May 2000

Triodyne Inc.

ISSN 1097-7589

Vol. 2 No. 2

A SAFETY JOURNAL HIGHLIGHTING CRITICAL SAFETY DEVELOPMENTS

SAFETY ALERT

Interlocked Fixed Guards-Bolted Panels

By Ralph L. Barnett* and Theodore Liber**

INTRODUCTION

A fixed guard is defined as a protective barrier that is held in place with fasteners that may only be removed using tools not normally available to a machine's operators. The fixed barrier guard always appears at the top of the safeguarding hierarchy [Ref. 1]. When it is not feasible to use a fixed guard the hierarchy recommends the use of an interlocked movable guard. The combination case, the interlocked fixed guard, is simply not addressed. Fixed barrier guards are almost never interlocked because their infrequent removal leads to a quiescent interlock switch that cannot be relied upon when called into safety service [Ref. 2]. Furthermore, it is difficult and time consuming to test such interlocks at frequent intervals, such as once every shift. Reliability testing requires that the interlocks change states and this implies that the fixed barrier and its fasteners be removed and replaced for each test cycle.

TESTING CRITERIA:

There are three characteristics of a properly designed interlock system that must be regularly tested:

1. Shut down capability: the removal of a barrier guard from a running machine must instantly interrupt powered operation.
2. Sentinel capability: when an interlocked guard is removed from the machine it must not be possible to restart the machine from any operator's station.
3. Restart incapability: when an interlocked 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.

It should be noted that an interlock must be tested in both its open and closed states to verify its integrity.

BOLTED PANELS

Bolted panels, such as shown in Figure 1, represent an enormously popular type of fixed barrier guard. When the "B" Panel is unbolted, the last remaining fastener allows a rotation of the panel that will provide access to the machine's interior without fully removing the panel. Under these circumstances an interlock placed near the last bolt will not change states and deactivate the machine. Two interlocks placed at the locations indicated in Panel B cannot simultaneously be defeated by rotating the panel about any of the bolts located on its periphery.

