

requirements determined by the risk assessment of the machine and the applicable functional safety standards.

**9.2.1 Start Functions.** Start functions shall operate by energizing the relevant circuit.

**9.2.2\* Stop Functions.** Stop functions shall override related start functions. The reset of the stop functions shall not initiate any hazardous conditions. The three categories of stop functions shall be as follows:

- (1) Category 0 is an uncontrolled stop by immediately removing power to the machine actuators.
- (2) Category 1 is a controlled stop with power to the machine actuators available to achieve the stop then power is removed when the stop is achieved.
- (3) Category 2 is a controlled stop with power left available to the machine actuators.

### 9.2.3 Operating Modes.

**9.2.3.1** Each machine shall be permitted to have one or more operating modes (e.g., automatic, manual, normal, and bypass) determined by the type of machine and its application.

**9.2.3.2** Where a hazardous condition results from mode selection, inadvertent selection shall be prevented from occurring (e.g., key-operated switch, access code). Mode selection by itself shall not initiate machine operation. A separate action by the operator shall be required.

**9.2.3.3\*** Safeguarding means shall remain effective for all operating modes.

**9.2.3.4** Indication of the selected operating mode shall be provided (e.g., position of mode selector, provision of indicating light, visual display indication).

**9.2.4 Overriding Safeguards.** Where it is necessary to temporarily override one or more safeguards, a mode selection device or means capable of being secured (e.g., locked) in the desired mode shall be provided to prevent automatic operation. The control circuit for the suspension of a safeguard shall have the same safety requirements as the suspended safeguard itself. In addition, one or more of the following measures shall be provided:

- (1) Initiation of motion by a hold-to-run or other control device.
- (2) A portable control station (e.g., pendant) with an emergency stop device, and where used, an enabling device. Where a portable station is used, motion shall only be initiated from that station.
- (3) Limiting the speed or the power of motion.
- (4) Limiting the range of motion.

### 9.2.5 Operation.

#### 9.2.5.1 General.

**9.2.5.1.1** The necessary interlocks shall be provided for safe operation.

**9.2.5.1.2** Measures shall be taken to prevent movement of the machine in an unintended manner after any stopping of the machine (e.g., locked-off condition, power supply fault, battery replacement, lost signal condition with cableless control).

#### 9.2.5.2 Start.

**9.2.5.2.1** The start of an operation shall be possible only where all of the safeguards are in place and functional except for conditions as described in 9.2.4.

**9.2.5.2.2** On those machines where safeguards cannot be applied for certain operations, manual control of such operations shall be by hold-to-run controls together with enabling control, where appropriate.

**9.2.5.2.3** Interlocks shall be provided to ensure correct sequential starting.

**9.2.5.2.4** On machines requiring the use of more than one control station to initiate a start, the following criteria shall be met:

- (1) Each control station shall have a separate manually actuated start control device.
- (2) All required conditions for machine operation shall be met.
- (3) All start control devices shall be in the released (off) position before a start operation is permitted.
- (4) All start control devices shall be actuated concurrently.

#### 9.2.5.3 Stop.

**9.2.5.3.1\*** Category 0, Category 1, and/or Category 2 stops shall be provided as determined by the risk assessment and the functional requirements of the machine. Category 0 and Category 1 stops shall be operational regardless of operating modes, and Category 0 shall take priority.

**9.2.5.3.2** Where required, provisions to connect protective devices and interlocks shall be provided. Where applicable, the stop function shall signal the logic of the control system that such a condition exists.

**9.2.5.4\* Emergency Operations (Emergency Stop, Emergency Switching Off).** Emergency operation requirements are as follows:

- (1) This section specifies the requirements for the emergency stop and the emergency switching-off functions of the emergency operations, both of which are initiated by a single human action.
- (2) Once active operation of an emergency stop (*see Section 10.7*) or emergency switching off (*see Section 10.8*) actuator has ceased following a command, the effect of this command shall be sustained until it is reset. This reset shall be possible only at that location where the command has been initiated. The reset of the command shall not restart the machinery but only permit restarting.
- (3) It shall not be possible to restart the machinery until all emergency stop commands have been reset. It shall not be possible to reenergize the machinery until all emergency switching off commands have been reset.

**9.2.5.4.1 Emergency Stop.** Emergency stop functions provided in accordance with 9.2.5.3 shall be designed to be initiated by a single human action.

**9.2.5.4.1.1** In addition to the requirements for stop, the emergency stop shall have the following requirements:

- (1) It shall override all other functions and operations in all modes.
- (2) Power to the machine actuators, which causes a hazardous condition(s), shall be removed as quickly as possible

without creating other hazards (e.g., by the provision of mechanical means of stopping requiring no external power, by reverse current braking for a Category 1 stop).

- (3) The reset of the command shall not restart the machinery but only permit restarting.

