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SAFETY ALERT



# A New Interlock System

## Movable Interlocked Barrier Guards With Motorized Openers for Testing

by Ralph L. Barnett * and Dr. Theodore Liber **

### Abstract

A unique system is introduced for monitoring the viability of conventional position switch interlocks on movable barrier guards. At closely spaced intervals a test device motor causes the guard to open slightly to check if the interlock will change state in an attempt to interrupt control power to the protected machine. The machine will not in fact shut down during the testing phase because the interlock system will be isolated from the machine operating motor contactors during the test duration. Testing of a guard is annunciated just before and during the automatic testing phase. Any failures of an interlock or its testing system will also be annunciated until their causes are corrected. When a latching system is used in conjunction with the guard, a faulty interlock will cause the guard to be locked closed until it is convenient to effect a repair. Production is not interrupted because the interlock remains bypassed during this period. If an interlock is temporarily circumvented or if the interlock guard is sabotaged, the test device motor will not cause a change in state of the interlock during the test phase; again, system malfunction will be annunciated and/or the guard will remain latched and/or the machine will be shut down.

The proposed process provides the following advantages:

- A quantum leap in system reliability and safety is obtained using even the most ordinary “limit switch” type interlocks.
- The tamper-resistance of all known interlocks will be greatly enhanced; all popular forms of temporary interlock circumvention are eliminated.
- Long term sabotage which involves simultaneous guard removal and interlock bypassing is addressed for the first time; to defeat the proposed process involves the most outrageous restructuring of the control system.
- The system will safely endure adhesive environments that may cause interlock activators to stick in their “fail to danger” states.
- The monitored machine is almost never shut down nor production interrupted during or after the testing phase, even if mischief is uncovered.
- The testing of large numbers of interlocks will not expose the machines’ electric power motors to the frequent restart demand associated with some conventional manual testing procedures.
- Without compromising safety, maintenance of even multiple interlock failures may be deferred until their repair is convenient.
- The assurance of working interlocks may enable OSHA to expand applications where maintenance is performed under “control stop” as opposed to the more elaborate “lock out.”
- The design of the new test and monitoring system may be executed and implemented using straightforward hardware and software that are firmly entrenched technology.

### I. Introduction:

An interlock may be used to indicate whether a barrier guard is open or closed or whether a mechanism is running or stationary. Interlocks are go/no go devices which monitor physical

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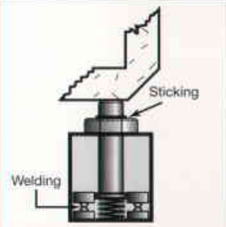
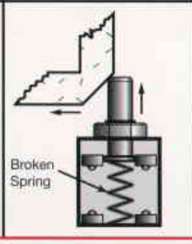
| MACHINE GUARD CLOSED/SWITCH CLOSED | MACHINE GUARD OPEN/SWITCH OPEN | DESCRIPTION |
|---|---|---|
|  |  | • Normally Open, Held Closed Contacts<br>• Negative Mode Switch<br>• Conventional Interlock<br>• Single Channel Interlock<br>• Movable Machine Guard Activating a Conventional Limit Switch with Spring-Disconnect Contacts |

*Figure 1 – Conventional Electrically Interlocked Barrier*

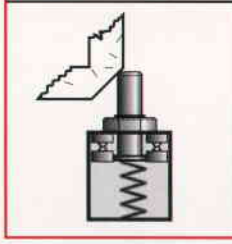
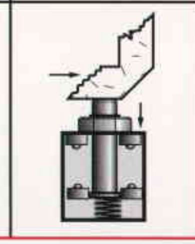
| MACHINE GUARD CLOSED/SWITCH CLOSED | MACHINE GUARD OPEN/SWITCH OPEN | DESCRIPTION |
|---|---|---|
|  |  | • Normally Closed, Held Open Contacts<br>• Positive Mode Switch<br>• Forced Disconnection<br>• Single Channel Interlock<br>• Movable Machine Guard Activating a Safety Interlock Switch with Positive-Opening or Positve-Break Contacts |

*Figure 2 – Positive Opening Safety Contacts*

systems that exhibit simple dual conditions. They may operate electrically, mechanically, pneumatically, magnetically or with any combination of physical phenomena.

