# DEVELOPMENT OF SAFETY TECHNOLOGY TO ENSURE SAFETY OF TWO OR MORE OPERATORS IN HAZARDOUS AREAS BY PREVENTING ERRONEOUS RESETTING

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**Abstract**

In Human Machine Interface (HMI) environments, safety measures are required in various situations to prevent inadvertent machine startup. Even though a production system can be highly automated, there may still be cases where operators need to enter hazardous areas, and safety measures corresponding to risk levels must be provided. These measures ensure protection for the worker in the event that a human error causes a machine to start unexpectedly. In this paper, we report on the effectiveness of installing padlocks on interlocking devices as a safeguard. We also discuss using emergency stop switches as a complementary protective measure, which is among the safety measures described in the ISO 12100 standard for reliably preventing machinery from hazardous startup.

## 1. Introduction

In industrial fields with HMI environments, such as factory automation, increased efforts have been made in recent years to improve usability and safety. The International Safety Standard ISO 12100 denotes that performing risk assessment is an obligatory effort. This standard has been incorporated into many countries national standards and has become the "de facto" safety standard when dealing with machinery and workers.

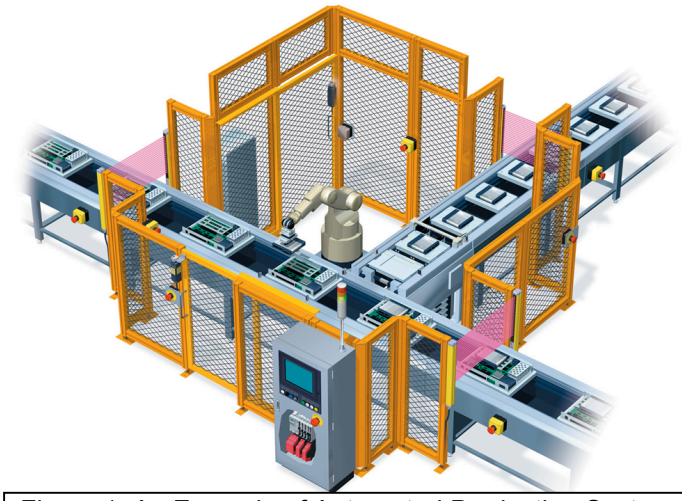

Figure 1. An Example of Automated Production System

IDEC actively presents proposals and reports concerning concept and development of safety components that can be used for risk reduction. In this paper, we analyze how installing a padlock on a door interlock device or emergency stop device, as a complementary protective measure, can ensure the safety of two or more operators in a hazardous area. We also report on the effectiveness of applying a padlockable structure to safety products [12-13].

## 2. Safety issues and solutions: Two or more operators working in a hazardous area

Even if a machine system is highly automated, there are many situations where operators must work in hazardous areas, as illustrated in Figure 1 (below). For example, when an operator is changing settings or performing repairs and maintenance, as well as for emergency work in case of a breakdown. In these situations, the operator is forced to approach a hazardous area creating higher risk of a serious accident if the machine starts unexpectedly. If there is only one operator involved, safe operation is ensured by the safety product, which keeps the machine stopped. [12-13]

However, when there are two or more operators working at the same time, operators are exposed to additional hazards, as described below and illustrated in Figure 2 (a).

Figure 2: Comparison of operation in hazardous areas - with and without padlock

Figure 2 (a) shows a situation where the operator works without installing a padlock before entering the hazardous area.

(1) When Operator Z opens the guard door for machinery maintenance and for other reasons, the door interlock devices keeps the machinery stopped.

(2) Operator Z enters the hazardous area for operation, leaving the guard door open.

(3) Operator Y arrives and not knowing that operator Z is inside the hazardous area, closes the door, which starts the machinery.

(4) Operator Z is injured.