**9.2.5.4.1.2** Where required, provisions to connect additional emergency stop devices shall be provided in accordance with Section 10.7.

**9.2.5.4.1.3** The emergency stop shall function as either a Category 0 or a Category 1 stop (see 9.2.2). The choice of the category of the emergency stop shall be determined by the risk assessment of the machine.

**9.2.5.4.1.4\*** Where a Category 0 or Category 1 stop is used for the emergency stop function, it shall have a circuitry design (including sensors, logic, and actuators) according to the relevant risk as required by Section 4.1 and 9.4.1. Final removal of power to the machine actuators shall be ensured and shall be by means of electromechanical components. Where relays are used to accomplish a Category 0 emergency stop function, they shall be nonretentive relays.

*Exception: Drives, or solid state output devices, designed for safety-related functions shall be allowed to be the final switching element, when designed according to relevant safety standards.*

**9.2.5.4.2\* Emergency Switching Off.** Where the emergency switching-off function is used, it shall be initiated by a single human action.

**9.2.5.4.2.1** Emergency switching off shall be permitted under any of the following conditions:

- (1) Where protection against direct contact (e.g., with collector wires, collector bars, slip-ring assemblies; control gear in electrical operating areas) is achieved only by placing out of reach or by obstacles
- (2) Where other hazards or damage caused by electricity are possible

**9.2.5.4.2.2** Emergency switching off shall be accomplished by disconnecting the machine supply circuit of the machine effecting a Category 0 stop. Where the machine cannot tolerate the Category 0 stop, it shall be necessary to provide other protection (e.g., against direct contact), so that emergency switching off is not necessary.

#### **9.2.5.5 Hold-to-Run Controls.**

**9.2.5.5.1\*** Hold-to-run controls (e.g., jog, inch functions) shall require continuous actuation of the control device(s) to achieve operation.

**9.2.5.5.2** Jog or inch functions shall operate only in the manual mode. Manual reverse shall be considered a jog function. The prevention of run or automatic operation during jog or inch shall be accomplished by an operator interface and a separate jog or inch selection method.

**9.2.5.6\* Two-Hand Controls.** All two-hand controls shall have the following features:

- (1) The provision of two control devices shall require the concurrent actuation by both hands.
- (2) It shall be necessary to actuate the control devices within a certain time limit of each other, not exceeding 0.5 second.

- (3) Where this time limit is exceeded, both control devices shall be released before operation is initiated.
- (4) The control devices shall require continuous actuation during the hazardous conditions.
- (5) Machine operation shall cease upon the release of either control device when hazardous conditions are still present.
- (6) Machine operation shall require the release of both control devices before the machine operation is re-initiated.

#### **9.2.5.7 Enabling Control.**

**9.2.5.7.1** An enabling control function incorporating the use of an enabling device shall, when activated, allow machine operation to be initiated by a separate start control and, when deactivated, stop the machine and prevent initiation of machine operation. An enabling device provided as a part of the enabling control function shall be designed to allow motion when actuated in one position only. In any other position, motion shall be inhibited.

**9.2.5.7.2** Enabling controls shall have the following features:

- (1) Connect to a Category 0 or a Category 1 stop (see 9.2.2)
- (2) Design follows ergonomic principles
- (3) For two-position types, the positions are as follows:
  - (a) Position 1 is the off function of the switch (actuator is not operated).
  - (b) Position 2 is the enabling function (actuator is operated).
- (4) For three-position types, the positions are as follows:
  - (a) Position 1 is the off function of the switch (actuator is not operated).
  - (b) Position 2 is the enabling function (actuator is operated in its mid position).
  - (c) Position 3 is the off function of the switch (actuator is operated past its mid position).
- (5) A three-position enabling control shall require manual operation to reach Position 3. When returning from Position 3 to Position 2, the function shall not be enabled.

**9.2.5.7.3** An enabling control shall automatically return to its off function when its actuator is not manually held in the enabling position.

**9.2.6 Combined Start and Stop Controls.** A single pushbutton and other devices that alternately start and stop motion shall only be used for secondary functions where no hazardous condition arises when they are operated.

#### **9.2.7 Cableless Control Functions.**

**Δ 9.2.7.1\* General.** Cableless control (e.g., radio, infrared) techniques for transmitting commands and signals between a machine control system and operator control station(s) shall meet the requirements of 9.2.7.1.1 through 9.2.7.1.4.

**9.2.7.1.1** Means shall be provided to verify the memory elements of the operator control station with the machine.

**9.2.7.1.2** Means (e.g., key-operated switch, access code) shall be provided, as necessary, to prevent unauthorized use of the operator control station.

**9.2.7.1.3** Each operator control station shall carry an unambiguous indication of which machine(s) is intended to be controlled by that operator control station.