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Technical Information

SERVO PRESS -----
SAFETY REQUIREMENTS AND MEASURES

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Japan Forming Machinery Association Technical Information

Servo Press -- Safety Requirements and Measures

Foreword

This TI103:2008 standard is a revision of the Japan Forming Machinery Association TI103:2006 standard issued in 2006 by the Japan Forming Machinery Association. This updated standard acknowledges the distinctive hazards inherent in servo presses and especially in the servo systems used to drive them, and moreover, takes into consideration conformity with the ISO/IEC functional safety standards which have been significantly augmented in recent years.

1. Scope of Application

This standard stipulates the distinctive hazards inherent in a servo press (see 4.1), and stipulates the requirements to be used to eliminate such hazards or to reduce the risks associated with such hazards to an appropriate level.

The scope of application of this standard is not limited by the specifications of the servo press, such as the tonnage capacity, the strokes per minute, or its dimensions. However, this standard does not apply to mechanical presses with linear servo mechanisms and hydraulic presses equipped with servo valves.

2. Related Standards

The act of citing the following standards denotes that they are incorporated as a part of this standard. If a specific year is called out in one of the following cited standards, the edition for that given year is applicable, and subsequent revised editions (including supplements) are not applicable. If a specific year is not called out in a referenced standard, the latest version of that standard (including supplements) is applicable.

2.1 JIS B 0111 Presswork machinery – Vocabulary

2.2 JIS B 8361 (ISO 4413) General rules for hydraulic equipment --Safety of machinery -- Basic concepts, general principles for design -- Part 1: Basic terminology, methodology

2.3 JIS B 9700-1:2004 (ISO 12100-1:2003) Safety of machinery -- Basic concepts, general principles for design -- Part 1: Basic terminology, methodology

2.4 JIS B 9700-2:2004 (ISO 12100-2:2003) Safety of machinery -- Basic concepts, general principles for design -- Part 2: Technical principles

2.5 JIS B 9702:2000 (ISO 14121:1999) Safety of machinery -- Principles of risk assessment

2.6 JIS B 9703 (ISO 13850:1996) Safety of machinery -- Emergency stop -- Principles for design

2.7 JIS B 9704-1:2006 (IEC 61496-1) Safety of machinery – Electro-sensitive protective equipment -- Part 1: General requirements and tests

2.8 JIS B 9705-1:2000 (ISO 12849-1:1999) Safety of machinery -- Safety-related parts of control systems -- Part 1: General principles for design

2.9 JIS B 9714:2006 (ISO 14118) Safety of machinery -- Prevention of unexpected start-up

2.10 JIS B 9960-1:1999 (IEC 60204-1:1997) Safety of machinery -- Electrical equipment of machines -- Part 1: General requirements

2.11 ISO 13732-1 Ergonomics of the thermal environment -- Methods for the assessment of human responses to contact with surfaces -- Part 1: Hot surfaces

2.12 IEC 61800-3 Adjustable speed electrical power drive systems -- Part 3: EMC requirements and specific test methods

2.13 IEC 61800-5-1 Adjustable speed electrical power drive systems -- Part 5-1: Safety requirements – Electrical, thermal and energy

3. Table of Contents

4. Terminology and Definitions

The terminology and definitions used in this standard are based on those given in JIS B 0111 and JIS B 9700-1 and those given below.

4.1 Servo press

A mechanical or hydraulic press where the motion of the slide is controlled by a servo system

(see 4.2).

4.1.1 Mechanical servo press

A servo press configuration where the power of a servo motor is transmitted to the slide by means of a crank or some other rotating mechanism or by means of a ball screw or some other direct drive mechanism. Such a system configuration is shown in Figure 1.

Note 1: Mechanical servo presses are included in Definition 1000 of a “Mechanical Press” given in JIS B 0111.

4.1.2 Mechanical servo press brake

Primarily a mechanical servo press designed for bending plate-shaped material.

4.1.3 Hydraulic servo press

A servo press configuration where the power of the servo motor is transmitted to the slide by means of hydraulic pressure. Such a system configuration is shown in Figure 2.

Note 1: Hydraulic servo presses are included in Definition 2000 of a “Hydraulic Press” given in JIS B 0111.

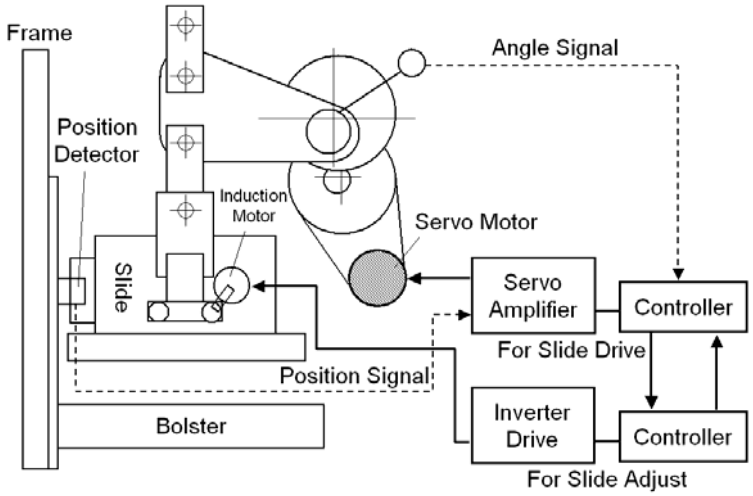


Figure 1: Example of a Mechanical Servo Press System Configuration

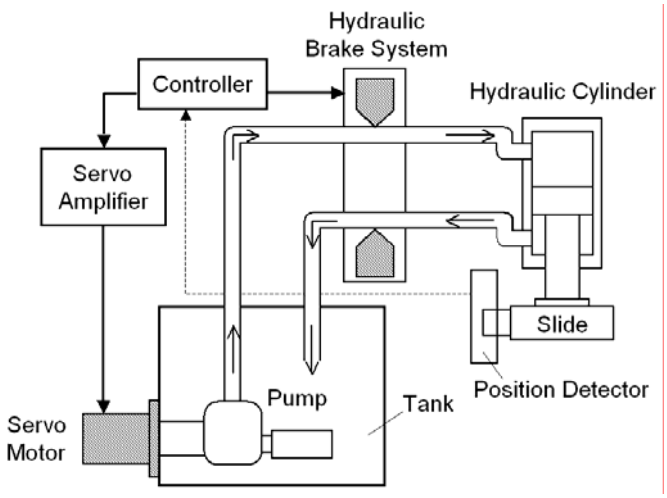


Figure 2: Example of a Hydraulic Servo Press System Configuration

4.1.4 Hydraulic servo press brake

A hydraulic servo press primarily designed for bending plate-shaped material.

4.2 Servo system

A system for moving the slide that includes a servo motor, a servo amplifier (inverter circuit), a feedback detection device, electrical braking equipment, and control equipment (a controller).

Note: A servo system is defined as the entire system related to slide motion, and aside from the element examples given in Figure 1 and Figure 2, it also includes interface equipment that enables the user to make program settings, and safety programmable logic controllers (safety PLCs) that are used to monitor protective device and standard control system faults. The areas (subsystems) related to safety functions in the servo system are considered to be the safety-related parts.

4.3 Brake system

A mechanism outside of the servo system that slows and stops the slide, then holds the slide in a stopped state. There are mechanical brake systems and hydraulic brake systems.

Note: These are considered to be systems that hold the slide for relatively short periods of time in order to insert or remove workpieces, etc., and these are clearly differentiated from the slide restraint means explained in 4.12.

4.3.1 Mechanical brake system

A brake system that uses mechanical friction to slow and stop the slide and then holds the slide in a stopped state.

4.3.2 Hydraulic brake system

A brake system that shuts off or adjusts the pressure or flow rate of the fluid that transmits the power of the servo motor in order to slow and stop the slide and then hold the slide in a stopped state. Such a system is composed of cylinders, solenoid valves that control the pressure or flow rate of the fluid, and the requisite piping. Also referred to as a hydraulic gravity restraint device.

4.4 Electrical braking

A servo system function that slows and stops the slide using electrical means such as electrical, electronic, and programmable electronic circuits and/or elements.

Note 1: It is permissible for electrical braking not to be able to hold the slide in a stopped state.

Note 2: It is to be a Stop Category 1 stop as defined in JIS B 9960-1, 9.2.2 only when a power shutdown (see 4.5) is being performed.

4.5 Power shutdown

Operations or servo system functions that shut off or prevent the supply of electrical power to the servo motor. The methods can be classified as follows, based on the different principles used.

Note 1: A Stop Category 0 or 1 stop as defined in JIS B 9960-1, 9.2.2 accompanies the performance of a power shutdown.

Note 2: Refer to Annex 8.4 for detailed explanations about power shutdown method classifications.

4.5.1 Main power shutdown

A power shutdown method where electromechanical components are utilized to shut down (disconnect) the entire servo system's electrical power supply from the main line.

Note: It is permissible not to disconnect the power supply going to 'exempted circuits' stipulated in JIS B 9960-1, 5.3.5 and to display equipment that provides necessary information during inspections or repairs as long as the equipment conforms with the relevant requirements given in JIS B 9960-1.

4.5.2 Electromechanical shutdown

A power shutdown method where electromechanical components are utilized to disable the transmission of electrical power to the servo amplifier and/or servo motor.

4.5.3 Electronic shutdown

A power shutdown method where, in response to a signal from an external device which does not include (does not go through) a programmable electronic circuit (control circuit) between the signal input point and the inverter circuit, a semiconductor element is used to disable the servo amplifier's alternating current generation.

Note 1: Depending on the semiconductor element being used, it may also be referred to as a gate off or base current shutdown, etc.

Note 2: Electronic shutoff systems do not include systems where a signal from an external device is processed by a control circuit within the servo amplifier (see 8.4).

4.6 Stops

4.6.1 Emergency stop

A condition where the slide has come to a stop in response to the operation of an emergency stop device.

4.6.2 Protective stop

A condition where the slide has automatically stopped for protective purposes in response to a detection signal. Protective stop types include protective stops that are executed in response to a signal from an interlocking device, an active opto-electronic protective device, or a two-hand operation control device, etc., and protective stops that are executed in response to a signal from an internal subsystem that monitors faults, etc., in the servo system or brake system.

4.6.3 Normal stop

A condition where the slide has come to a stop at a specifically programmed position (e.g., top dead center, a standby position, or a planned stop position). This is a condition intended for the intrusion of some part of the body of the operator inside the hazard zone in order to insert or remove a workpiece.

Note: During a normal stop, protective devices such as guard interlocking devices, active opto-electronic protective devices, or two-hand operation control devices are muted (see 4.8), and risk reduction is achieved by functions and/or systems that securely hold the slide in place.

4.6.4 Temporary stop

A condition where the slide has come to a temporary stop in response to a standby signal or direction change signal in the program, or in response to the stopping of a start operation (e.g., due to a hand being removed from start button, or a foot being removed from a foot switch). There is no intent to have some part of the body of the operator enter inside the hazard zone.

Note: Protective devices such as guard interlocking devices, active opto-electronic protective devices, or two-hand operation control devices are not muted (see 4.8), and the stop condition changes to a protective stop condition if the intrusion of any part of the operator's body is detected.