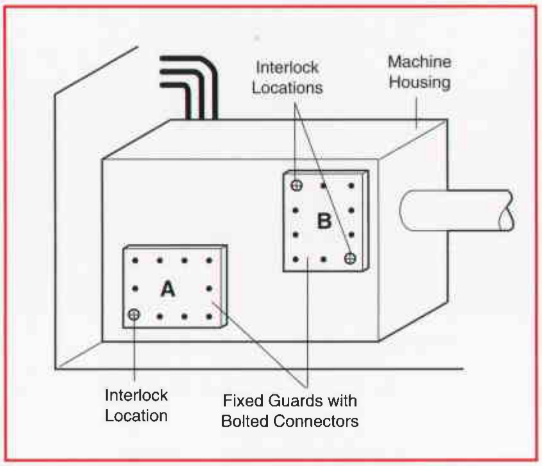
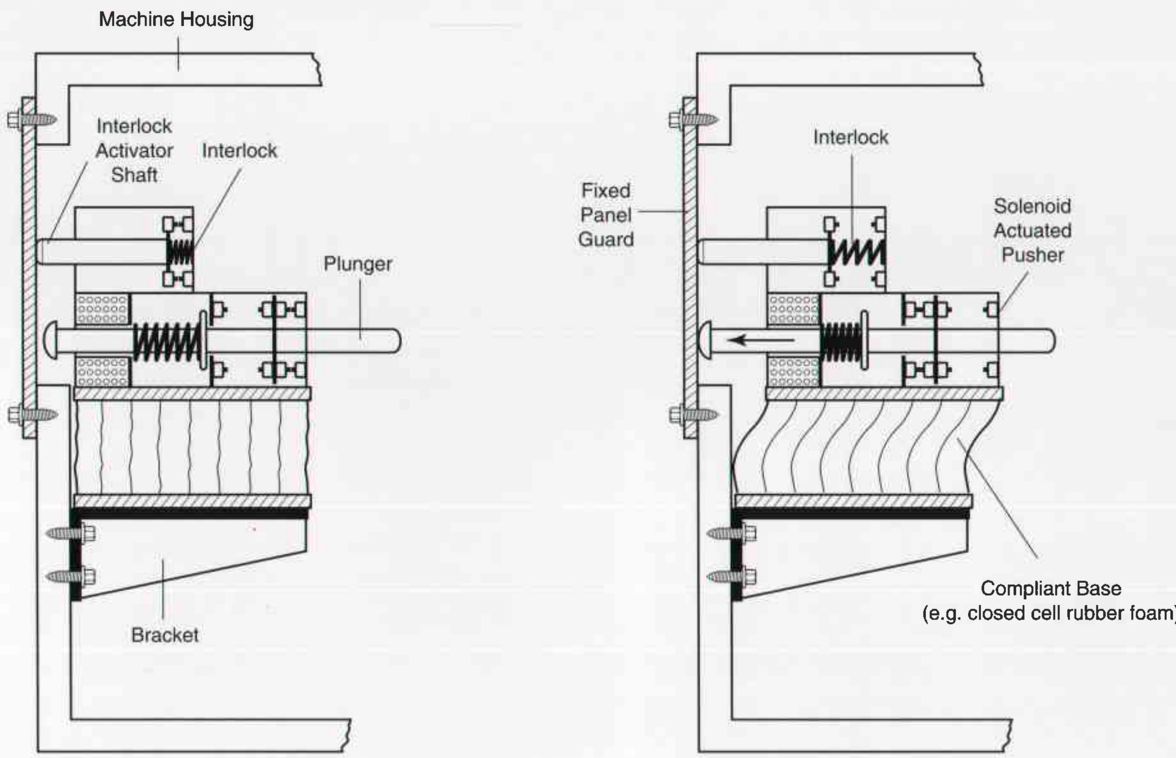


Figure 1 - Fixed Panel Guards with Interlock Locations

* Professor, Mechanical and Aerospace Engineering, Illinois Institute of Technology, Chicago, and Chairman, Triodyne Inc., Niles, IL.
** Senior Science Advisor, Triodyne Inc., Niles, IL.



a) Running State - Plunger Retracted; Normally Open Interlock - Held Closed by Guard; Base in Normal Position.

b) Test State - Plunger Extended; Interlock - Open Contacts; Base Shifted from Barrier.

Figure 2 - Self Checking Interlock System

The "A" Panel depicted in Figure 1 cannot be rotated about a bolt located in its lower left corner because the floor and wall preclude this motion. Consequently, a single interlock placed at this location will provide proper "interlock protection" if prying up the panel does not allow sufficient access to the interior hazards.

SELF-TESTING INTERLOCK SYSTEM

A patented automatic self-testing interlock system [Ref. 3] is illustrated in Figure 2. A standard negative mode interlock [Ref. 4] is shown in a closed or running state in Figure 2a. If the fixed panel guard were removed in this setup, the interlock activator shaft would spring to the left and open (shutoff) the running circuit of the host machine. The interlock system can be tested on a running machine without removing the fixed panel. The first part of the test is depicted in Figure 2b. A solenoid activated pusher is mobilized by a programmable logic controller (PLC) to extend its plunger to the left causing its compliant base to shift to the right. Because the interlock is mounted on the same base as the pusher, the relative distance between the fixed guard and the interlock body opens up. This allows the interlock activator shaft to extend and simulate a stop command to the machine which will be monitored by a PLC to check the "shutdown" veracity of the interlock in accordance with testing criterion 1.

In the second part of the test, the plunger is withdrawn causing the interlock system to return to its normal running position shown in Figure 2a. A PLC checks on the permissive nature of the reactivated interlock and on the inability of the closed interlock to activate the motor controller by itself. This second part of the test protocol will verify test criterion 3. Satisfying criteria 1 and 3 automatically verifies the sentinel criterion, number 2.

