified stop time is used, at least 20% should be added to allow for possible clutch/brake system deterioration.

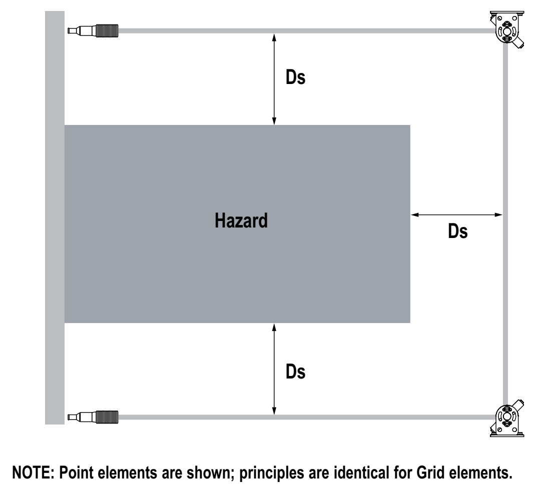


Figure 7-8. Separation distance

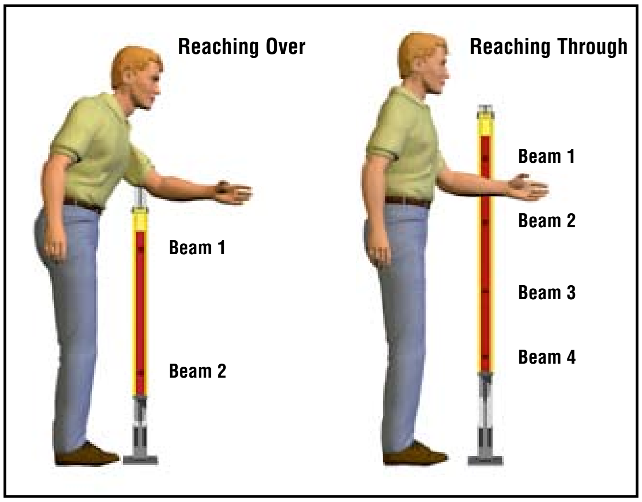


Figure 7-9. Determining Dpf (reach-through versus reach-over hazards per ANSI-RIA R15.06)

Notice Regarding MPCEs

Each of the two Machine Primary Control Elements (MPCE 1 and MPCE2) must be capable of immediately stopping the dangerous machine motion, irrespective of the state of the other. These two channels of machine control need not be identical, but the stop time performance of the machine (Ts, used to calculate the separation distance) must take into account the slower of the two channels.

WARNING . . . Determine Correct Stop Time

The measurement of stop time (Ts) must include the response time of all devices or controls that react to stop the machine. If all devices are not included, the calculated safety distance (Ds) will be too short. This can lead to serious bodily injury or death. **Be sure to include the stop time of all relevant devices and controls in your calculations.**

WARNING . . . Proper Separation Distance

Optical elements must be mounted at a distance from the nearest hazard such that individuals cannot reach the hazard before the hazardous motion or situation ceases. **Failure to establish and maintain the minimum separation distance could result in serious bodily injury or death.**

Example – U.S. Applications

Using the formula, **Ds = K x (Ts + Tr) + Dpf,** separation distance for a PICO-GUARD grid (42" protected height, 3 beams, 21" apart) is calculated (per ANSI/RIA R15.06):

K = 63"/second

Ts = 0.32 (0.250 second is specified by the machine manufacturer; plus 20% safety factor; plus 20 ms for interface module IM-T-9A response)

Tr = 0.013, the maximum response time of the PICO-GUARD SFCDT-4A1.. controller in seconds;

Dpf = 36"

Ds = 63 x (0.32 + 0.013) + 36 = 57"

In this example, the PICO-GUARD optical elements must be mounted so that no part of the light grid will be closer than 57" from the closest reachable hazard point of the guarded machine.

Example – European Applications

Using the same formula, separation distance for a PICO-GUARD grid (800 mm protected height, 3 beams, 400 mm apart), is calculated (per ISO13855/EN 999):

K = 1600 mm/second

Ts = 0.32 (0.250 second is specified by the machine manufacturer; plus 20% safety factor; plus 20 ms for interface module IM-T-9A response)

Tr = 0.013, the maximum response time of the PICO-GUARD SFCDT-4A1.. controller in seconds;

Dpf = 850 mm

Ds = 1600 x (0.32 + 0.013) + 850 = 1,383 mm

In this example, the PICO-GUARD optical elements must be mounted so that no part of the light grid will be closer than 1383 mm from the closest reachable hazard point of the guarded machine.

NOTE: Other machine standards may require different separation factors from those illustrated. Also, the physical abilities of workers and operators, plant procedures and other factors may affect Ds.

7.7.3 Supplemental Safeguarding and Hard Guarding

Supplemental safeguarding is used to restrict access to the hazard only through the sensing field of the optical elements (i.e., the light grid). This means that mechanical barriers (such as screens or bars) or supplemental safeguarding must be installed, wherever needed, to prevent any person from entering into or remaining in the hazardous area undetected. The use of mechanical barriers for this purpose is called hard guarding (see the Warning at right and Figure 7-10).

There must be no gaps between the hard guarding and the edges of the light grid (i.e., the PICO-GUARD optical elements). Also, any openings in the hard guarding must comply with the safe opening requirements of ANSI B11 or other appropriate standard. These requirements specify a relationship between the distance of the hard guard from the hazard and the maximum allowable size of openings in that barrier.

Figure 7-10 shows an example of supplemental safeguarding inside a robotic work cell. The PICO-GUARD optical elements, in conjunction with the hard guarding (the wall and the fencing), provide the primary safeguarding. Supplemental safeguarding (such as a horizontal mounted safety light screen as an area guard) is required in areas that can not be viewed from the PICO-GUARD reset switch (i.e., behind the robot and the conveyor). Additional supplemental safeguarding may be required by relevant standards, such as preventing clearance or trapping hazards as described by ANSI/RIA R15.06 (e.g., the safety mat as an area guard between the robot, the turntable, and the conveyor).

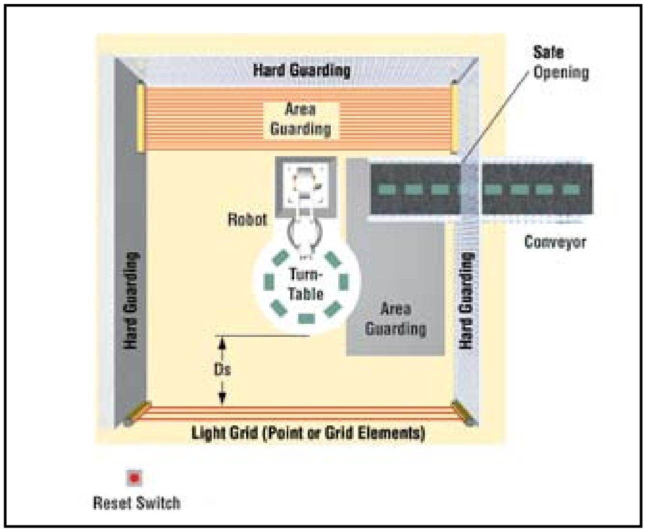


Figure 7-10. An example of supplemental safeguarding

WARNING . . . The Machine Hazard Must Be Accessible Only Through the Light Grid.

Mechanical barriers ("hard guarding") or supplemental safeguarding, as described by the ANSI B11 series of safety requirements or other appropriate standards, **must be installed wherever needed to prevent any person from:**

- **Reaching around, under, or over the light grid and accessing the hazard, and**
- **Entering or remaining anywhere within the guard area without being detected and a stop command being issued to the guarded machine** (see ANSI/RIA R15.06).

7.7.4 Adjacent Reflective Surfaces

A reflective surface located adjacent to the light grid may deflect one or more beams around an object in the light grid. In the worst case, such a situation may allow an object to pass undetected through the light grid, which is known as an “optical short circuit.”

This reflective surface may result from shiny surfaces or glossy paint on the machine, the workpiece, the floor or the walls. Beams deflected by reflective surfaces are discovered by performing the trip test portion of the final alignment procedure and the periodic checkout procedures (Sections 7.8.3 and 7.9).

To eliminate problem reflections:

- **If possible, relocate the sensors** to move the beams away from the reflective surface(s), being careful to maintain adequate separation distance (see Figure 7-11).
- **Otherwise, if possible, paint, mask or roughen the shiny surface** to reduce its reflectivity.
- **Where these are not possible (as with a shiny work piece),** include a means of restricting the receiver’s field of view or the emitter’s spread of light in the sensor mounting.
- **Repeat the trip test** to verify that these changes have eliminated the problem reflection(s). If the work piece is especially reflective and comes close to the light grid, perform the trip test with the work piece in place.

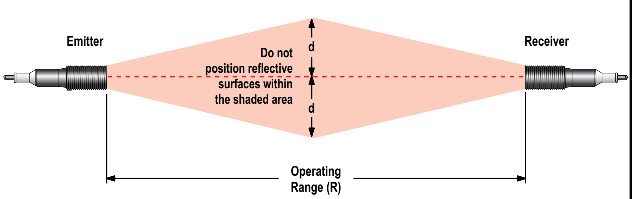


Figure 7-11. Positioning the light grid adjacent to reflective surfaces

WARNING . . . Avoid Installation Near Reflective Surfaces

Avoid locating the light grid near any reflective surfaces. A reflective surface located nearby may reflect light around an object or person within the sensing field, preventing its detection by the PICO-GUARD. The Trip Test must be performed as described in Section 7.9 to detect any reflections and the resulting optical short circuit(s).

Failure to prevent reflection problems will result in incomplete guarding; serious bodily injury or death could result.

7.7.5 Use of Corner Mirrors

PICO-GUARD Point and Grid optical elements may be used with one or more corner mirrors (see Section 7.6.1 for models).

NOTE: The use of corner mirrors reduces the maximum specified optical element separation by approximately 8 percent per glass-surface mirror.

Corner mirrors are not allowed for applications that would allow personnel undetected access into the safeguarded area.

If corner mirrors are used, the difference between the angle of incidence from the emitter to the mirror and from the mirror to the receiver must be between 45° and 120° (see Figure 7-12). If placed at a sharper angle, as shown in the example, an object in the light grid may deflect beam(s) to the receiver, preventing the object from being detected (i.e., "false proxing"). Angles greater than 120° result in difficult alignment and possible optical short circuits.

WARNING . . . Avoid Retroreflective Installation and Optical Short Circuits

Do not install Safety Points or Grids in "retroreflective" mode (less than a 45°) or greater than 120° angle of incidence, as shown in Figure 7-12. **Sensing could be unreliable in this configuration; serious bodily injury or death could result.**

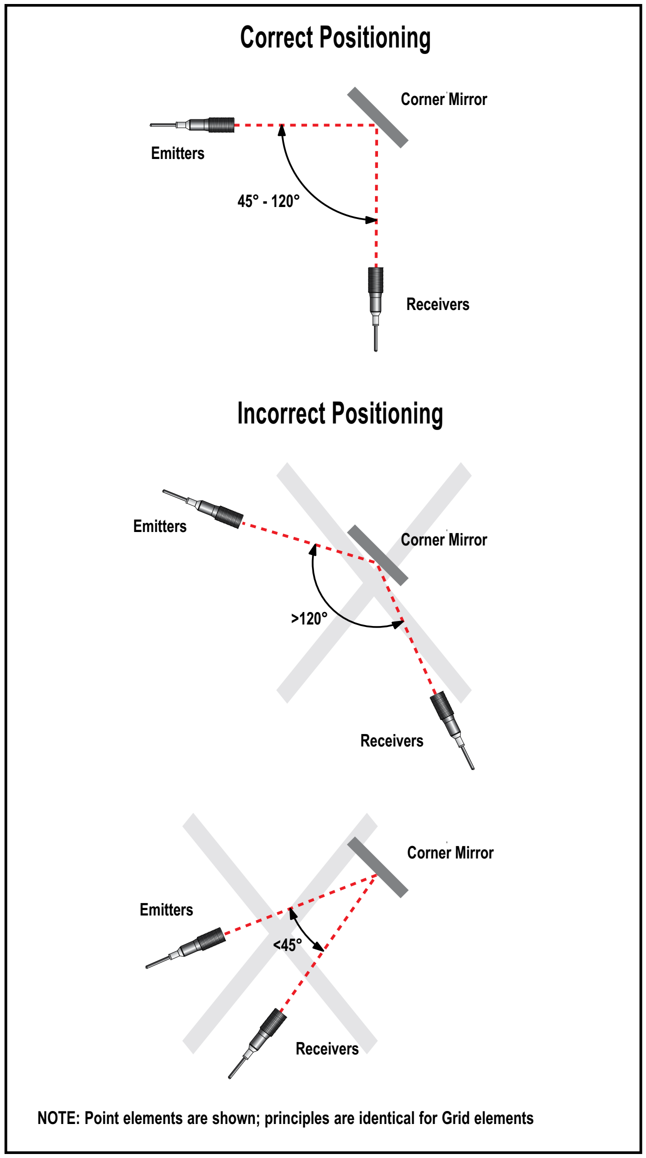


Figure 7-12. Positioning of corner mirrors

7.7.6 Installing Multiple Safety Light Grids

Whenever two or more PICO-GUARD emitter and receiver pairs are located adjacent to one another, optical crosstalk between them is a potential problem. To minimize optical crosstalk, it is recommended to alternate emitter and receiver positions, as shown in Figure 7-13.

When three or more light grids are installed in the same horizontal or vertical plane, (as shown for two pairs in Figure 7-13), optical crosstalk may occur when emitter and receiver lenses of two or more grids are oriented in the same direction. In this situation, control optical crosstalk by mounting these sensor pairs exactly in line with each other within one plane, or by adding a mechanical light barrier between the pairs.