4.7 Protective open

A safety function in response to a signal from a protective device that moves the slide in the direction that will increase the distance between the upper and lower dies (the opening direction) for protective purposes instead of executing a protective stop.

Note: The term 'protective open' is also used to refer to special kinds of protective actuations,

even including cases where the slide upstroke does not correspond to the opening stroke and the slide downstroke does not correspond to the closing stroke.

4.8 Muting

The temporary automatic stopping of the safety functionality of safety-related parts of the control system.

Note: Refer to JIS B 9705-1, definition 3.7.

4.8.1 Muting during slide opening

The muting of protective devices in the operational single stroke mode that is executed by moving the slide in a direction that increases the clearance between the upper and lower dies (opening stroke) during the timeframe from when the slide movement has reached a position where the decrease in clearance between the upper and lower dies (closing stroke) will end before any part of the body of an operator will reach the hazard zone until the slide reaches the end point and stops .

Note: The term 'muting during slide opening' is also used to refer to special kinds of muting, even including cases where the slide upstroke does not correspond to the opening stroke and the slide downstroke does not correspond to the closing stroke.

4.9 Programmed slide stroke

The distance between the upper and lower dies at the position where a programmed normal stop is performed during the current stroke.

Note: This has been redefined for servo presses because the slide motion range during the process currently executed does not necessarily match the structurally determined natural stroke length, and there may even be times when changes are occurring in every cycle.

4.10 Monitoring function

A safety function that detects the occurrence of a monitored hazardous condition, initiates the protective stop function, and displays the fault.

4.10.1 Start/stop monitoring

A monitoring function that compares and detects disagreement between the start initiation, operation permission, and stop signals from start (operation) and protective devices and the motion conditions of the servo motor, the brake system, and the slide that are related to the starting and stopping of the slide.

4.10.2 Overrun monitoring

A monitoring function that monitors the slide stopping time or the braking distance when a normal stop function is executed, and detects when the allowable values have been exceeded.

4.10.3 Standstill monitoring

A monitoring function that monitors whether the slide is being held at the programmed stop position during a normal stop, and detects unintended starts (actuation malfunctions).

4.10.4 Brake performance monitoring

A monitoring function that statically or dynamically monitors brake system actuation and brake performance, and detects non-actuations or degraded performance.

4.11 Presence sensing before initiation

A function, device, and/or procedure that detects and gives warning of the presence of personnel other than the operator inside the hazard zone before the initiation of slide motion.

4.12 Slide restraint means

A slide restraint device or component used to prevent hazardous slide motion or the slide from

falling while performing adjustment, cleaning, inspection, and maintenance tasks.

4.12.1 Mechanical slide restraint device

A slide restraint means that uses the strength of a built-in mechanical impediment (e.g., a wedge, spindle, or brace) to prevent hazardous slide motion.

Note: This is also sometimes referred to as a mechanical gravity restraint device, but devices that use mechanical friction principles (e.g., devices that utilize a worm gear self-lock) are not included in the definition of mechanical slide restraint devices.

4.12.2 Safety block

A slide restraint means where the strength of a block shape that is inserted between the bolster or lower die and the slide or upper die is used to prevent hazardous slide motion.

4.13 Operation mode

4.13.1 Operational single stroke

An operation mode where the slide moves along a programmed path from a start point to an end point for only one cycle when the start operation is performed, and when the end point is reached the slide stops even if the start operation continues to be performed.

Note: This term has been newly stipulated as it is a term that expresses the uniqueness of servo presses, where slide path changes are made via the program, and it has also been adopted because it has become standard to equip the power presses of today with a single stroke function.

4.13.2 Inching stroke

An operation mode where the slide moves along a programmed path while the start operation is being continuously performed, and then the slide stops immediately once the start operation is discontinued.

4.13.3 Continuous stroke

An operation mode where the slide moves repeatedly and continuously along a programmed path when the start operation is performed once, and does not stop until a stop operation is performed.

4.14 Cycle

The slide motion or stroke cycle from a programmed start point to a programmed end point.

4.15 Manual pulse generator

A device used for manual feeding where command pulses are generated by manually turning a handle.

4.16 Hand-in-die

A press machine or a press work method where the workpiece is manually fed and removed.

4.17 No-hand-in-die

A press machine or a press work method where the workpiece is fed and removed mechanically or automatically, thereby eliminating the necessity of having the operator place any part of their body inside the hazard zone during the forming process.

5. Identification of Distinctive Hazards Inherent in Servo Presses and Risk Assessment

A table showing the distinctive hazards inherent in servo presses that are covered in this standard is given in Annex 8.1.

A hazard analysis shall identify all possible future hazards. A risk assessment that takes into consideration all of the following shall be performed for the identified hazards.

a) Intentional servo press operations, including settings, adjustments, die changes, setup, cleaning, maintenance, and repairs.
b) Unexpected start-up.
c) Access of personnel from any direction.
d) Usage by unqualified and untrained personnel
e) Reasonably foreseeable misuse.
f) Effects of control system and component part failures.
g) Transportation, installation, and startup-related aspects.
h) Removal from service and disposal-related aspects.
i) Hazards related to specific usages or applications.

Risks shall first be eliminated or minimized by means of the design (e.g., designs where a person or some part of their body will not enter inside the hazard zone), and second by protective and other additional measures (e.g., providing interlocking guards or protective devices). All types of residual risks shall be reduced through other measures (e.g., warnings, caution signs, and training)

The safety requirements in item 6 were formulated by implementing risk assessments for the hazards given in Annex 8.1 and the repeated application of the risk reduction strategies given in JIS 9700-1, Figure 1 and Figure 2, and in JIS B 9700-2.

Note 1: Examples of risk assessment results for servo presses with different intended usages are shown in Annex 8.2.

Note 2: JIS B 9700-1, JIS B 9700-2, and JIS B 9702 give the requirements and guidelines when performing hazard identification and risk reduction.

<Commentary>

The requirements in item 6 are limited in scope to the hazards stipulated in Annex 8.1, but the identification and risk evaluation of hazards that take into consideration all aspects of the servo press usages given in item 5 are to be performed during the risk assessment, and at the same time it is necessary to eliminate or reduce significant hazards not stipulated in Annex 8.1 by implementing the 3-step risk reduction process method stipulated in JIS B 9700-1.

6. Safety Requirements and Protective Measures

6.1 Overview

Servo presses shall be designed and manufactured in compliance with the requirements given in this item with respect to the hazards stipulated in item 5. Hazards and risks other than those given in item 5 shall be eliminated or reduced in the design and manufacture of the machine in accordance with all applicable regulations, such as the Ordinance on Industrial Safety and Health and the Construction Code for Power Press, and with JIS B 9700-1.

6.2 Basic Safety Requirements

6.2.1 Guarding Power Transmission Components

Exposure to hazards originating from components related to power transmission, such as motors shafts, gears, belts, or link mechanisms, shall be prevented by means of fixed or movable guards. Movable guards shall incorporate interlocking system that will stop hazardous motion before contact

is made with a hazard. Based on the results of a risk assessment, the safety performance of the interlocking system shall be designed to comply with 6.3.

6.2.2 Belt Drive Malfunctions

For servo presses with mechanisms that utilize a belt to transmit the power or torque used to brake the slide, a single failure of a belt due to belt breakage, etc., shall not lead to the loss of the stopping functionality. A single failure shall be detected immediately, and at the time it is detected a shutdown of the power source shall be performed and the slide shall be held by means of the brake system, and restarting shall be prevented until the failure is repaired.

Note 1: Single failures aside from belt breakage that shall be taken into consideration include belt elongation, looseness, and separation, belt pulley idling, tooth skipping, etc.

Note 2: Designs where the transmission of the braking power or braking torque does not reside in a belt include designs where an electromagnetic brake is mounted on the mechanical structures on the driven side and the braking torque is mechanically transmitted to the slide.

6.2.3 Electrical Equipment

In order to prevent electric shock resulting from direct contact or indirect contact, the electrical equipment of the servo press shall be designed and manufactured in accordance with the relevant requirements in JIS B 9960-1 and IEC 61800-5-1.

6.2.4 Electrical Power Supply Loss and Fluctuation

Fluctuations in the electrical power supply, such as the loss of the electrical power supply due to a power outage or a momentary power loss, shall not result in the creation of a hazard. Especially as it relates to the safety-related parts of the servo system stipulated in 6.3, it should be designed to comply with the power source voltage fluctuation and momentary power outage requirements stipulated in JIS B 9704-1, 4.3.2.

No slide motion of any kind must be caused by the restoration of power after a power outage. For example, even in a condition where servo deviation has been caused due to the effects of coasting, restarting shall not be permitted until the reset operation is performed.

<Commentary>

Compliance with JIS B 9704-1, 4.3.2 has been recommended in view of the fact that many of the safety PLCs applicable for usage on power press machines assure conformance with electro-sensitive protective equipment resistance characteristics with respect to power source voltage fluctuations and momentary power outages.

6.2.5 Energy Controls That Use Capacitors

Servo presses that convert and store servo motor energy at the time of braking, etc., shall be designed so that the slide will not move in response to electrical discharges from capacitors after a slide stop that is accompanied by a power shutdown.

In order to reduce the risk of electric shock or burn resulting from residual energy in a capacitor when an enclosure is opened, etc., the circuits related to capacitor and energy storage functionality shall comply with JIS B 9960-1, 6.2.4.

6.2.6 Electromagnetic Compatibility (EMC)

The servo system shall be designed and manufactured in accordance with the relevant

requirements in IEC 61800-3 in order to prevent hazardous slide motion due to the effects of electromagnetic interference (EMI), radio frequency interference (RFI), and electrostatic discharge (ESD). Moreover, as it relates to the safety-related parts of the servo system stipulated in 6.3, the design should comply with the requirements of JIS B 9704-1, 4.3.2.3—4.3.2.7 just as Type 4 electro-sensitive protective equipment does.

If the placement of a servo press in the vicinity of electrical discharge machines, welding machines, and high-current capacity switches can be foreseen and noise countermeasures become necessary in addition to circuit countermeasures that use parts with high noise resistance, appropriate warnings and instructions shall be included in the information for use. Prescribed noise countermeasures include but are not limited to the usage of covers, shields, noise filters, and surge absorbers.

Note: Also included in the meaning of hazardous slide motion is 'not stopping at the normal position.'

<Commentary>

Compliance with JIS B 9704-1, 4.3.2.3—4.3.2.7 has been recommended in view of the fact that many of the safety PLCs applicable for usage on power press machines assure electromagnetic compatibility that conforms with Type 4 electro-sensitive protective equipment. IEC-61800-3 is the European EMC protocol compliance standard for variable speed drive systems.

6.2.7 High Temperature Protection

Servo system components or circuits where the creation of a hazardous condition is possible due to a servo motor or resistor reaching an abnormally high temperature shall be protected by one of the following:

a) Designs that prevent the occurrence of abnormally high temperature conditions by providing detection methods that have adequate responsiveness.

b) The usage of guards to prevent direct contact with locations that reach high temperatures.

Warnings shall be provided for any residual risks even when the above protective measures are implemented.

