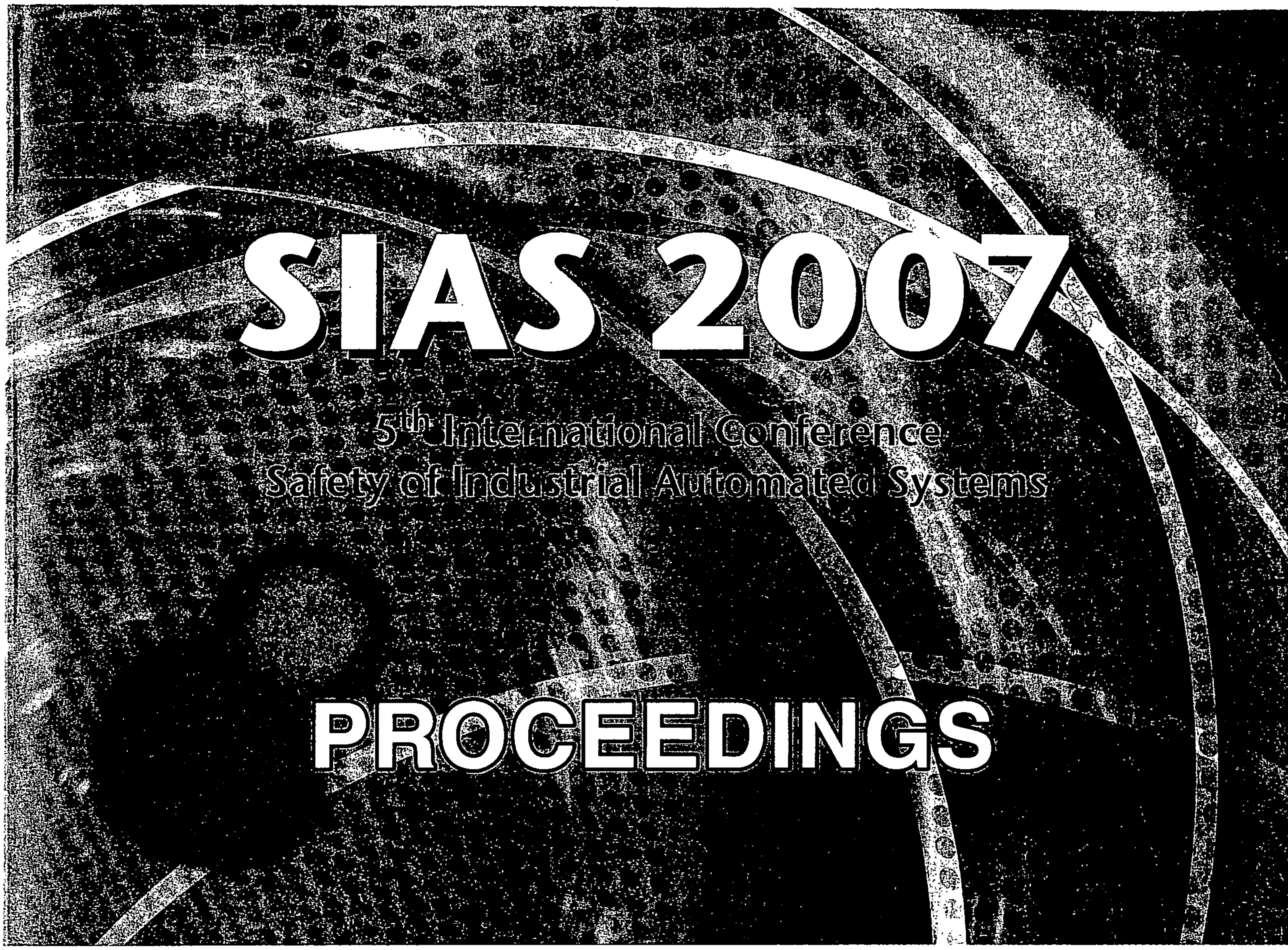

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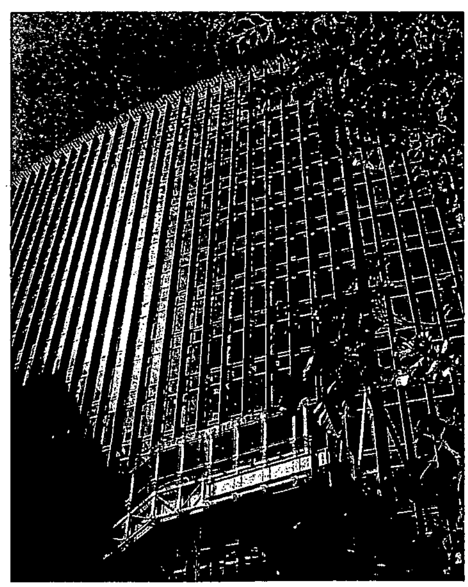