WARNING . . . Multiple Sensing Fields

The installer must properly route and connect the plastic fibers and cables to the intended optical channel of the correct PICO-GUARD controller. **Misconnection can result in voids in the sensing field.** The installer must perform the commissioning checkout and the user must perform daily/semi-annual checkout as described in Section 6 of the PICO-GUARD controller manual and the appropriate checkout cards.

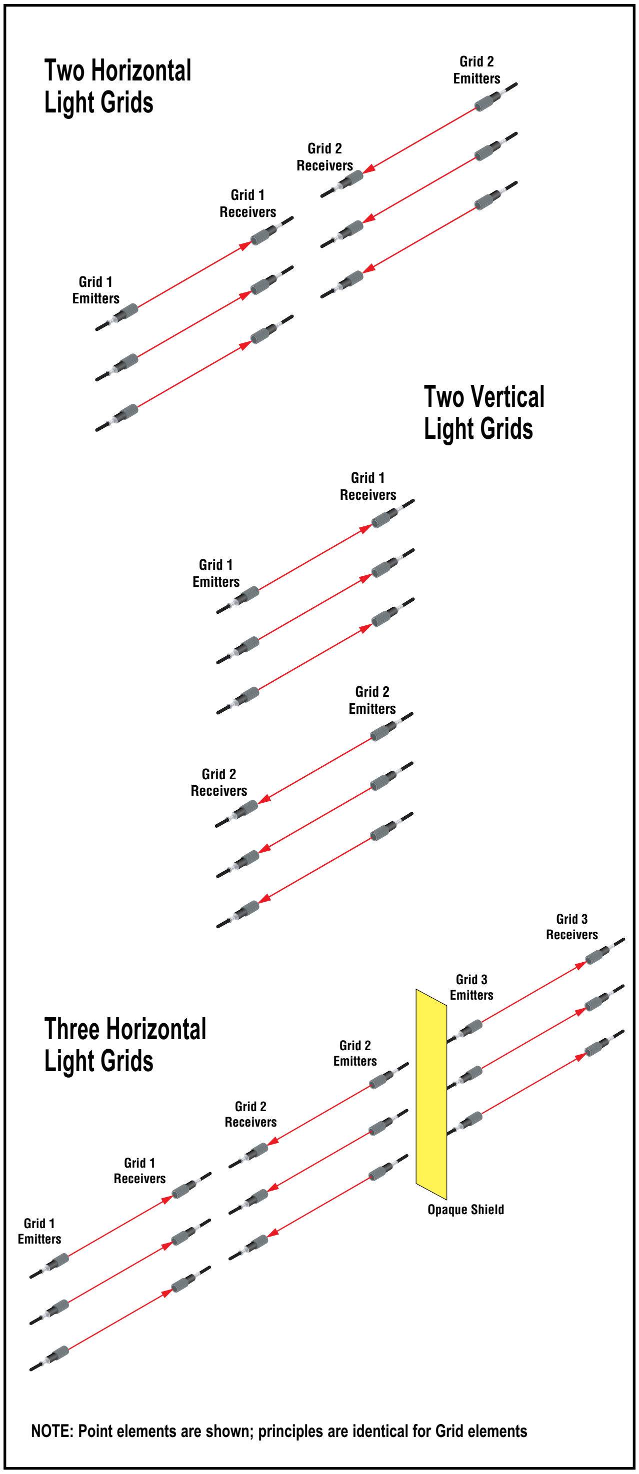


Figure 7-13. Mounting multiple PICO-GUARD emitters and receivers to mechanically prevent optical crosstalk

7.8 Installing and Aligning Point and Grid Elements

Install the PICO-GUARD controller per Section 3 of that manual (p/n 69761) up to Section 3.8.2 Optical Element Alignment. Once the mechanical installation considerations described in Section 7.7 are addressed, mount the Optical Elements and the plastic fibers as follows.

Do not apply power to the PICO-GUARD controller or to the machine control or actuators until after successfully completing the trip test and the commissioning checkout, as described in the PICO-GUARD controller manual.

Emitter and receiver elements may be spaced according to the table in Figure 7-4 and Sections 7.3.1, 7.3.2, and 7.5, Specifications.

The maximum distance between an emitter and its receiver is reduced if corner mirrors are used. If Banner MSM or SSM Series (glass-surface) corner mirrors are used, the total range decreases by approximately 8 percent per mirror.

The optical elements must be mounted parallel to each other; see Figure 7-6. If corner mirrors are used, they must also be mounted in the same parallel line. Several mounting bracket options are available; refer to Sections 7.3.3 and 7.5.1 for more information.

7.8.1 Mounting and Mechanical Alignment

All light grid components (optical elements and corner mirrors, if used), must be parallel to each other and perpendicular to the floor. If the floor is level, the components may be checked for plumb, using a level, for example. If the floor is sloped, alignment is more complex, because the floor-to-bottom beam measurement must remain constant, or not exceed the maximum height above the floor.

If the floor has a dip, as for a drain, or is raised up within the path of the beams, corrective measures must be taken to ensure that the requirements of ANSI/RIA R15.06, ANSI B11 or EN 999 are met (see Figure 7-5). It is important that the distances between the top and bottom beams and the floor meet the requirements of the applicable standards, throughout the length of the beam path.

WARNING . . . Proper Beam Configuration

The beam configuration of the PICO-GUARD safety light grid must meet the requirements of applicable standards for each application. **It is the user's responsibility to verify proper beam configuration.**

From a common point of reference (ensuring the minimum separation distance calculated in Section 7.7.2), make measurements to locate the optical elements in the same plane with their midpoints directly opposite each other. **Important: The corresponding emitters and receivers (e.g., both optical channel #1) must be oriented across from one another (see drawings and WARNING, page 43).**

Ensure that beam placement and configuration are as described by Section 7.7.1 and Figure 7-5 or that they comply with the relevant standards.

If using through-hole mounting, verify that the mounting surfaces are perpendicular to the intended optical path, and that each optical element is pointed directly at its opposite element.

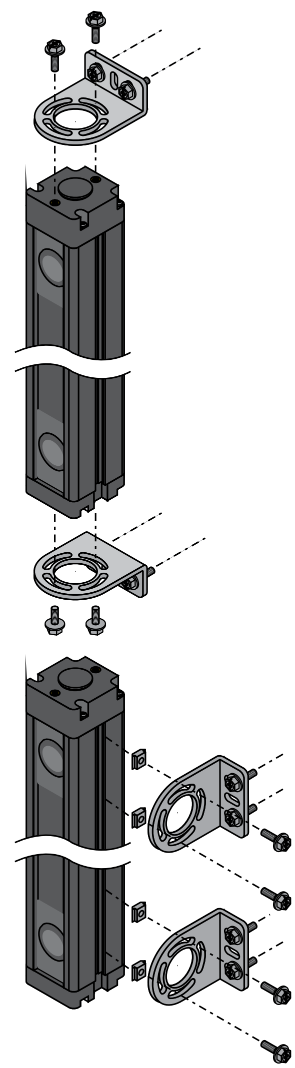


Figure 7-14. Attaching standard brackets to the end caps or side of the PICO-GUARD Grid element

Pre-Alignment

To verify alignment before drilling any holes or installing the optical elements, a LAT-1 laser alignment tool may be used (see Accessories, Section 7.6). Remove the screw and mounting clip from the LAT-1, then hold it in front of the intended mounting location with the mounting bracket screw hole centered over the mounting location (ensure the surface is flat). Turn on the laser; the red dot should be at the approximate location for the hole of the opposing optical element. Mark this location and then repeat the procedure at this mark to verify that the red dot appears approximately at the first location. The distance between the red dot and the expected receiver location should not be more than $\pm d = 0.0524 \times R$, where R is the operating range.

If there is a large discrepancy between the mark locations and the red laser dot, then either:

- The surfaces must be squared, or
- Through-hole mounting is not recommended; use an adjustable mounting bracket (see Sections 7.3.3 and 7.5.1).

Installation Procedure

1. If using Banner MSA series stands and bases or other stands, position the stand bases at the desired locations (see Separation Distance, Section 7.7.2). Mount the stands, verifying that they are level/plumb and at a right angle (square) to each other. Use stands that allow vertical and horizontal/rotational adjustability to accommodate sloping floor surfaces, irregularities in the mounting surface, and the alignment procedure.

   If installing onto a mounting plate or the machine frame, verify that the mounting surface is level/plumb and is at a right angle (square) to the opposite mounting surface.

   Adjustable swivel mounting brackets, such as the model SMB1812SF or SMB30SC, may be used to provide the necessary adjustability for alignment.

2. On one side of the light grid (ideally the emitter side), identify the location of mounting holes or optional mounting brackets, taking into consideration the requirements of Figure 7-5 and the appropriate standard. Drill all holes or mount all brackets on only the one side (do not fully tighten the hardware yet, to allow for adjustability).

   Verify that mounting surfaces or brackets are level/plumb and are at a right angle (square) to the opposite mounting surface using one of the following methods.

   - Use a carpenter's square to determine the direction the sensor is facing to ensure that the face of each sensor is perpendicular to the optical axis. See Figure 7-15.
   - Look along either side of each sensor for the opposite sensor (as you would with a gun sight). You should be able to see equal amounts of the opposite sensor from one side as from the other. If the opposite sensor is optically square, you may be able to view a reflection of the sensor you are behind in the opposite sensor lens.
   - Use a model LAT-1 Laser Alignment Tool to provide a visible red dot at the point the optical axis is directed (see Figure 7-15).

   NOTE: The useable range of the LAT-1 (the red dot viewed at the target) depends on the color and reflectance of the target, the level of ambient light present, and the presence of airborne contaminants. With a 90 percent reflectance white test card, under average lighting and with no airborne contaminants, the red dot is viewable at approximately 150' or more. For longer ranges or applications with multiple mirrors, dim the ambient lighting or use a retroreflective target.

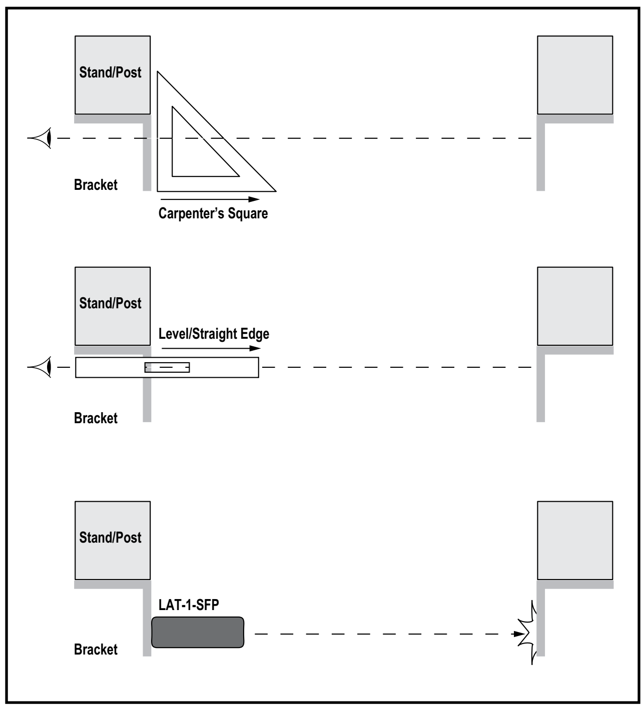


Figure 7-15. Mechanical alignment methods for Point or Grid elements (SFP) (overhead view)

3. Identify the locations of the corresponding optical elements (the receiver side of the grid), using one of the following methods.

Measurement method:
Duplicate the mounting bracket or mounting hole location(s) for each corresponding beam.

Verify that the location falls within the field of view of the corresponding optical element, per the following table:

Emitter/Receiver Separation Distance	**1 m (3')**	**3 m (10')**	**6 m (20')**
Field of View	52 mm (2")	157 mm (6.2")	314 mm (12.4")
Optimal Field-of-View Diameter = Operating range x 0.0524			

Laser Alignment Tool (model LAT-1-..) method:

a. Attach appropriate bracket to the LAT-1 and either mount or hold the LAT-1 in the mounting hole(s) from step #2 (see Figure 7-16).

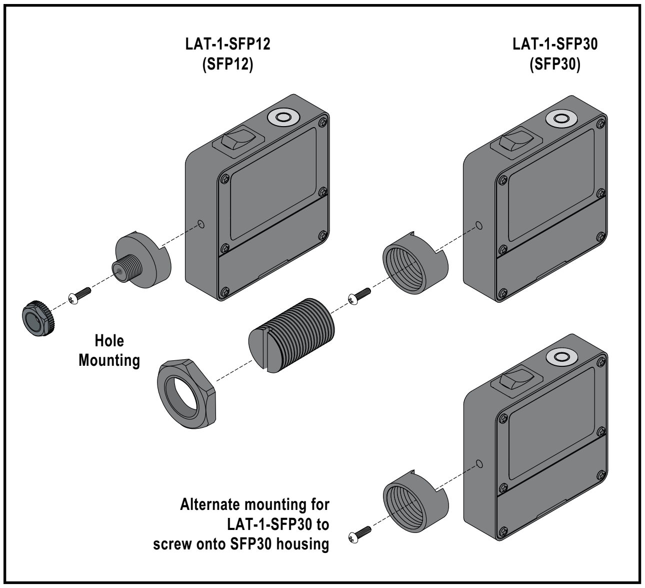


Figure 7-16. LAT-1 and mounting brackets for Point elements

b. Verify that the LAT-1 and the mounting brackets are level/plumb and are at a right angle (square) to the opposite mounting surface.

c. Turn on the LAT-1 and mark the location of the red laser light spot. This should ensure that the location falls within the field-of-view of the corresponding optical channel, as described in the table at left.

d. Verify that the requirements of Figure 7-5 (or the appropriate standard) are complied with.

NOTE: The PICO-GUARD controller may lock out if light from the LAT-1 shines into a receiver optical element. If this occurs, turn off the LAT-1 and perform a manual reset of the PICO-GUARD controller.