Note: Refer to ISO 13732-1 and IEC 61800-5-1.

6.2.8 Prevention of Unintended Startup

In order to prevent unintended starting of the slide, the slide of a servo press shall not actuate by any switch operation other than the switch operation of the specified start (operation) equipment, except in cases where a process is selected where the slide is started in response to a signal from external equipment as stipulated in 6.12.5.

Note 1: Refer to JIS B 9714.

Note 2: The 'process for starting the slide in response to a signal from a protective device' explained in 6.12.5 and the 'process for starting the slide in response to a signal from external equipment' explained in 6.12.6 are not mandatory operation modes.

6.2.9 Prevention of Unanticipated Pressure

The hydraulic systems in servo press shall be designed and manufactured in accordance with the relevant requirements given in JIS B 8361. When the occurrence of pressure that exceeds the maximum usage pressure is avoided by relying solely on the pressure of the servo system or the flow control functions, the related subsystems shall comply with 6.3.

<Commentary>

In JIS B 8361 it stipulates that hydraulic systems are to either be designed to anticipate the

occurrence of pressure that exceeds the rated pressure or to be equipped with one or more release valves, and pressure adjustment control functions that reside in the servo system shall not serve as the primary countermeasure for preventing high pressure. Especially in the case of hydraulic systems in servo press, a safe condition is a condition where the pressure has fallen, but if a failure has occurred in the servo system, it is not necessarily the case that a servo motor power shutdown can guarantee a reduction in pressure.

6.3 Safety-related parts of Servo System

Control functions for protective purposes whose malfunction would be directly linked to increased risks are defined as safety functions (Refer to JIS B 9705-1:2000, Item 5). Subsystems, components, and devices related to the attainment of safety functions shall be identified as safety-related parts of the servo system, and the clear information for use shall be provided in supplemental documents.

The safety-related parts of a servo system shall comply with the Category 4 requirements stipulated in JIS B 9705-1, 6.2.5. Specifically, they shall be designed as follows:

a) No single failure of any part will result in the loss of the safety function.
b) All single failures are to be detected by or before the time of a demand for the actuation of the subsequent safety function.
c) When a single failure occurs, the safety function is always to be executed, and a safe condition is to be maintained until the detected failure is repaired.
d) In cases where detection is not possible, cumulative failures will not result in the loss of the safety function.

Note 1: As long as the achievement of an equivalent risk reduction level can be assured, it is permissible to employ performance standards other than those stipulated in JIS B 9705-1:2000, such as performance levels and safety integrity levels.

However, for an intended usage (e.g., no-hand-in-die usage), etc., and as necessary, a performance standard other than Category 4 (i.e., Category 2 or 3) can be selected based on the results of individual risk assessments. In such cases, it shall be clearly stated that a category other than Category 4 has been selected, and appropriate limitations and warnings shall be included in the information for use. Examples of risk assessment results in cases where a category other than Category 4 has been selected are given in Annex 8.2.

6.4 Stop Functions

6.4.1 Overview

Servo presses shall have the emergency stop function stipulated in 6.4.2.

Stops made for protective purposes in response to a stop signal from protective devices (e.g., guard interlocking devices, active opto-electronic protective devices, or two-hand operation control devices) or in response to a stop signal from a monitoring function that detects faults in the servo system or the brake system shall be achieved using a protective stop function that complies with 6.4.3.

Stops performed for the purpose of feeding and removing workpieces shall be achieved by means of a normal stop function that complies with 6.4.5. A summary of the above is given in Table 1, and a comparison of safety function implementations and a comparison of the methods for attaining such are given in Annex 8.3.

Table 1: Summary of Requirements Stipulated in 6.4: Stop Functions

Stop Function	Function Demand/Initiation	Stop Category	Power Shutdown while Maintaining a Stop	Brake System while Maintaining a Stop	Remarks (Related Items)
Emergency Stop Function	Manual	0 or 1	Yes	Yes	6.4.2
Protective Stop Function	By a monitoring function	0 or 1	Yes	Yes	6.4.3.2
	By a protective device	0 or 1	Yes	Yes	6.4.3.3 a)
		—	—	Yes	6.4.3.3 b)
Normal Stop Function	By a program; by an intended operation	0 or 1	Yes	Yes	6.4.5.2
		—	—	Yes	6.4.5.3
		2	—	—	6.4.5.4
Note: Items shown as "—" are not stipulated in this standard.					

6.4.2 Emergency Stop Function

Servo presses shall have the following emergency stop function which can be initiated by a single manual motion.

a) Functions as a Stop Category 0 or 1 stop.
b) Complies with the relevant requirements in JIS B 9960-1 and with 6.3.
c) Holds the slide immediately or after the braking of the slide by means of the brake system.
d) Takes precedence over all other operations, controls, and functions.
e) Can only be manually reset at the position where the emergency stop command was output. A manual reset only serves to permit a restart, and the resetting itself does not immediately restart the slide.
f) After the manual reset operation is performed, no operation mode other than an inching stroke is to be initiated until the slide is returned to the start point position.

The emergency stop device shall comply with JIS B 9960-1, 10.7 and with JIS B 9703. The examples of a redundant design of a power shutdown system intended to comply with 6.3 are shown in Annex 8.4, Figure 8.4.2,8.4.3,8.4.4.

6.4.3 Protective Stop Function

6.4.3.1 Overview

To the extent that a servo press does not employ intrinsic safety design measures to eliminate crushing hazards or appropriately reduce the risks associated with such, it shall have the protective stop functionality stipulated in 6.4.3.2 and 6.4.3.3. It is permissible for these stop categories to be different.

Subsystems related to protective stop function shall comply with 6.3.

The time from the actuation request for a protective stop function until the stop is completed (i.e., the protective stopping time) shall comply with 6.4.3.4.

6.4.3.2 Protective Stops Resulting from Monitoring Functions

Protective stop functions initiated by signals from the monitoring functions stipulated in 6.6 and as a result of the detection of some other servo system fault shall function as a Stop Category 0 or 1 stop and shall hold the slide by means of the brake system.

Note: See 6.6.1 for other requirements at the time a hazardous condition is detected by a monitoring function.

6.4.3.3 Protective Stops Resulting from Protective Devices

A protective stop function initiated by a signal from a protective device must comply with one of the following:

a) It is to function as a Stop Category 0 or 1 stop, and hold the slide by means of the brake system.

b) It is to hold the slide by means of a brake system that has the capacity to hold the slide in position even when the maximum starting torque of the servo motor is being applied. Electrical braking may be used for braking the slide. Power shutoff is not mandatory, but if there is the possibility of a hazard condition (e.g., unexpected slide slippage) or a new hazard due to an overload when the servo motor torque continues to be applied (e.g., extremely high temperatures or fluids spraying out under high pressure), the implementation of a power shutdown shall be studied as a protective measure.

If a protective stop is initiated by a signal from a protective device, the design should maintain the protective stop function until the protective device is manually reset.

6.4.3.4 Protective Stopping Time

The completion of a protective stop is defined as a condition where all of the following have been achieved.

a) Slide motion has decelerated to a speed of 10 mm/s or less.

b) The brake system has been actuated.

c) If it functions as a Stop Category 0 or 1 stop, the power shutdown has been performed..

The time from the actuation request for a protective stop function to the time the stop is completed (i.e., the protective stopping time) shall not exceed the time given in 7.2 regardless of the type of single failure that has occurred. For example, in a case where the protective stop function works as a Stop Category 1 stop, the attainment of a protective stop condition shall not be delayed due to the effects of a power source failure. Accordingly, the manufacturer shall specify the longest single failure condition (i.e., worst case) as the time required for the stop, and shall display the stopping time under such a condition as the protective stopping time.

Note 1: In definition 3.2 'total system stopping performance' in JIS B 9715, the protective stopping time is equivalent to the machine's maximum response time t2, and does not include the time t1, which is defined as the time from when a protective device detection monitor actuates until the output signal switch reaches an OFF state.

Note 2: For servo presses where electrical braking (deceleration control) is performed at the time of a protective stop, an analysis of the servo system hardware and/or software may be required in some cases in order to determine the worst case (refer to IEC 61800-5-2).

<Commentary>

Included in protective stop functions are those initiated by a stop signal from monitoring equipment and those initiated by a stop signal from protective devices, and it is permissible for these stop categories to be different. However, when determining the protective stopping time, an analysis shall be performed for all protective stop functions and it will be necessary to specify the worst case

condition as being the longest time required to achieve a), b), and c) when a single failure has occurred.

6.4.4 Protective Open

It is permissible to execute a protective open function instead of the protective stop function stipulated in 6.4.3.3 that is initiated in response to a protective device. However, subsystems related to protective open functionality shall comply with 6.3. Additionally, the direction of slide motion shall change to the opening direction before any part of an operator's body can reach the slide and/or die, and moreover, shall be able to surely prevent a change to the closing direction of the slide during the execution of the protective open function. Also, hazards that are caused by a sudden reversal in the direction of motion (e.g., falling dies, etc.) shall be eliminated by the design.

The protective open function shall not take the place of the protective stop function stipulated in 6.4.3.2 that is initiated in response to monitoring equipment.

6.4.5 Normal Stop Functions

6.4.5.1 Overview

Normal stop functions are functions used to stop the slide for the purpose of feeding and removing a workpiece, and they shall comply with any one of 6.4.5.2—6.4.5.4.

In cases where protective device muting is performed during a normal stop, the muting shall not expose any personnel to a hazardous condition (refer to JIS B 9705-1, 5.9). Accordingly, subsystems related to muting shall comply with 6.3. Also, the muting initiation timing shall comply with 6.4.5.2—6.4.5.4 and shall not permit a slide restart until the muting has ended and all safety functionality has been restored.

The time required to execute a normal stop function shall be designed to be less than or equal to the protective stop time given in 7.2. The normal stopping time shall be monitored each time by means of the overrun monitoring function stipulated in 6.6.3.

The type of servo presses which reverse the direction of movement from the opening direction to the closing direction when their slide overshoots the position where a normal stop is performed (e.g., mechanical servo presses having the same mechanism as a crank press) shall comply with the additional requirement given in 6.4.5.5.

<Commentary>

If the normal stop functionality complies with any one of 6.4.5.2—6.4.5.4, there is no need to continue to comply with any single chosen stipulation in all cases, such as cases where these requirements are used interchangeably depending on the programmed stroke length. Also, there is no requirement to comply with 6.3 (processing/executing normal stop functions in Category 4 safety-related parts) except for the standstill monitoring functions associated with 6.4.5.4. This is because one can foresee servo presses where the entire control of the slide is performed by a standard control system, and where the same subsystem used for the protective stop function is used for a normal stop without muting protective devices.

Muting initiation methods when muting is performed at the time of a normal stop include the following:

a) After moving the slide to the normal stop position using standard control equipment, perform a power shutdown and initiate muting in response to the power shutdown execution.
b) After moving the slide to the normal stop position using standard control equipment, actuate the brake system, and initiate muting in response to that actuation.
c) Using interface equipment(e.g., the slide position detector),detect that the slide has reached the

normal stop position programmed by the user, and initiate muting in response to that detection result.

