

## Interlocking Principles and Devices

One of the most important types of protective devices is a safety interlock switch which interlocks a guard door with the power source of the hazard.

When the guard door is opened, the power is isolated, ensuring that the machine is safe when the operator requires access.

There are many variations of interlock switches, each with their own characteristics.

It is important to ensure that the type of device chosen is correct for its application. Later in this chapter we will look at a series of logical decisions leading to the exact choice of device to be used. First, let's familiarize ourselves with some of the general features and requirements which make devices suitable for interlocking duties.

### Standards

The European Standard EN 1088 - "Interlocking devices associated with guards" gives guidance. It is intended to be used in conjunction with EN 60947-5-1 for electromechanical switches and an equivalent standard for magnetic and proximity type switches.

### Reliability

An interlock switch must operate reliably even under extreme conditions and rough treatment. The operating mecha-

nism should be kept as simple as possible and all materials used in its manufacturer should be of the highest quality. The design should ensure that component wear is kept to a minimum. The mechanism should be enclosed in a strong, sealed case.

### Security

The security of an interlock switch is dependent on its ability to withstand attempts to "cheat" or defeat the mechanism. An interlock switch should be designed so that it cannot be easily defeated.

In some circumstances, personnel may be tempted to override the switch in some way. Information concerning the use of the machine, gathered at the risk assessment stage, will help to decide whether this is more likely or less likely to happen. The more

likely it is to happen, then the more difficult it should be to override the switch or system. The level of estimated risk should also be a factor at this stage. Switches are available with various levels of security ranging from resistance to impulsive tampering, to being virtually impossible to defeat.

It should be noted at this stage, that if a high degree of security is required, it is sometimes more practical to achieve this by the way in which the switch is mounted.

For example, if the switch is mounted as in *fig. 44* with a covering track, there is no access to the switch with the guard door open. The nature of any "cheating" prevention measures taken at the installation stage will depend on the operating principle of the switch.

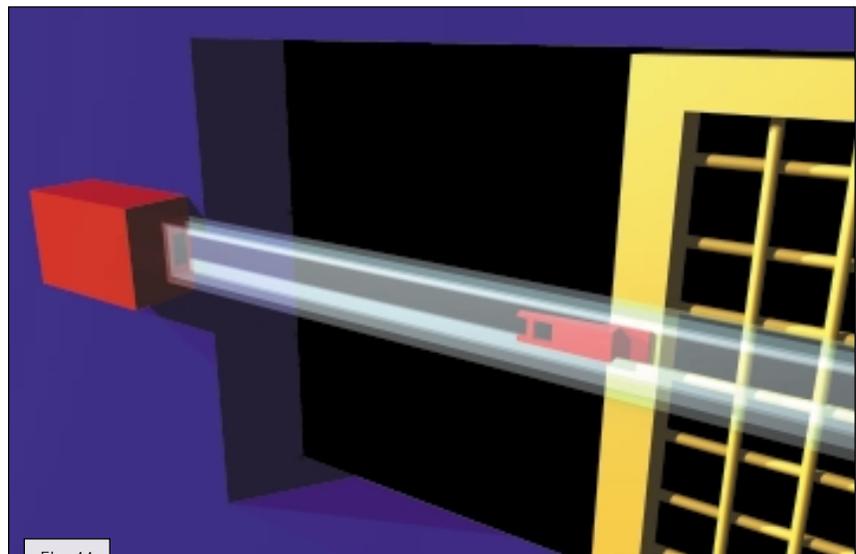
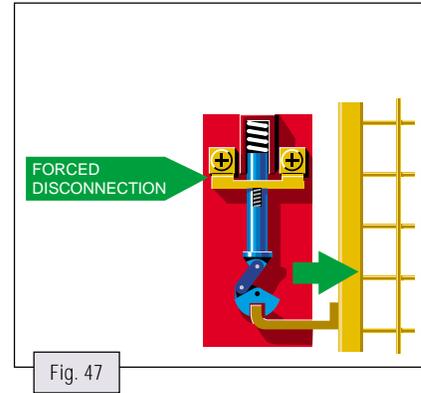
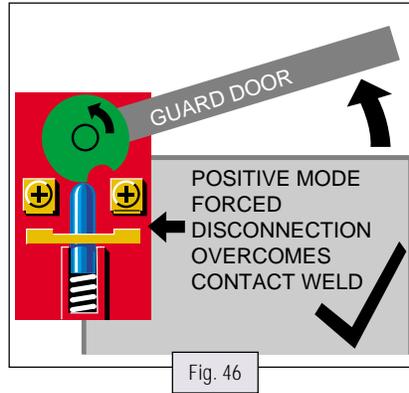
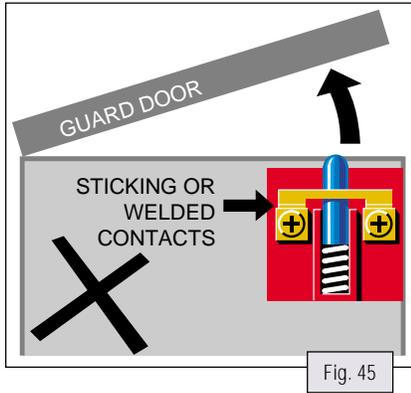


Fig. 44



## Positive Mode Operation (also referred to as direct operation)

EN 292 explains that if a moving mechanical component inevitably moves another component along with it, either by direct contact or via rigid elements, these components are said to be connected in the positive mode.

With single mechanical type interlocking switches, when the guard is opened the movement of the guard should be connected in the positive mode to the safety related contacts of the switch. This ensures that the contacts are physically pulled apart or “force disconnected” by the movement of the guard.

The switch should NOT rely solely on spring pressure to open the contacts, as the force exerted may not be able to overcome sticking or welded contacts. There is also the possibility that the switch could fail to danger if the spring breaks and there is no other means of opening the contacts.