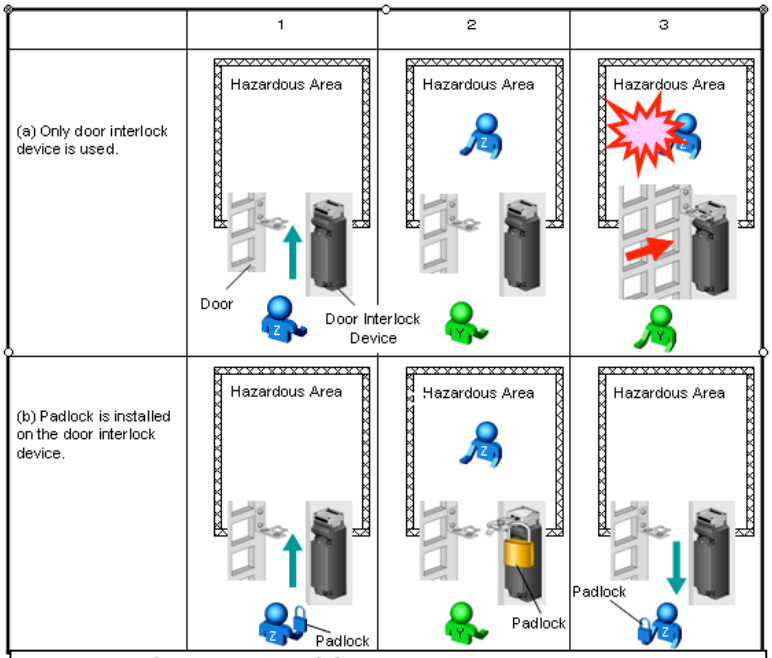


Figure 2. Comparison of Operation in Hazardous Areas – with and without Padlock

This is an actual example of an unfortunate accident possible at a worksite. Figure 2 (b) shows the same situation, except this time the operator works safely by installing a padlock before entering the hazardous area.

(1) Operator Z engages a padlock on the door interlock device and enters the hazardous area for operation.

(2) Operator Y arrives and notices from the padlock on the door interlock device that Operator Z is inside the hazardous area. Or, Operator Y does not notice about Operator Z and attempts to close the door, but the padlock prevents it therefore the machinery remains stopped. In the latter case, with a padlock installed on the door interlock, the operator can safely work inside the hazardous area. In addition, as the system becomes larger, there will be more cases where more than two operators enter the hazardous area. In such cases, all of the operators who approach the hazardous area should install their own padlocks on the door interlock device. This way the machinery cannot run unless each padlock is disengaged by the individual who placed it there, namely until all of the padlocks are disengaged. This way the safety of all operators is guaranteed.

The procedure for two or more operators to enter the safety guard for operation is described in Figure 3.

(1) When Operators X, Y and Z open the door to the hazardous area to perform machinery maintenance, the door interlock device keeps the machine stopped.

(2) Each of the operators installs his own padlock on the door interlock device before entering the hazardous area.

(3) Because the padlocks are installed on the door interlock device, the door cannot be closed and the operators can safely work in the hazardous area.

(4) When their work is completed, Operators X and Y leave the hazardous area, and remove the padlocks they have attached to the door interlock device. Operator Z is still inside the hazardous area and Operator Z's padlock is still also engaged, therefore the door cannot be closed and Operator Z can safely work in the hazardous area. Also, Operators X and Y can recognize that Operator Z is still in the hazardous area.

(5) Operator Z leaves the hazardous area and disengages the padlock from the door interlock device, and finally the door interlock device is unlocked, enabling the door to be closed and the machine to be restarted.

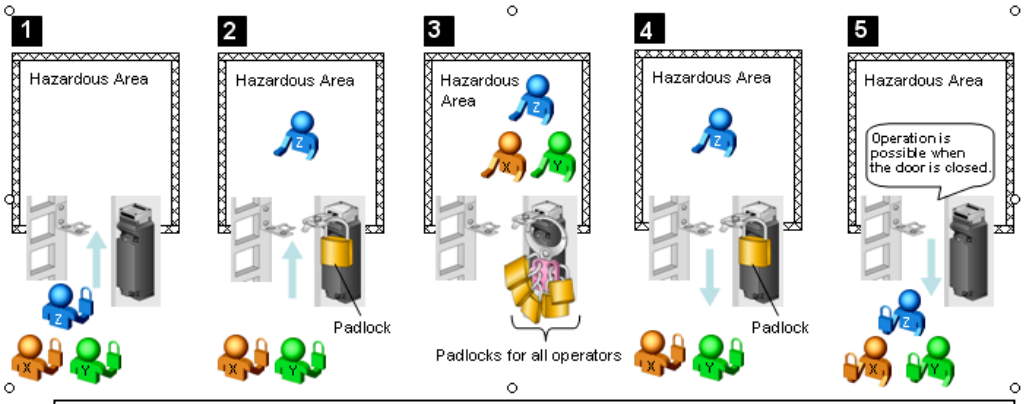


Figure 3: Padlocks providing safety to multiple operators in a hazardous area

### 3. Added safety functions of a padlockable door interlock device

The door interlock device has an important function as part of the three-step method of safety measures described by ISO 12100 [1, 16]. The safety switch used in the door interlock device opens and closes its contacts by means of the insertion and removal of a dedicated actuator. As the actuator fastened to the door is inserted and removed by opening and closing the door, the safety switch functions as a door interlock device.

