I. Man-Machine Safeguarding Principles & Practices

1 Why should machine guard interlocks be "tamper resistant"?

Safety professionals recognize that, in many factories, workers often override or bypass safeguards intended to protect them from injury. Reported motivation includes real or perceived inconvenience, production incentives, familiarity with the equipment, or simply the challenge presented by the presence of the safeguard to be defeated.

Consequently, manufacturers are increasingly recognizing the need for, and their obligation to provide, safety interlocks which are not easily defeated/bypassed by the operator or maintenance personnel.

Additionally, safety standards-making groups encourage use of interlocks which are not easily defeated using simple, readily-available means (such as a paper clip, tape, rubber band, piece of rope, screwdriver, etc.).

For example, the American National Standards Institute's (ANSI) B11.19 1990, Reference Standard for Safeguarding Machine Tools specifically requires:

- Barrier guards that protect against unauthorized adjustment or circumvention.
- Interlock devices that are not easily bypassed.
- Reduced liability

With the growing number of product liability cases, companies are recognizing the benefits of designing safety circuits with interlock devices that are difficult to defeat. To further reduce their liability exposure, firms are selecting only those devices that have been tested and certified for use in safety applications by a recognized, independent third-party agency.

Manufacturers are encouraged to surpass safety design expectations. As cited at a recent DESIGN NEWS seminar entitled "Product Liability — A Survival Kit for the 90's", jurors expect companies to go beyond mere compliance. They give greater benefit to firms who have designed their products with the latest state-of-the-art machine guarding safety devices.

2 What is meant by the term "difficult to defeat" when related to safety interlock switches in safety standards such as ANSI B11.19, ANSI B11.20, ANSI-RIA 15.02, OSHA 1910.212, et al?

"Difficult to defeat" is a subjective term related to workers' propensity to override or bypass safety devices intended to protect them from injury. Colloquially it means that the relevant devices or systems cannot be defeated or bypassed using readily available means (such as a piece of wire, tape, simple hand tool, etc.). It implies the basic safety interlock switch design serves as a deterrent to easily overriding or bypassing its intended function.

3 How is this requirement ("difficult to defeat") being addressed by safety interlock switch manufacturers?

Safety interlock switch manufacturers are addressing this requirement by:

- Designing two-piece keyed interlocks which feature a geometrically-unique actuating key and associated operating mechanism which function together to deter "bypassing".
- Designing "coded-magnet" sensors whose multiple reed contacts can only be actuated in the presence of a matched magnetic field array.
- Encouraging "positive-mode" mounting of single-piece interlock switches.

4 What are "positive-break" safety interlocks?

"Positive-break" safety interlocks are electromechanical switches designed with normally-closed (NC) electrical contacts which, upon switch actuation, are *forced to open by a non-resilient mechanical drive mechanism*. (Spring actuators are not considered positive-break mechanisms.)

One example of a "positive-break" safety interlock is shown in the photo below. This third-party certified and widely used safety switch features a two-piece construction: an electromechanical switching mechanism and a geometrically-unique actuator key.

A simple illustration of this design concept is shown in Figure 2.

The actuator key is typically mounted to a movable guard – such as an access door, protective grating, equipment hood, or plexiglass safety cover. When the guard is closed, the actuator mates with the electromechanical switching mechanism. Upon opening of the movable guard, the actuator key mechanically rotates a cam mechanism – *forcing the NC electrical contacts to open the safety circuit.*

For machine applications with residual motion after shutdown, key actuated interlocks are available with a solenoid latch – which, in conjunction with a time-delay, motion detector, position sensor or other machinery status monitor, can delay access to hazardous areas until safe conditions exist.