Fig. 45 shows a typical negative (or non-positive) mode operating system. There is no direct link between the guard door and the safety contacts, so the system

relies entirely on spring pressure to open the contacts. In the event of spring failure, contact weld or sticking, the system will fail to danger and is therefore unacceptable. This type of system is easily defeated by pushing the plunger while the guard is open. Even worse, the switch can be tripped accidentally by an operator leaning onto or into the machine while the guard is open.

Fig. 46 shows a simple example of positive mode operation giving forced disconnection of the contacts. A cam is mounted on the door hinge so that it directly operates the contacts whenever the guard door is open. Spring pressure can only close the contacts when the guard is fully closed. Any spring breakage will only result in a failure to a safe condition.

## Enclosure

The positive mode operation principle shown in fig. 46 is used wherever it is relevant in safety interlock switches. They also avoid any possible abuse by enclosing the contact block and cam in a strong and secure enclosure. This means that the

cam and the contact block cannot become separated and it is impossible to defeat the switch by cutting another slot in the cam.

The principle is adapted further for actuator operated interlock switches as shown in fig. 47. These devices are widely used as they are simple to mount at the opening edge of the guard and can be used on sliding, hinged and removable guard doors. The actuator is mounted on the guard door and opening the guard causes it to force disconnect the contacts. The switch mechanism is enclosed and is designed to resist tampering.

## Fitness for Purpose

As a minimum, all designs and materials must be able to withstand the expected operating stresses and external influences.

## Other Safety Principles

For non-mechanical devices, there is usually no physical contact between the switch and actuation method. Therefore, positive mode operation cannot be used as the way of ensuring the switching action and we need to use other methods as follows.

## Oriented Failure Mode

With simple devices, we can use components with an oriented failure mode as explained in EN 292-2: 3.7.4. This means using components in which the predominant failure mode is known in advance and always the same. The device is designed so that anything likely to cause a failure will also cause the device to switch off.

An example of a device using this technique is the MA Series non-contact magnetically actuated interlock switch. The contacts are protected by being in series with an internal non-resettable overcurrent protection device. Any overcurrent situation in the circuit being switched will result in an open circuit at the protection device which is designed to operate at a current well below that which could endanger the safety related contacts.

## Duplication (also referred to as Redundancy)

EN 292-2: 3.7.5 explains that if components which are not inherently safe are used in the design and they are critical to the safety function, then an acceptable level of safety may be provided by duplication of those components or systems. In case of failure of one component, the other one can still perform the function. It is usually necessary to provide monitoring to detect the first failure so that, for ex-

ample, a dual channel system does not become degraded to a single channel without anybody being aware of the fact. Attention also needs to be given to the issue of common cause failures.

Any failure which will cause all duplicated components (or channels) to fail at the same time must be protected against. Suitable measures may include using diverse technologies for each channel or ensuring an oriented failure mode.

## Galvanic Isolation

On contact blocks with two sets of contacts a galvanic isolation barrier is required if it is possible for the contacts to touch each other back-to-back in the event of contact weld or sticking (fig. 48).

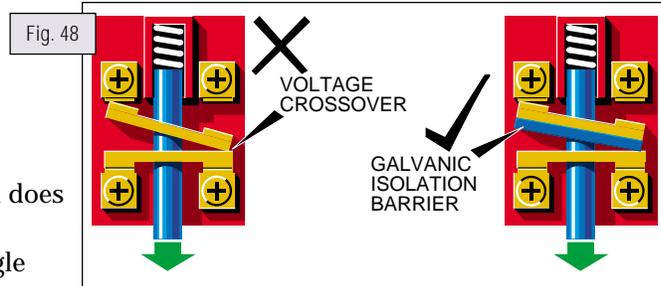


Fig. 48

## Typical Forms of Interlocking Devices

In the broadest terms there are two basic types of electrical interlocking systems:

**Power interlocking** - The power source of the hazard is directly interrupted due to the opening of the guard.

**Control interlocking** - The power source of the hazard is interrupted by the switching of a circuit which controls the power switching device.

The following text deals with the interlocking of electrical power supplies as this is by far the most common requirement, but the same basic principles can be applied to hydraulic and pneumatic systems.

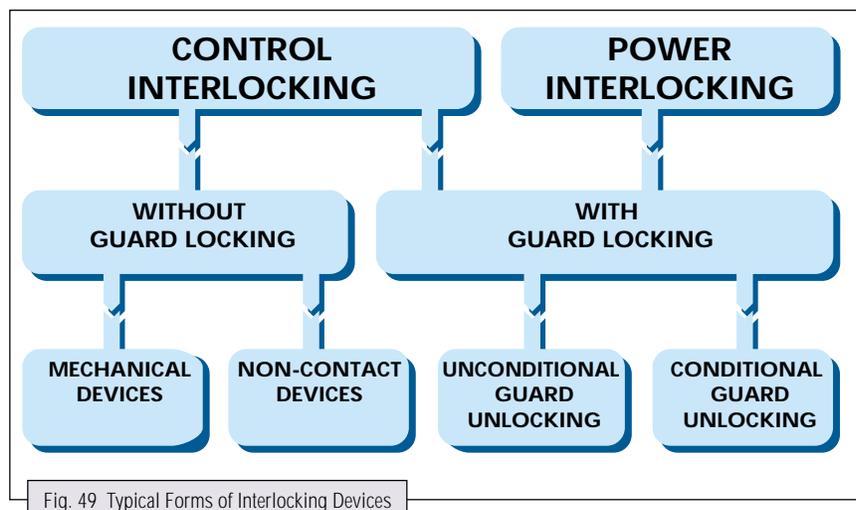


Fig. 49 Typical Forms of Interlocking Devices

## POWER INTERLOCKING

The movement of the guard is interlocked with the direct switching of the power to the hazard. For equipment using low voltage and power most types of interlock switches can be used for power interlocking. But because most industrial machinery uses a relatively high power three phase supply, we need specially de-

signed power interlocking systems with the power interrupting switch capable of handling and breaking the load reliably.

The most practicable method of power interlocking is a trapped key system such as the PROSAFE system (see fig. 50). The power isolation switch is operated by a key which is trapped in position while the switch is in the ON

position. When the key is turned the isolation switch contacts are locked open (isolating the power supply) and the key can be withdrawn. The guard door is locked closed and the only way to unlock it is by using the key from the isolator. When this key is turned to release the guard locking unit it is trapped in position and cannot be removed until the guard is closed and locked again.