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Development of Safety System for Press Brake

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Abstract:

The number of industrial disasters caused by press-brakes has been leveling out for these 15 years. In view of this, this research aims to identify the conditions for preventing such industrial disasters caused by secondary processing press-brakes equipped with servo mechanisms and develops an appropriate safety system based on the results of such identification. In order to prevent a disaster of being pinched by press dice, this research suggests a system equipped with a mechanism that monitors the slide position directly by combining a laser safety device and two encoders. Also, in order to prevent a disaster of being pinched between a steel sheet under bending and the slide side, this research suggests a contact type bumper incorporated with a reed switch. This bumper is designed to stop the slide also in case that the steel sheet under bending pinches the operator's finger.

1.Introduction

Industrial disasters caused by press-brakes occur frequently when operators conduct press working while holding a work piece with their both hands. As a protective device, a photoelectric safety device of multi-optical-axis shielding type (turning on enabling signal when one light axis is shielded and tuning off the enabling signal when two or more light axes are shielded, where one optical axis is shielded when there is a steel sheet and two or more optical axes are shielded when there is a finger to distinguish between the steel sheet existence and the finger ingress) is recommended. However, in the secondary processing of a box or the like, the operator has to work with his/her finger brought closer to the press die. At this time, since the operator's finger may shield the photoelectric safety device, it is considered difficult to use the photoelectric safety device of multi-optical-axis shielding type.

2. Safety Conditions for Secondary Processing Press-Brake Equipped with a Servo Mechanism

2.1 General Conditions

A disaster caused by being pinched between the punch and die of a press-brake occurs when an operator extends his/her finger by mistake into the dangerous zone (operating sphere of the slide or die plus the safety distance D)[1]. Therefore, in order to prevent this type of disasters, whether or not the operator's finger is in the dangerous zone or whether or not the slide is lowering should always be monitored. On the other hand, a disaster caused by being pinched between a steel sheet under bending and the slide (or die) occur when the operator's finger is caught by the steel sheet under bending. Therefore, in order to prevent this type of disasters, whether or not the operator's finger is being pinched by the steel sheet under bending should always be monitored.

When $H_N(t)=1$ is the state when the operator's finger is not in the dangerous zone of the press-brake at the time t and $H_N(t)=0$ is the state when the operator's finger is in the dangerous zone of the press-brake at the time t, $A_N(t)=1$ is the state when the slide is not lowering at the time t and $A_N(t)=0$ is the state when the slide is lowering at the time t, and $B_N(t)=1$ is the state when the operator's finger is not pinched by the steel sheet under bending at the time t and $B_N(t)=0$ is the state when the operator's finger is pinched by the steel sheet under bending at the time t, the above causal relation can be expressed by using the following equation:

$$[H_N(t) \vee An(t)] \wedge Bn(t)=1 \qquad (1)$$

where, $\wedge$ is a sign expressing the logical product and $\vee$ is a sign expressing the logical addition.

However, the Equation (1) may not be satisfied in case of failure in control. In this case, the press-brake should be stopped immediately to protect the operator from hazard. This relation can be formulated as follows by using the Equation:

When $[H_N(t) \lor A_N(t)] \land B_N(t) = 1, W(t) = 1$ (2)

When $[H_N(t) \lor A_N(t)] \land B_N(t) = 0, W(t+\Delta t_B) = 0$ (3)

2.2 Monitoring the Movement Direction of the Slide

The logic variable $A_N(t)$ indicating the movement direction of the slide, among of all above terms, can be confirmed for a press-brake equipped with a flywheel by detecting the slide passing the bottom dead center or the upper dead center by using a cam switch or by other means. This is because the instantaneous reverse of the movement direction of the slide is improbable due to the inertia moment of the flywheel.