During the interlock testing program, the actual interlock signal is bypassed so that a running machine will not shut down and interrupt production. Furthermore, the fully extended and fully retracted contacts in the pusher mechanism may be combined with the dual positions of both the interlock and the system relays to provide a check on the testing system itself. If an interlock fails to pass the test or if a test device becomes nonfunctional, the failure status can be annunciated and/or the machine can be shut down. Failure of testing devices alone may be treated by causing the machine to demand manual interlock testing at fixed intervals like every eight hours of machine time; violation of the manual testing interval will cause the machine to annunciate and/or shut down. While the test program is in process the "test state" will be communicated. The same PLC and test relays are used to test every machine interlock. The testing interval may be adjusted to achieve any desired level of reliability; indeed, the highest European reliability requirements, Category 4 [Ref. 5], can be achieved. No prior known system of electro-mechanical interlocks can attain Category 4 status [Ref. 6].

TAMPER-RESISTANCE

Frequent testing of the interlock system not only improves its reliability, it also hardens the interlock system against short-term temporary bypassing and long-term sabotage, i.e., simultaneous guard removal and interlock bypassing. Consider three classical types of interlock circumvention:

- Interlock Tie-down: The interlock activator shaft may be taped, wedged or wired into its closed position as depicted in Figure 2a. When the pusher extends its plunger, the interlock will not change states as ordered by the PLC.

- Plunger Tie-down: The plunger may be physically restrained from movement. When ordered to extend by the PLC, the "retracted contacts" will not open and the "extended contacts" will not close.

- Interlock System Removal: The entire interlock system may be removed from the host machine or its terminals may be jumpered. Under these conditions, neither the interlock nor the pusher will change states when the test program is automatically initiated.

The longest period of temporary bypassing cannot exceed the preset test interval of, perhaps, five minutes. Either long- or short-term bypassing will be annunciated as a malfunction and/or the machine will be shut down.

CONCLUSIONS

The proposed interlock testing system 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 is addressed for the first time; to defeat the proposed process involves the most outrageous restructuring of the control system.

- The three most important failure modes of the negative mode interlock will result in a fail-to-safety state:

    1. Sticking of the interlock activation shaft by adhesives.
    2. Welding of the interlock contacts.
    3. Failure of the interlock return spring.

- The monitored machine is never shut down nor production interrupted during the testing phase.

- The testing of large numbers of interlocks will not expose the machine's electric power motors to the frequent restart demand associated with conventional manual testing procedures.

- The design and implementation of the proposed test and monitoring system may be executed and implemented using straightforward hardware and software that are firmly entrenched technology. There are an unlimited number of systems that will provide a compliant base.

- The quiescent interlock switch normally associated with fixed guards is regularly exercised.

REFERENCES

1. "Principles of Guarding and Transmission Guards," *Accident Prevention Manual for Industrial Operations,* 5th ed., Chicago, National Safety Council, 1964, pp. 22-1 to 22-30.

2. Hall, Frank B., "Safety Interlocks - The Dark Side," *Triodyne Safety Brief* v.7 #3 (June 1992).

3. Barnett, Ralph L. and Liber, Theodore, "Remote and Proximal Interlock Testing Systems", U.S. Patent Number 5,870,317 Feb. 9, 1999.

4. "British Standard Code of Practice for Safety of Machinery," BS 5304: 1988. British Standards Institution, 1988, Section Nine.

5. European Standard prEN 954-2:1996, Safety related parts of control systems, pp. 18 & 19.

6. Safe Book 2, "Machinery Safety", Scientific Technologies Inc., Fremont, CA, p.55.

CLOSING STATEMENT

A detailed treatment of the notions introduced in this paper may be found in the U.S. Patent Number 5,870,317 by inventors, Ralph L. Barnett and Theodore Liber.