For all of the above methods, the circuits and equipment related to muting are safety-related parts, and muting shall not be initiated at any timing other than the timing stipulated in 6.4.5.2—6.4.5.4 as a result of a single failure of hardware and/or software. Safety performance that is identical to that of a rotary cam switch system used on a crank press is required

6.4.5.2 Stop Category 0 or 1 Stops

The normal stop function works as a Stop Category 0 or 1 stop, and holds the slide by means of the brake system. In cases where the same subsystem used for the protective stop function is not used for the normal stop function, protective device muting can be initiated simultaneously with a power shutdown.

6.4.5.3 Holding the Slide Using a Brake System with Sufficient Holding Capacity

The slide is to be held by means of a brake system that has the capacity to hold the slide in position even when the maximum starting torque of the servo motor is being applied. Electrical braking may be used for braking the slide. Power shutoff is not mandatory, but in cases where an overload causes a new hazard or hazardous condition, it shall be implemented as a protective measure.

In cases where the same subsystem used for the protective stop function is not used for the normal stop function, protective device muting can be initiated simultaneously with a power shutdown.

6.4.5.4 Stop Category 2 Normal Stops Accompanying Standstill Monitoring

It is to function as a Stop Category 2 stop (i.e. servo stop). However, in cases where a standstill monitoring function that complies with 6.6.4 is executed and erroneous slide motion is then detected, it is change to a protective stop. At such times, one of the following must be complied with:

a) The slide is to be stopped and held while assuring a clearance between the dies that is considered sufficient to avoid crushing any part of the human body. A clearance that is 98% or greater than the programmed slide stroke should be assured.

b) Slide motion in the die closing direction up until the time the slide is stopped and held is to be small enough not to be considered a crushing hazard. Movement should be 2 mm or less.

The muting of protective devices can be initiated simultaneously with the execution of the standstill monitoring function.

Note: Refer to JIS B 9714, 6.4.

<Commentary>

The specific requirements for cases where a Stop Category 2 stop is used for a normal stop function are the same as JIS B 9714, 6.4. However, in order to show a more detailed performance standard for the meaning of the term ‘immediately,’ compliance with a) or b) has been made a requirement in this standard. The value of 98% of the programmed slide stroke recommended in a) is derived from a crank press where the stop position is set at top dead center, as the slide will descend approximately 2% of the stroke length from its upper limit when the crankshaft rotation overshoots (overruns) by approximately 0.26 rads (15 degrees). On the other hand, the 2 mm value recommended in b) is derived from special research conducted by the National Institute of Occupational Safety and Health,Japan in its measurements of the maximum allowable displacement range of each part of the human body, where it found that the 5th percentile value of the maximum

allowable displacement range of the foreheads of 9 adult male subjects was 2.1 mm. (Reference literature: Saito, Ikeda: *Industrial Safety Research Institute Special Report*, NIIS-SRR-No.33 (2005), p. 22.）

In the case of a normal stop, there is the presumption that part of the body of an operator has already entered inside the hazard zone, and thus it is necessary to take into sufficient consideration the possibility that slide movement from the time a malfunction occurs until the protective stop function is completed could immediately result in a hazardous event. Now, as stated previously, depending on the programmed slide stroke settings, it is also permitted to substitute the compliance requirements in 6.4.5.4 with those in 6.4.5.2 or 6.4.5.3.

6.4.5.5 Additional Requirements

For servo presses constructed such that overshooting of the slide at the position where a normal stop is performed will result in a reversal of the direction of slide movement from an opening direction to a closing direction, in cases where the stop position is programmed to be in a position where this kind of reversal could be foreseen, the protective stop function shall be initiated if the slide overshoot exceeds 2% of the programmed slide stroke regardless of any single failure that may occur. This can be achieved by means of the overrun monitoring function stipulated in 6.6.3 when the allowable value is set to 2% of the programmed slide stroke.

Note: This stipulation would be applicable in a case where the planned stop position is set at top dead center for a mechanical servo press with features identical to a crank press, but it is not limited to this situation.

<Commentary>

This is equivalent to the overrun monitoring equipment stipulated in the Construction Code for Power Presses, and at this point in time it applies to mechanical servo presses with a construction similar to a crank press where the planned stop position is set at top dead center. The tolerance value is a value derived from crank presses where if the crankshaft rotation overshoots by approximately 0.26 rads the slide will descend approximately 2% of the stroke length. Now, as explained in the Note in 6.6.3, if the same subsystem is used to execute both the normal stop function and the protective stop function, at that point it will be initiating the protective stop function and thus it is permissible to merely prevent the initiation of any mode other than an inching stroke until the slide is returned to the start point position.

6.5 Slide Position Detectors

Safety functions executed in response to a signal from a detector such as an encoder or limit switch that detects the position of the slide shall not become unable to comply with the performance standards stipulated in 6.3 as a result of the failure of the slide position detector.

Note: Slide position detector failures aside from a loss of detection functionality include faults in mechanism areas that operate together with the slide(e.g., broken chains or lost couplings).

Slide position detectors related to safety functions shall not be installed in locations where they can be easily changed by the user. Measures to prevent changes include but are not limited to providing a locked housing over the installation area.

6.6 Monitoring Functions

6.6.1 Overview

The monitoring functions stipulated in 6.6.2—6.6.5 are safety functions, and in order for the related subsystems to comply with 6.3 they are to be configured as redundant systems that also jointly

cross-monitor their own normal actuations, and one side of a system shall be able to independently execute a power shutdown and actuate the brake system regardless of the condition of the other side of the system. A single failure that causes the loss of either side of a system shall be detected immediately or detected before the start of the next cycle, and cumulative failures shall not result in a loss of functionality.

When a monitored hazardous condition has been detected, a protective stop function that complies with 6.4.3.2 shall be initiated. also the fault shall be displayed, and the stop condition shall be maintained until the safety requirements for restarting are fulfilled.

The motion condition of the slide should be measured directly. For example, in cases where the actual condition of the slide is not measured directly and is instead inferred based on the measurement results of the servo motor rotation conditions or the electrical power conditions, a single fault (defect) in the power transmission area, namely to a loss of agreement between the servo motor motion and the slide motion, would result in the loss of the monitoring function.

6.6.2 Start/Stop Monitoring

The relationship between the signals from the start (operation) equipment and protective devices related to slide starting, operation permissions, and stopping shall be compared with the actuation conditions of the servo motor, brake system, and slide, and disagreement faults., shall be detected. Start/stop monitoring functions shall check the relationship between all signals at least once per cycle.

6.6.3 Overrun Monitoring

Servo presses shall monitor the stopping time or the stopping distance every time a normal stop is performed, and the protective stop function shall be initiated if the designed tolerance value is exceeded. Once the tolerance value is set, it shall not be easily changed by the user. After stopping, no operation modes other than an inching stroke shall be enabled until the slide is returned to the start point position.

Note: If overrun has occurred on a servo press where both the normal stop function and the protective stop function are performed by the same subsystem, once the slide has come to a stop it is permissible to merely prevent the initiation of any mode other than an inching stroke until the slide is returned to the start point position.

6.6.4 Standstill Monitoring

Servo presses which perform the normal stop function given in 6.4.5.4 shall monitor the slide stopping position during a normal stop and shall detect motion errors that would exceed the designed tolerance values.

Note: Refer to JIS B 9714, 6.4.

<Commentary>

When a normal stop function that complies with 6.4.5.4 is performed, the slide position detector shall continue to monitor that the slide should remain stopped at the normal stop position setting programmed by the user via the interface equipment. The circuits and/or equipment related to standstill monitoring (also including normal stop position information settings programmed by the user) are safety-related parts, and slide motion error detection shall not become disabled as a result of a single failure of hardware and software.

6.6.5 Brake Performance Monitoring

Servo presses that use the brake system for slide braking for the protective stop function but do not use the brake system for slide braking for the normal stop function shall have one of the following brake performance monitoring functions to periodically confirm the brake performance of the brake system alone.

a) Static monitoring that confirms brake performance by actuating the brake system while the slide is in a stopped condition.
b) Dynamic monitoring that confirms brake performance by actuating the brake system while the slide is moving at maximum speed.

Servo presses with multiple brake systems shall be able to independently confirm the performance of each brake system.

The brake performance monitoring function should be designed for independent initiation, using methods such as incorporating it in the slide initiation sequence. In cases where monitoring is only initiated manually, and the frequency of such is not executed at the frequency stipulated by the specification, continued operation shall be disabled or warnings shall be given via visual displays, visual signals, and/or auditory signals.

Regarding the execution frequency, monitoring should be performed at the time the servo press is started and then at least once every 8 hours in the case of static monitoring, and at least once every 24 hours in the case of dynamic monitoring.

Note: An implementation example of the static brake performance monitoring function is shown in Annex 8.5.

<Commentary>

In a case where the brake system is used for protective stops but electrical braking is the primary means for braking the slide at the time of a normal stop, it is not necessarily the case that the overrun monitoring given in 6.6.3 alone will be able to detect degradation of the brake performance of the brake system. Accordingly, it is necessary to periodically confirm brake performance of the brake system alone. And this is not limited to mechanical brake systems. Regarding the preferred execution frequency of brake performance monitoring, guidance was given for executing such at the time of startup and then once every 8 or 24 hours, but taking into consideration the operation configurations of current servo presses, it was not deemed to be necessarily advisable to stipulate that operation be interrupted in order to perform brake performance monitoring, and thus the decision was made to show this as a recommended value in this standard.

6.7 Presence sensing before initiation

In the case of servo presses where it is anticipated that an operator would not be able to confirm from the operation location whether personnel were present within the hazard zone before startup (e.g. in the case of large servo presses where personnel could enter into the hazard zone or enter into the area between sensing protective devices and the hazard zone), protective detection devices such as auxiliary light curtains, laser scanners, and mat switches shall be provided and interlocking system that directly monitor inside the hazard zone shall be constructed so as not to allow a slide restart while personnel are within the hazard zone.

In cases where it is not reasonably feasible to implement the usage of sensing protective devices because of intended usages, usage environments, or operational restrictions, a means of lock-out shall be provided, and instructions that specify that this is to be used to control personnel access inside the hazard zone shall be included in the information for use.

In cases where a sensing protective device such as an active opto-electronic protective device is used to guard the sides or rear of the press, the protective design shall be made so that the

necessity of pre-initiation presence sensing at the time of restarting after a protective stop has been initiated by signals from such equipment. For example, it may be designed so that the protective stop function is maintained until the sensing protective device that has been actuated is manually reset from a position where the detection zone of that device can be sufficiently confirmed (see 6.4.3.3).

6.8 Muting during Slide Opening

For servo presses that perform muting during slide opening, the slide motion speed (i.e., the upstroke speed for presses that open during the upstroke) shall be monitored during the opening stroke, and unintended motion speed reductions (i.e., reductions in the upstroke speed) due to servo system malfunctions shall be detected. Subsystems involved in such speed monitoring functions shall comply with 6.3 and be configured as redundant cross-checking systems, and no single failure shall result in the loss of functionality. Moreover, at least one system shall be designed in a configuration that directly measures the slide motion speed.