By contrast, for a servo press, the instantaneous reverse of the movement direction of the slide is probable due to no flywheel equipped. To add, since it is unknown where such instantaneous reverse will occur in the process, the movement direction of the slide should always be monitored after all.

2.3 Monitoring the Ingress of the Operator's Finger

The logic variable $H_N(t)$ indicating the ingress of the operator's finger in the dangerous zone can be expressed as follows when $h_s(t)$ is the work area of the operator at the time t and Y_s is the dangerous zone (Refer to Fig. 1(a)):

When $H_s(t) \cap Y_s = \phi$, $H_N(t) = 1$ (4)

When $H_s(t) \cap Y_s \neq \phi$, $H_N(t) = 0$ (5)

where, $\cap$ is a sign expressing the product of the area, and ϕ is a sign expressing the blank area.

In practical press working using a secondary processing press-brake, the operator has to hold a steel sheet with their both hands in the dangerous zone Y_s. As aforementioned, this is called "Hazardous point nearby operation."

In such way of working, no photoelectric safety device can be used since the operator's finger shields its optical axis. To counter this problem, the danger point close zone $D_s(t)$ at the time t is always monitored by using laser light or pattern recognition instead of the dangerous zone Y_s (Refer to Fig. 1 (b)). Thereby, the Equations (4) and (5) can be edited as follows:

When $h_s(t) \cap D_s(t) = \phi$, $H_N(t) = 1$ (6)

When $h_s(t) \cap D_s(t) \neq \phi$, $H_N(t) = 0$ (7)

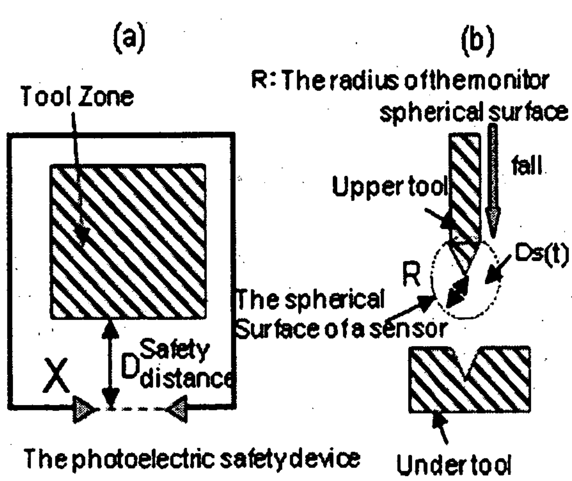

Fig.1 The monitoring method for press brake

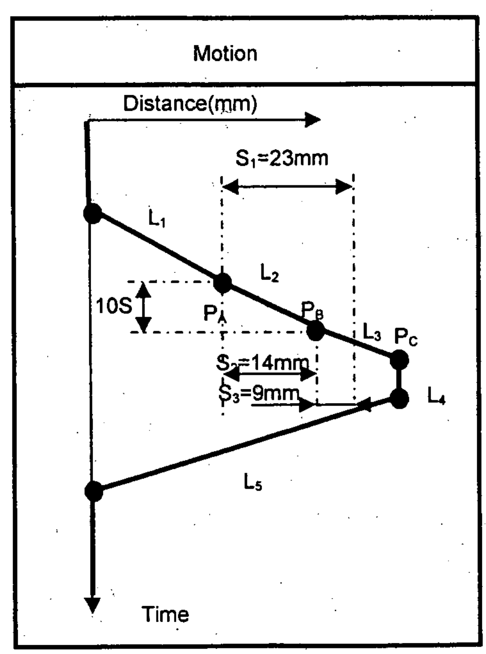

Fig.2 The time-chart of press brake

In this case, it should be confirmed that the finger ingress can be detected in whatever the direction is with respect to the area $D_s(t)$. It should also be confirmed that the finger ingress can be detected at the moment of the finger ingress into even a part of $D_s(t)$.

According to the above composition, when the punch is lowering to such an extent that the area $D_s(t)$ overlaps the work or the die existent area, the slide stops to disable the continuation of the press working. Therefore, at times like this, the protective device is invalidated (muted) to prevent the slide from stopping. However, if the protective device is invalidated and the finger comes in between the punch and the die, a resultant disaster could not be prevented. To counter this problem, the timing of the invalidation should be adjusted so that the clearance between the punch and the work (steel sheet) can be not more than 9mm before the protective device is invalidated.