This paper is concerned with movable point of operation guards that are equipped with a single electrical interlock. The guards are typically hinged or sliding; they may be removable without tools such as hook-on or detented panels, or they may rotate into position like a pressure cooker lid. The interlocks are incorporated into the same control circuits as emergency stop devices where they may also instantly interrupt powered operation of the guarded machine.

A succinct statement of the design criteria for interlocked guards may be found in the 1993 European Standard entitled "Safety of machinery interlocking devices with and without guard locking - General principles and provisions for design"(Ref. 1):

**3.2 interlocking guard (without guard locking) [3.22.4 of EN 292-1:1991]**

Guards associated with an interlocking device, so that:

- the hazardous machine functions "covered" by the guard cannot operate until the guard is closed,
- if the guard is opened while the hazardous machine functions are operating, a stop instruction is given,
- when the guard is closed, the hazardous machine functions "covered" by the guard can operate, but the closure of the guard does not by itself initiate their operation.

**3.3 interlocking guard with guard locking [3.22.5 of EN 292-1]**

Guard associated with an interlocking device and a guard locking device so that:

- the hazardous machine functions "covered" by the guard cannot operate until the guard is closed and locked,
- the guard remains closed and locked until the risk of injury from the hazardous machine functions has passed,
- when the guard is closed and locked, the hazardous machine functions "covered" by the guard can operate, but the closure and locking of the guard do not by themselves initiate their operation.

**3.4 control guard [3.22.6 of EN 292-1]**

Guard associated with an interlocking device (with or without guard locking) so that:

- the hazardous machine functions "covered" by the guard cannot operate until the guard is closed,
- closing the guard initiates the hazardous machine function(s).

The so called "interlocking guard (without guard locking)" is the focus of this paper. Opening such a guard interrupts the power to a machine and eliminates the hazard before access to it is possible. The door guard on a microwave oven meets this condition. The condition is also met by mechanical systems where the separation distance between the hazard and the guard door is such that it takes longer for the operator to reach the hazard than it does for the hazard to disappear. Suitable braking devices may be used to rapidly terminate mechanical hazards.

## II. Interlock Reliability

The conventional interlock or position switch is far and away the most often used concept for interlocking guards in the U.S. The construction of the doorbell switch provides an example of a conventional interlock; its concept is embodied in Figure 1. Interlock guards are primarily used to control risk-taking [Ref. 2]. Their presence fundamentally changes the man-machine interaction [Ref. 3] in the sense that a foreseeable number of people will misuse them as control devices in the same manner that the safety edges on elevator doors are purposely blocked to prevent door closure. Because a certain percentage of operators will transfer their personal vigilance to dependence on interlocks, safety demands that such devices be reliable.[1]

For commercial usage, the reliability of conventional position switch interlocks may be judged from a study involving the upper limit switches on hoists and cranes ranging in capacity from one-quarter to two tons. The study was first described in 1964 by the National Safety Council in the Fifth Edition of their Accident Prevention Manual for Industrial Operations [Ref. 4]: "During a 20-year period, one division of an automobile manufacturing company made 72,000 formal hoist inspections involving over 600

[1] Reliability: The probability that an item will preform a required function under stated conditions for a stated period of time.