Installations With Corner Mirrors

PICO-GUARD Safety Point and Grid elements may be used with one or more corner mirrors for guarding more than one side of an area. However, due to the reduced range and the possible difficulty in alignment, avoid using more than four mirrors in any one application.

Section 7.6.1 lists some available corner mirror models. The model SSM-… rear-surface glass mirrors are rated at 85% efficiency, which reduces sensing range and excess gain by approximately 8% per mirror used.

NOTE: It is highly recommended to use a model LAT-1 Laser Alignment Tool in applications using mirrors.

If corner mirrors are used in the application, measure and position them as for the optical elements. Refer to the data sheet packed with the mirrors for specific installation instructions.

a. Follow optical element installation steps above for installation without mirrors.

b. Mount the mirror(s) at the desired locations, parallel to the optical elements. (Use a level to verify plumb, if the floor surface is level.) Measure up from the floor to center the mirror's reflective surface on the vertical center of the light grid, to allow sufficient reflective area above the top beam and below the bottom beam. Rotate the mirror(s) relative to the sensors, so that one sensor's front surface can be seen in the first mirror when standing directly in front of the other sensor, looking into the mirror.

4. Install SFP optical elements and route optical fiber per Section 7.8.2.

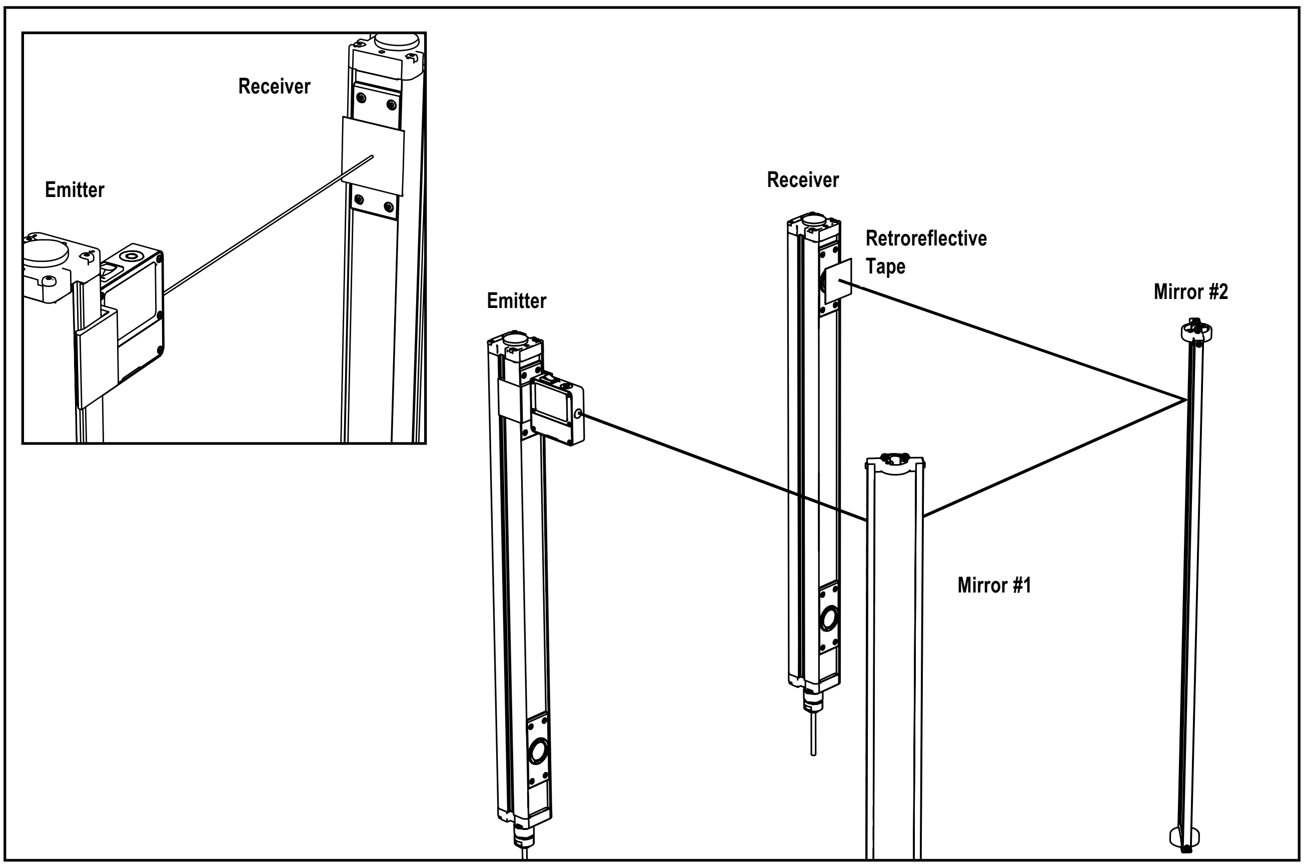


Figure 7-17. Optical alignment of Grid elements using the LAT-1

7.8.2 Routing Fiber Cables and Fiber Connections

NOTE: Review Sections 3 and 4 for complete recommendations for installing, cutting, and routing fiber optic cable. See the PICO-GUARD controller manual for controller-to-fiber connection information.

PICO-GUARD Point optical elements come standard with integral fiber cables with polished ends. **It is not recommended to cut the end of the polished fiber.** Cutting the end will reduce the potential working range between the opposing optical elements. If cutting is necessary (e.g., the end has been damaged or contaminated or it must be cut to length), see Section 3.2 for fiber cutting procedure.

Routing Fiber Optic Cable
Do not exceed the minimum bend radius for the fiber optic cable (see Section 3.2). Among other factors, the specified excess gain is dependent on fiber bend radius; too tight a bend may result in a weak signal or beam break condition.

Route plastic fibers away from sources of excessive heat, and isolated from excessive abrasion resulting from vibration or movement of the guard. Accessory sheathing is available to protect the fiber optic cable from damage (see Section 1.3.3).

Do not crush or otherwise deform the fiber optic cable. When using cable tie-straps (e.g., nylon cable ties), do not over-tighten so that the outer jacket is deformed or damaged. This will reduce excess gain and may allow the ingress of contamination or sever the fiber optic cable.

It may be necessary to route the fiber optic cable in conduit or otherwise protect the fiber from damage and contamination.

See Section 7.6 for cable gland and conduit models.

WARNING . . . Cutting Optical Fibers

If the optical fibers are to be cut, the fibers must be correctly re-labeled with supplied labels before cutting to minimize the possibility of incorrect optical channel assignment.

Under no circumstances should the fibers be cut to less than 2.4 m (8') long, or the Effective Aperture Angle (EAA) may increase, resulting in a greater possibility of an optical short circuit and preventing detection of an individual. This could result in serious bodily injury or death.

7.8.3 Optical Alignment and Initial Checkout

If not previously accomplished, install the PICO-GUARD controller per Section 3 of that manual (p/n 69761) up to Section 3.8.2 Optical Element Alignment. Connect the fiber ends to the appropriate controller fiber terminals. **At this point, power should be applied to only the PICO-GUARD controller and NOT to the machine under control.**

The Alignment and Initial Checkout procedure must be performed by a Qualified Person. The Initial checkout procedure is performed on two occasions:

- To ensure proper installation when the system is first installed, and
- To ensure proper system function whenever any maintenance or modification is performed on the system or on the machinery being guarded by the system. (See Controller Manual Section 6.1 for a schedule of required checkouts.)

If mirrors are used in the installation, also verify:

- that the sensors and all mirrors are level (plumb),
- the middle of the light grid and the center point of the mirrors are approximately the same distance from a common reference point, such as the same height above a level floor. Verify that there are equal amounts of mirror surface above and below the light grid such that the optical path does not pass below or above the mirror,
- during adjustments, allow only one individual to adjust any one item at any one time.

1. Verify that each of the PICO-GUARD controller's Optical Channel indicators is ON steady Green. If so, no further adjustment is required. Tighten all hardware, ensuring the optical alignment does not drift during tightening.
2. **If the Status indicator begins flashing Red** at any time, the controller has entered a Lockout condition. See Section 5 of the PICO-GUARD controller manual for further information.
3. If any optical channel indicators are *not* ON steady Green (see table below) or to optimize alignment:
   a. Verify that the red light is visible at the emitter optical element,
   b. Verify that the optical elements are level/plumb,
   c. Verify that the optical elements are facing squarely to each other (within the field-of-view of the corresponding optical element),
   d. Verify that the correct optical fiber is properly connected/ seated to the appropriate optical element (e.g., that channel #2 receiver is not looking at channel #1 emitter),
   e. While observing the optical channel indicator on the PICO-GUARD controller or the SFA-RD Remote Display, loosen the mounting hardware and slightly adjust the optical elements left/right and up/down until the indicator turns ON steady Green.

To optimize alignment, note the position where the Optical Channel indicator comes ON steady RED when the optical element is rotated both left/right and up/down. Center the sensor between the four positions, and tighten the mounting hardware, making sure the positioning does not drift as the hardware is tightened.

Controller Optical Channel Status Indicator Conditions (one bi-color Red/Green indicator for each optical channel)	
Indicator Condition	**Optical Channel Status**
ON Green	Channel is closed (clear)
Double-Flashing Green	Channel was interrupted, but is closed again (latch mode only)
Flickering Green	Weak or marginal signal
ON Red	Channel is open (blocked)
Flashing Red	Channel fault detected
OFF	Channel is disabled or during lockout (except for optical channel faults)
Flashing Burst (Red or Green)*	Noise on the channel
*A flashing burst is three short consecutive flashes, followed by a pause.	

7.9 Trip Test and Commissioning Checkout

After optimizing the optical alignment, perform the "trip test" to verify the detection capability of the PICO-GUARD Safety Point installation. This test will also ensure correct sensor orientation, correct fiber hookup and connections, and identify the occurrence of optical short circuits (see Section 7.7). Once the installation has passed the trip test, the commissioning checkout that is contained in the PICO-GUARD controller manual may be performed.

1. Select the proper specified test pieces that were supplied with the optical elements. Test piece #STP-13 should be used with the 12 mm Safety Point optical elements and #STP-14 with the 30 mm; test piece #STP-3 should be used with Grid elements.
2. Ensure that the PICO-GUARD controller is in Run mode with the appropriate Channel Status indicators (one for each optical channel used) ON steady Green.
3. Slowly pass the specified test piece through each beam in three places (Figures 7-18, 7-19 and 7-20):
   - close to the emitter optical element,
   - close to the receiver optical element, and
   - midway between them.
4. During each pass, while the test piece is fully interrupting a beam, that beam's corresponding Optical Channel Status indicator should come ON Steady Red and remain ON whenever the test piece is interrupting the beam.

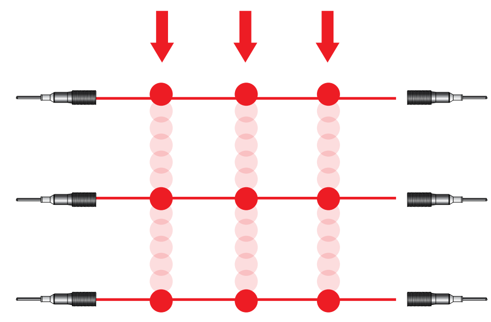
   If the status indicator comes ON Green at any time when the test piece is interrupting the beam, the installation has failed the trip test. Check for correct sensor orientation, reflective surfaces, and incorrect fiber hookup. **Do not continue until the situation is corrected.**

   When the test piece is removed, the Channel Status indicator must come ON steady Green.

If the PICO-GUARD Safety Point system passes all of the three checks during the trip test, go on to the Commissioning Checkout contained in the PICO-GUARD controller manual.

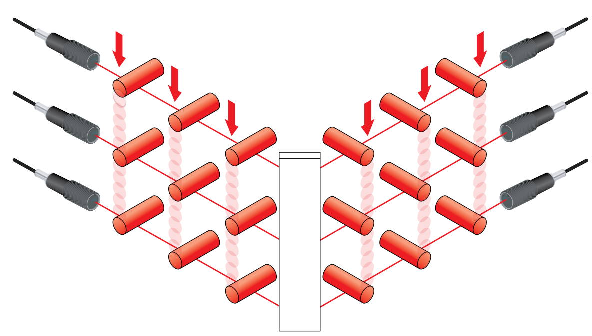
WARNING . . . Trip Test

If the PICO-GUARD light grid fails any of the checks during the trip test, **do not attempt to use it or the guarded machine until the reason for all failures are identified and corrected.**



NOTE: Point elements are shown; principles are identical for Grid elements.

Figure 7-18. Grid trip test



NOTE: Point elements are shown; principles are identical for Grid elements.

Figure 7-19. Grid trip test with corner mirrors

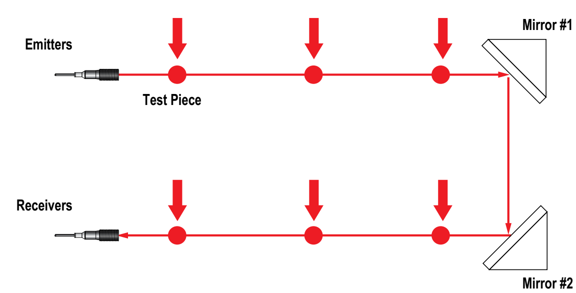


Figure 7-20. Trip test, ACCESS-GUARD configuration

8. Fiber Optic Emergency Stop Button Elements

General Requirements for Emergency Stop Devices

Per ANSI B11.19 and ISO 12100-1/-2, emergency stop devices are not in themselves safeguarding devices. Considered part of the safe use of a machine, they provide complementary protective measures to safeguarding devices that detect or prevent inadvertent access to a hazard, typically without requiring overt action by personnel. Since an individual must actuate an emergency stop device to issue the stop command, usually in reaction to an event or hazardous situation, it neither detects nor prevents exposure to the hazard.

An Emergency Stop device must not be used as a substitute for appropriate safeguarding.