There are important safety requirements for a safety switch, which has the important role of preventing the operator from approaching machinery, while it is running and hazardous. One requirement is "direct opening action" based on the International Safety Standard IEC 60947-5-1 Attachment K, which requires that when the door is opened, the contacts are securely separated so that the safety control circuit is shut down. Another requirement is "defeat prevention" based on ISO14119, 5.7.1, a means of construction that can be operated only by the proprietary actuator, and cannot be operated by hand or by a readily available object (such as screws, needles, sheet-metal pieces, keys, coins, tools) [4, 6, 16].

In the case of machine tools, such as a machining center or lathe turning machine, the rotating tools or the objects being machined might not stop immediately when the power is shut down, thus there may be a hazard associated with inertial movement of the tools and the objects. For example, the door is opened and the door interlock device shuts down the safety circuit, yet the moving parts cannot stop completely or slow down to a safe speed by the time the operator arrives at the hazardous machine's moving parts. For this case, a lockable door interlock device is necessary in order to prevent the operator from approaching the hazardous area, by way of locking the door until the machinery is stopped completely or slowed to a safe speed. A solenoid-type safety switch is used for this purpose [1, 6, 16].

The padlockable safety switch presented here can prevent an operator from being confined inside the safety fence, without losing any of the functionality of a conventional safety switch. As shown in Figure 4, the operator who has opened the door installs a padlock hasp on the actuator entry slot of the safety switch and locks it with a padlock before entering the guarded area. With a safety switch that has a padlock hasp blocking the actuator entry slot, the actuator cannot be inserted and the door cannot be closed, therefore the machine cannot be started. Since the safety switch is always installed near the door entry, there is also an added advantage that operators can easily engage the padlock before entering the guarded area. The procedure for mounting the padlock hasp on the safety switch and engaging the padlock is shown in Figure 5 [12]. A padlock hasp can accommodate several locks, and for cases where more

operators are involved, an auxiliary fitting can be mounted on the padlock hole of the hasp. Installing padlocks on the auxiliary fitting ensures the safety of additional workers.

The door-handle type safety switch shown in Figure 6 provides improved usability as a human interface. Turning the door handle removes the actuator from the safety switch, and the door can then be pulled open. Furthermore, the padlock engaging method of this type does not require attaching a separate hasp. Closing a shutter incorporated in the safety switch allows padlocks to be installed, making this switch suitable for large equipment which may require two or more operators to work inside the guarded area.

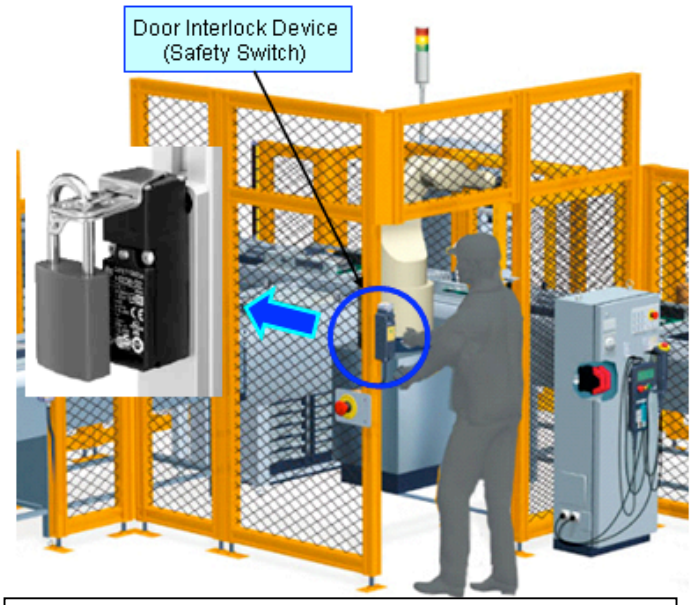


Figure 4. Prevention of machine start-up with a door interlock device when entering the guarded area