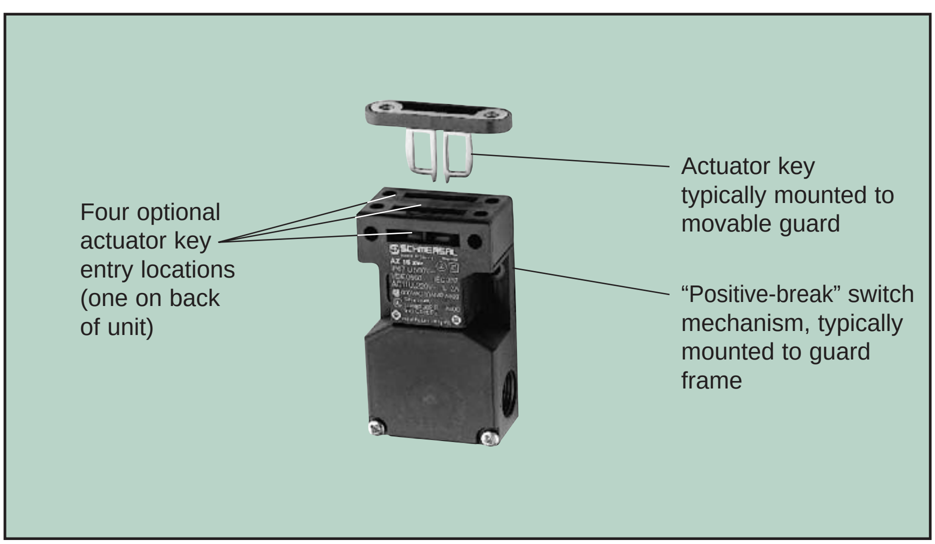

FIGURE 1

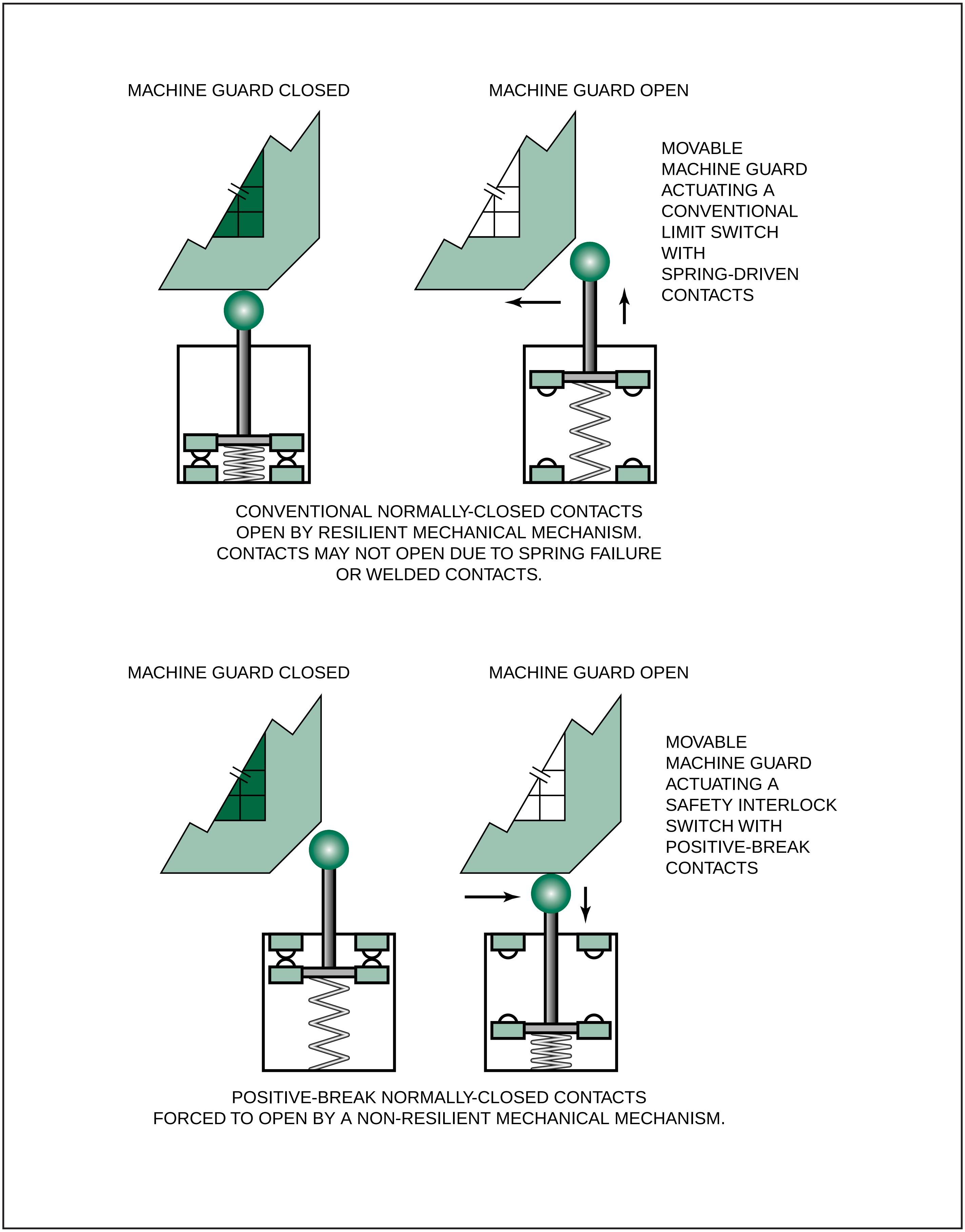

FIGURE 2
Conventional versus Positive-Break Contacts

5 Are conventional electromechanical limit switches designed with "positive-break" contacts?

Conventional "limit" switches are typically designed to use a spring force to open normally-closed electrical contacts. Such designs are subject to two potential failure modes:

- Spring failure
- Inability of the spring force to overcome "stuck" or "welded" contacts.

When "actuated," either situation may result in an unsafe condition due to failure to open normally-closed contacts. Consequently, such designs are not certified or recognized as suitable for safety applications.

SCHMERSAL offers several "limit" switches designed with "positive-break" contacts in both snap-acting and slow-action models for use in safety applications.

6 How can I recognize "positive-break" safety interlock switches?

Devices which feature a "positive-break" design carry the following internationally-recognized (IEC) safety symbol:

These designs meet the international requirements established for such safety interlock switches.

FIGURE 3

7 What is meant by a "positive linkage" switch actuator, and why is it recommended for safety applications?

A "positive linkage" switch actuator is designed to eliminate possible slippage between the actuator and its mounting shaft. Examples of such designs are pinned, square and serrated shafts (see Figure 4, below).

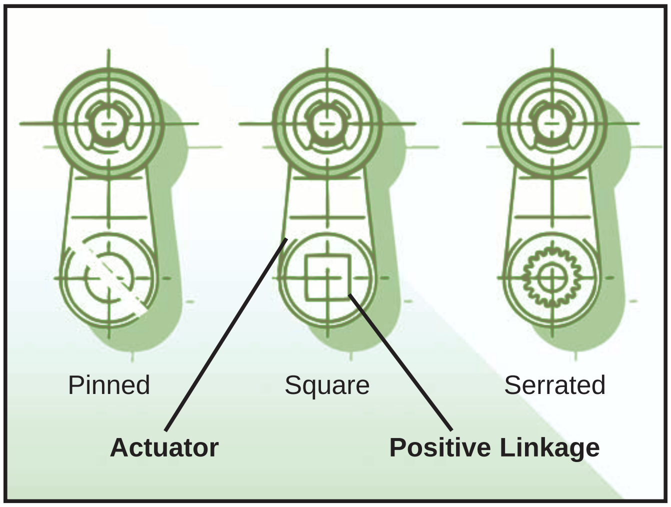

FIGURE 4

8 What is "positive-mode" mounting and why is it essential in safety applications?

"Positive-mode" mounting assures that an electro-mechanical safety interlock switch is positively-actuated when equipment or machinery shut-down is desired.

Safe "Positive-Mode" Mounting (Figure 5)
When mounted in the positive-mode, the non-resilient mechanical mechanism which forces the normally closed (N.C.) contacts to open is directly driven by the safety guard. In this mounting mode, opening the safety guard physically forces the N.C. contacts to open when the guard is open.