Therefore, it is impossible to open the guard without first isolating the power source and it is also impossible to switch on the power without closing and locking the guard.

This type of system is extremely reliable and has the advantage of not requiring electrical wiring to the guard. The main disadvantage is that because it requires the transfer of the key every time, it is not suitable if guard access is required frequently.

Whenever whole body access is required, the use of a personnel key is recommended (see fig. 51, 52 and 53). The PROSAFE range is available in double key versions to serve this requirement.

The use of a personnel key ensures that the operator cannot be locked in the guarded area. The key can also be used for robot teach mode switches, inch mode controls etc.

By using double key locking units and keys with different codes together with a key exchange unit, complex systems can

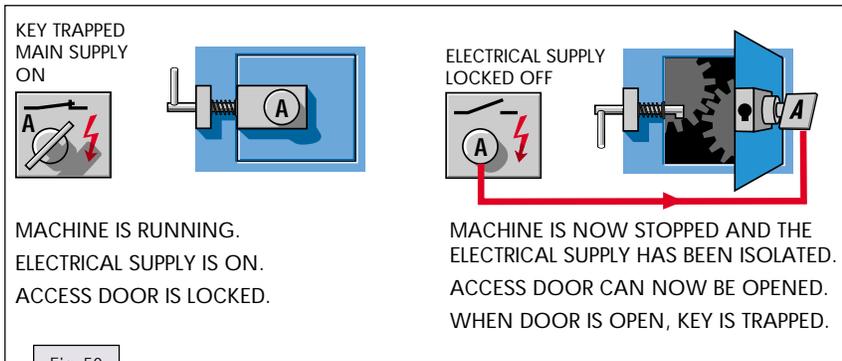


Fig. 50

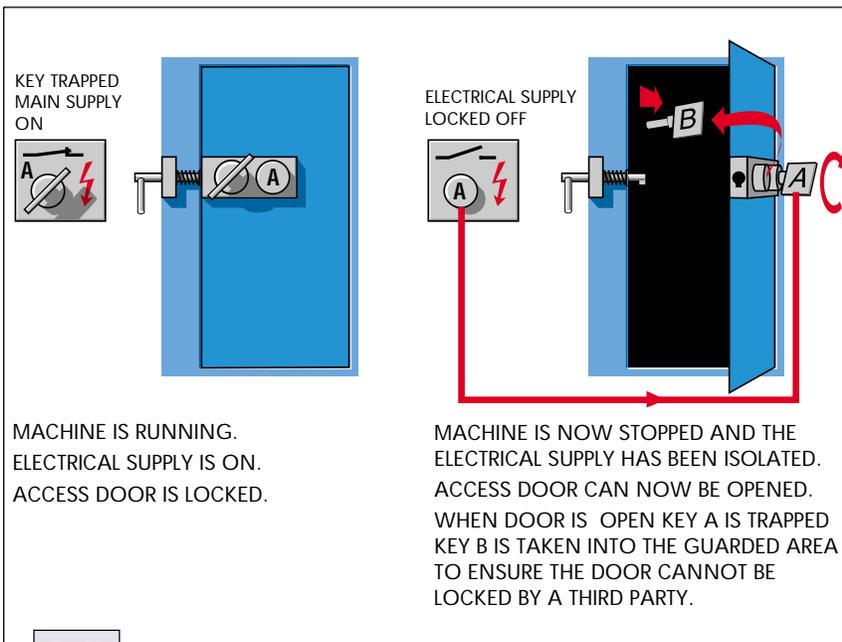


Fig. 51

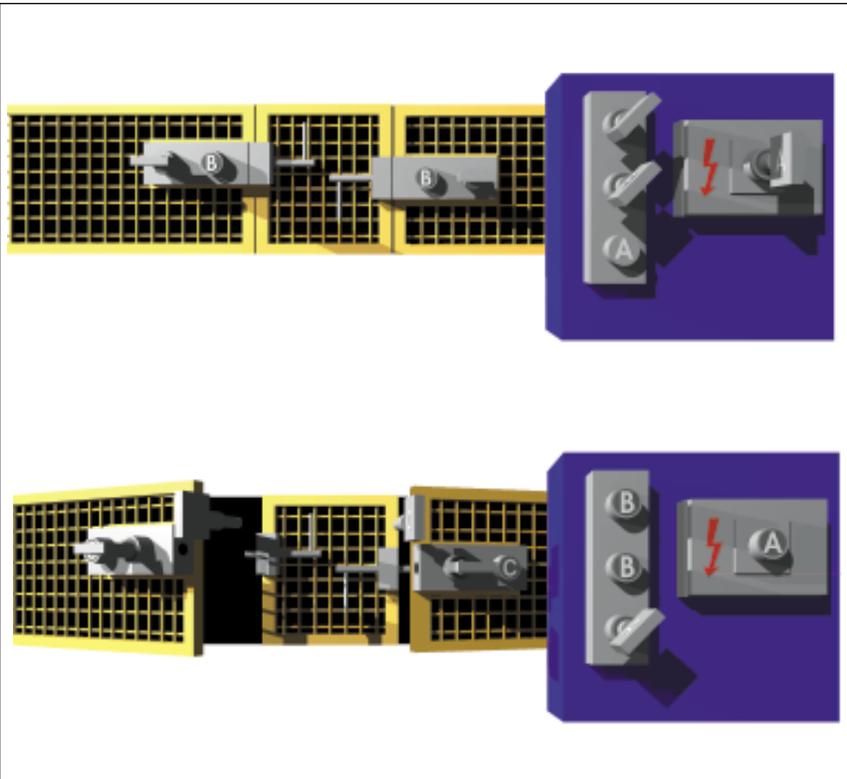


Fig. 52 (Top)  
Double access guard doors interlocked with the Power Isolation Switch. Key "A" is trapped in the isolation switch. Both "B" keys are trapped in a Key Exchange Unit. Power is ON and there is no access available to the machine through the locked guard doors.