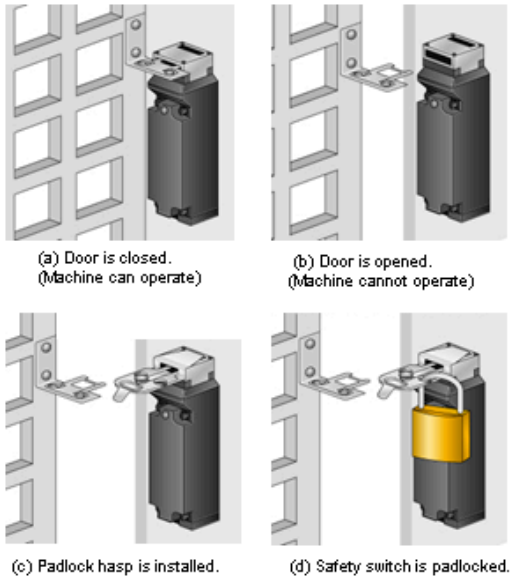


Figure 5. Padlock Locking Procedure on Safety Switches

## 4. Padlockable E-stop device and its added safety functions

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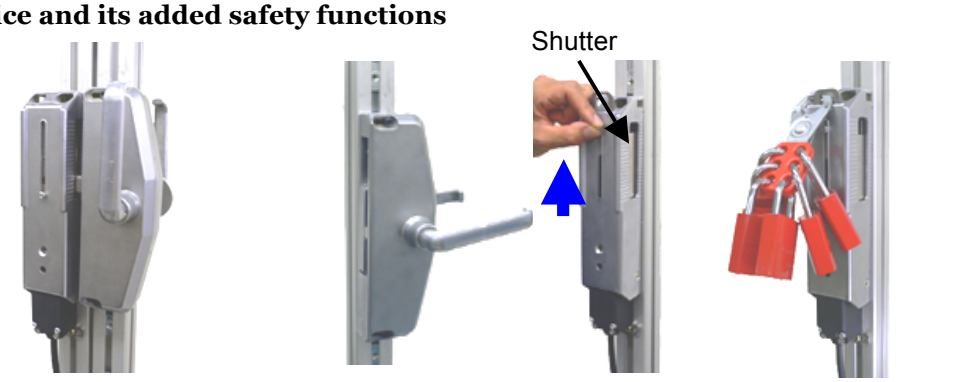
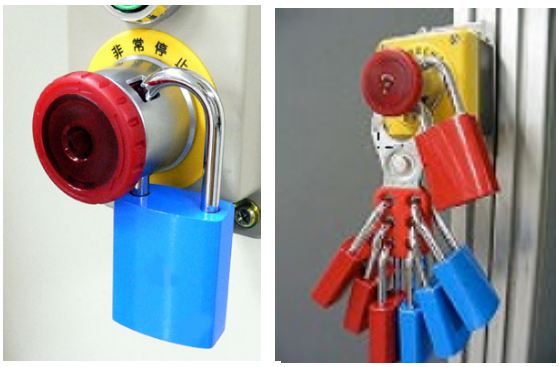



Figure 6. Door-handle-type padlockable safety switch

Padlocking is also effective with an emergency stop device, which is a human interface for transmitting a stop command to the machine and is a complementary protective measure of the three-step method. The emergency stop switch used in an emergency stop device is subject to strict construction requirements under the international safety standards ISO 13850 and IEC 60947-5-5. This is because the E-stop device is the last means available for ensuring the safety of the operator and when activated, it must be able to reliably transmit the stop command to machinery in any situation [3, 5]. For example, when the emergency stop switch is pressed to stop failed machinery and two or more operators approach the machine for repairs. In this case, there are concerns that even if the emergency stop switch has been designed to satisfy the requirements of the current international safety standards, an accident may be incurred by an operator's failing to conduct proper checks at the start of his operation or by an operator's human error. To protect the operator from an unexpected machine startup, each of all operators must ensure the OFF status of the emergency stop switch, which is keeping the machinery stopped.

The padlockable emergency stop switch presented in this paper is able to accept a padlock when the button is latched, without losing any of the conventional safety features or usability. As shown in Figure 7 (a), the padlockable E- stop switch has a through-hole on the operating button, and installing a padlock on the through-hole prevents the switch from being turned or pulled. In addition, if the number of operators increase beyond the capacity of a padlock, it is possible to attach an auxiliary fitting as shown in Figure 7 (b), to allow all operators to install padlocks.



(a) For One Operator (b) For Two or More Operators

Figure 7: Padlockable Emergency Stop switch

Figure 8 shows how safety is ensured in a system with a padlockable emergency stop switch, when two or more operators enter a hazardous area.