E-Stop Switch Requirements (Positive-Opening)

The optical E-stop switch provides a “closed” optical path, which is clear (the beam is “made”) when the switch is in the armed position. When activated, the E-stop switch blocks the optical path and clears only after deliberate twisting of the red mushroom-head button.

The blocking mechanism provides a “positive-opening” function, similar to that described by IEC947-5-1/-5. The mechanical force applied to the button is transmitted directly to the blocking member, causing an “open” optical path. This blocking is not dependent on springs; the design and construction of the SFS.. Fiber Optic E-Stop device ensures that the optical path will open whenever the switch is activated.

WARNING . . . Emergency Stop Functions

If the PICO-GUARD is used for an Emergency Stop function, do not mute or bypass the safety outputs (OSSDs) of the PICO-GUARD controller. NFPA79 requires that the Emergency Stop function remain active at all times. **Muting or bypassing the safety outputs will render the Emergency Stop function ineffective.**

WARNING . . . Reset Routine Required

U.S. and international standards require that a reset routine be performed after returning the E-stop switch to its armed position. When automatic reset is used, an alternate means must be established to require a reset routine, after the E-stop switch is armed. **Allowing the machine to restart as soon as the E-stop switch is armed creates an unsafe condition which could result in serious injury or death.**

ANSI/NFPA 79 specifies the following requirements:

- Emergency Stop push buttons shall be located at each operator control station and at other operating stations where emergency shutdown shall be required.
- Stop and Emergency Stop push buttons shall be continuously operable from all control and operating stations where located. Do not mute or bypass the optical channel with an Emergency Stop Button.
- Actuators of Emergency Stop devices shall be colored Red. The background immediately around the device actuator shall be colored Yellow. The actuator of a push-button-operated device shall be of the palm or mushroom-head type.
- The Emergency Stop actuator shall be a self-latching type.

In addition, the Emergency stop function must:

- Override all other functions and operating modes,
- Remove power (energy) to the hazard as quickly as possible without causing additional hazards, and
- Prevent initiating a restart by resetting the emergency stop.

Furthermore, the emergency stop button and its function should be part of the overall risk assessment of the machine. The emergency stop button should be accessible from all angles, and not be obstructed nort guarded.

NOTE: Some applications may have additional requirements. **The user must comply with all relevant regulations.** These include, but may not be limited to, ANSI NFPA79, IEC 60204-1, and ISO 13850.

8.1 Fiber Optic Emergency Stop Button Description

When the PICO-GUARD controller is used with the Fiber Optic Emergency Stop Button, the system can signal a functional stop category 0 (uncontrolled emergency stop) to the machine (per ANSI NFPA 79 and IEC 60204-1). If additional hazards are created by the uncontrolled stop, a functional stop category 1 (controlled stop) may be required (see ANSI NFPA 79 or IEC 60204-1 for more information).

The PICO-GUARD controller and associated optical elements comply with requirements of software- and firmware-based controllers used for safety-related functions, which in the event of a single failure include:

- The shutdown of the system in a safe state,
- Prevention of subsequent operation until the failure has been corrected, and
- Prevention of unintended equipment startup upon correction of the failure.

As described above, the SFS-EBM-01E.. Fiber Optic Emergency Stop Button uses a “positive opening” or “direct opening” means to block the optical path when actuated. Unlike most electro-mechanical emergency stop buttons, the SFS-EBM-01E.. is third-party certified for use in potentially explosive environments. Up to three E-stops can be serially connected in one fiber optic channel (see Section 8.4.1).

PICO-GUARD Fiber Optic Emergency Stop Buttons are rated at IEC IP65. The PC resin housing material makes them impact resistant and robust enough for most industrial environments. Models are available for either one-sided or two-sided (opposite sides) fiber connection.

CAUTION . . . Enclosure Use

The PICO-GUARD Fiber Optic Emergency Stop Button is designed for use within its IP65 PC resin enclosure to ensure the integrity of the switching action. **After the fibers are installed, the enclosure cover must be reassembled with its base.**

CAUTION . . . Multiple Optical E-Stop Switches

Whenever two or more optical E-stop switches are connected to the same optical channel:

- The switches must be connected together in series.
- **During checkout, each switch must be individually actuated (engaged), then re-armed and the controller must be reset (if using manual reset mode).** This allows the controller to check each switch to detect faults. Failure to test each switch individually in this manner could result in undetected faults and create an unsafe condition which could result in serious injury or death.

8.2 Models

Models	Housing Description
SFS-EBM-01E1	One-sided fiber connection
SFS-EBM-01E2	Two-sided fiber connection (opposite sides)

8.3 Specifications

Mounting	Holes (x4) for M5 screws (mounting hardware not included)
Construction	**Enclosure and Base:** Polycarbonate **Button:** Polymide **Button Base:** Aluminum/Zinc alloy
Environmental Rating	IEC IP65
Operating Conditions	**Temperature:** 0° to +70° C (+32° to 158° F) **Max. Relative Humidity:** 95% (non-condensing)

8.3.1 Fiber Optic Emergency Stop Button Dimensions

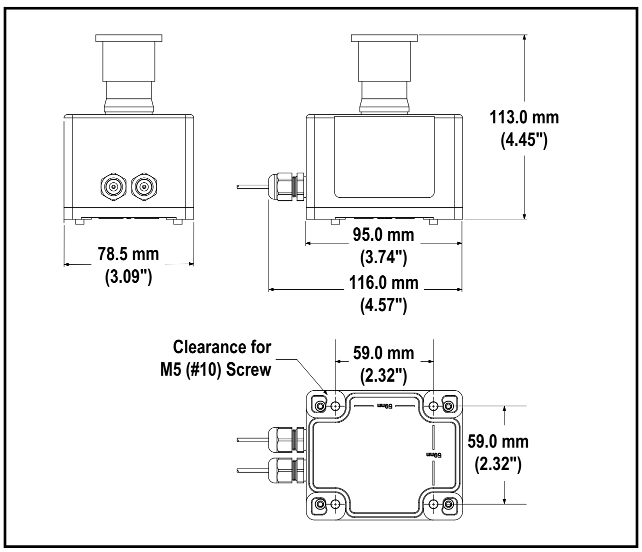


Figure 8-1. Model SFS-EBM-01E1 E-Stop Button dimensions

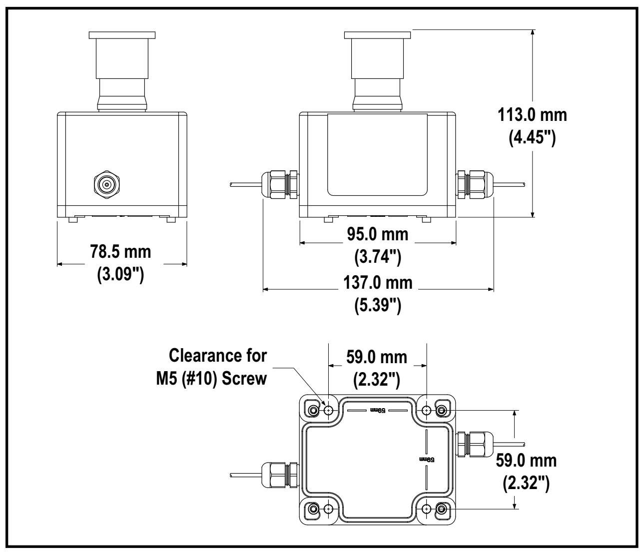


Figure 8-2. Model SFS-EBM-01E2 E-Stop Button dimensions

8.4 Mounting and Installation Considerations

NOTE: Review Sections 3, 4, and 6.5 for complete recommendations for installing, cutting, and routing fiber optic cable.

1. Locate the position for the Emergency Stop Button and mount the black plastic base with four M5 mounting screws (not included), with the gasket facing away from the mounting surface.
2. Route the fibers from the PICO-GUARD controller per Sections 3 and 6.5. Ensure that the amount of fiber corresponding to the number of serially connected SFS E-stop buttons complies with the table in Section 8.4.1. The excess gain is dependent on number of buttons, fiber length, fiber bend radius, and other loss factors, which may result in a weak signal or beam break condition.

To use a fiber with unpolished ends (PIU4 series), cut the optical fiber to length (see Section 3.2 for fiber cutting procedure) or trim a short length off the end. A new cut ensures a flat termination of the fiber for good optical coupling. *Do not cut the end of a polished fiber (PW.. series) unless the end has been damaged or contaminated or if it must be cut to length*. If a polished end is cut, the excess gain will be reduced and the advantage of polishing will be lost. Model SFA-FFP Field Polishing Kit is available to polish the end of a field-cut fiber.

3. If the fiber gripper is closed (flush with the body of the interlock switch inside the enclosure), use a small flat screwdriver to carefully pry up the gripper until the fiber can be inserted into the body (see Figure 6.12). When using PVC-jacketed fiber, strip the PVC jacket approximately 25 mm (see Figure 8.3). Insert the fiber end into the body until it bottoms out (approximately 60 mm). Then carefully push the fiber gripper tab until flush with the body of the interlock switch. Repeat with the second fiber.
4. Re-install the SFS enclosure onto the base with the four captive screws (9 to 10 in-lbs.). Tighten the fiber glands until a good seal is made (do not over-tighten).
5. Perform commissioning checkout procedures as described in the appropriate SFCDT controller manual.

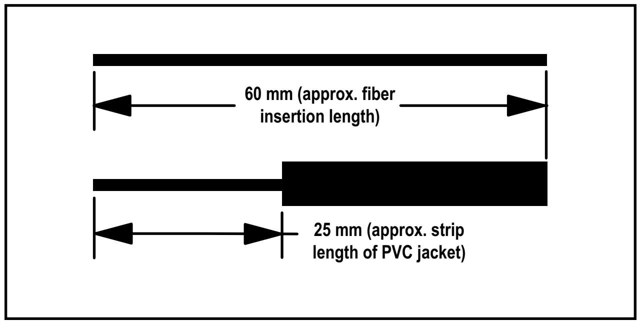


Figure 8-3. Fiber insertion guide (actual size)

8.4.1 Determining Fiber Optic Emergency Stop Optical Channel Configuration

SFS E-Stop Combinations	Number of Optical E-Stop Pairs on Circuit		
	1*	2	3
Maximum total length of cut fiber	95 m (312')	50 m (164')	—
Maximum total length of polished fiber	125 m (410')	55 m (180')	25 m (82')

NOTE: The information in the table above is provided as a guide for installation of the PICO-GUARD Fiber Optic Emergency Stop Buttons using 1 mm core plastic fiber, either polished or cut, as specified. The total length of installed fiber may be affected by certain variables, such as bend radii of the fiber, environmental conditions, etc.

*For a single E-stop with short total fiber length, a single attenuator (model SFA-FA) may be required to eliminate a lockout condition. If the system does not lock out with the E-stop button down, but does when the E-stop button is up, then the single attenuator is required. Contact the factory applications department for additional information.

Appendix A. Application Examples

> **WARNING . . . User Is Responsible for Safe Application of this Product**
> The application examples described in Appendix A depict generalized situations. Every guarding application has a unique set of requirements. **Extreme care is urged to ensure that all legal requirements are met and that all installation instructions are followed.** In addition, any questions regarding safeguarding should be directed to the factory applications department at the number or addresses listed on the front cover.

A.1 USSI Multiple Safety Systems

The PICO-GUARD SFCDT-4A1(C) controller has two USSI inputs (one with a Trip function and one with a Latch function) that can be used in a wide variety of applications. Sections A.1.1 to A.1.4 provide examples of integrating the USSIs into the safeguarding or process control of a machine or cell.

A.1.1 USSI Monitoring Safety Modules

Figure A-1 depicts supplemental safeguards (a safety mat and two magnetic switches) interfaced with the PICO-GUARD to provide a control-reliable interface that results in a single Stop command to the machine control.

In this example, a Safety Mat Monitoring Module is being monitored by the latching USSI#1 to provide a reset function after an individual steps off the safety mat. As a variation to this application, a sequenced reset can be accomplished if the Safety Mat Monitoring Module is configured for manual reset. This forces the operator to reset one system before the other to ensure that the safeguarded area is clear of other individuals.

The trip USSI#2 is monitoring a Gate Monitor Module that is interfaced with two magnetic sensors on individual interlocked gates. A reason for mixing styles of interlocking switches is if part of the machine process generates an excessive airborne contamination that could impact the performance of the fiber optic interlocks. In this case, the trip USSI is used when an individual can reach only through the opening, thus allowing an automatic reset to occur after the gates are shut. If a pass-through hazard exists, other safeguarding may be required, or the gate monitor module could be configured for manual reset.

