

Theory of Operation and Terminology

■ How Safety Light Curtains Work

Concept

Safety light curtains are an advanced method of safeguarding personnel around many hazardous machines. Also called light screens, optical guards, and *presence sensing devices*, safety light curtains offer freedom, flexibility and reduced operator fatigue when compared with traditional guarding methods such as mechanical barriers, sliding gates and pull-back restraints. By reducing the need, where applicable, for solid guards, safety light curtains simplify routine tasks like machine setup, maintenance and repair.

How They Work

Safety light curtains are easy to understand. A photoelectric *transmitter* projects an array of synchronized, parallel infrared light beams to a *receiver* unit. When an opaque object interrupts one or more beams the control logic of the light curtain sends a stop signal to the guarded machine.

The transmitter unit contains light emitting diodes (LEDs) which emit pulses of invisible infrared light when energized by the light curtain's timing and logic circuitry. The light pulses are both *sequenced* – one LED is energized after another – and *modulated* – pulsed at a specific frequency. Corresponding photo-transistors and

supporting circuitry in the receiving unit are designed to detect only the specific pulse and frequency designated for it. These techniques offer enhanced safety and rejection of external light sources.

The control logic, user controls and diagnostic indicators may be contained in a separate enclosure or be enclosed in the same housing as the receiver electronics.

One significant difference between safety light curtains and standard photoelectric sensors is a design concept known as *Control Reliability*. Required by the Occupational Safety and Health Act (OSHA) and the American National Standards

Institute (ANSI) for safety related ANSI B11.19-2003, sub-clause 3.14 defines Control Reliability as “*the capability of the machine control system, the safeguarding, other control components and related interfacing to achieve a safe state in the event of a failure within their safety related functions.*”

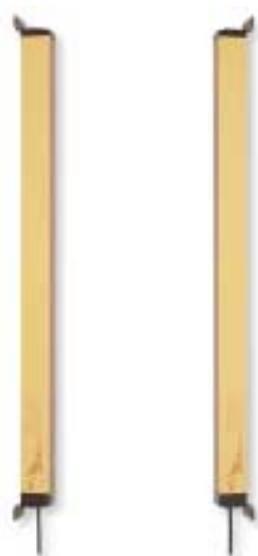
Additionally, informative Annex C of B11.19-2003 offers an expanded discussion on control reliability.

To meet this requirement, STI light curtains use self-checking circuitry to monitor the curtain for internal faults. If an internal fault is detected, the safety light

Fig. 1.1 MiniSafe

MiniSafe® MS4600

The MiniSafe MS4600 Light Curtain is a “two-box” light curtain .



MiniSafe® MS4700

The MiniSafe MS4700 Light Curtain is a “three-box” light curtain.



curtain immediately sends a stop signal to the guarded machine. The light curtain then enters a *lockout* condition. Only after replacement of the failed component and an appropriate reset will the light curtain be restored to operating condition.

Redundant safety outputs are another example of safety monitoring. STI light curtains provide one of two possible types of safety outputs. The first are relays with *force-guided* contacts (also called *captive* contacts). In this type of relay, the two sets of contacts are mechanically connected and move together. This design permits monitoring of the relay contacts and guards against the danger caused by welded contacts. Redundant relays are used for additional safeguarding. Should one relay fail, the second is used to send a stop signal to the protected machine. The second type of safety outputs are redundant, solid-state devices. These devices are electronically cross-monitored and self checking. Should one output fail, the second is used to send a stop signal to the protected machine. Solid-state outputs are capable of directly powering some machine primary control elements.

Typical Applications

Light curtain applications are often categorized by the type of guarding required. Protecting an operator from the hazards associ-

ated with material positioning or where a process is performed is called *point of operation guarding*.

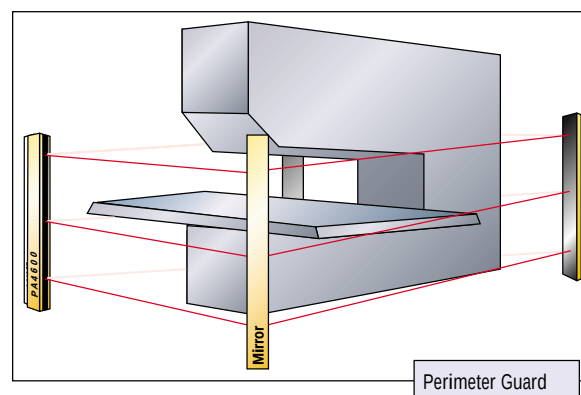
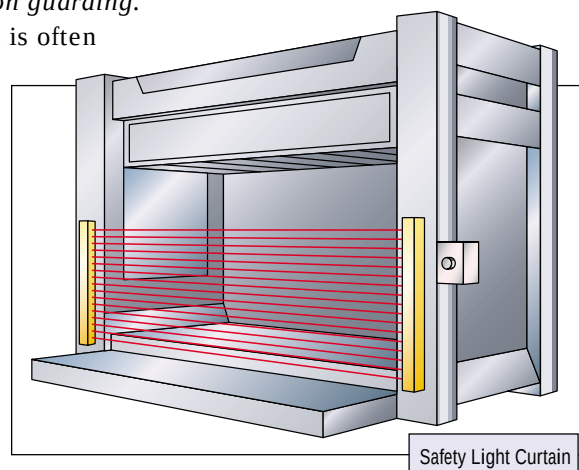
The point of operation is often called the *zone of hazardous operation*, or the *pinch point*.