Fig. 53 (Bottom)  
Rotate and remove Key "A" from power isolator. Power is then OFF. To gain access through guard doors Key "A" is inserted and rotated in Key Exchange Unit. Both "B" Keys are then released for guards locks. Key "A" is trapped preventing power being switched on. Two "C" Keys are released from the guard door locks for use in the next sequence step or as personnel keys.

be formed. Besides ensuring that the power is isolated before access can be gained, it is also possible to use the system to enforce a pre-defined sequence of operation.

### Required Features

Because the entire safety of this type of system depends on its mechanical operation, it is critical that the principles and materials used are suitable for the expected demand made on them.

If an isolation switch is part of the system, it should have positive mode operation and it should satisfy the requirements of the relevant parts of EN 60947.

The integrity and security of the system revolves around the fact that under certain conditions the keys are trapped in place, therefore two basic features need to be ensured:

1- THE LOCK CAN ONLY BE OPERATED BY THE DEDICATED KEY. This means that it

should not be possible to "cheat" the lock by using screwdrivers etc., or defeat the mechanism by mistreating it in any straightforward manner. Where there is more than one lock on the same site it also means that the specifying of key codes must in itself prevent any possibility of spurious operation.

2 - IT IS NOT POSSIBLE TO OBTAIN THE KEY IN ANY WAY OTHER THAN THE INTENDED MANNER. This means that (for example) once the key is trapped, any excessive force applied to it will result in a broken key as opposed to a broken lock.

### CONTROL INTERLOCKING

Control interlocking is the most commonly used method of interlocking. An interlock switch is attached to the guard to detect movement and open the switch contacts whenever the guard is not fully closed. The contacts are connected via a control circuit to the hazard source primary control element (contactor).

So first of all let us, by reference to fig. 49, look at the different types of devices suitable for control interlocking.

The first major distinction is between devices without guard locking and with guard locking.

### Interlock Switches Without Guard Locking

These devices do not restrict access and the guard door can be

opened at any time; but as soon as it is opened the switch isolates the power to the hazard via the contactor control circuit. If the hazard always ceases immediately, then the requirements are satisfied because the operator cannot reach the parts while they are dangerous.

If the hazard does not cease immediately, there is a possibility that an operator can reach it while it is “running down” and still dangerous. To avoid this unacceptable situation, there are three alternatives as illustrated in the figures on the bottom of this page.

Note: The integrity of the braking device needs to be considered both in terms of fault resistance and wear characteristics.

If a precise calculation is required, the European standard EN 999 deals with the positioning of protective equipment in respect to approach speeds of parts of the human body. At present it does not specifically cover interlocked guard doors, but its principle for the positioning of other safety devices based on approach speed and machine stopping time can reasonably be extrapolated to cover interlocked guard doors without guard locking.

The next subdivision for interlocking devices without guard locking is their designation as **mechanical actuation or non-contact actuation**.

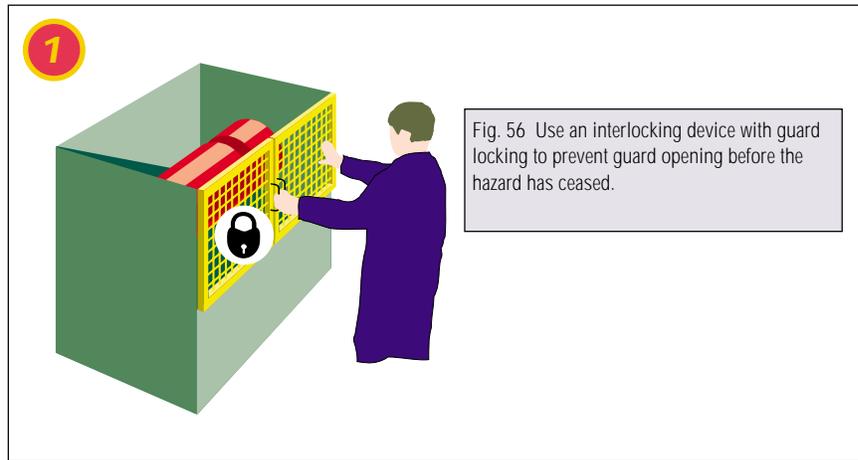


Fig. 56 Use an interlocking device with guard locking to prevent guard opening before the hazard has ceased.

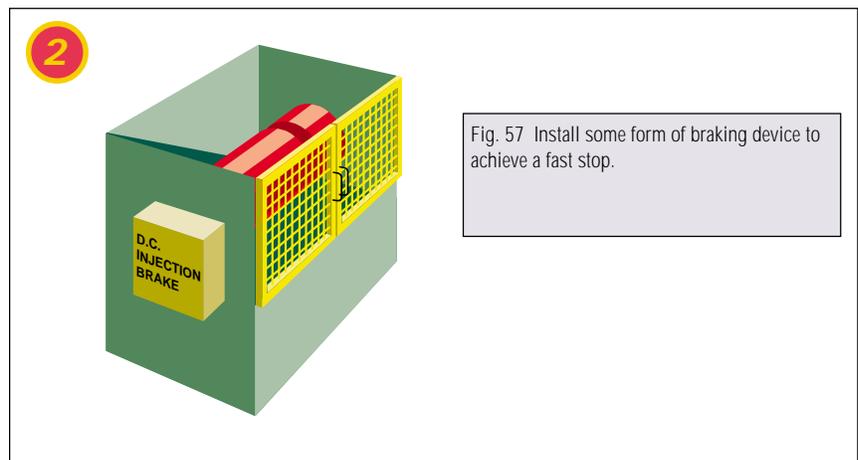


Fig. 57 Install some form of braking device to achieve a fast stop.