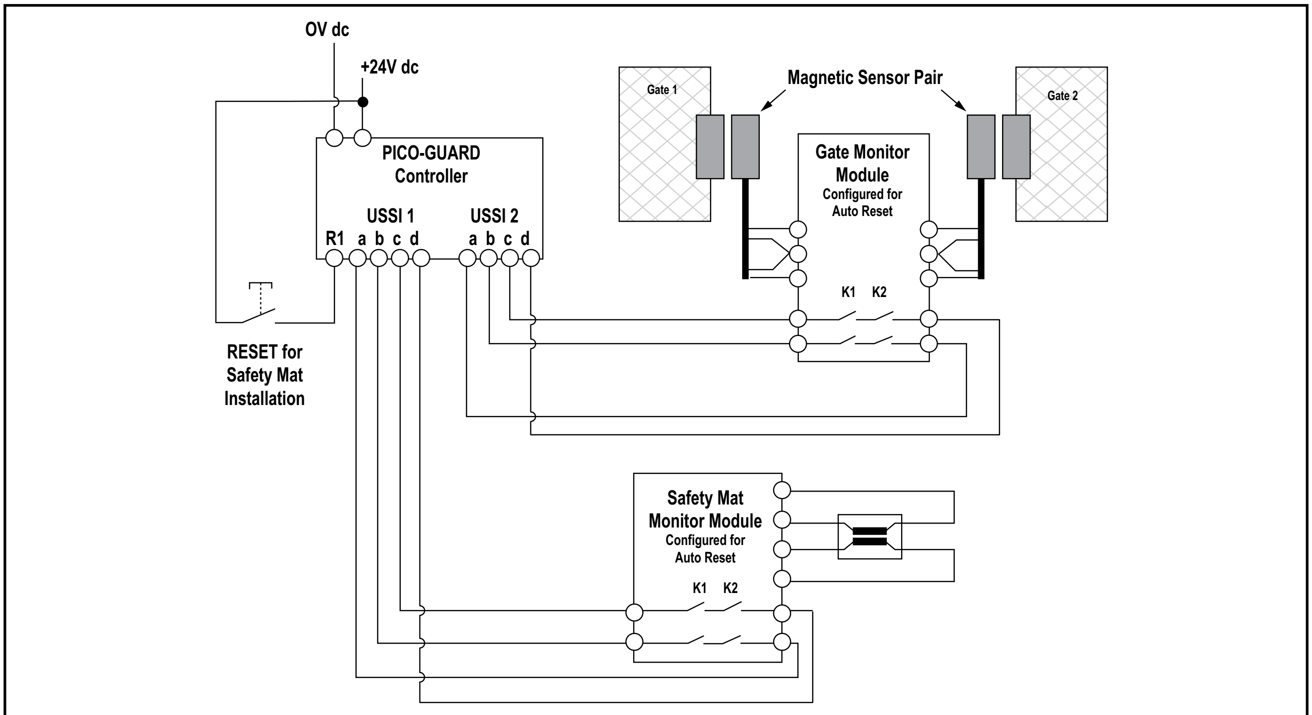


Figure A-1. USSI monitoring a safety mat monitoring module and a 4-wire safety mat

A.1.2 Sequenced Reset Routine

Safety Light Screens and Multiple-Beam Safety Systems
In Perimeter Guarding, large areas are controlled by a single safeguard (e.g., multiple-beam EZ-SCREEN Grid), so if an individual passes through the safeguard, it issues a Stop command and latches its output OFF. The safeguard will remain latched until the individual exits the hazardous area and resets the safeguarding device. Before a system reset is preformed, the individual must ensure that the area is clear of other personnel, which can be difficult if there are areas that are out of view from the location of the reset. To ensure the individual visually verifies that no one goes undetected, a “Sequenced Reset Routine” can be employed.

After the individual leaves the guarded area behind the Power Press, the safety grid system must be reset (Button "B") before the PICO-GUARD Latch USSI input (Button "A") can be reset.

In the example shown in Figure A-2, an individual can only reach through the defined area of the safety light screen. A system with a Trip output may be interfaced with the Trip USSI; thus a reset of the safety light screen will not be required when the area becomes clear. This allows the operator to initiate the next machine cycle by the normal actuating means (e.g. two-hand control) without the additional step of resetting the safety light screen.

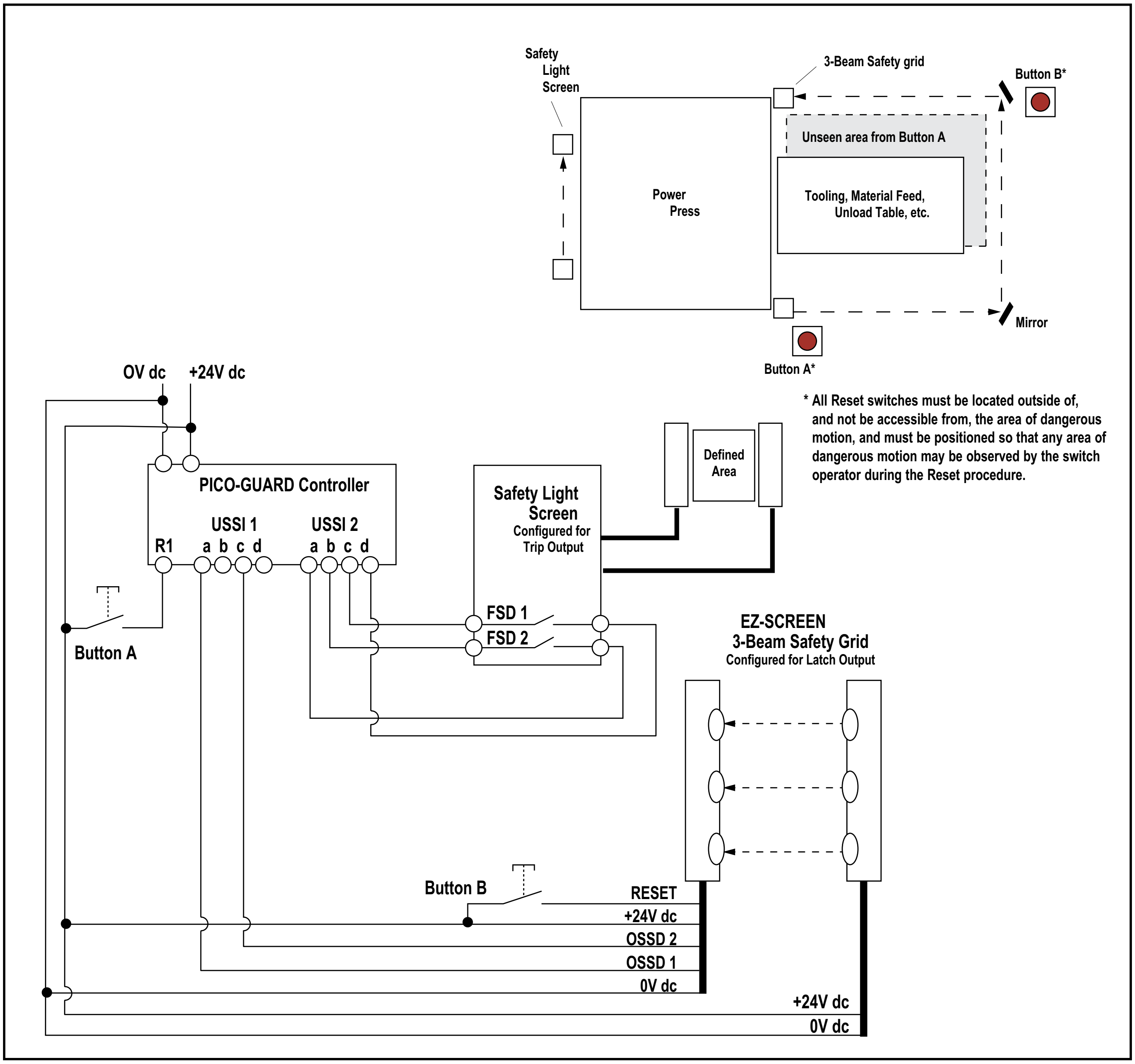


Figure A-2. Safety light screens and multiple-beam safety systems — sequenced reset routine

A.1.3 Individual (Separate) Reset Routines

Multiple-Beam Safety Systems

In this example of perimeter guarding, an operator can visually inspect an entire area for the absence of other personnel (or other supplemental safeguards are employed), then the two areas can be individually reset by using the USSI inputs.

Figure A-3 shows individual safeguards (e.g. two multiple-beam EZ-SCREEN Grids) guarding the areas along the sides of a Power Press. Safety Grid “A” is configured for Trip Output (automatic reset) and interfaced with the latch USSI such that to clear an interruption, Button “A” must be pressed and released. Safety Grid “B” is configured for Latch Output (manual reset) and interfaced with the trip USSI such that to clear an interruption Button “B” must be pressed and released.

In this configuration, each safeguard could also be individually muted.

*NOTE: The Reset switch must be located outside of – and not be accessible from – the area of hazardous motion, and must be positioned so that any area of hazardous motion may be observed by the switch operator during the Reset procedure.

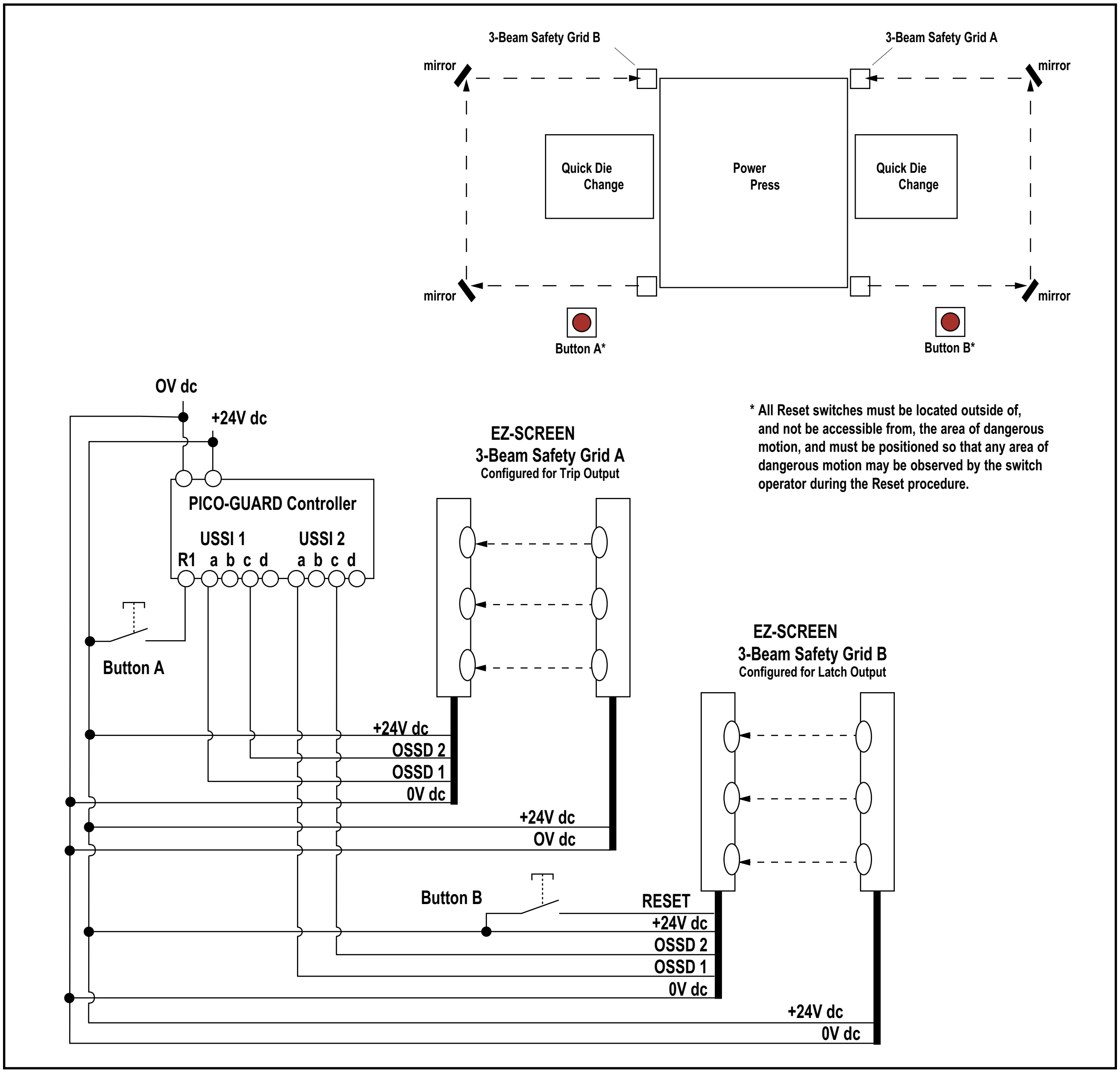


Figure A-3. Multiple-beam safety systems — individual (separate) reset routines

A.1.4 Process Control and Equipment Protection

Non-Safety Applications
The USSI inputs can be used in a similar fashion to the optical channels, when used for equipment protection that does not impact personnel safety (see the Warnings in Section 5). In applications where the optical channels provide highly reliable sensing, the USSIs can provide highly reliable switching in situations where the loss of a stop signal (e.g., due to a failed switch or output) could possibly result in the destruction of – or damage to – expensive equipment.

Figure A-5 shows an example of Process Control that employs the USSI inputs (e.g., PLC relay N/O outputs, or N/O held-closed limit switches as a process Stop command or for a Test signal).

NOTE: Solid-state hookup to the USSI requires a handshake signal that is incorporated in Banner Engineering safety devices with OSSD solid-state outputs. This handshake verifies that the interface of the two devices can detect certain failures, such as a short-circuit to a secondary source of power or to the other channel, high-input resistance, or the loss of signal ground (see Section 2). If the devices to be interfaced are not capable of the Banner “Safety Handshake” (i.e., non-Banner safety devices), hard contacts must be used and wired as shown in Figure A-5.