ADDITIONAL REFERENCES

7. Barnett, Ralph L. and Peter Barroso, Jr., "On Classification of Safeguard Devices (Part I)," *Triodyne Safety Brief* v.1 #1 (April 1981).

8. Barnett, Ralph L. and Peter Barroso, Jr., "On Classification of Safeguard Devices (Part II)," *Triodyne Safety Brief* v.1 #2 (September 1981).

9. Barnett, Ralph L. and Beth A. Hamilton, "Philosophical Aspects of Dangerous Safety Systems," *Triodyne Safety Brief* v.1 #4 (December 1982).

10. Barnett, Ralph L., "On Safety Codes and Standards," *Triodyne Safety Brief* v2 #1 (July 1983).

11. Barnett, Ralph L., Gene D. Litwin and Peter Barroso, Jr., "Dependency Hypothesis (Part I)," *Triodyne Safety Brief* v.2 #3 (November 1983).

12. Barnett, Ralph L., Gene D. Litwin and Peter Barroso, Jr., "Dependency Hypothesis (Part II)," *Triodyne Safety Brief* v.3 #1 (Decemberr 1984).

13. Barnett, Ralph L. and Dennis Brickman, "Safety Hierarchy," *Triodyne Safety Brief* v.3 #2 (June 1985)

14. Barnett, Ralph L. and Dennis Brickman, "Deadman Controls on Lawn Mowers and Snowblowers," *Triodyne Safety Brief* v.5 #2 (July 1988)

15. Barnett, Ralph L. and Steven R. Schmid, "Safeguard Evaluation Protocol-A Decision Tree for Standardizing, Optionalizing, Prohibiting, Ignoring, Enhancing, or Characterizing Safeguards," *Triodyne Safety Brief* v.11 #2 (May 1995).

16. Schmid, Steven R., "Interlocks - The Baking Industry Experience," *Triodyne Safety Bulletin* v.5 # 2 (January 1997).

17. Barnett, Ralph L., "Interlocked Barrier Guards: Risk Taking Philosophy," *Triodyne Safety Bulletin* v.7 #4 (September 1998).

18. Barnett, Ralph L. and Dr. Theodore Liber, "A New Interlock System - Moveable Interlocked Barrier Guards with Motorized Openers for Testing," *Triodyne Safety Alert* v.1 #4 (August 1999)

SAFETYALERT

May 2000 **Vol. 2 No. 2**

AFFILIATED COMPANIES

Triodyne Inc.
5950 W. Touhy Ave.
Niles, IL 60714-4610
Phone: (847) 677-4730
FAX: (847) 647-2047
E-mail: infoserv@triodyne.com
Web: http://www.triodyne.com

Triodyne Safety Systems, L.L.C.
5950 W. Touhy Ave.
Niles, IL 60714-4610
Phone: (847) 677-4730
FAX: (847) 647-2047

Institute for Advanced Safety Studies
5950 W. Touhy Ave.
Niles, IL 60714-4610
Phone: (847) 647-1101

Alliance Tool & Manufacturing, Inc.
91 East Wilcox Street
Maywood, IL 60153-2397
Phone: (708) 345-5444
FAX: (708) 345-4004

Triodyne-Wangler Construction Company, Inc.
5950 W. Touhy Ave.
Niles, IL 60714-4610
Phone: (847) 647-8866
FAX: (847) 647-0785

Triodyne-Wangler Construction Specialties, L.L.C.
5950 W. Touhy Ave.
Niles, IL 60714-4610
Phone: (847) 647-9291
FAX: (847) 647-0785

Alliance Building Maintenance Corporation
5950 W. Touhy Ave.
Niles, IL 60714-4610
Phone: (847) 647-1379
FAX: (847) 647-0785

Triodyne Environmental Engineering, Inc.
5950 W. Touhy Ave.
Niles, IL 60714-4610
Phone: (847) 647-4730
FAX: (847) 647-0785

Editor: ***Paula L. Barnett***

Illustrated and Produced by
Triodyne Graphic Communication Group