The protective stop function is to be initiated when an unintended reduction in speed is detected. At such times, one of the following must be complied with:

a) The slide is to be stopped and held while assuring a clearance between the dies that is considered sufficient to avoid crushing any part of the human body. A clearance that is 98% or greater than the programmed slide stroke should be assured.

b) Slide motion in the die closing direction up until the time the slide is stopped and held is to be small enough not to be considered a crushing hazard. Movement should be 2 mm or less.

In cases where a path is programmed whereby motion in the opening direction is performed multiple times during an operational single stroke operation, muting during slide opening at any time other than the final opening motion shall not cause a hazardous condition.

Note: See Annex 8.2 for information relating to the suitable categories for system controls and protective measures for muting during slide opening.

<Commentary>

Reversal of the motion direction of the slide is to be monitored when performing muting during slide opening, and a protective stop of the slide shall be performed under conditions that comply with a) or b) when a malfunction occurs. However, in the case of a), the position where a motion error that causes a reversal occurs will become an issue, making it difficult to always comply with this. The basis for the 98% of the programmed stroke value recommended in a) and the 2 mm value recommended in b) is the same as that given in the 6.4.5.4 Commentary.

Excluding the deceleration time just before a normal stop, reductions in the slide motion speed (upstroke speed) in the opening direction are monitored, and a reversal can be detected in advance, and thus there is the possibility that a protective stop that is faster than a Stop Category 2 normal stop can be achieved.

6.9 Software Safety Requirements

The software used for a servo press shall not cause the safety-related parts of the servo system to become incapable of complying with the requirements of this standard, and it shall be tested, evaluated, and proved that it is reliable, and additionally, that it can permit the requisite behavior when a failure occurs. Moreover, in cases where software is used for multiple safety functions, it shall comply with the strictest malfunction-related requirements.

Examples of recommended measures that apply to software in order to achieve these aims are given in Annex 8.6.

6.10 Brake Systems

6.10.1 Overview

Servo presses shall be equipped with mechanical or hydraulic braking systems that do not reside in the servo system (i.e., independent systems) and that slow and stop the slide and then hold it in that stopped state.

The brake system shall be able to hold the stopped condition of the slide even under conditions where the maximum starting torque of the servo motor is being applied. In cases where this requirement cannot be met, the servo motor torque shall not be transmitted to the slide during the execution of a stop function that utilizes the brake system. One method for not permitting the torque of the servo motor to be transmitted to the slide is to have the torque become 0 by performing a power shutdown, but this is not the only possible method.

6.10.2 Mechanical Brake Systems

Mechanical brake systems shall be designed and manufactured to comply with the following:

a) Band brakes shall not be utilized.
b) It shall be a normally closed spring-return type system that brakes the slide by means of springs when the inputted energy has shifted from a high state to a low state (e.g., the energy supply is interrupted, or the input signal is turned OFF or eliminated).
c) Multiple springs are to be used, and the brake function shall not be lost even if 50% of all the springs break.
d) For systems where load is applied to the springs, it shall be constructed such that the position of the springs are fixed when in an appropriately adjusted state and no loosening will occur.
e) When operated by means of a solenoid valve, the solenoid valve shall be a dual-solenoid type. When a single failure has occurred, the slide shall be stopped and restarting shall be prevented.
f) A single failure shall not result in the loss of brake functionality and holding functionality. Types of single failures that shall be taken into consideration include a cutoff or drop in hydraulic or pneumatic pressure, a cutoff of the electrical power supply, a cut wire, and the intrusion of lubricants onto the braking surfaces of a dry-type brake.

6.10.3 Hydraulic Brake Systems

Hydraulic brake systems shall be designed and manufactured to comply with the following items:

a) It shall be a normally closed-type system that brakes the slide when the input energy has shifted from a high state to a low state.
b) It shall be configured as a redundant system with multiple solenoid valves arranged in series at the exit port on the slide closing side.
c) Single failures are to be detected by or before the time of a demand for the actuation of the subsequent safety function. When detected, the protective stop function shall be initiated and, moreover, restarting shall not be permitted until the failure is repaired.
d) Those solenoid valves located in a position near the exit port on the slide closing side shall be welded directly to the cylinder or be connected via a flange.

In hydraulic brake systems constructed of multiple cylinders, it is permissible to use a construction where those solenoid valves positioned far from the exit port on the slide closing side are shared by multiple cylinders.

<Commentary>

In this standard, counterbalance valves used for the purpose of primarily holding the slide for

relatively long periods of time are considered to be slide restraint means, and thus are not included in hydraulic brake systems.

6.11 Slide Restraint Means

6.11.1 Overview

During adjustment, cleaning, inspection, and maintenance work, a power shutoff of the servo system is to be performed, and appropriate means for restraining the slide such as a mechanical slide restraint device that complies with 6.11.2 and/or a safety block that complies with 6.11.3 shall be prepared. Additionally, warnings regarding the hazards involved when adjustment, cleaning, inspection, and maintenance work is performed without using these kinds of slide restraint means shall be provided by means of warning signs, instruction manuals, etc.

For the design of large servo presses where personnel can enter inside the hazard zone or between the sensing protective device and the hazard zone, the consideration shall be made for the necessity of presence sensing before initiation given in 6.7 related to starting and restarting after the power supply is restored.

6.11.2 Mechanical Restraint Devices

Mechanical restraint devices shall be designed and manufactured to comply with the following items:

a) It is to be a normally closed type that initiates the slide restraint when the energy of the input control signal changes from a high state to a low state (i.e., the input signal is turned OFF or eliminated).
b) Mechanical impediments are actuated by means of gravity or springs.
c) The strength of the mechanical impediment supports the total weight of the slide and the mounted dies (e.g., upper dies).
d) It is linked to the interlocking system which shutdown the servo system power.
e) The hazards caused by unintended actuation of a mechanical restraint device (e.g., dies falling due to impact) have been analyzed and eliminated.

In cases where the mechanical slide restraint device is constructed only to be able to restrain the slide at a certain specified position (the restraint enabling position), warning means shall be provided using visual displays, visual signals, and/or auditory signals to notify that the device has been correctly set in the restraint enabling position or that the mechanical restraint device is not effectively functioning.

6.11.3 Safety Blocks

Safety blocks shall be designed and manufactured to comply with the following items:

a) Able to support the total weight of the slide and the mounted dies (e.g., upper dies).
b) Is a shape (dimension) that can be inserted and used between the slide or upper die and the bolster or lower die.
c) Linked to the interlocking system which shutdown the servo system power..

<Commentary>

The ‘power shutdown’ stipulated in 6.11.2 d) and 6.11.3 c) is a requirement that uses slide restraint means for the purpose of preventing unintended startup while performing adjustment, cleaning, inspection, and maintenance work, and regarding electrical shock protection during such work it is necessary to separately study the disconnection of the power feed system, etc., based on a risk assessment.

6.12 Operation Modes

6.12.1 Overview

Servo presses shall be provided with operational single stroke and inching stroke operation modes. Mode changes shall be performed by means of an operation mode selection device that complies with 6.12.2. Depending on the usage, other operation modes, such as a continuous stroke mode, may also be provided. Regarding special operation modes, items related to slide movement, the operation of start (operation) equipment and/or functional limitations of protective devices shall be provided as the information for use.

6.12.2 Operation Mode Selection

The servo press operation mode shall be selected using a mode selector switch (e.g., a keyed operation switch) that can securely maintain the selected position and will not involuntarily change position due to the effects of its own weight, minor vibrations, etc. In addition to displaying the available operation mode selections, mode selector switches shall be equipped with a switch position that displays “OFF” or “◯” used for the purpose of deliberately performing a power shutdown of the servo system.

When changing start (operation) equipment and/or protective devices associated with operation modes, these selections shall be performed by means of one of the following selection devices and/or mechanisms.

a) A keyed operation control switch with a direct open circuit (a forced open contact) motion function (refer to JIS C 8201-5-1, Annex K). Non-selected positions (switch contacts) are to be securely isolated from the servo system by means of forced open contact motion.
b) Redundant hardware with a keyed operation switch and monitoring functionality.
c) Safety-related parts that comply with 6.3 (including software when applicable). When operation mode selections are performed on a display screen, it shall not be possible to start the slide before the selected content has been displayed.

<Commentary>

If the selection device used for the start (operation) equipment and/or protective device equipment is different from the one used to select the operation mode, it is permissible for the latter not to comply with a)—c) in 6.12.2.

6.12.3 Inching Stroke

When the inching stroke has been selected, a protective stop shall be performed when any part of an operator’s body is detected as having entered inside the hazard zone, also including during temporal stops (inching stops) during the inching stroke. In other words, it is permissible to achieve an inching stop by means of standard control functionality, but muting of protective devices shall not be executed.

However, for mechanical or hydraulic servo press brakes where it is not reasonably feasible to use protective devices because of restrictions related to its intended usage, protective device muting is permissible only in the case of servo press brakes that comply with all of the following:

a) An inching stop is achieved by means of a normal stop function that complies with any one of 6.4.5.2—6.4.5.4.
b) During an inching stroke, the operation for moving in the direction that decreases the clearance between the slide and bolster is independent of the operation for moving in the direction that increases the clearance, and separate control devices are provided for each operation.

In an inching stroke, the slide can be started at any and all slide positions. However, in the case of large servo presses where personnel can enter inside the hazard zone or between the sensing protective devices and the hazard zone, the necessity of presence sensing before initiation given in 6.7 shall be taken into consideration.

6.12.4 Continuous Stroke

No muting of any kind shall be executed in the continuous stroke mode.

When the continuous stroke mode is provided, unintended changes to the continuous stroke as a result of a malfunction shall be prevented. Aside from the operation mode selection device in 6.12.2, this can be achieved by providing devices such as a continuous stroke mode ON/OFF switch, a dedicated continuous stroke initiation switch, and a setup button, where a conditional operation is performed to start the continuous stroke mode. A time limit shall be provided for this conditional operation, and if the slide is not started within this time limit once the operation mode has been changed to the continuous stroke mode, the start command shall be cancelled and the mode shall not be started unless the operation is repeated. Operations where no separate device for the conditional operation is provided, such as pressing and holding down the start buttons for a specified period of time, shall not be used as a substitute for this conditional operation.

6.12.5 Modes Where the Slide is Started in Response to Signals from Protective Devices

It is permissible to execute slide start controls by means of a signal from special protective devices (e.g., controlled guarding) only when in the operation mode specifically designated for that purpose. However, such shall comply with all of the following:

a) The structural stroke length of the servo press shall not exceed 600 mm.
b) The bolster front-to-back dimension shall not exceed 1000 mm.
c) In cases where the protective device that starts the slide is a interlocking guard equipped with a start function (i.e., controlled guard), it shall be designed to comply with the requirements of JIS B 9700-2, 6.3.2.5.
d) In cases where the protective device that starts the slide is an electro-sensitive protective device, it shall be designed to comply with the requirements of JIS B 9704-1, A.8. The bottom edge of openings guarded by an electro-sensitive protective device shall be at least 750 mm above floor level.