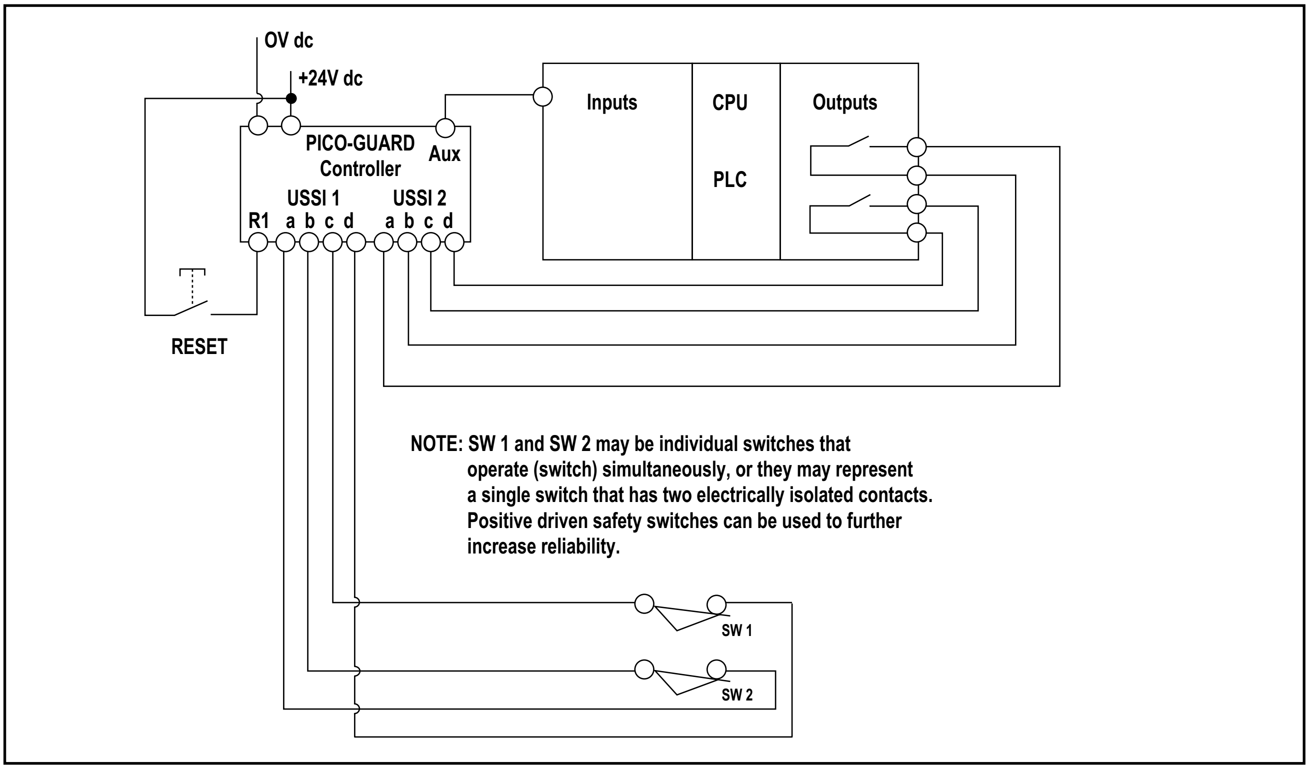


Figure A-5. Process control and equipment protection (non-safety)

A.2 Fiber Optic Equipment Protection (Non-Safety)

The PICO-GUARD System can provide a means of highly reliable photoelectric sensing when used for equipment protection that does not impact personnel safety. Unlike standard limit switches, or photoelectric or inductive sensors, the PICO-GUARD controller and optical elements are designed to default into a Beam Break condition. With standard switches and sensors that can fail in an On or Go condition, the loss of a stop signal could result in extremely costly damage (see the Warnings in Section 5).

Fiber optic equipment protection is not intended for personnel safety. The user must ensure that the fiber optic assembly is appropriate for the intended application and that all relevant standards are complied with. Contact the applications group at Banner Engineering for assistance in choosing appropriate plastic fiber(s) for equipment protection applications. See Section 5 for more information.

CAUTION . . . "Standard" Plastic Fibers

Standard plastic fiber optic assemblies are available in a variety of sensing end styles and are listed in the Banner Engineering Photoelectric Sensor catalog. **The machine designer should contact the applications group at Banner Engineering for assistance in choosing appropriate plastic fiber(s) for equipment protection (non-safety) applications.**

A.2.1 Position Monitoring

Figure A-6 shows a Fiber Optic Safety Interlock Switch pair (e.g., SFI-D1 and SFI-A1) used to verify the correct positioning of a moving or rotating table before an operation begins. A similar application would be monitoring the position of a Safety Block or Slide Lock for the home or run position.

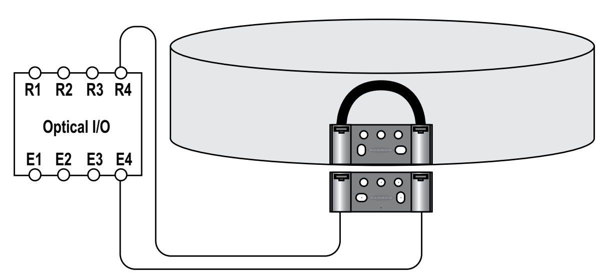


Figure A-6. Position monitoring – non-safety

A.2.2 Leak Detection in Corrosive Environments

Through the use of specialized fiber optic assemblies, other specialized applications can be solved. Figure A-7 depicts clear liquid detection using a Bifurcated fiber cable (model PBT26UM6M.1) with probe (model TGR3/8MPFMQ). In the application of this probe, the liquid to be detected must have an index of refraction different from that of air (i.e., clear), and it must be non-viscous (so that it does not cling to the probe tip) for the optical principle of the probe to function correctly.

Due to the hazardous nature of the chemicals used in the processing of semiconductors, leak detection is vital. If the plumbing or valves begin to leak, an immediate signal is required. To sense and report such a leak, the probe is threaded onto the sensing end of the bifurcated fiber; the PICO-GUARD will issue a stop signal when the clear liquid is present on the tip of the probe. The liquid contacting the tip causes the red light to scatter into the liquid, creating a "Dark" condition, which turns OFF the OSSDs.

The probe must be mounted a minimum of 50 mm (2.0") from a light-colored (e.g., white) or shiny (e.g., stainless steel) background to prevent false proxing in the presence of the fluid.

The SFA-FA attenuator generally must be used to reduce the excess gain to an acceptable level. This will ensure that the amount of internal probe reflection will reliably drop below the threshold level when fluid is present.

Scheduled maintenance must include inspecting and cleaning the probe tip to prevent contamination (e.g. dust) from building up on the probe tip.

CAUTION: When bifurcated plastic fiber assemblies are used, the installation must exclude or eliminate the possibility of the loss of switching, due to optical short circuits or self-reflection. See Section 5 for more information.

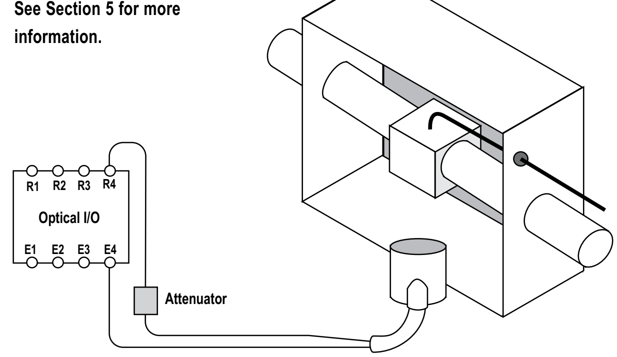


Figure A-7. Leak detection – non-safety

A.2.3 Non-Mechanical Limiting and Dynamic Limiting

The convergent photoelectric beam initiates a Go signal when the Cam, Dogleg, or other physical target is sensed. For reliable operation, the optical element and the target must be securely attached and rugged enough to not be easily removed or bent out of position.

Figure A-7 shows a P12-C1 Plastic Fiber Optic Assembly using convergent-mode sensing. Due to the red light emitters of the PICO-GUARD, a white target will be seen more reliably than a black target (see Caution in A.2 and the Banner Engineering Photoelectric Sensors catalog). Sheathing of the optical fibers may be required.

In a robotic application, Base Limit switches or other axis-limit switches can be replaced by a convergent photoelectric beam, if the base cam is high enough above the pedestal to not generate a false ON signal. The limiting of other axes can be similarly accomplished, by alternate means (depending on the application).

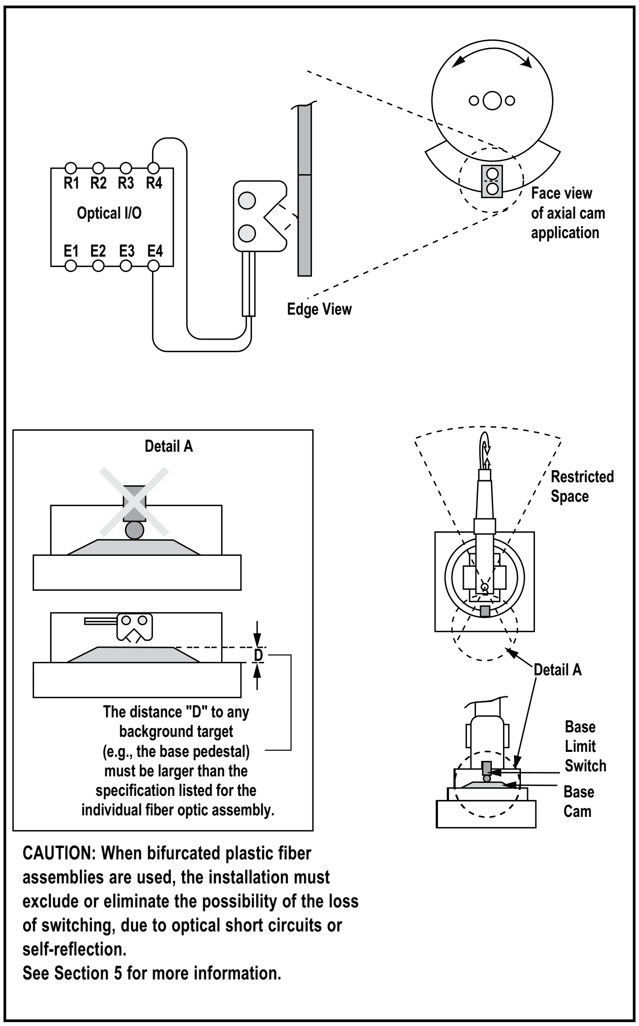


Figure A-7. Non-mechanical limiting and dynamic limiting – non-safety

A.2.4 Part Quality Monitoring/Inspection (Error Proofing)

In most error-proofing applications, one event or operation is dependent on the occurrence of a previous event or operation. To ensure that the process does not generate poor quality or flawed parts, plastic fiber optic assemblies used in light operate mode can verify whether certain conditions exist, before allowing the next action.

Figure A-8 shows the monitoring of pilot holes in a strip-feed for the front end of a die-protection application. The PICO-GUARD System's optical channels are complementary to other die-protection sensors (e.g., inductive proximity, laser measurement, photoelectrics). Two PIT46U (or PIAT46U) individual fibers can be used in situations that have adequate height clearance, or a model PIPS46U side-view fiber can be used in tight spaces when adequate excess gain is expected. A fiber optic slot sensor (such as PDIS46UM3.2 or PDIS46UM8MSL30) provides another integrated package option without creating alignment issues.

A limiting factor is the duty cycle or speed of the operation. A cycle can not exceed 500 ms. Limiting factors must be added to the response time and the recovery time of any interposing interfacing modules or contactors.

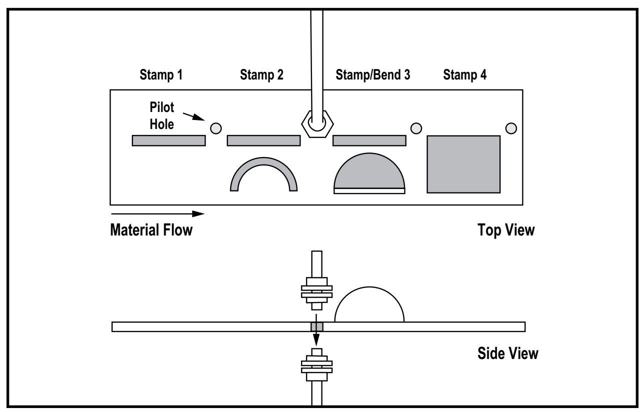


Figure A-8. Part quality monitoring and inspection (error proofing) – non-safety

Bifurcated diffuse fiber assemblies (such as PBP46U Bendable Probe or the PBPS46U "Side View") can also be used to verify part-in-place. Care must be taken to prevent false triggering on the tooling or other background objects (see Figure A-9).

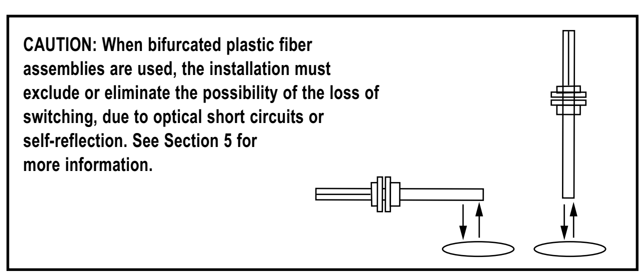


Figure A-9. Specialized diffuse fiber assemblies for inspection – non-safety

A.3 Application Examples for Point Optical Devices

A.3.1 Over-Travel Prevention (Non-Safety)

Moving Fixture or Gantry
The PICO-GUARD Safety Point optical elements can provide highly reliable sensing to provide a “soft” stop for a moving fixture or gantry if it moves beyond the normal range of motion, thus preventing contact with the hard stops and damage.

The soft stops (i.e., the optical elements) must be located in a position at which the speed and momentum of the moving fixture or gantry can be controlled appropriately. As a guideline, this position can be determined using the following formula:

Stopping Distance = S x (Tr + Ts)

where:

S = speed of the moving fixture. It is recommended to use the maximum speed of the fixture.

Tr = the reaction time of the PICO-GUARD system

Ts = the reaction time of the machine control, plus an adder to compensate for momentum under full rated load or brake wear (usually a percentage of machine control response time).

The correct mounting position of the optical elements can be confirmed on a trial basis by issuing a stop signal to the fixture when it reaches the calculated position and noting the result. Measure the stopping distance and reposition the optical elements as needed.