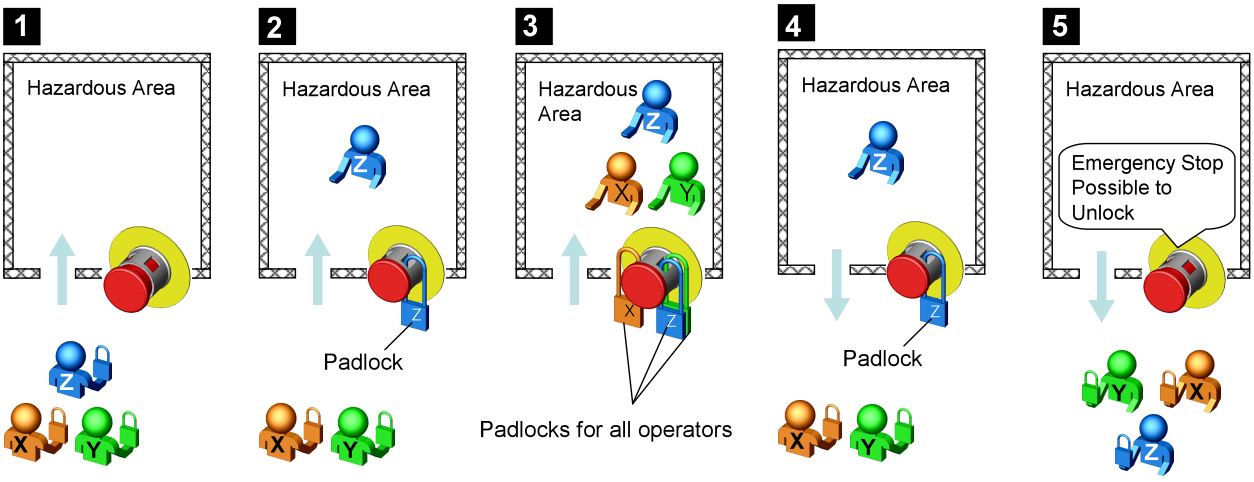


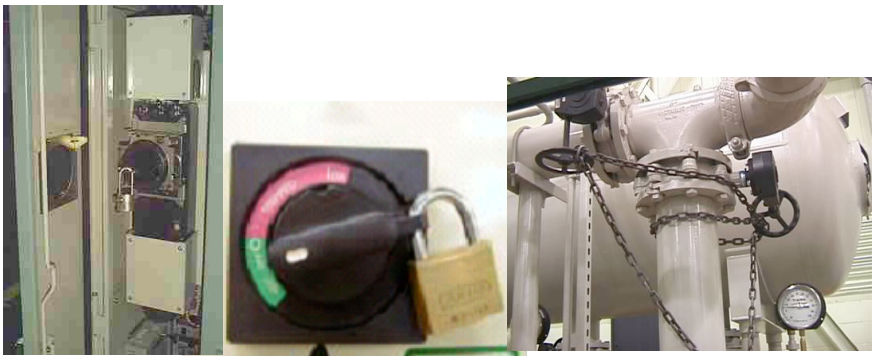

Figure 8. Padlockable E-Stop switch for two or more operators

(1) A system malfunctions and Operators X, Y and Z come to work in the hazardous area. The padlockable emergency stop switch is pressed and the button is latched.
(2) Each of the operators engages an individual padlock on the emergency stop switch and enters the hazardous area.

(3) The emergency stop switch locked by the padlocks allows the operators to work safely in the hazardous area.
(4) When their work is finished, Operators X and Y leave the hazardous area, and remove the padlocks they have installed on the emergency stop switch. Operator Z is still in the hazardous area and Operator Z's padlock is still engaged, so the button of the emergency stop switch cannot be unlocked, ensuring his safety. Also, Operators X and Y are able to recognize that Operator Z is still in the hazardous area.
(5) Operator Z leaves the hazardous area, removes the padlock from the emergency stop switch, and finally the button of the emergency stop switch can be unlocked.Accordingly, until one's own padlock is removed, that is until all padlocks are removed, the machine cannot start and the safety of all operators can be ensured [13].