This type of guarding is associated with mechanical and hydraulic power presses, molding presses, stamping, forming, riveting, eyelet and automated assembly machinery.

Light curtains used in these applications are typically selected for finger and hand protection.

Perimeter guards protect the perimeter or boundary defined by a machine, robot or other equipment. In these applications, the light curtains are generally selected to detect the presence of personnel and signal the machine controller to prevent hazardous conditions while

personnel are present within the protected area. Also, the light curtain reset switch must be located outside and within view of the protected area to prevent inadvertent resumption of machine motion. Light curtains for perimeter guarding applications are generally selected for torso detection.



■ Light Curtain Terminology and Features

Introduction

The purpose of this section is to familiarize the reader with some of the terms and features associated with light curtain selection, installation and operation. Please note that not all light curtain models have all of the features explained. Words in *italics* are defined elsewhere in the section.

Angle of Divergence/Acceptance – The angle of divergence indicates how wide the transmitter “broadcasts” its light while the angle of acceptance defines how much of that light the receiver will accept. Generally speaking, tighter angles of acceptance and divergence (smaller numeric values) allow a *light curtain* to be more immune to problems caused by outside light sources, reflective surfaces, and other adjacent light curtains. Also, light curtains with small angles of acceptance and divergence can typically have a larger *operating range*.

Blanking – A means of disabling one or more sections of a light curtain’s sensing field. The purpose is to allow objects such as tooling, feed stock, work pieces, etc. to pass through the sensing field without sending a stop signal to the guarded machine. Available in two forms,

either *floating blanking* or *fixed channel blanking*. STI calls fixed channel blanking *Exact Channel Select*.

End Device – See MPCE.

Exact Channel Select – STI’s term for *fixed channel blanking*, which purposely disables one or more **fixed** locations within the *sensing field*. This is accomplished by disabling various channels (beams) at fixed locations. This is used when stationary objects such as tooling, fixtures or conveyors obstruct a specific portion of the sensing field. The system employed by STI is Exact Channel Select and requires that any beams which are disabled by the presence of an object must remain blocked. If an obstruction is removed or relocated to another position, a stop signal is sent to the guarded machine.

Control Reliable – It is defined by ANSI B11.19-2003, sub-clause 3.14 as “*The capability of the machine control system, the safeguarding, the other control components and related interfacing to achieve a safe state in the event of a failure within their safety related functions.*”

Fixed Channel Blanking – Refer to *Exact Channel Select*, STI’s name for this option.

Floating Blanking – Allows

the disabling of up to two light curtain beams at any location in the sensing field, hence the term “floating”. Effectively changes the *minimum object resolution* of the light curtain by allowing a larger object to pass through the sensing field without being detected.

Guard Mode – See Restart Interlock.

Latch Mode – See Restart Interlock.

Light Curtain – An active optoelectronic device which contains one or more transmitting elements and one or more receiving elements which form a *sensing field* with a specified *minimum object resolution*. A light curtain is also called a “presence sensing device”.

Lockout Condition – This condition will require a reset before the light curtain will return to a *machine run condition*. A lockout condition can be caused by a faulty component, *start interlock mode* active, *restart interlock mode* active or an improper configuration setting. The safety outputs are de-energized and a stop signal is sent to the machine.

Machine Run Condition – In this operating mode, the *sensing field* is clear of any detected objects and the transmitter and

receiver units are in alignment. A Green indicator is illuminated and all safety outputs are energized.

Machine Stop Condition – In this condition, the light curtain sends a stop signal to the guarded machine. A number of situations may cause a stop condition, the most usual are a detected object in the *sensing field* and misalignment of the transmitter and receiver units. A Red indicator is on in this mode.

Minimum Object Resolution – The smallest diameter, opaque object that will be reliably detected anywhere in the light curtain *sensing field*. Certain features of the light curtain, when allowed, can change the value of the minimum object resolution.