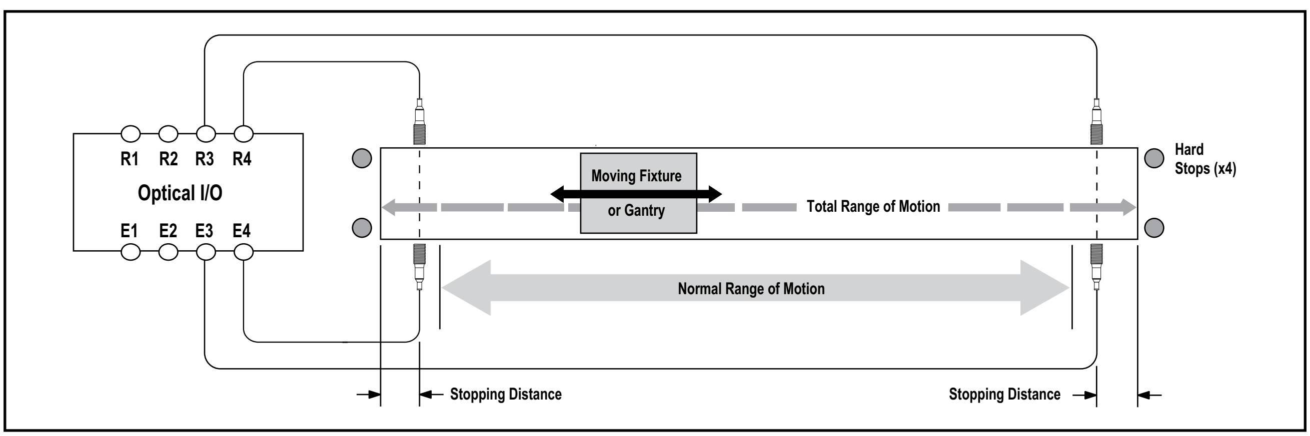


Figure A-10. PICO-GUARD Point elements used for over-travel prevention – non-safety

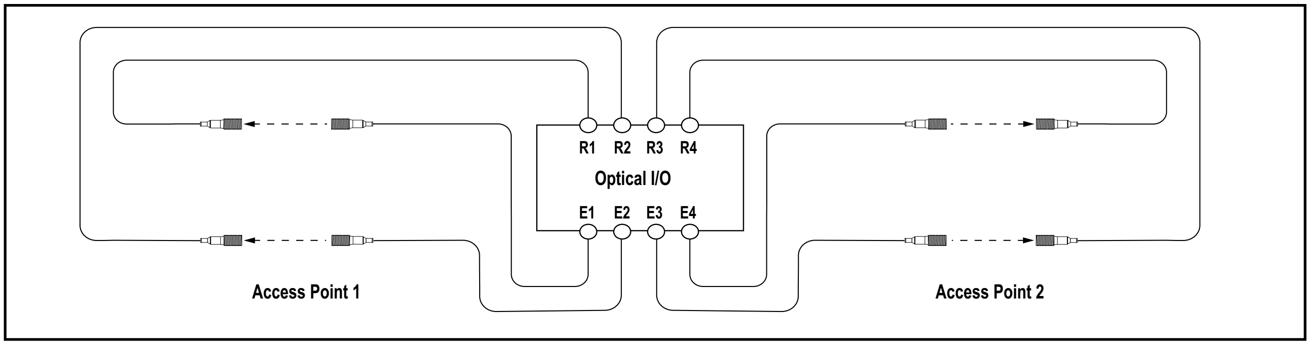


Figure A-11. Two 2-beam PICO-GUARD light grids (Point elements) used for perimeter or access guarding

A.3.2 Two 2-Beam Grids

Perimeter- or Access-Guarding

The optical channels can be interfaced with individual Safety Points to solve perimeter guarding and access-guarding applications. Figure A-11 shows an example of using four pairs of Safety Points to guard two access (entry) points to a safeguarded area.

A.3.3 One 4-Beam Grid

Perimeter- or Access-Guarding

A single access point can be guarded using four pairs of Safety Points, providing a flexible, "customized" sensing grid. See Figure A-12.

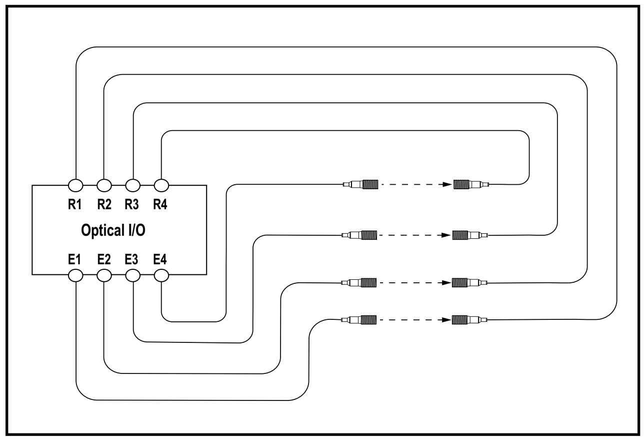


Figure A-12. One 4-beam PICO-GUARD light grid (Point elements) used for perimeter or access guarding

A.3.4 One 3-Beam Grid Plus Interlock Guard

Perimeter- or Access-Guarding and Two Gates

Different safeguarding options can be incorporated into the PICOGUARD controller's four optical channels. Figure A-13 shows three of the optical channels configured in an optical grid for perimeter- or access-guarding; the fourth channel is used to interlock hard guarding in two areas that either are accessed infrequently or can not be otherwise guarded.

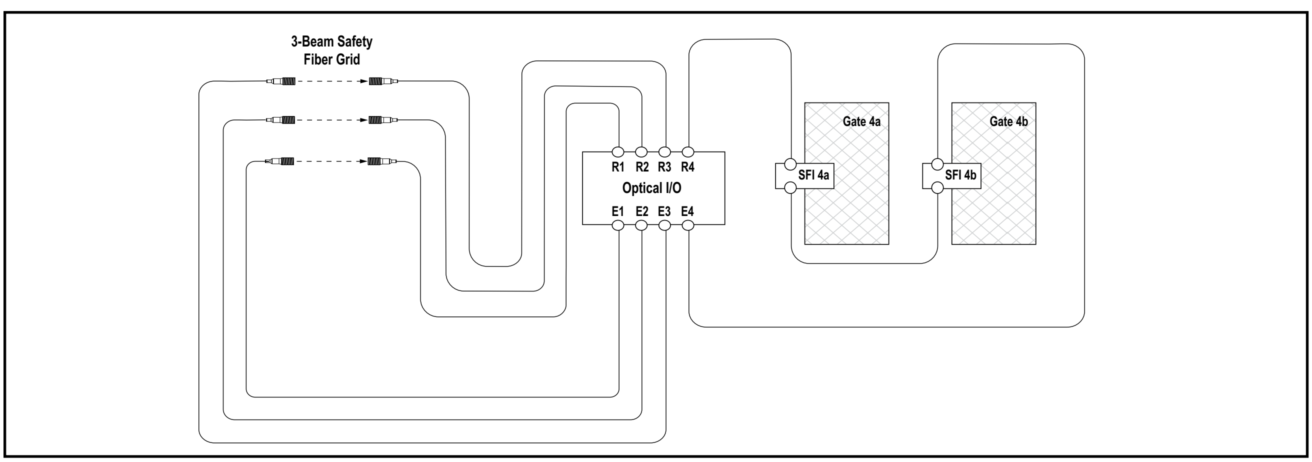


Figure A-13. One 3-beam PICO-GUARD light grid (Point elements) used for perimeter or access guarding, plus optical interlock switches to guard two gates

A.3.5 SFP12 Safety Light Screen

Multiple SPF12.. Fiber Optic Safety Point optical elements can be used to create a sensing field that is similar to a Safety Light Screen for hand detection (Resolution ≤ 64 mm [2.5"] in the U.S. per ANSI B11 and ANSI/RIA R15.06, and ≤ 40 mm [1.58"] for European installations per EN999).

In Figure A-14, two Protected Heights ("A" and "B") result, depending on whether an individual can reach over or under the sensing field. If the four optical beams are placed such that the beam's centers are 51 mm (2"), then a 161 mm (6.35") protected height "A" is created. If the same installation (centered as drawn) is surrounded by hard guarding or an opening in the machine frame, then protected height "B" can safeguard up to a 254 mm (10") opening while maintaining a resolution less than 64 mm (2.5").

Resolution is the minimum size (diameter or cross section) object that a safety light screen will reliably detect. Objects of this size or larger will be detected anywhere in the sensing field. Resolution is calculated by adding the beam spacing dimension to one effective beam diameter, also known as "Minimum Object Detection Size" (MODS) or "Minimum Object Sensitivity" (MOS).

For the example shown in Figure A-14, SFP12 Fiber Optic Safety Points have an effective beam diameter of 9 mm (0.35"), and the beam spacing is 51 mm (2.0"). This results in a resolution of approximately 62 mm (2.5").

Resolution = Beam Spacing + Beam Diameter
= 51 mm (2") + 9 mm (0.35") = 60 mm (2.35")
≈ Resolution = 62 mm (2.45") for use with the STP-12 Test Piece

This value is used to calculate the Depth Penetration Factor (Dpf) added in the separation (safety) distance formula. **See Section 7 for installation instructions and Section 7.7.2 for complete safety distance calculation information.**

Per ANSI B11.19 and ANSI/RIA R15.06 (S = Resolution)
Dpf = 3.4 x (S - 7 mm) or 3.4 x (S - 0.275")
Dpf for 62 mm (2.45") resolution = 187 mm (7.4")*

*Smaller beam spacing will result in a tighter resolution and a smaller Dpf. Due to the dimensions of the mounting nuts, the smallest resolution that can be attained for the SFP12 optical elements is 40 mm (1.57").

CAUTION . . . SFP30 Optical Elements

The SFP30 Optical Elements are typically NOT recommended for creating a sensing field that is similar to a Safety Light Screen for hand detection. The 25 mm (1") beam diameter is too large for reliably detecting a hand or finger while maintaining a resolution ≤ 64 mm (2.5"). If used, the beam spacing must not exceed 38 mm (1.5") to be capable of detecting a hand.

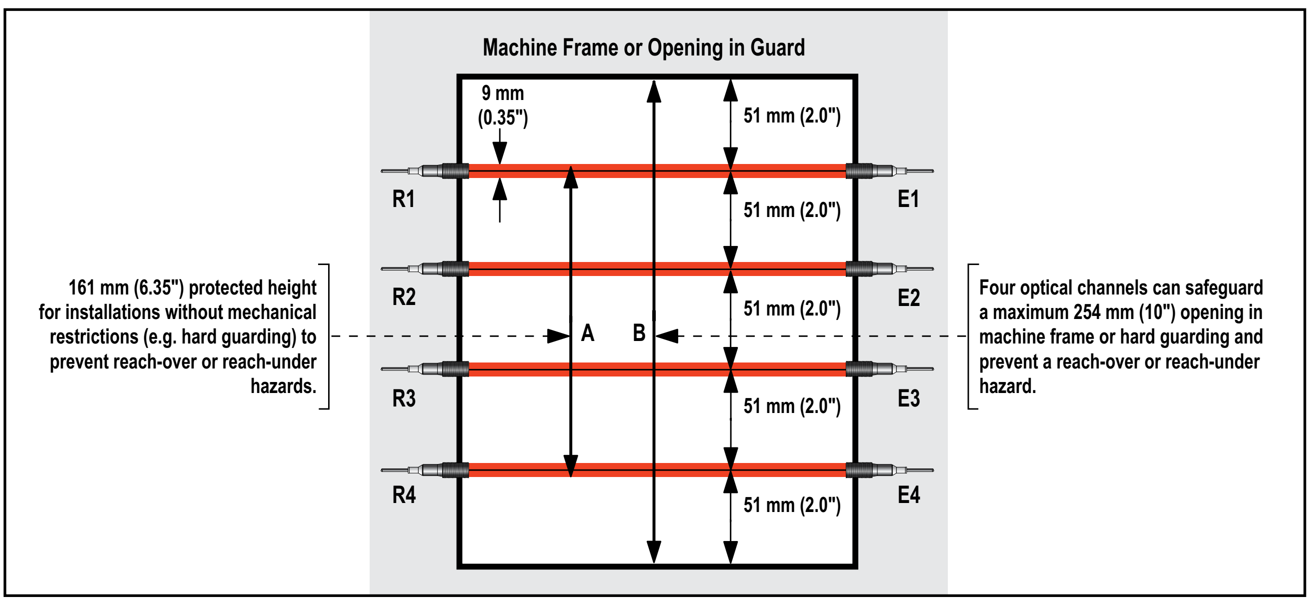


Figure A-14. SFP12 Safety Light Screen

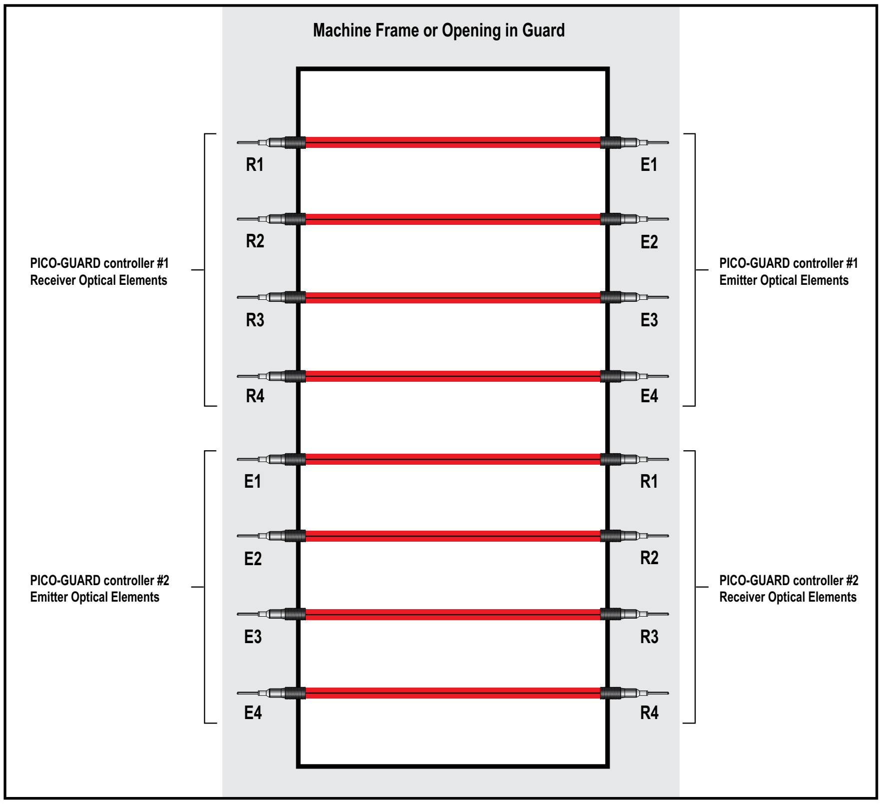


Figure A-15. Multiple SFCDT-4A1.. controllers

WARNING . . . Minimum Object Sensitivity (MOS)

After installing per the requirements of Section 7, a Trip test must be performed (see Section 7.9). Select the proper test pieces from the list below. Care must be taken to ensure that gaps in the sensing fields do not occur (see "Unacceptable Orientations" in Figure 7-7).