6.12.6 Modes Where the Slide is Started in Response to Signals from External Equipment

It is permissible to execute slide start controls by means of a signal from external equipment other than start equipment and special protective devices only when in the operation mode specifically designated for that purpose. However, to the extent that intrinsic safety design measures have not eliminated crushing hazards or appropriately reduced the risks associated with such, it shall comply with all of the following:

a) No muting of any kind shall be executed in this dedicated operation mode.
b) Signals from external equipment shall not take precedence over protective device stop signals.
c) No conditional operation mechanism that starts this dedicated mode (e.g., a setup button, circuit reset equipment) aside from the operation mode selection device in 6.12.2 shall be provided.
d) Just like the continuous stroke mode, a time limit shall be provided for the equipment that performs this conditional operation, and if it is left idle while waiting for a signal from external equipment for a period longer than the time limit , the start command shall be cancelled.
e) Signals from external equipment shall be redundant inputs and shall be processed in a redundant

system.

6.12.7 Modes Where the Slide is Moved Using a Manual Pulse Generator

Manual operation using a manual pulse generator is only permitted when in the operation mode specifically designated for that purpose. This dedicated operation mode shall employ one of the following to eliminate a crushing hazard or appropriately reduce the risks associated with such.

a) Implement intrinsic safety design measures.
b) Use guards and/or protective devices.
c) Restrict slide travel speed to 10 mm/s or less. Additionally, a 3-position type hold-to-run control device or enabling device (refer to JIS B 9960-1, 9.2.5.8) is to be provided, and if such is not operated simultaneously with the manual pulse generator, the protective stop function stipulated in 6.4.3.3 is to be initiated.

Note 1: A foot-actuated device may be used as the hold-to-run control device.

However, a manual pulse generator shall be manufactured and designed to comply with all of the following:

a) The slide cannot be started by other equipment when the manual pulse generator has been selected.
b) Unintended pulses are not generated as a result of the effects of its own weight, minor vibrations.
c) It cannot be selected until an intended operation has been performed.

Note 2: For example, unintended selection can be prevented by only enabling the manual pulse generator when an operation panel pushbutton with an internal indicator light has been pushed and the button light turns on to notify the operator that the manual pulse generator is enabled.

6.13 Display Equipment

6.13.1 Stroke Indication Equipment

Servo presses shall be provided with equipment that displays the current position of the slide during the programmed stroke. Also the equipment shall be positioned so that the operator and work-related personnel can easily view the display. Additionally, the following items should be displayed if reasonably feasible:

a) The direction of slide movement (upstroke, downstroke, etc.)
b) The position of the upper and lower limits of the programmed stroke or the position of the limit switches that are used for such settings.
c) The parameter settings for the overrun monitoring function (allowable stopping distance, etc.) and those execution results (excluding when operating in the continuous stroke mode).

6.13.2 Stop Condition Display Equipment

In order to prevent operators and work-related personnel from mistakenly recognizing the state of the electrical power being supplied to the servo motor or the actuation/release state of the brake system while performing adjustment, cleaning, inspection, or maintenance work, servo presses shall be provided with notification equipment that clearly displays or turns indicator lights on and off in order to notify personnel whether the stopped condition of the slide is due to a power shutdown or is due to a servo stop(see 6.4.5.4), and whether the brake system is engaged.

7. Information for Use

7.1 Overview

The provision of machine displays (e.g., signs and symbols) and instructional documentation (e.g., operation and maintenance manuals) shall be in accordance with the relevant requirements in JIS B 9700-1, JIS B 9700-2, and JIS B 9960-1.If warning devices are provided, the provisions shall be complied with JIS B 9700-2 and JIS B 9960-1.

7.2 Marking

The following shall be displayed on the servo press itself in a clear, easily read, and durable method:

a) The manufacturing number.
b) The name of the manufacturer.
c) The year and month of manufacture.
d) The type of press (either mechanical servo press, mechanical press brake, hydraulic servo press, or hydraulic servo press brake).
e) The protective stopping time.
f) If designed intentionally for a specific usage, the intended usage method (e.g., no-hand-in-die or automatic).

In cases where a servo press is intentionally designed for “no-hand-in-die” operations but it cannot be technologically prevented from being used in “hand-in-die” operations, instruction manuals or other appropriate media shall be provided to warn of the hazards related to such.

Additionally, there may be some cases where the following items shall be added in order to reduce the risks associated with machine installation, test operation, and disassembly, etc.:

a) The maximum stopping time (the worst-case value for the time from the actuation of the detection function of a protective device until a protective stop is completed).
b) Tonnage capacity (pressure capacity).
c) Structural stroke length.
d) Machine weight.
e) The lifting locations used for transportation and installation purposes.

Note: There may be cases where there are legal requirements to display items other than the ones given above.

7.3 Service Life of Electrical and Electronic Equipment and Parts

The service life of electrical and electronic parts and the instructions related to the inspection and replacement frequencies of such parts shall be clearly shown in the instruction manuals or other appropriate media. When necessary, information shall be included about requirements for specialized knowledge related to the replacement of parts or the hazards related to the usage of parts other than the recommended parts. When reasonably feasible, servo presses should be provided with equipment that tracks the number of actuations or the utilization times of components.

<Commentary>

The primary component parts and equipment on a servo press are electrical, electronic, and programmable electronic parts and equipment. Unlike defects in mechanical parts that result from wear, failures caused by the age deterioration of electrical and electronic parts characteristically occur abruptly, and thus it is difficult to know the predictive signs of such failures based on the operational state of the machine. From the viewpoint of changing from conventional maintenance and inspection concepts that were based on the mechanical service life to concepts primarily revolving around the electrical service life, it is important to provide the user with service or designed life information in the instruction manuals, etc.

8. Annex

8.1 Overview of Distinctive Hazards Inherent in Servo Presses

Annex 8.1 stipulates the distinctive hazards inherent in servo presses that are covered in this standard.

Table 8.1: List of Hazards (Excerpted from JIS B 9702, Annex A)

No.	Hazard	Related Hazard Areas	Referenced Items	JIS B 9700	
				Part 1	Part 2
1. Mechanical Hazards					
1.1	Crushing	Between the upper and lower dies, between the slide and upper die, between the bolster and lower die, between the workpiece and the dies. Power transmission parts such as motor shaft, gears, and belts.	**6.2.2, 6.3—6.6, 6.10**	**4.2.1**	**4.2**
1.2	Shearing		**6.2.2, 6.3—6.6**	**4.2.1**	**4.2**
1.4	Entanglement		**6.2.1**	**4.2.1**	**4.2**
1.6	Impact		**6.2.2, 6.3—6.6**	**4.2.1**	**4.2**
1.9	High-pressure fluid ejection	Hydraulic systems (pumps, cylinders, piping, etc.) and in their periphery.	**6.2.9**	**4.2.1**	**4.10**
2. Electrical Hazards					
2.1	Contact of persons with conductive parts (direct contact)	Electrical cabinets, terminal boxes, control panels.	**6.2.3**	**4.3**	**4.9, 5.5.4**
2.2	Contact of persons with parts that become live under fault conditions (indirect contact)	Exposed conductive areas, electrical devices during maintenance.	**6.2.3 6.2.5**	**4.3**	**4.9**
3. Thermal Hazards					
3.1	Burns, scalds, and other injuries due to extreme high temperatures	Motors, resistors, and their periphery	**6.2.7**		**4.4**
Hazards Generated by Neglecting Ergonomic Principles in the Machine Design					
8.6	Human error; human behavior	Between the upper and lower dies, between the slide and upper die, between the bolster and lower die, at the safety block placement position.	**6.2.8, 6.7, 6.8, 6.11**	**4.9**	**4.8, 5.5.4, 5.5.5, 6**
8.7	Inappropriate design or placement of manual control devices	Two-hand operation control device, emergency stop devices, operation positions.	**6.4.2 6.12.2—6.12.4 6.12.7**		**4.11.8 4.11.10 5.5.2**
8.8	Inappropriate design or placement of visual display devices.	Stroke display devices, operation positions.	**6.12.7, 6.13**		**4.8.8**
10 Unexpected Starts, Unexpected Excessive Travel/Speed, or Similar Malfunctions Caused by the Following Events					
10.1	Failure/malfunction of the power shutdown means	Between the upper and lower dies, between the slide and upper die, between the bolster and lower die, between the workpiece and the dies. Power transmission parts such as motor shaft, gears, and belts.	**6.4—6.6, 6.11**		**4.11, 5.5.4**
10.2	Restoration of the energy supply after interruption		**6.2.4, 6.2.5**		**4.11.4**
10.3	External effects (electromagnetic interference) on electrical equipment		**6.2.6**		**4.11.11**
10.4	Other external effects (gravity, etc.)		**6.11**		**4.11.5**
14	Hazard-side failures of control systems (hardware, software, pneumatic circuits, hydraulic circuits)	Between the upper and lower dies, between the slide and upper die, between the bolster and lower die, between the workpiece and the dies. Power transmission parts such as motor shaft, gears, and belts.	**6.2.3—6.2.6, 6.2.9, 6.3—6.12**		**4.11, 4.12**

8.2 Examples of Servo Press Risk Assessment Results

This annex 8.2 is a supplement to this standard and Annex 8.1, and is not part of this standard.

8.2.1 Comparison of Risk Assessment Results Based on Differences in Intended Usage

As examples of implemented risk assessments with respect to excerpts taken from the distinctive hazards inherent in servo presses stipulated in Table 8.1, Table 8.2.1 shows the case of a servo press intended for hand-in-die usage, and Table 8.2.2 shows the case of a servo press intended for no-hand-in-die usage (a servo press designed as an automatic press).

The hand-in-die press shown in Table 8.2.1 is based on the following assumptions:

- The machine equipment is in a line that manufactures metal parts for automotive applications.
- The press has an 8000 kN rated tonnage. It is a 2-point, 2-shaft drive straightside power press machine.
- Feeding and removing of the workpieces is performed by workers, and multiple workers are involved.
- The workers and maintenance inspectors have received special education and training.
- The protective devices are fixed guards on the sides of the press room. Photo-electric safety devices are installed at the feeding and removing side where the workers access the machine after each cycle.

Also, the no-hand-in-die press shown in Table 8.2.2 is based on the following assumptions

- The machine equipment is in a line that manufactures metal parts for automotive applications.
- The press has an 8000 kN rated tonnage. It is a 2-point, 2-shaft drive straightside power press machine.
- Feeding and removing of the workpieces is performed by feed equipment, and the workers are not directly engaged during production.
- The workers and maintenance inspectors have received special education and training.
- The protective devices are fixed guards on the sides of the press room, and the front and back are equipped with interlocking guards.

8.2.2 Risk Estimation and Evaluation

In Table 8.2.1 and Table 8.2.2, the standards used when estimating risks and evaluating risk levels are as follow:

a) Risks are estimated based on the combination of the severity of an injury (bodily injury and/or health hazard) and the probability that such harm will occur.

1) Severity of injury (S): Estimations are to be made using the following standards based on the degree of the injury and/or health hazard.

- S1: Minor cut/Abrasion—Injuries not accompanied by lost work time.
- S2: Minor injury—Accidents not accompanied by lost work time
- S3: Serious injury—Lost work time; Grade 8－14 consequences.
- S4: Major Harm—Death; Grade 7 or higher consequences

2) Probability of occurrence: Estimated based on the frequency of exposure to a hazard (F) and the probability of avoiding a hazard (P).