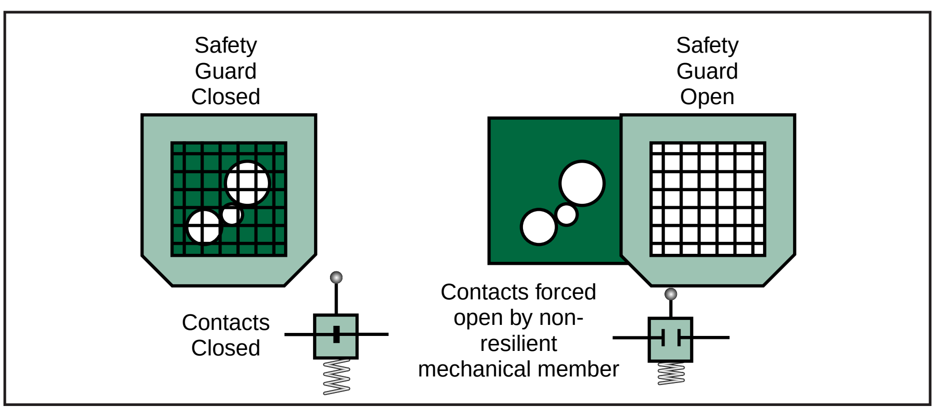

FIGURE 5
POSITIVE-MODE INSTALLATION

Unsafe "Negative-Mode" Mounting (Figure 6)
When mounted in the "negative-mode," the force applied to open the normally-closed (N.C.) safety circuit contacts is provided by an internal spring. In this mounting mode the N.C. contacts may not open when the safety guard is "Open." (Here welded/stuck contacts, or failure of the contact-opening spring, may result in exposing the machine operator to a hazardous/unsafe area of the machinery.)

Positive-mode installation is especially important when using single-piece safety interlock switches. This installation mode takes full advantage of the device's "positive-break" design — using the *external* force applied by the safety guard to open the N.C. contacts.

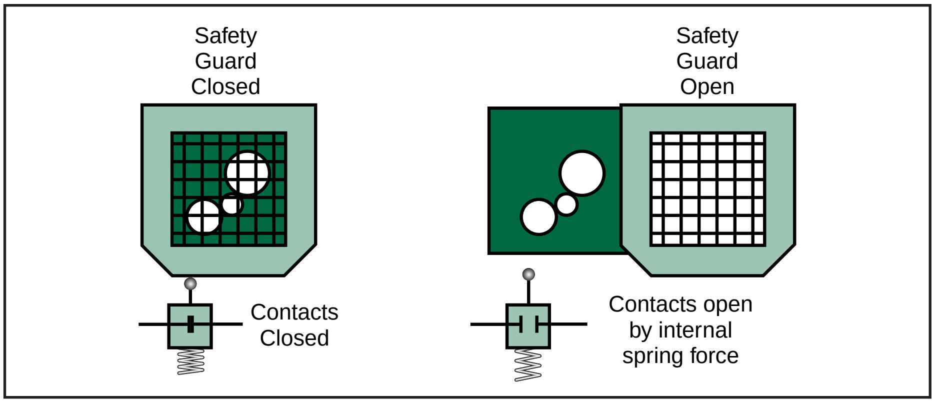

FIGURE 6
NEGATIVE-MODE INSTALLATION

9 What are the risks of installing single-piece, safety interlock switches in the "negative mode"?

When mounted in the "negative-mode" (see Figure 6 above), single-piece safety interlock switches can be easily defeated/circumvented by the operator … often simply by taping down the switch actuator when the safety guard is open.

In addition, spring-driven, normally-closed contacts can fail to open due to sticking, contact welding, or a spring failure.

Under such circumstances the operator or maintenance personnel may be exposed to *an unsafe or hazardous condition.*

Consequently, where possible, two-piece, key-actuated, tamper-resistant safety interlocks are recommended. These devices are designed to be difficult to defeat, while providing the assurance of safety circuit interruption inherent with "positive-break" interlock switch designs.