Available Test Pieces:

STP-3 = 44 mm (1.75")
STP-8 = 51 mm (2.0")
STP-5 = 57 mm (2.25")
STP-12 = 62 mm (2.45")

NOTE:
The above test pieces can be ordered through a local Banner Engineering representative at www.bannerengineering.com or by calling the factory at the number listed on the back cover.

Two SFCDT-4A1.. PICO-GUARD controls using eight SFP12.. Fiber Optic Safety Point optical element pairs can be used to create a larger sensing field for an increased protected height.

In Figure A-15 above, the mounting pattern from Figure A-14 is duplicated (i.e., repeating the 51 mm [2.0"] beam spacing). This configuration can create a protected height of 364 mm (14.35") and safeguard a maximum opening of 457 mm (18.0")

To prevent possible cross-talk, the emitter and receiver Optical Elements must be opposite (as shown) between Controller #1 and Controller #2. See Section 7.7.6 for information on installing multiple PICO-GUARD systems.

Appendix B. Glossary

ANSI (American National Standards Institute): An association of industry representatives that develops technical standards, including safety standards. These standards represent a consensus from a variety of industries on good practice and design. ANSI standards relevant to application of the PICO-GUARD System include ANSI B11.1 (mechanical power presses), ANSI B11.2 (hydraulic power presses), and ANSI/RIA R15.06 (industrial robots and robot systems).

Blocked condition: A condition of the PICO-GUARD System when an opaque object of sufficient size blocks/interrupts one or more beams of the light grid. When a Blocked condition occurs, OSSD1 and OSSD2 outputs simultaneously turn off within the system response time.

Control reliability: A method of ensuring the performance integrity of a control system. Control circuits are designed and constructed so that a single failure or fault within the system does not prevent the normal stopping action from being applied to the machine when required, and it does not create unintended machine action, but it does prevent initiation of successive machine action until the failure is corrected.

Designated Person: A person or persons identified and designated in writing, by the employer, as being appropriately trained and qualified to perform a specified checkout procedure.

Diverse redundancy: A design feature in which two components of different design, running from two different instruction sets (if programmed components), constantly check all system components, including each other.

Emitter: The light-emitting component of the PICO-GUARD System, consisting of synchronized modulated infrared LEDs. The emitter, together with the *receiver*, optical fibers and optical elements, creates an optical circuit.

Final Switching Device (FSD): The component of the machine's safety-related control system that interrupts the circuit to the machine primary control element (MPCE) when the output signal switching device (OSSD) goes to the OFF-state.

FMEA (Failure Mode and Effects Analysis): A testing procedure by which potential failure modes in a system are analyzed to determine their results or effects on the system. Component failure modes that produce either no effect or a *lockout condition* are permitted; failures that cause an unsafe condition (a *failure to danger*) are not. Banner PICO-GUARD Systems are extensively FMEA tested.

Forced-guided contacts: Relay contacts that are mechanically linked together, so that when the relay coil is energized or de-energized, all of the linked contacts move together. If one set of contacts in the relay becomes immobilized, no other contact of the same relay will be able to move. The function of forced-guided contacts is to enable the safety circuit to check the status of the relay. Forced-guided contacts are also known as "positive-guided contacts," "captive contacts," "locked contacts," or "safety relays."

Full-revolution devices: A type of machine drive arranged such that, once started, the machine can only be stopped when the full cycle is complete. Examples include positive- key clutches and similar mechanisms. Banner PICO-GUARD Systems may not be used with full-revolution devices.

Handshake/safety handshake: A means that a Universal Safety Stop Interface uses to verify that any device connected to its inputs meets certain fault-detection requirements.

Hard guarding: Screens, bars, or other mechanical barriers that prevent a person from entering or remaining in the hazard area undetected.

Internal lockout: A *lockout condition* that occurs due to an internal PICO-GUARD System problem. Indicated by the red Status indicator (only) flashing. Internal lockouts require the attention of a *Qualified Person*.

Latch condition: The response of the OSSD outputs (they turn OFF) when an object blocks/interrupts a light beam of the PICO-GUARD system operating in Latch mode. A manual reset must be performed after all objects are removed (all beams clear) to reset the output latch and allow the outputs to turn ON.

Lockout condition: A condition of the PICO-GUARD System that is automatically attained when the System detects internal or certain external errors. A lockout condition causes all of the PICO-GUARD System OSSD outputs to turn OFF or remain OFF, sending a stop signal to the guarded machine. To restore the PICO-GUARD System to Run mode, all errors must be corrected and a manual reset must be performed.

Machine primary control element (MPCE): An electrically powered element, external to the PICO-GUARD System, that directly controls the machine's normal operating motion in such a way that it is last (in time) to operate when motion is either initiated or arrested.

Machine response time: The time between the interruption by the PICO-GUARD OSSDs and the instant when the dangerous parts of the machine reach a safe state by being brought to rest.

Machine secondary control element (MSCE): A machine control element independent of the *Machine Primary Control Element(s) (MPCEs)*, capable of removing the source of power from the prime mover of the relevant dangerous machine parts.

MPCE monitor contacts: The normally closed contacts of a guarded machine's MPCEs that are connected to the PICO-GUARD System EDM inputs. These contacts must be mechanically linked to the control elements (*forced-guided*).

Muting: The automatic suspension of the safeguarding function of a safety device during a non-hazardous portion of the machine cycle.

OFF state: The state in which the output circuit is interrupted and does not permit the flow of current.

ON state: The state in which the output circuit is complete and permits the flow of current.

Optical elements: The device(s) that are part of an optical circuit used for detecting the presence of on individual or the opening of a guard.

OSHA (Occupational Safety and Health Administration); OSHA CFR 1910.217: Occupational Safety and Health Administration (a US Federal agency), the division of the US Department of Labor that is responsible for the regulation of workplace safety. OSHA regulations often follow ANSI standards, including mechanical power press requirements (OSHA CFR 1910.217). These regulations become law when adopted by OSHA, and must be followed.

Output signal switching device (OSSD): The component of the electro-sensitive protective equipment (ESPE) connected to the control system of the machine which, when the sensing device is actuated during normal operation, responds by going to the OFF-state.

Pass-through hazard: A situation that may exist when personnel pass through a safeguard (at which point the hazard stops or is removed), and then continue into the guarded area. At this point the safeguard may not be able to prevent an unexpected start or restart of the machine with personnel within the guarded area.

Point of operation: The area of the *guarded machine* where a workpiece is positioned and a machine function (e.g., shearing, forming, punching, assembling, welding) is performed upon it.

Protected height: The distance between the center of the top beam and the center of the bottom beam of a light grid.

PSDI (Presence-Sensing-Device Initiation): An application in which a presence-sensing device is used to actually start the cycle of a machine. In a typical situation, an operator manually positions a part in the machine for the operation. When the operator moves out of the hazardous area, the presence-sensing device starts the machine (no start switch is used). The machine cycle runs to completion, then the operator can insert a new part and start another cycle. The presence-sensing device continually guards the machine. Single-break mode is used when the part is automatically ejected after the machine operation. Double-break mode is used when the part is both inserted (to begin the operation) and removed (after the operation) by the operator. PSDI is defined in OSHA CFR 1910.217. *Banner PICO-GUARD Systems **may not** be used as PSDI devices on mechanical power presses, per OSHA regulation 29 CFR 1910.217.*

Qualified Person: A person who, by possession of a recognized degree or certificate of professional training, or who, by extensive knowledge, training, and experience, has successfully demonstrated the ability to solve problems relating to the subject matter and work.

Receiver: The light-receiving component of the PICO-GUARD System, consisting of synchronized modulated infrared LEDs. The receiver, together with the *emitter*, optical fibers and optical elements, creates an optical circuit.

Reset: The use of a manually operated switch to restore the OSSDs to the ON state from a *lockout or a latch condition.*

Self-checking (circuitry): A circuit with the capability to electronically verify that all of its own critical circuit components, along with their redundant backups, are operating properly. Banner PICO-GUARD Systems are self-checking.

Separation distance: That distance, along the direction of approach, from the outermost position at which the appropriate test piece will just be detected to the nearest dangerous machine parts. Also called safety distance.

Single-stroke press: See *full-revolution devices.*

Supplemental guarding: Additional electrosensitive safety device(s), and/or hard guarding measures, used to prevent a person from entering or remaining in the hazard area undetected.

Test piece: An opaque object of sufficient size used to block a light beam to test the operation of the PICO-GUARD System.

UL (Underwriters Laboratory): A third-party organization that tests a manufacturer's products for compliance with appropriate standards, and electrical and/or safety codes. Compliance is indicated by their listing mark on the product.

U.S. Application Standards

ANSI B11.1 Mechanical Power Presses

ANSI B11.2 Hydraulic Power Presses

ANSI B11.3 Power Press Brakes

ANSI B11.4 Shears

ANSI B11.5 Iron Workers

ANSI B11.6 Lathes

ANSI B11.7 Cold Headers and Cold Formers

ANSI B11.8 Drilling, Milling, and Boring Machines

ANSI B11.9 Grinding Machines

ANSI B11.10 Metal Sawing Machines

ANSI B11.11 Gear Cutting Machines

ANSI B11.12 Roll Forming and Roll Bending Machines

ANSI B11.13 Single- and Multiple-Spindle Automatic Bar and Chucking Machines

ANSI B11.14 Coil Slitting Machines/ Systems

ANSI B11.15 Pipe, Tube, and Shape Bending Machines

ANSI B11.16 Metal Powder Compacting Presses

ANSI B11.17 Horizontal Extrusion Presses

ANSI B11.18 Machinery and Machine Systems for the Processing of Coiled Strip, Sheet, and Plate

ANSI B11.19 Performance Criteria for Safeguarding

ANSI B11.20 Manufacturing Systems/Cells

ANSI B11.21 Machine Tools Using Lasers

ANSI B11.22 Numerically Controlled Turning Machines

ANSI B11.23 Machining Centers

ANSI B11.24 Transfer Machines

ANSI B11.TR3 Risk Assessment

ANSI/RIA R15.06 Safety Requirements for Industrial Robots and Robot Systems

ANSI NFPA 79 Electrical Standard for Industrial Machinery

OSHA Regulations

OSHA Documents listed are part of: Code of Federal Regulations Title 29, Parts 1900 to 1910

OSHA 29 CFR 1910.212 General Requirements for (Guarding of) All Machines

OSHA 29 CFR 1910.147 The Control of Hazardous Energy (lockout/tagout)

OSHA 29 CFR 1910.217 (Guarding of) Mechanical Power Presses

International/European Standards

ISO/TR 12100-1 & -2 (EN 292-1 & -2) Safety of Machinery – Basic Concepts, General Principles for Design

ISO 13852 (EN 294) Safety Distances . . . Upper Limbs

ISO 13850 (EN 418) Emergency Stop Devices, Functional Aspects – Principles for Design

ISO/DIS 13851 (EN 574) Two-Hand Control Devices – Functional Aspects – Principles for Design

ISO 13853 (prEN 811) Safety Distances . . . Lower Limbs

ISO 13849 (EN 954-1) Safety-Related Parts of Control Systems

ISO/DIS 13855 (**EN 999)** The Positioning of Protective Equipment in Respect to Approach Speeds of Parts of the Human Body

ISO 14121 (EN 1050) Principles of Risk Assessment

ISO 14119 (EN 1088) Interlocking Devices Associated with Guards – Principles for Design and Selection

IEC/EN 60204-1 Electrical Equipment of Machines Part 1: General Requirements

IEC/EN 61496 Electro-sensitive Protection Equipment

IEC 60529 Degrees of Protection Provided by Enclosures

IEC/EN 60947-5-1 Low Voltage Switchgear – Electromechanical Control Circuit Devices

IEC/EN 60947-1 Low Voltage Switchgear – General Rules

SOURCES

OSHA Documents

Superintendent of Documents
Government Printing Office
P.O. Box 371954
Pittsburgh, PA 15250-7954
Tel: (202) 512-1800
http://www.osha.gov

ANSI Accredited Standards

American National Standards Institute (ANSI)
11 West 42nd Street
New York, NY 10036
Tel: (212) 642-4900
http://www.ansi.org

B11 Documents

Safety Director
The Association for Manufacturing Technology (AMT)
7901 Westpark Drive
McLean, VA 22102
Tel: (703) 893-2900
http://www.mfgtech.org

RIA Documents

Robotics Industries Association (RIA)
900 Victors Way, P.O. Box 3724
Ann Arbor, MI 48106
Tel: (734) 994-6088
http://www.robotics.org

NFPA Documents

National Fire Protection Association
1 Batterymarch Park
P.O. Box 9101
Quincy, MA 02269-9101
Tel: (800) 344-3555
http://www.nfpa.org

Alternate sources for these, plus ISO, IEC, EN, DIN, & BS Standards:

IHS/Global Engineering Documents
15 Inverness Way East
Englewood, CO 80112-5704
Tel: (800) 854-7179
http://www.global.ihs.com

National Standards Systems Network (NSSN)
25 West 43rd Street
New York, NY 10036
Tel: (212) 642-4980
http://www.nssn.com

Document Center, Inc.
111 zindustrial Road, Suite 9
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