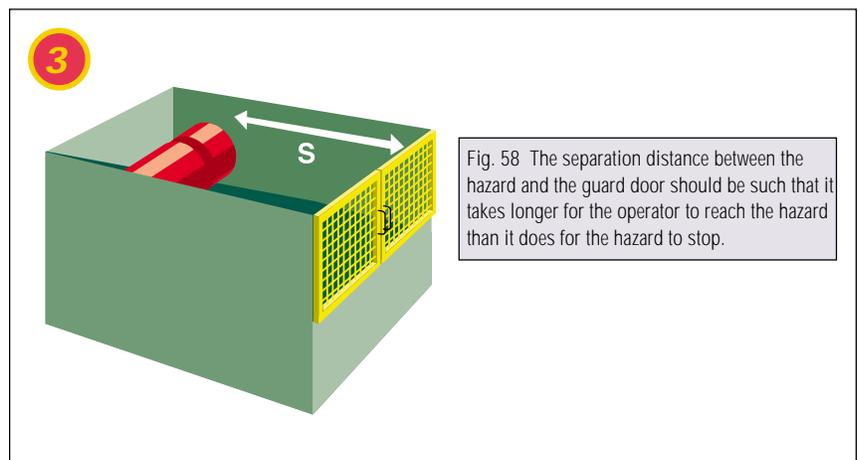


Fig. 58 The separation distance between the hazard and the guard door should be such that it takes longer for the operator to reach the hazard than it does for the hazard to stop.

## Mechanically Actuated Devices

With these devices the guard door is linked mechanically to the control circuit contacts of the switch using positive mode operation. There are three main types of mechanical actuation. These are:

### Actuator Operated

With the T2010 switch, as shown in Fig. 59, the guard mounted actuator “tongue” opens or closes the contacts via the internal mechanism.

#### Features:

The actuator and mechanism are designed to prevent easy cheating of the switch. These devices are straightforward to install and are very reliable.

They can be used on sliding, hinged and lift-off guards and because of their versatility they are one of the most commonly used types of interlock switches.

#### For consideration:

The guard mounted actuator needs to remain reasonably well aligned with the entry hole in the switch body. Actuator operated switches can be difficult to clean thoroughly. This may be a problem in industries such as food manufacturing and pharmaceuticals.

### Hinge Operated Actuation

The device is mounted over the hinge-pin of a hinged guard. The opening of the guard is transmitted via a positive mode operating