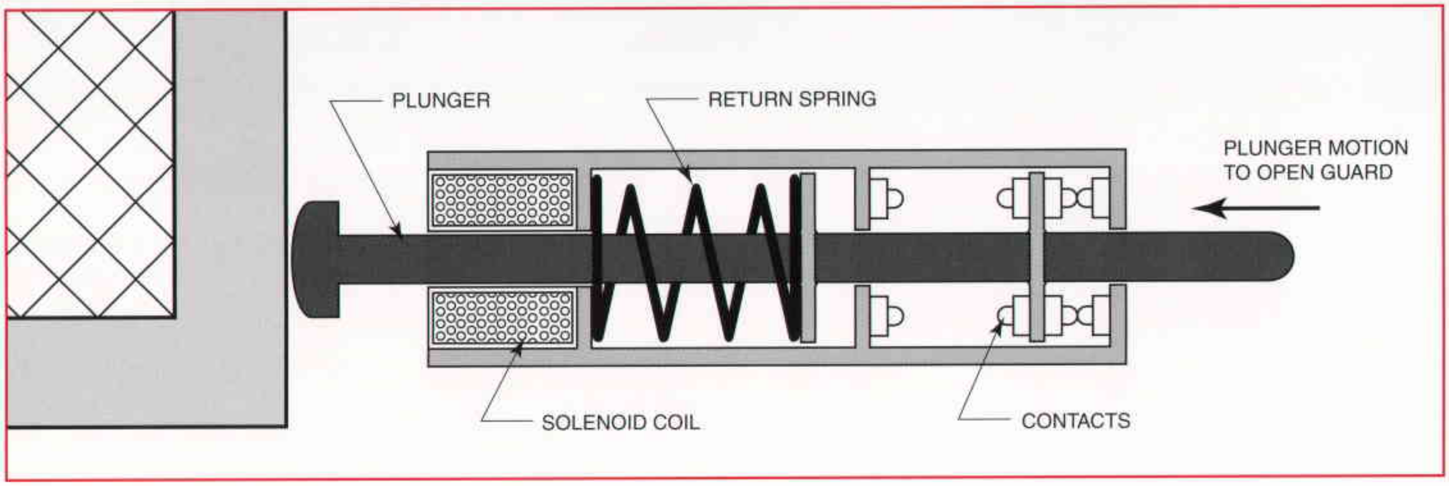



*Figure 3 – Solenoid Activated Guard Opener (Shown at Rest with Guard Closed)*

electric hoists and cranes. The inspections disclosed approximately 3,000 unsafe cables, 1,000 faulty brakes, and 1,000 defective limit switches." It can be seen by this study that the reliability of conventional limit switch interlocks is unacceptably low for safety applications. In a consumer setting, the National Highway Transportation Safety Administration (NHTSA) stated that vehicles built between August 1973 and 1975 must have either passive restraints or lap-shoulder belts in conjunction with a starter interlock. Such a system prevents the vehicle's engine from starting whenever the front-seat occupants' manual seatbelts are unfastened. Many consumers complained that the interlock system failed to operate effectively, i.e., it was not reliable. Thus, on October 27, 1974, President Ford signed a bill that prohibited starter interlocks. Four days later, NHTSA deleted the starter interlock regulation from the Federal Motor Vehicle Safety Standard 208.

To deal with the low reliability of conventional interlocks in safety applications in this country, most machinery manufacturers require that the interlocks be tested at the beginning of every shift. Either of the following two methods is used for manual testing:

Method 1. If a machine operates with all of the interlocked guards closed, one may stop the machine, successively prop open each guard, and attempt to start the machine. Clearly, if the machine remains benign all of the interlocks function in this static mode. This is a relatively fast procedure when two people conduct the tests; one at the control and one successively opening the barriers. Strict coordination must be maintained between the two testers or guards may be opened and closed so rapidly that they don't get tested, or a properly operating interlocked guard may accidently be closed during attempted start up which would result in the machine being turned on and a defective interlock falsely proclaimed.

Method 2. A guard opened on a running machine will shut down the motor if the interlock is functional. Restarting the machine and repeating the procedure for each interlocked barrier completes the test protocol. This testing method is more failure provoking than the static test because contacts are more difficult to break electrically when they are carrying current. Furthermore, if the contacts are vibrating they can continuously make and break the circuit and pass enough current through the interlock to sustain the motion of the motor. Interrupting power on a running machine is a more vigorous testing protocol than establishing the inability to start the machine.

Both testing methods are time consuming and both expose the testers to an unguarded running machine when faulty interlocks are encountered. The second method is not prone to sequencing errors; however, the frequent motor restarting when testing large numbers of guards will compromise large horsepower electric motors.

Experience has shown that testing of interlocks is rarely undertaken. When it is, and the testing reveals an interlock that will not shut off the machinery, (fail to danger), the requirement to immediately shut down the machine and fix or replace the interlock is commonly violated. Unfortunately, the fault is not annunciated or displayed.

A new approach to enhancing the reliability of single mechanical interlocks was officially introduced into the European Community in 1988. The effects of reasonably foreseeable failure modes were either eliminated or minimized. For example, Figure 1 indicates three recurring failure scenarios that involve contact welding, actuator sticking, and broken springs. These conditions are particularly vexing and lead to "fail to danger" modes where contacts remain closed and the protected machines continue to run after their guards are opened. To overcome these faults, the European Community replaced the spring disconnect mechanism with a force disconnect mechanism as shown in Figure 2. This positive mode operation will