10 What are "self-checking," "redundancy," and "single-fault tolerance"?

Self-Checking: The performing of periodic self-diagnostics on a safety control circuit to ensure critical individual components are functioning properly. Faults or failures in selected components will result in system shut-down.

Redundancy: In safety applications, redundancy is the duplication of control circuits/components such that if one component/circuit should fail, the other (redundant) component/circuit will still be able to generate a stop signal. When coupled with a "self-checking" feature, a safety circuit component failure, or component failure within the safety circuit monitoring module or safety relay module, will be automatically detected and the machine shut down until the failure is corrected.

Single-Fault Tolerance: A safety circuit is considered to be single-fault tolerant if no foreseeable single fault will prevent normal stopping action from taking place.

Rugged, "fail-to-safe," safety circuit controllers (often called safety relay modules) are also available that incorporate the above features to satisfy the "control reliability" requirements of existing domestic and international safety standards.

11 Are cable-pull switches acceptable for use in E-Stop circuits?

OSHA and the European safety standards permit use of cable-pull switches in E-Stop circuits provided they:

(1) Operate whether the cable is pulled or goes slack (e.g. breaks or is cut).

(2) Feature positive-break NC contacts.

(3) Must be manually reset before the controlled equipment can be restarted.

In addition, European Norm EN418 requires that the switch latch at the same time that the contacts change state.

SCHMERSAL offers a variety of cable-pull switches that meet both EN418 and the OSHA guidelines. These are complemented by several safety circuit controllers and safety relay modules designed expressly for use in E-Stop circuits.

12 Are reed switches recommended or acceptable in safety circuits and, if so, under what conditions?'

Reed switches may be used as interlocks in safety circuits provided:

- they are designed to be actuated by a specific (coded) magnetic-field array matched to the switch's reed-array pattern.
- they are used in combination with a safety controller capable of periodically checking the integrity and performance of the reed switch contacts.

One such combination is shown in Figure 8, below.

Coded-magnets are required to actuate the sensor, thus making it difficult for the operator or maintenance personnel to "defeat" or "bypass."

The safety controller features multiple safety relays with positive-guided contacts, redundant control circuits, and self-diagnostics that check safety system operation. In the event of a component or interconnection wiring failure in the safety circuit, or in the safety circuit controller, the unit will shut down the system in a "safe" state.

Note: Reed switches used without an approved safety circuit controller do not satisfy safety requirements. Reed switches are susceptible to sticking due to power surges, shock, or vibration. Additionally, reed switches tend to fail in the "closed" position. This failure mode cannot be addressed by using a fuse. To ensure reliability of a safety circuit using reed-type switches, use of a safety controller is required. Depending upon the application, it is also recommended that they feature two independent contacts to permit dual-channel monitoring.

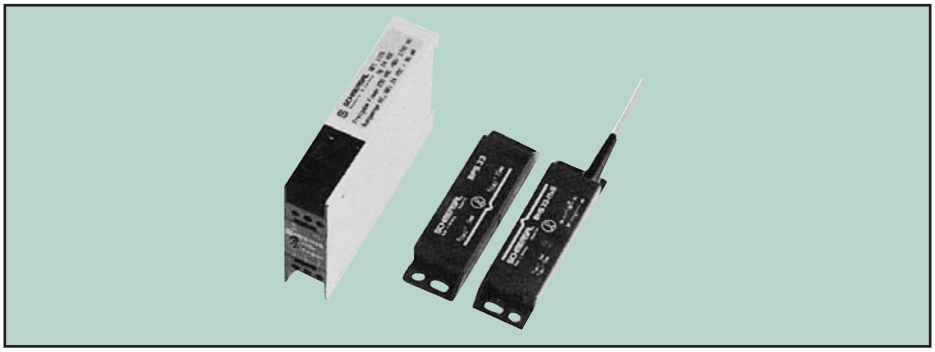

FIGURE 8

13 What is meant by "controlled access"?

"Controlled access" generally refers to a movable machine guard that is designed such that it can only be opened under specific conditions. Typically such movable guards restrict access to an area of a machine which continues to present a hazard to the operator immediately upon the removal of power. In these situations opening of the guard is prevented until the hazardous condition has abated.