Fig. 2 shows the above process in time chart. The important point here is that the slide lowering speed V should be the specified speed V_{DN} . This is because, when V increases, the slide could not be stopped within the specified distance and, when V decreases, the operator's finger could enter the die even after the invalidation. That is, V would pose a problem even if it is faster or slower that V_{DN}.

Then, $V = V_{DN}$ is confirmed in the position P_A of Fig. 2. If there is any speed error, the slide will be stopped, and if there is no speed error, the protective device will be invalidated after the slide reaches the position P_2, where the clearance between P_A and P_B (S_3 of Fig. 2) should be not more than 9mm to prevent the finger ingress.

2.4 Monitoring a Disaster of the Finger Pinching by the Steel Plate under Bending

The logic variable $B_N(t)$ indicating whether or not the operator's finger is pinched by the steel sheet under bending can be confirmed by comparing the position of the operator's finger with the shape of the steel sheet under bending. However, for this purpose, the whole area of the slide should be monitored, which is generally determined unfeasible.

To counter this problem, a contact type detector (bumper) is attached to the side of the press-brake slide so that, if the operator's finger is caught by the steel sheet under bending, the bumper can detect it and stop the slide. This relation can be expressed as follows:

When $f(t) \leqq f_{LH}$, $B_N(t) = 1$ (8)
When $f(t) > f_{LH}$, $B_N(t) = 0$ (9)

In this case, it should be confirmed that the bumper does not apply any force larger than the allowable limit to the operator's finger during a period from when the bumper contacts the finger to when the slide stops.

3. Composition of the Protective Device

The basic composition of the protective device is the following components:

1) Monitoring Device for the Movement Direction of the Slide and Others

This is a device for monitoring the movement direction and speed of the slide. Specifically, the linear movement of the slide is converted into a rotary movement by the rack and pinion mechanism, the signal from the encoder connected directly with the rotary mechanism is processed by the general-purpose safety controller, and thereby the movement direction and speed of the slide are obtained. By installing this device by two sets, redundancy is ensured.

2) Monitoring Device for the Operator's Finger Ingress

This is a device for monitoring whether or not the operator's finger is in the area $D_s(t)$ between the punch and the die. This device monitors the area $D_s(t)$ by using laser light.

3) Monitoring Device for the Operator's Finger Being Pinched between the steel sheet and the side or die

This device monitors whether or not the operator's finger is being pinched between the steel sheet under bending and the slide or die.

4) Safety Control System

This system controls the operation under the safety conditions of the respective monitoring devices. If any of the safety conditions is not satisfied, this system will stop the slide of the press-brake.

4. Experimental Setup and Method

4.1 Experimental Setup

Photo 1 shows the appearance of the experimental setup used for this research. The laser type safety device used for the experiment is AKAS II 190S made by Germany's Fissler, and the general-purpose controller equipped with disparate redundancy function and automatic monitoring function is PSS3100 made by Germany's Pilz. These devices enable the direct drive of the contact without routing the safety relay.

The encoders used for detecting the slide position are ECN425 made by German Heidenhain and E6C2-CWZ1X made by Japan's Omron. The device used for detecting the contact is Magnetic Switch (Power Reed Switch) R15 made by Japan's Yasukawa Control.