Frequency of exposure to a hazard (F): To be estimated based on the following standards, taking into consideration the necessity of exposure (e.g.: hand-feeding of workpieces, maintenance and repair work), the frequency of exposure and the exposure time, and the

number of exposed personnel, etc.

- F1: Rarely — occasionally for short periods of time.
- F2: Frequently — continuously for long periods of time.

Probability of avoiding a hazard (P): To be estimated based on the following standards, taking into consideration who the operator is (experienced personnel, inexperienced personnel, unmanned) and the speed at which the hazardous event occurs (abruptly, at high speed, at low speed), etc.

- P1: Possible under specific conditions.
- P2: Scarcely possible.

b) The risk level is determined according to the risk matrix in Table 8.2.3 based on the severity (S), frequency (F), and avoidance probability (P) of the injury. Levels III—V were determined to be unacceptable risks in this standard, and protective measures are required.

Table 8.2.3: Risk Matrix

			Probability of Injury			
			High Probability	Probability	Low Probability	Scarcely Probable
	Frequency of exposure to a hazard		F2		F1	
	Probability of avoiding the hazard		P2	P1	P2	P1
Severity of Injury	Major Harm	S4	V	V	IV	III
	Serious Injury	S3	V	IV	III	III
	Minor Injury	S2	IV	III	II	II
	Minor cut/Abrasion	S1	III	II	II	I

Table 8.2.1: Risk Assessment Results for a Servo Press Intended for Usage as a Hand-in-Die Press (Excerpted)

	Hazard Identification				Operation Mode			Risk Estimation & Evaluation					Protective Measures & Categories for Control System Safety-Related Parts		Risk Estimation & Evaluation after Implementing Protective Measures					
No.	Hazard	Hazard Area	Hazard Condition	Subject Personnel	Production	Setup	Maintenance	Probability of Exposure to Hazard	Severity of Consequence S	Frequency of Exposure to Hazard F	Probability of Hazard Avoidance P	Evaluation	Corresponding Protective Measures	Control System Categories	Probability of Exposure to Hazard	Severity of Consequence S	Frequency of Exposure to Hazard F	Probability of Hazard Avoidance P	Overall Assessment (Hazard Level)	Information for Use
1	Mechanical Hazards																			
1.1	Crushing Hazard	Hazard Area (between the upper & lower dies; in the press room)	Slide is descending	Operators Unspecified peripheral personnel	○ During “operational single stroke” operation			Yes	S4	F2	P2	**V**	Installation of photo-electric safety devices. Implement measures whereby the interruption of a photo-electric safety device beam will shut down the servo power and a protective stop of the press is performed by means of a mechanical brake.*1	*1 4	No					
			Slide does not stop at the planned stop position (waiting point) and continues to descend.	Operators Unspecified peripheral personnel	○ While stopped during “operational single stroke” operation			Yes	S4	F2	P2	**V**	Installation of overrun detection device. Implement measures whereby the detection of an overrun will shut down the servo power, a protective stop of the press will be performed by means of a mechanical brake, and restarting will be prevented. *2	*2 4	No					
			Slide is descending	Operators Unspecified peripheral personnel		○ During "Inching" operation		Yes	S4	F1	P2	**IV**	Ultra-slow speed of 10mm/s or less is implemented. *3 (First measure) The interruption of a photo-electric safety device beam causes a protective stop of the press to be performed. *1 (Second measure)	*3 4 *1 4	No					
			Slide does not stop at the planned stop position (waiting point) and continues to descend.	Setup personnel Unspecified peripheral personnel		○ While stopped during "Inching" operation		Yes	S4	F1	P2	**IV**	Installation of photo-electric safety devices. Implement measures whereby the interruption of a photo-electric safety device beam will shut down the servo power and a protective stop of the press is performed by means of a mechanical brake. *1	*1 4	No					
			While stopped, the slide unexpectedly descends or falls.	Maintenance/Inspection personnel Service personnel			○ "OFF" (Maintaining stop)	Yes	S4	F1	P2	**IV**	Installation of safety blocks. To be equipped with a power shutdown interlock, where the usage of a safety block will cause a servo motor power shutdown and the slide will be held in place by a mechanical brake. *5 Additionally, it is to	*5 4	No					
8	Hazards That Result from Ignoring Ergonomic Principles during the Design Phase.																			
8.6	Operation actions; human error.	Hazard Zone (between the upper & lower dies; in the press room)	The slide unexpectedly descends or falls during maintenance/inspection work (the safety block is not used)	Maintenance/Inspection personnel Service personnel			○	Yes	S4	F1	P2	**IV**		–	Yes	S4	F1	P2	**IV**	Affix warning nameplates. Describe risks and warnings in instruction manual. (Work standard creation; user education and training)
			The slide is operated due to negligence, and the slide descends while personnel are in the hazard zone.	Operators Unspecified peripheral personnel Setup personnel Maintenance/Inspection personnel Service personnel	○	○	○	Yes	S4	F1	P2	**IV**	Installation of a lockout device. *11 (A work management system attained by means of a power shutdown and a padlocked safety switch.)	*11 (4)	Yes	S4	F1	P2	**IV**	Affix warning nameplates. Describe risks and warnings in instruction manual. (Work standard creation; user education and training)
10	Unexpected Starts and Unexpected Excessive Travel/Speed Caused by the Following Events (or Similar Malfunctions)																			
10.2	Power outage; Power supply interruption due to a circuit/device malfunction	Hazard Area (between the upper & lower dies; in the press room)	Hazards where the slide will not stop in time because the protective stopping time has become longer due to a power outage or regenerative braking circuit malfunction.	Operators Unspecified peripheral personnel Setup personnel Maintenance/Inspection personnel Service personnel	○	○	○	Yes	S4	F1	P2	**IV**	・A power outage (zero voltage) will shut down the servo power, perform a protective stop by means of a mechanical brake, and maintain the stopped condition. ・Regenerative braking is not used at the time of a protective stop.	–	No					
			Hazards where the slide will not stop in time because the protective stopping time has become longer due to a resistive braking circuit.		○	○	○	Yes	S4	F1	P2	**IV**	Install a resistive braking circuit monitor. *12	*12 4	No					
14	Control System Malfunctions																			
	Control System Malfunctions	Hazard Area (between the upper & lower dies; in the press room)	The slide cannot be stopped due to a malfunction in the brake system control system.	Operators Maintenance/Inspection personnel Service personnel	○	○	○	Yes	S4	F1	P2	**IV**	**・Install spring-actuated normally closed mechanical brakes. ・A system where brake performance is maintained even if 50% of all of the mechanical brake springs break. ・Install a brake performance monitor. *6 Detects brake faults and prohibits press operat**	*6 4	No					
			Slide braking becomes impossible due to inoperative servo system deceleration controls during electrical braking and while stopped.	Operators Unspecified peripheral personnel	○ "Operational Single Stroke" standby position stop (while muting)			Yes	S4	F1	P2	**IV**	Installation of an overrun detection device*2 and a reversal detection device. *8 Implement measures whereby the overrun detection device or the reversal detection device causes a servo power shutdown, performs a protective stop using a mechanical brake,	*2 4 *8 4	No					
					○ Maintaining a downstroking process stop in "Operational Single Stroke"			Yes	S4	F1	P2	**IV**	Installation of photo-electric safety devices. Implement measures whereby the interruption of a photo-electric safety device beam will shut down the servo power and a protective stop of the press is performed by means of a mechanical brake. *1	*1 4	No					
				Setup personnel Unspecified peripheral personnel Service personnel		○ Maintaining a downstroking process stop in "Inching" operation	○ Maintaining a downstroking process stop in "Inching" operation	Yes	S4	F1	P2	**IV**	Same as above.	*1 4	No					
			Slide descending during an upstroke.	Setup personnel Unspecified peripheral personnel Service personnel		○ During "Inching" upstroking process and when stopped	○ During "Inching" upstroking process and when stopped	Yes	S4	F1	P2	**IV**	Installation of photo-electric safety devices. Implement measures whereby the interruption of a photo-electric safety device beam will shut down the servo power and a protective stop of the press is performed by means of a mechanical brake. *1	*1 4	No					
			Slide descends during muting during slide opening.	Operators Unspecified peripheral personnel	○ "Operational Single Stroke" upstroking process			Yes	S4	F1	P2	**IV**	Installation of a reversal detection device. *8 Implement measures whereby detection of a reversal will shut down the servo power, a protective stop of the press will be performed by means of a mechanical brake, and restarting will be prevented.	*8 4	No					
			Slide motion is initiated during loading and unloading due to malfunctioning servo system controls.	Operators Unspecified peripheral personnel	○ Maintaining a standby point stop in "Operational Single Stroke"			Yes	S4	F1	P2	**IV**	Installation of an overrun detection device*2 and a reversal detection device. *8 Implement measures whereby the overrun detection device or the reversal detection device causes a servo power shutdown, performs a protective stop using a mechanical brake,	*2 4 *8 4	No					
			The slide cannot be stopped and maintained while the servo system is stopped due to malfunctioning controls.	Maintenance/Inspection personnel Service personnel Unspecified peripheral personnel			○ "OFF" Maintaining stop	Yes	S4	F1	P2	**IV**	Implement measures whereby turning the operation mode selector switch to OFF will shut down servo power, and the stopped condition of the press will be maintained by a mechanical brake.	*7 4	No					
			A protective stop of the slide becomes impossible due to the failure of a control system related to the Emergency Stop function.	Operators Maintenance/Inspection personnel Service personnel Unspecified peripheral personnel	○	○	○	Yes	S4	F1	P2	**IV**	**・Installation of an emergency stop control system. Redundancy and monitoring circuits.** ・Installation of a power (energy) shutdown system. Redundant shutdown circuit. *5 ・Installation of a spring-actuated normally closed type mechanical brake. ・A system**	** 4 *5 4 *6 4	No					
			A protective stop of the slide becomes impossible due to the failure of a control system related to the protective stop function.	Operators Setup personnel Maintenance/Inspection personnel Service personnel Unspecified peripheral personnel	○	○	○	Yes	S4	F1	P2	**IV**	Installation of a power (energy) shutdown system. Redundant shutdown circuit. *9 ・Installation of a spring-actuated normally closed type mechanical brake. ・A system where brake performance is maintained even if 50% of all of the mechanical brake springs b	*9 4 *10 4	No					
			A protective stop of the slide becomes impossible due to the failure of a control system related to the protective stop function.	Operators Maintenance/Inspection personnel Service personnel Unspecified peripheral personnel	○	○	○	Yes	S4	F1	P2	**IV**	Installation of a power (energy) shutdown system. Redundant shutdown circuit. *9 ・Installation of a spring-actuated normally closed type mechanical brake. ・A system where brake performance is maintained even if 50% of all of the mechanical brake springs b	*5 4 *6 4	No					

Note: Asterisked (*) items are related to control system safety functions.