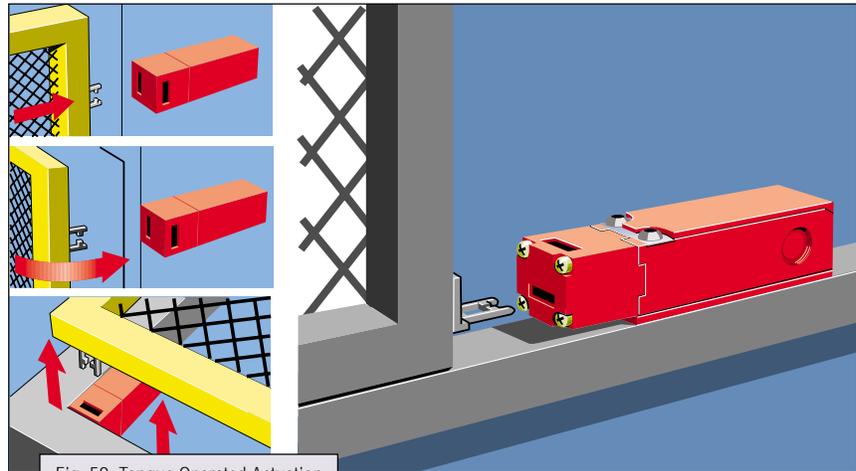


Fig. 59 Tongue Operated Actuation

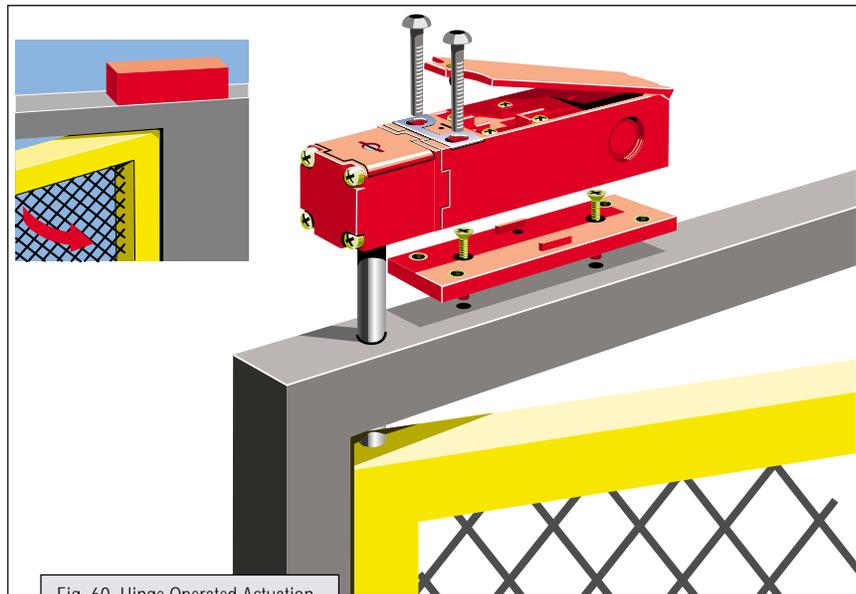


Fig. 60 Hinge Operated Actuation

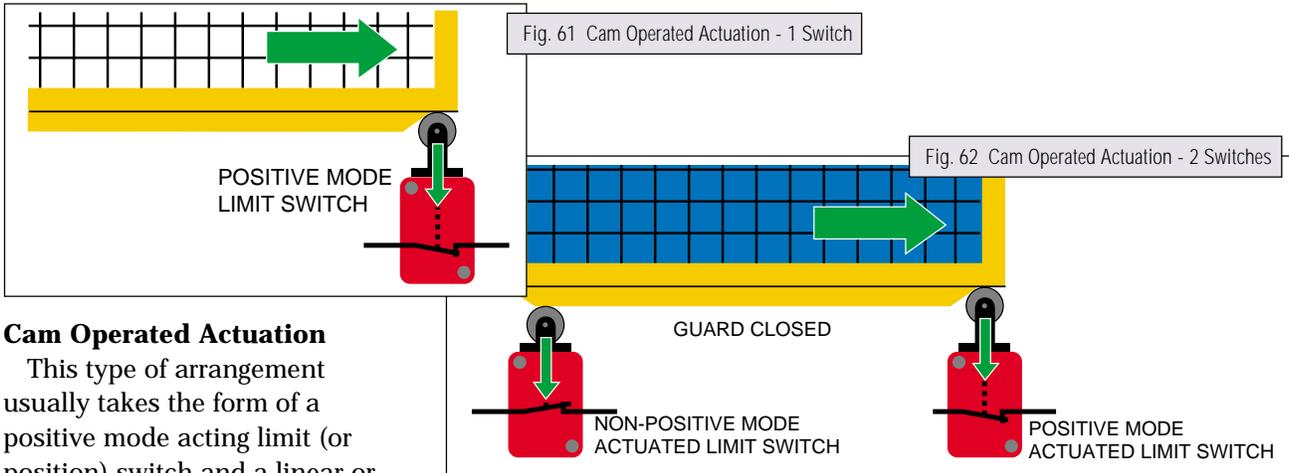
mechanism to the control circuit contacts (fig. 60).

#### Features:

When properly installed, these types of switches are ideal for most hinged guard doors where there is access to the hinge center line. They can isolate the control circuit within 3° of guard movement and they are extremely difficult to defeat without dismantling the guard.

#### For consideration:

Care must be taken on very wide guard doors, as an opening movement of only 3° can still result in a significant gap at the opening edge. It is also important to ensure that a heavy guard does not put undue strain on the switch actuator shaft.



## Cam Operated Actuation

This type of arrangement usually takes the form of a positive mode acting limit (or position) switch and a linear or rotary cam. It is usually used on sliding guards and when the guard is opened the cam forces the plunger down to open the control circuit contacts (fig. 61).

### Features:

The simplicity of the system enables the switch to be both small and reliable.

### For consideration:

It cannot be used on hinged or lift-off guards.

It is extremely important that the switch plunger can only extend when the guard is fully closed. This means that it may be necessary to install stops to limit the guard movement in both directions.

It is necessary to fabricate a suitably profiled cam which must operate within defined tolerances. The guard mounted cam must never become separated from the switch as this will cause the switch contacts to close. This system can be prone to failures due to wear especially in the presence of abrasive materials or with badly profiled cams.

It is often advisable to use two switches as shown in fig. 62.

## Non-Contact (Non-Mechanical) Actuation

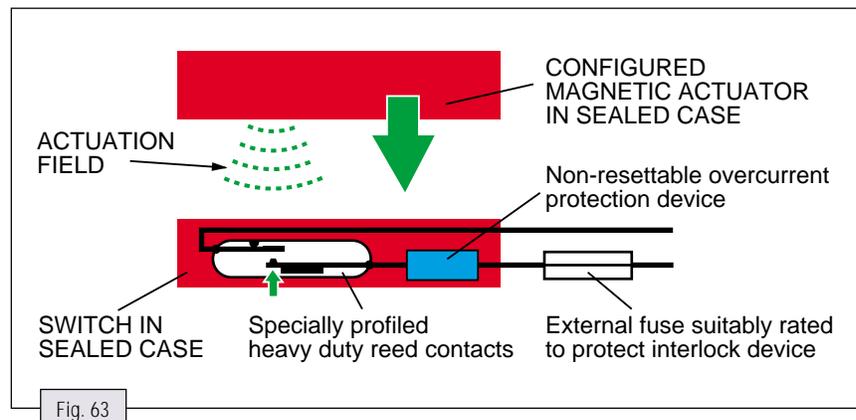
With these devices, the guard door is linked to the control circuit contacts of the switch via a magnetic or electronic field. To make these types of devices suitable for interlocking applications, they must incorporate enhancements to ensure their satisfactory operation.

Because they do not have the benefit of true mechanical positive mode operation, they must have other ways of ensuring that they cannot fail to a dangerous condition. This is achieved by either "oriented failure mode"

principles or by the use of duplication and monitoring.

The MA Series uses the principle of oriented failure mode. Due to the use of special components, the only safety critical fault likely to occur would be a welding of the reed contacts due to excessive current being applied to the switch.

As shown in fig. 63, this is prevented by the non-resettable overcurrent protection device. There is a large margin of safety between the rating of this device and the reed contacts. Because it is non resettable, the switch should be protected by a suitably rated external fuse.



It is important that the switch is only operated by its intended actuator. This means that ordinary proximity devices which sense ferrous metal for example are not appropriate. The switch should be operated by an “active” actuator.

The security can be further improved by coding such as on the MC K-Series. This switch uses the same oriented failure mode principle as the MA Series but has higher security due to its coded actuator and sensor.

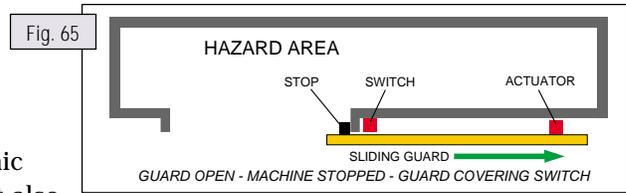
**Features:**

Non-contact devices are available in fully sealed versions which makes them ideal for hygiene sensitive applications, as they can be pressure cleaned and have no

feature an electronic coding principle. It also has two separate and diverse switching “channels”. A control unit is available which monitors up to six sensor sets and can also monitor the contactors and wiring (fig. 64).

**For consideration:**

For the simpler actuation types, if security is an important issue, it may be necessary to install them as shown in fig. 65 so that they cannot be accessed while the guard is open. It is important, particularly for the non coded types, that they are not subjected to extraneous interference by fields which are the same as their operating principle.



They provide interlocking of the hazard power source with guard movement and also prevent the opening of the guard until it is safe to do so.

These devices can be divided into two types: Unconditional and conditional guard unlocking.

**Unconditional Guard Unlocking**

These devices are manually operated and the guard can be opened at any time. A handle or knob which releases the guard lock also opens the control circuit contacts.