Minimum Safe Distance – The calculated distance from the sensing field of the light curtain to the nearest recognized hazard such that the operator or others cannot reach the hazard with a hand or other body part before cessation of motion during the hazardous portion of the machine cycle. Also called safety distance.

Machine Primary Control Element – MPCE, defined as “The electrically powered element that directly controls the normal operation of a machine in such a way that it is the last element (in time) to

function when machine operation is to be initiated or arrested.” [IEC61496, Part 1 (3.14)].

It is important to note that the method to arrest hazardous machine motion will vary depending on the type of machine. Control methods include hydraulic, pneumatic, clutch and mechanical braking systems. Thus, there are several variations of MPCEs. For example, your MPCE may consist of relays, contactors, solenoids or electromechanical valves.

The purpose of monitoring the action of each MPCE is to make sure it is responding correctly to the light curtain safety outputs and to detect any inconsistency between the two MPCEs. Monitoring of the light curtain to machine control interface is necessary to detect a malfunction within the interface that would prevent a stop signal from the light curtain from reaching the machine controller. This is required by OSHA for *control reliability* of the machine controller to safety device wiring.

Machine Secondary Control Element – MSCE, is defined as “a machine control element independent of the machine primary control element(s) that is capable of removing the source of power from the prime mover of the relevant hazardous parts.” [IEC61496, Part 1 (3.15)] For example, the MSCE may be a

relay used to interrupt power to the machine motor.

The MSCE is normally controlled by the auxiliary output. Refer also to *Output Relays*.

Machine Test Signal – MTS is a feature which allows a machine controller to simulate an interruption of the *sensing field*. When the MTS is open, the light curtain controller will send a stop signal to the guarded machine.

Muting – A control reliable method of allowing the complete bypass or disabling of the light curtain’s *sensing field* or stop signal to the protected machine during the nonhazardous (usually upstroke) portion of the machine cycle. Generally accomplished by either of two methods. The first method involves using the light curtain controller to initiate the muting and generally results in disabling the sensing field. The second uses *control reliable* auxiliary circuits or machine controller circuits and would result in the bypassing of the light curtain’s output signal.

Operating Range – The maximum distance between the transmitter and receiver elements that will allow the light curtain to reliably operate. Some applications use mirrors to “bend” the infrared beams from the transmitter around corners and back to the receiver. All mirrors absorb

the infrared light to some degree. Thus, using mirrors will reduce the operating range of the light curtain by 12 to 18% per mirror, depending on the type of mirror used.

OSSD (Output Signal Switching Device) – The component of a safety light curtain connected to the machine control system which, when the light curtain is actuated during normal operation, responds by going to the off-state.

Output Relays – Light curtains with relay outputs contain three relays. Two, often called control relays, are used for connection to the machine control relay(s). The third relay is called an alarm relay, status relay or secondary switching device and is used to signal an interlock condition or may be used as an auxiliary output signal.

Light curtains use special relays with force-guided contacts (also called positive-guided or captive contacts). In this type of relay, the contact sets are forced to move together because they are mechanically interconnected. If one set of contacts should become immobilized by a welded contact, for example, the other contacts of the same relay will be unable to move. These relays are selected for the

operating characteristics to function with the relay checking circuit.

Power Up Inhibit – See Start Interlock.

Protective Height – The height of the *sensing field* in a vertically mounted light curtain.

Presence Sensing Device Initiation (PSDI) – Common term used to describe an industrial machine control application where a presence sensing device is actually used to start a machine cycle. OSHA has very strict requirements regarding the use of PSDI on mechanical power presses.

Reflective Surfaces – Use caution when installing any light curtain where the *sensing field* is adjacent to a reflective surface, such as shiny metal, foil, plastic or other similar material. A reflective surface can deflect the optical beam and may cause an obstruction in the sensing field not to be detected. A test procedure will help to test for this condition. Correction methods include increasing the distance of the sensing field from the reflecting surface, and reducing the reflectivity of the surface by painting, masking or substituting materials.

Response Time – The maxi-

mum time between the actuation of the sensing function and the safety outputs of the light curtain changing state.

Restart Interlock – Restart Interlock was created primarily for perimeter guarding applications. Once the sensing area of the light curtain has been penetrated and a stop signal sent to the guarded machine, the light curtain will not remove the stop signal until the controls are manually reset by an authorized individual located outside the protected area.

Safety Distance – See Minimum Safe Distance.

Sensing Field – A zone of light beams formed by an array of sensing elements. The sensing field defines the active sensing area of the light curtain.

Start Interlock – This feature will place the light curtain in a *lockout condition* when power is applied to the light curtain. This results in sending a stop signal to the guarded machine. The light curtain requires a reset to return to a *machine run* condition.