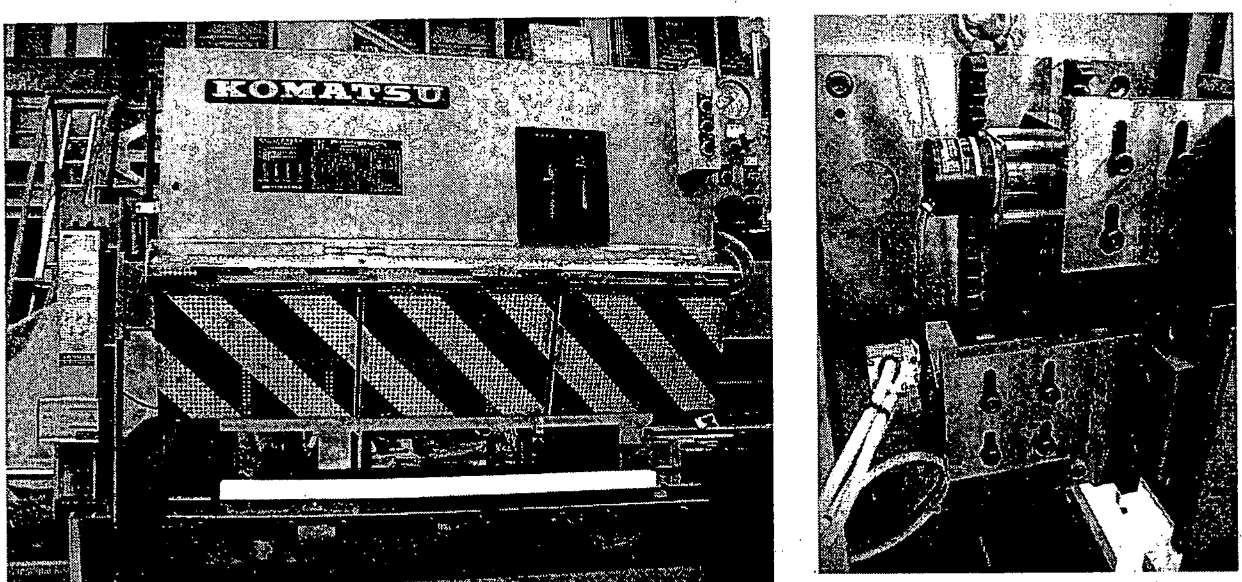

Photo.1 The appearance of the experimental setup used for this research

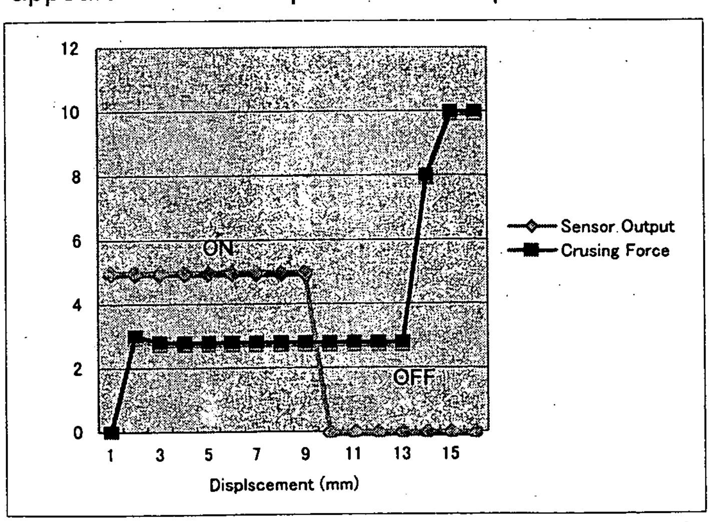

Fig.3 The outputs of the reed switch according to the bumper displacement and load on the bumper.