On a device such as the BL6009 time delay bolt switch, a time delay is imposed (fig. 66). The bolt which locks the guard in place also operates the contacts. The bolt is withdrawn by turning the operating knob. The first few turns open the contacts but the locking bolt is not fully retracted until the knob is turned many more times (taking up to 20 secs.).

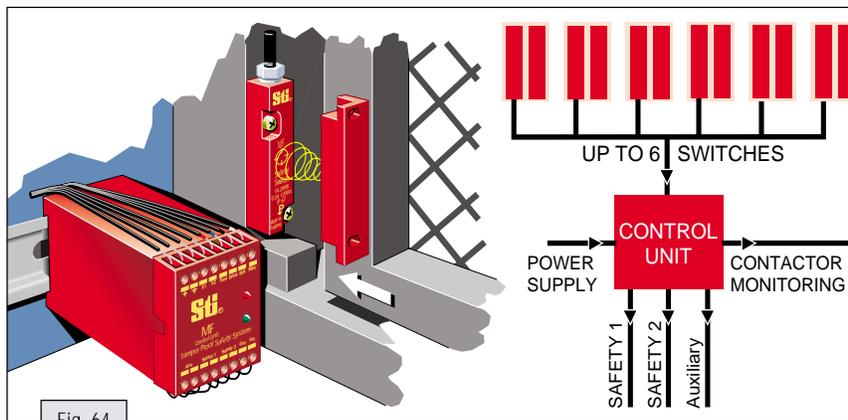
The PROSAFE trapped key system (see power interlocking section) can be used to provide unconditional guard locking.

**Features:**

These devices are simple to install and they are extremely rugged and reliable. The time delay bolt switch is suitable mainly for sliding guards.

**For consideration:**

The stopping time of the hazard being guarded must be predict-



dirt traps. They are extremely easy to install and have a considerable operating tolerance, which means that they can accept some guard wear or distortion and still function properly.

Sophisticated non-contact devices, such as the MF Series,

**INTERLOCKING SWITCHES WITH GUARD LOCKING**

These devices are suited to machines with run down characteristics but they can also provide a significant increase of protection level for most types of machines.

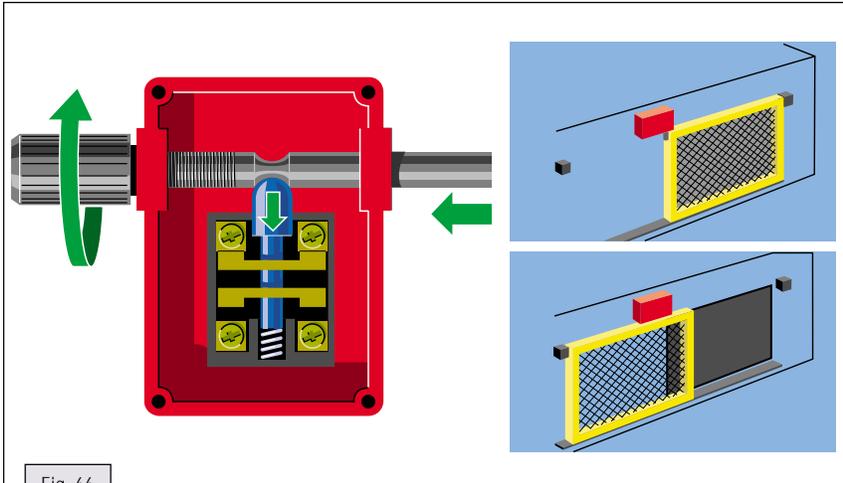


Fig. 66

able and it must not be possible for the bolt to be withdrawn before the hazard has ceased. It must only be possible to extend the bolt into its locked position when the guard is fully closed. This means that it will usually be necessary to install stops to restrict the travel of the guard door.

### Conditional Guard Unlocking

With these devices, the guard can only be opened on receipt of a signal showing that:

- the contactor is OFF.
- a pre-set time interval has elapsed or alternatively that dangerous motion has ceased.

These signals are usually derived from the auxiliary contacts of the contactor and either a fail safe timer unit such as the SMT01 or a stopped motion detection unit such as the SMD02 or SMD03.

They provide interlocking of the hazard power source with guard movement and also prevent the opening of the guard until it is safe to do so. Because an externally generated signal is required for

lock release, it makes them particularly suitable for use with PLC or other programmable electronically controlled machines.

The usual type of interlocking device for these purposes is a solenoid operated locking switch such as the TL8012 (fig. 67), TL8018, or TL5012.

For less frequently accessed applications, the PROSAFE trapped key system (see power interlocking section) can be configured to operate in this way.

In the example shown in fig. 68, the hazard ceases as soon as power is isolated by switching the machine OFF at the normal controls. The guard cannot be opened until the contactor has switched OFF. Once the guard is opened the control circuit contacts ensure that the contactor cannot be re-energized until the guard is closed and locked.

With the configuration shown in fig. 69, the switch will not release the guard until the contactor is OFF and a pre-set