## 5. Examples of padlock application on other devices

One method that has been used commonly to ensure the safety of an operator approaching a hazardous area is so-called “hostage control,” in which the operator enters the hazardous area carrying a key switch or safety plug in order to keep the machine from being started [16]. However, as systems grow larger, there will be many situations where two or more operators are required to enter hazardous areas, and since it is difficult to predict the number of operators at the time of designing a system, in most cases the exact number of key switches or safety plugs required are not provided. Consequently, the safety of an operator who must work inside the hazardous area without a key or plug must depend on the care of the person who is responsible for holding the key or plug.



(a) Lockout for Energy Isolating Device (b) Lockout for Hydraulic Valve

Figure 10. Lockout Application Examples

As to the technology to support detection of the presence of an operator in the hazardous area, the usage of a laser scanner, mat switch and most recently, a method to employ image processing technology have been introduced. However, the method that has proved most effective to ensure an operator’s safety from an unexpected machinery startup is what is known as the lockout method shown in Figure 9, used mostly in North America.

==FIGURE 9==

Figure 9. Lockout application examples

In this method, all operators install their own padlocks on a power supply breaker, oil pneumatic valve or other energy isolation device [7-8]. Table 1 is a summary of standards applicable to lockout devices. As the table shows, startup prevention using padlocks is required under international safety standards and also by law, as a simple and highly reliable safety measure. In addition to OSHA and ANSI standards in the US, usage of a padlock is required under international safety standards ISO 12100-2 and IEC 60204-1.

Table 1 Safety Requirements of Lockout by Safety Standards

| Standard | Requirement |
|---|---|

| | |
|---|---|
| OSHA Regulations (Standards - 29 CFR)) The control of hazardous energy (lockout/tagout). - 1910.147 | 1910.147(b)<br>Lockout. The placement of a lockout device on an energy isolating device, in accordance with an established procedure, ensuring that the energy isolating device and the equipment being controlled cannot<br>be operated until the lockout device is removed.<br><br>Lockout device.<br>A device that utilizes a positive means such as a lock, either key or combination type, to hold an energy isolating device in the safe position and prevent the energizing of a machine or equipment. |
| ANSI/ASSE Z244.1-2003 Control of Hazardous Energy Lockout/Tagout and Alternative Methods | 2.14 lockout/tagout<br>The placement of a lock/tag on the energy isolating device in accordance with an established procedure, indicating that the energy isolating device shall not be operated until removal of the lock/tag, in accordance with an established procedure.<br><br>2.13 lockout device<br>A positive means, such as a lock, that secures an energy isolating device in a position that prevents the energizing of a machine, equipment or process. |
| ISO12100-2:2003 Safety of machinery — Basic concepts, general principles for design — Part 2: Technical principles | 5.5 Complementary protective measures<br>5.5.4 Measures for isolation and energy dissipation<br>Especially with regard to their maintenance and repair, machines shall be equipped with the technical means to achieve the isolation from power supply(ies) and dissipation of stored energy as a result of the following actions:<br>-locking (or otherwise securing) all the isolating units in the isolating position; |
| IEC60204-1:2005 Safety of machinery – Electrical equipment of machines – Part 1: General requirements | 5. Incoming supply conductor terminations and devices for disconnecting and switching off<br>5.3 Supply disconnecting (isolating) device<br>5.3.3 Requirements<br>When the supply disconnecting device is one of the types specified in 5.3.2 a) to d) it shall fulfill all of the following requirements:<br>- be provided with a means permitting it to be locked in the OFF (isolated) position (for example by padlocks). When so locked, remote as well as local closing shall be prevented;<br>5.6 Protection against unauthorized, inadvertent and/or mistaken connection<br>The devices described in 5.4 and 5.5 that are located outside an enclosed electrical operating area shall be equipped with means to secure them in the OFF position (disconnected state), (for example by provisions for padlocking, trapped key interlocking). When so secured, remote as well as local reconnection shall be prevented. |

## 6. Conclusion

In this paper, we reported on the analysis of various methods for preventing accidental startup of machinery when operators are working in hazardous areas. We also described the effectiveness of a padlockable safety switch and a padlockable emergency stop switch to ensure the safety of operators working in a hazardous area. Engaging a padlock to prevent machinery startup is a complementary protective measure based on operation rules. However, in cases where it is difficult at the design stage to predict the exact number of operators who will work at the same time in a hazardous area, machinery designers will increasingly be required to prepare safety measures for two or more operators, such as providing startup prevention with padlocks. IDEC will continue to make pre-emptive changes in safety concepts, and use our utmost efforts in pursuing safety of safety products and technological achievement.

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