This is usually achieved by a solenoid-latching interlock switch controlled by a motion detector, position sensor, time-delay or other machine-status monitor which releases the interlock (allowing the operator to open the guard) only after safe conditions exist.

14 What is "diverse redundancy," and how does it heighten the reliability of a safety circuit?

"Diverse redundancy" is the use of different types of components and software in the construction of redundant circuits/systems performing the same function. Its use is intended to minimize or eliminate failure of redundant circuits and components due to the same cause ("common-cause" failure). Such designs serve to increase the functional reliability of the safety circuits

15 Why are safety interlock switches and safety controllers required?

For machinery builders who export to the European Union, the use of such components designed expressly for machine guarding safety systems is mandated by the requirements of the European Machinery Directive and the need to comply with relevant safety standards. These requirements include:

- Use of interlock switches that feature positive-break normally closed contacts.
- Use of interlock switches or machine guarding position sensors, which are tamper-resistant/difficult to defeat.
- (Where risk level dictates) the need to monitor the integrity of the safety circuit components and its interconnection wiring to ensure the system will function properly when called upon to do so.

For machinery builders selling in the U.S., the use of such components is encouraged by the safety guidelines and standards of the Federal government and several industry standards-making groups including:

- OSHA (Occupational Health & Safety Administration)
- ANSI (American National Standards Institute)
- UL (Underwriters Laboratories)
- ISA (Instrument Society of America)
- SAE (Society of Automotive Engineers).

16 As an OEM, what are the benefits of using positive-break and tamper-resistant interlocks in safety applications?

Proper selection and installation of safety interlocks which have been *tested and certified by an approved, independent safety testing body* benefits the equipment manufacturer by:

- Providing greater protection from injury for machine operators, maintenance personnel, set-up and other user personnel.
- Satisfying international safety regulations … a must for U.S. equipment manufacturers who wish to export to the European Economic Community.
- Enhancing product marketability.
- Satisfying safety standards and guidelines against which manufacturer's responsibility, in the event of an injury, is judged.
- Reducing liability risks.
- Minimizing insurance claims/costs.

17 As an “in-plant” user, what are the benefits of using positive-break, and/or tamper-resistant interlocks in safety applications?

Proper selection and installation of such safety interlocks which have been *tested and certified by an approved, independent testing body* benefit the in-plant user by:

- Providing greater protection from injury for machine operators, maintenance personnel, and other employees.
- Reducing liability risks.
- Minimizing insurance claims/costs.
- Satisfying safety standards and guidelines against which employer responsibility, in the event of an injury, is measured.
- Reducing the indirect costs associated with worker injury (e.g. lost production, loss of skilled workers, reduced productivity due to employee stress, etc.)

18 What are the benefits of using SCHMERSAL safety interlock switches and related controls?

While SCHMERSAL is not the only manufacturer of such devices, there are a number of factors which favor your consideration. These include:

(1) All SCHMERSAL safety interlocks have been third-party tested and certified to meet relevant directives — all are CE-compliant.

(2) Each can be provided with a Declaration of Conformity.

(3) Each has been designed expressly for safety applications to meet the requirements of ANSI, OSHA and the European Machinery Directive.

(4) SCHMERSAL’s individually-coded keyed interlocks (AZ16zi, AZ17zi, and AZM170zi) provide the highest level of tamper resistance.

(5) SCHMERSAL’s safety interlocks and related controllers have been proven in thousands of installations worldwide.

(6) SCHMERSAL’s microprocessor-based Series AES safety controllers feature integrated systems diagnostics which, using a visual colored LED display pattern, help identify the type of system fault that has occurred and its location (to minimize downtime).

(7) SCHMERSAL’s safety controllers are easily integrated with their more than 200 “positive-break” interlock switches and coded-magnet sensors to achieve any desired safety level. And, they are also compatible with other manufacturers’ safety-approved components.