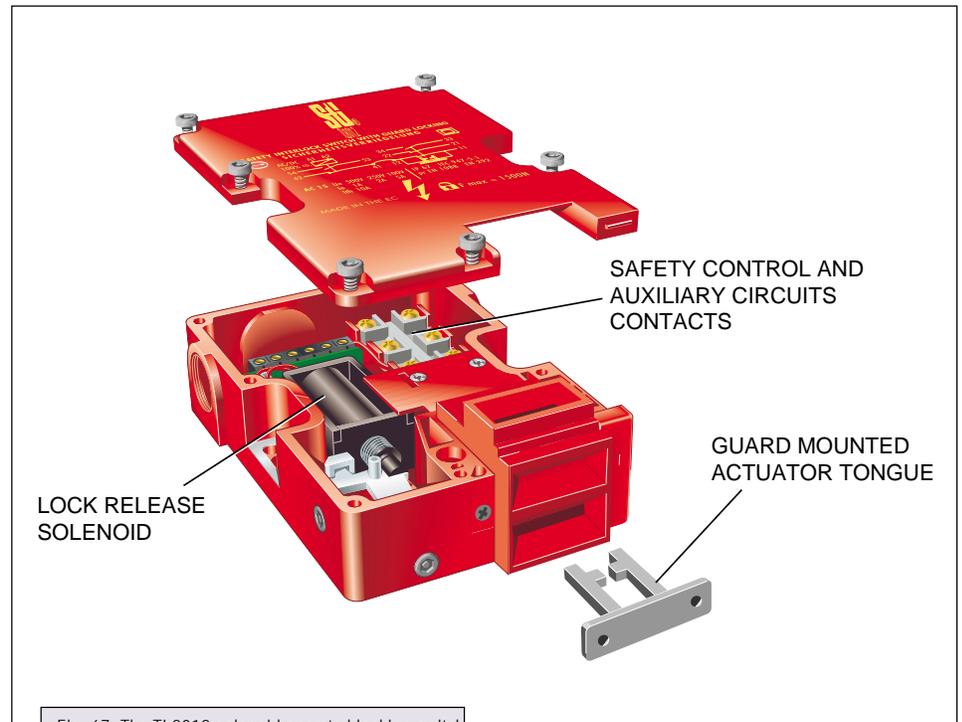


Fig. 67 The TL8012 solenoid operated locking switch

# Safety Interlock Switches and Monitoring Relays

time interval has elapsed. The time range can be set from 0.1 sec to 40 mins. The longest stopping time of the machine should be predictable and constant. It should not rely on braking methods which may degrade with use.

Fig. 70 shows a configuration where the switch will not release the guard until the contactor is OFF and all motion has stopped.

On the systems shown in figs. 69 & 70, the machine is stopped by its operational control system either manually or automatically. Therefore, these systems are especially useful on machines where tool damage or program loss could be caused by a crash stop due to inappropriate guard opening.

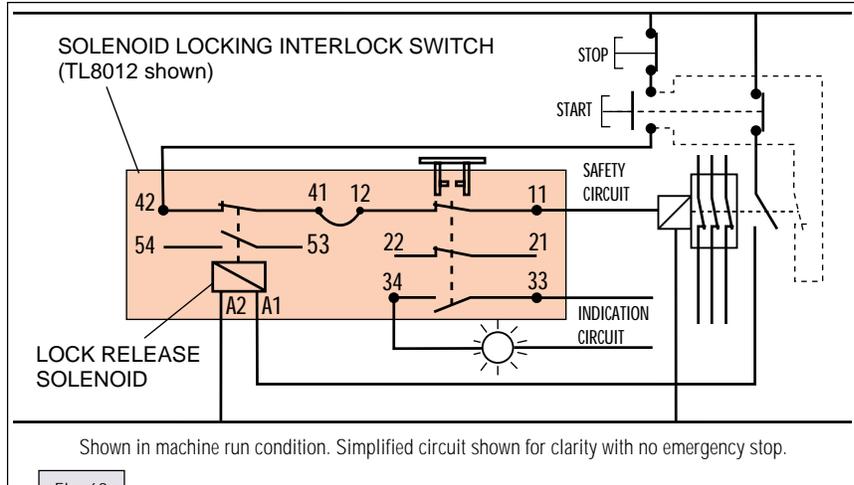


Fig. 68

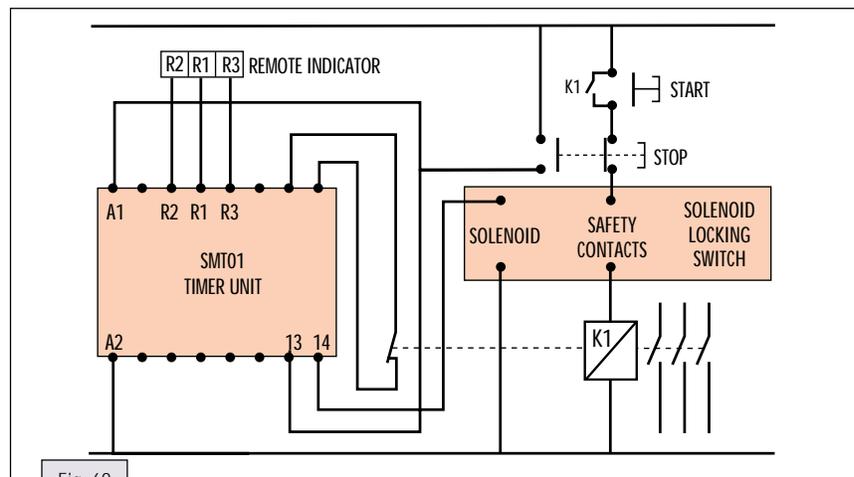


Fig. 69

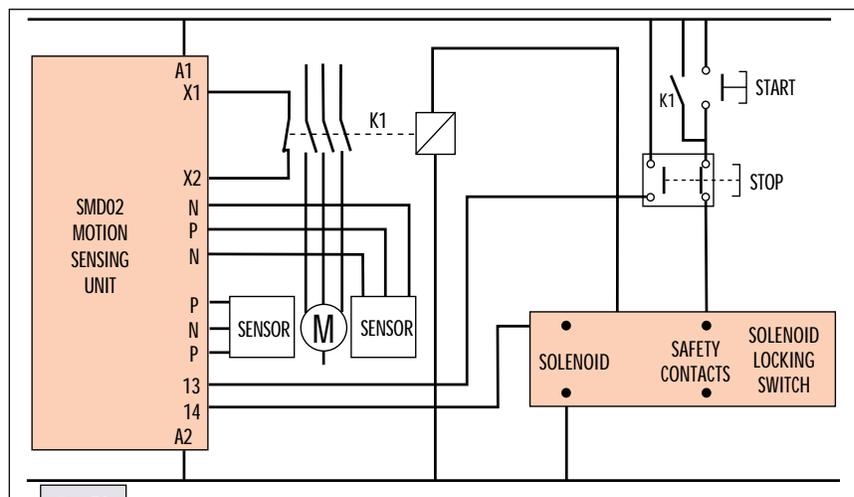


Fig. 70