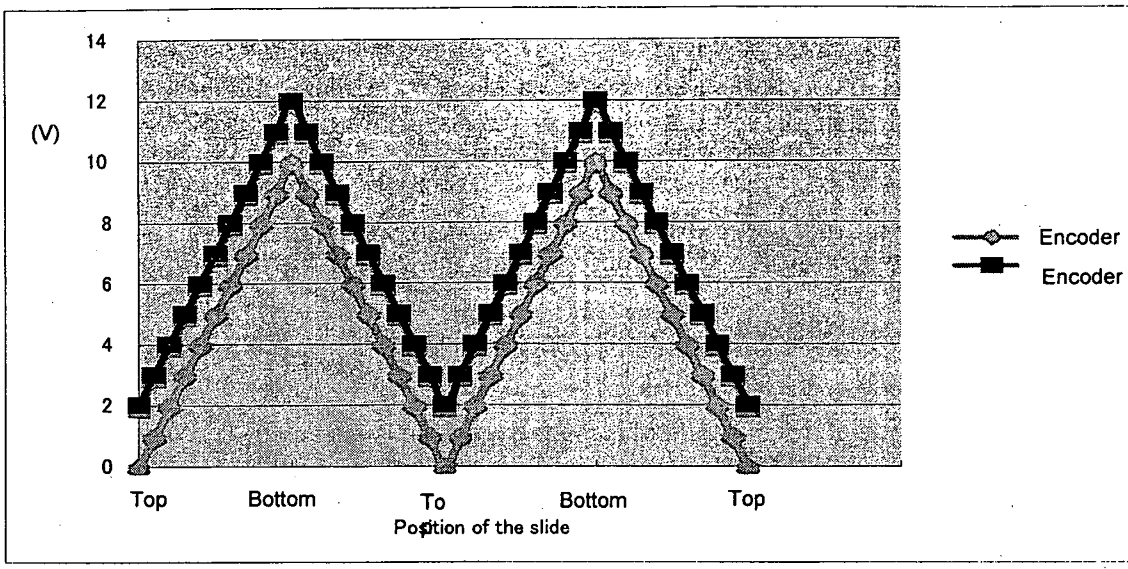

Fig.4 The positional displacements of the slide and the outputs of the encoder.

4.2 Experimental Method

1) Experiment for monitoring the operator's finger

This experiment aims to confirm that, when the slide is lowering, the operator's finger is detected and the slide is stopped.

2) Experiment for monitoring the operator's finger being pinched

This experiment aims to confirm that, when the bumper attached to the slide side is displaced, the built-in reed switch is turned off and thereby the slide is stopped.

3) Experiment for monitoring the slide movement direction

This experiment aims to monitor the movement direction and travel distance of the slide by using an encoder.

5. Experimental Results and Considerations

Fig. 3 shows the outputs of the reed switch according to the bumper displacement and load on the bumper. From these results, it was found that the force necessary for pressing the bumper to stop the slide was 280g and the displacement was 13mm. This force is by far smaller than the force under which humans sense pain. Fig. 4 shows the positional displacements of the slide and the outputs of the encoder. From these results, the current slide position can be identified by monitoring the encoder outputs.

6. Postface

Based on the disaster cases of press-brakes equipped with servo mechanisms, this research made a prototype of a safety device in order to prevent "disasters of the operator's finger being pinched between the punch and the die" and "disasters of the operator's finger being pinched between the slide side and the steel sheet under bending" and examined it. In the future, this research will improve the safety device toward commercialization.

DEPLOYING SAFETY TO STREAMLINE SERVICE PROCEDURES

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Abstract

Protecting the health and safety of employees is of paramount importance for all manufacturers. Machine safeguarding practices have been in use for decades to reduce the risk of harm to employees operating industrial equipment. For much of this time, the common practice for all machine servicing activities has been to bring the machine to a full stop and remove all sources of energy to the equipment. While safe, this practice can result in lost productivity for the machinery. This paper will discuss how contemporary machine safety designs can be used to enable employers to reduce downtime, improve productivity and maintain high standards of safety by streamlining the procedures required to diagnose, perform service and restore machinery to its normal production state.

Safety and Productivity

In today's competitive world, manufacturers are finding new opportunities to improve the productivity of their plant and the efficiency of their employees by adopting practices that can improve labor's ability to interact safely with machinery and thereby improve machine uptime.

Traditionally, safety systems have been deployed using safety relays and hard-wired relay logic, limiting the flexibility of the safety system. Innovation in this industry segment was limited by application standards that placed constraints on the flexibility of safety system design and practices and by a lack of safety product standards to allow manufacturers to design flexible or programmable safety solutions to augment traditional safety practices.

New application and product standards, as well as updates to existing standards, enable manufacturers to streamline their machine access strategies. This is accomplished by tailoring the operation of safety systems to the task that the operator is trying to perform. This in turn allows labor to more quickly diagnose, perform service and restore machinery to its production state which can yield significant improvement to machine uptime.

Because these practices streamline what otherwise may be cumbersome and time consuming safety procedures, these new system designs often improve overall employee safety by reducing their motivation to bypass the safety system.

The Safety Control System

All machinery is designed for one purpose: the production of goods that can be sold for a profit. As such, all machinery has a control system that is designed to maximize the production of goods on that machine. However, since most machinery requires some level of operator interaction, most machinery also requires safety systems to monitor the various machine hazards that may be present and to protect the operator from potential machine induced injury.

There are a variety of reasons that an operator may require access to a machine. Some of these reasons include:

Operator Access:

- Product inspection
- Loading of production parts
- Removal of product or parts jam
- Transfer of Work-in-Process (WIP)
- Clean-up of spills or ejected parts