Table 8.2.2: Risk Assessment Results for a Servo Press Intended for Usage as a No-Hand-in-Die Press (Excerpted)

	Hazard Identification				Operation Mode			Risk Estimation & Evaluation					Protective Measures & Categories for Control System Safety-Related Parts		Risk Estimation & Evaluation after Implementing Protective Measures					
No.	Hazard	Hazard Area	Hazard Condition	Subject Personnel	Production	Setup	Maintenance	Probability of Exposure to Hazard	Severity of Consequence S	Frequency of Exposure to Hazard F	Probability of Hazard Avoidance P	Evaluation	Corresponding protective measures	Control System Categories	Probability of Exposure to Hazard	Severity of Consequence S	Frequency of Exposure to Hazard F	Probability of Hazard Avoidance P	Overall Assessment (Hazard Level)	Information for Use
1	Mechanical Hazards																			
1.1	Crushing hazard	Hazard Area (between the upper & lower dies; in the press room)	Slide is descending	Operators Unspecified peripheral workers	○ During "Continuous" operation			Yes	S4	F1	P2	**IV**	Installation of interlocking guards. Shall be an interlock that disables press operation unless the guard is closed.*1	*1 4	No					
			Slide does not stop at the planned stop position (waiting point) and continues to descend.	Operators Unspecified peripheral personnel	○ When stopped during "Continuous" operation			Yes	S4	F1	P2	**IV**	Installation of interlocking guards. Shall be an interlock that disables press operation unless the guard is closed.*1	*1 4	No					
			Slide is descending	Setup personnel Unspecified peripheral personnel		○ During 'Trial Single Stroke' or 'Inching' operation		Yes	S4	F1	P2	**IV**	Installation of interlocking guards. Shall be an interlock that disables press operation unless the guard is closed.*1	*1 4	No					
			Slide does not stop at the planned stop position (standby position) and continues to descend.	Setup personnel Unspecified peripheral personnel		○ While stopped during 'Trial Single Stroke' or 'Inching' operation		Yes	S4	F1	P2	**IV**	Installation of interlocking guards. Shall be an interlock that disables press operation unless the guard is closed.*1	*1 4	No					
			While stopped, the slide unexpectedly descends or falls.	Maintenance/Inspection personnel Service personnel			○ "OFF" (Maintaining stop)	Yes	S4	F1	P2	**IV**	Installation of safety blocks. To be equipped with a power shutdown interlock, where the usage of a safety block will cause a servo motor power shutdown and the slide will be held in place by a mechanical brake. *2 Additionally, it is to physically suppor	*2 4	No					
8	Hazards That Result from Ignoring Ergonomic Principles during the Design Phase.																			
8.6	Operation actions; human error.	Hazard Area (between the upper & lower dies; in the press room)	The slide unexpectedly descends or falls during maintenance/inspection work (a safety block is not used)	Maintenance/Inspection personnel Service personnel			○	Yes	S4	F1	P2	**IV**	Installation of a slide lock device. Shall have an interlock that does not allow the interlocked guard to be opened unless it can be confirmed that the slide is fully locked. *7	*7 4	No					
			The slide is operated due to negligence, and the slide descends while personnel are still present inside the interlocked guard.	Operators Unspecified peripheral personnel Setup personnel Maintenance/Inspection personnel Service personnel	○	○	○	Yes	S4	F1	P2	**IV**	Installation of a device for detecting personnel within the hazard zone. Detection of personnel will cut off servo power and stop and maintain the slide by means of a mechanical brake.	* 4	No					
10	Unexpected Starts and Unexpected Excessive Travel/Speed Caused by the Following Events (or Similar Malfunctions)																			
10.2	Power outage; Power supply interruption due to a circuit/device malfunction	Hazard Area (between the upper & lower dies; in the press room)	Hazards where the slide will not stop in time because the protective stopping time has become longer due to a power outage or regenerative braking circuit malfunction.	Operators Unspecified peripheral personnel Setup personnel Maintenance/Inspection personnel Service personnel	○	○		Yes	S4	F1	P2	**IV**	Installation of an interlocked guard. The interlocked guard is closed during production and setup. Shall be an interlock that disables press operation unless the guard is closed.*1	*1 4	No					
							○	Yes	S4	F1	P2	**IV**	・A power outage (zero voltage) will shut down the servo power, perform a protective stop by means of a mechanical brake, and maintain the stopped condition.	* 4	No					
			Hazards where the slide will not stop in time because the protective stopping time has become longer due to a resistive braking circuit failure.		○	○		Yes	S4	F1	P2	**IV**	Installation of an interlocked guard. The interlocked guard is closed during production and setup. Shall be an interlock that disables press operation unless the guard is closed.*1	*1 4	No					
							○	Yes	S4	F1	P2	**IV**	Install a resistive braking circuit monitor. *9	*9 4	No					
14	Control System Malfunctions																			
	Control System Malfunctions	Hazard Area (between the upper & lower dies; in the press room)	The slide cannot be stopped due to a malfunction in the brake system control system.	Maintenance/Inspection personnel Service personnel			○	Yes	S4	F1	P2	**IV**	**・Install spring-actuated normally closed mechanical brakes. ・A system where brake performance is maintained even if 50% of all of the mechanical brake springs break. ・Install a brake performance monitor. *3 Detects brake faults and prohibits press operat**	*3 4	No					
				Operators Maintenance/Inspection personnel Service personnel	○	○		Yes	S4	F1	P2	**IV**	Installation of interlocking guards. Shall be an interlock that disables press operation unless the guard is closed.*1	*1 4	No					
			Slide braking becomes impossible during electrical braking due to inoperative servo system deceleration controls.	Operators	○ While stopped at the standby position while in Continuous mode.			Yes	S4	F1	P2	**IV**	Same as above.	*1 4	No					
				Maintenance/Inspection personnel Service personnel		○ While stopped during 'Trial Single Stroke' or 'Inching' operation	○ While stopped during 'Trial Single Stroke' or 'Inching' operation	Yes	S4	F1	P2	**IV**	Same as above.	*1 4	No					
			During a servo system controlled stop, the slide stop cannot be maintained due to inoperative controls resulting from a malfunction.	Maintenance/Inspection personnel Service personnel Unspecified peripheral personnel			○ "OFF" (Maintaining stop)	Yes	S4	F1	P2	**IV**	Implement measures whereby turning the operation mode selector switch to OFF will shut down servo power, and the stopped condition of the press will be maintained by a mechanical brake.	*4 4	No					
			Slide reverses and descends during an upstroke.	Setup personnel Unspecified peripheral personnel		○ During "Inching" upstroking process and when stopped	○ During "Inching" upstroking process and when stopped	Yes	S4	F1	P2	**IV**	Installation of interlocking guards. Shall be an interlock that disables press operation unless the guard is closed.*1	*1 4	No					
				Operators Unspecified peripheral personnel	○ "Continuous" upstroking process			Yes	S4	F1	P2	**IV**	Same as above.	*1 4	No					
			A protective stop of the slide becomes impossible due to the failure of a control system related to the Emergency Stop function.	Operators Maintenance/Inspection personnel Service personnel Unspecified peripheral personnel	○	○	○	Yes	S4	F1	P2	**IV**	**・Installation of an emergency stop control system. Redundancy and monitoring circuits.** ・Installation of a power (energy) shutdown system. Redundant shutdown circuit. *5 ・Installation of a spring-actuated normally closed type mechanical brake. ・A system**	** 4 *5 4 *6 4**	No					
			A protective stop of the slide becomes impossible due to the failure of a control system related to the protective stop function.	Operators Maintenance/Inspection personnel Service personnel Unspecified peripheral personnel	○	○	○	Yes	S4	F1	P2	**IV**	Installation of a power (energy) shutdown system. Redundant shutdown circuit. *9 ・Installation of a spring-actuated normally closed type mechanical brake. ・A system where brake performance is maintained even if 50% of all of the mechanical brake springs b	*5 4 *6 4	No					

Note: Asterisked (*) items are related to control system safety functions.

8.3 Stop Function Implementations and a Comparison of Attainment Means

Annex 8.3 is a supplement to this standard and Annex 8.1, and is not part of this standard.

8.3.1 Stop Function Implementation Examples

Tables 8.3.1－8.3.3 show a comparison of attainment means based on the servo press specifications when implementing stop functions in accordance with 6.4.

8.3.2 When Using a Brake System with Sufficient Holding Capability

Table 8.3.1 show the relationship between the stop function implementations and those attainment means when using a brake system capable of holding the slide even when the maximum starting torque of the servo motor is being applied. This servo press is based on the following assumptions:

- It is used for hand-in-die applications and it performs muting during slide opening.
- The protective stop function actuated by a protective device complies with 6.4.3.3 b). However, the Stop Category is 0, and slide braking is performed using a mechanical brake system.
- The normal stop function complies with 6.4.5.3. However, the Stop Category is 0, and slide braking is performed using a mechanical brake system.

8.3.3 When Performing a Stop Category 0 or 1 Stop

Table 8.3.2 shows the relationship between the stop function implementations and those attainment means when protective stops and normal stops are achieved by means of a Stop Category 1 stop function. This servo press is based on the following assumptions:

- It is used for hand-in-die applications and it performs muting during slide opening.
- The protective stop function actuated by a protective device functions as a Stop Category 1 stop that complies with 6.4.3.3 a).
- The normal stop function works as a Stop Category 1 stop that complies with 6.4.5.2.
  However, for protective stops initiated by the detection of a muting during slide opening malfunction (direction reversal fault), a Stop Category 0 stop is to be used because the fault is occurring in the servo system.

8.3.4 When Performing a Stop Category 2 Stop under Conditions That Assure Clearances That Avoid Crushing

Table 8.3.3 shows the relationship between the stop function implementations and those attainment means when a Stop Category 2 stop is used for the normal stop function under conditions where sufficient clearance is assured after the stop is completed. This servo press is based on the following assumptions:

- It is used for hand-in-die applications and it performs muting during slide opening.
- The protective stop function actuated in response to a protective device functions as a Stop Category 1 stop that complies with 6.4.3.3 a).
- The normal stop function works as a Stop Category 2 stop that complies with 6.4.5.4.
  However, for protective stops initiated by the detection of a muting during slide opening malfunction (direction reversal fault), a Stop Category 0 stop is to be used because the fault is occurring in the servo system.

Table 8.3.1: The Relationship between Stop Functions and Methodology
(When Using a Brake System with Sufficient Holding Capability)

Work Classification	Operation Mode	Stop Type	Stop Device・Interlock Device	Slide Status	Servo Stop	Power Shutdown	Brake System	Electrical Braking	Restraint Means	Stop Category JIS B 9960-1	Muting	Referenced Items
Production	"Operational Single Stroke" during Production	Temporal Stop	When RUN buttons are released	In operation: From the planned stop position to BDC	○ →	○ ←→	○			0		
		Normal Stop		Upstroking beyond BDC						–	○	**6.8 Muting during Slide Opening**
				Stopping (at destination)	○ →	○ ←→	○			0		**6.4.5 Normal Stop Functions**
				Stopping (while being held)	(○)	○	○				○	When Feeding & removing
			While RUN buttons are not released	Stopping (at destination)	○ →	○ ←→	○			0		Restart prevention system Fault operation Single stroke function
		Protective Stop	Photo-electric safety device interrupted	In operation: From the planned stop position to BDC		○	○			0		**6.4.3 Protective Stop Function**
				Upstroking beyond BDC						–	○	Photo-electric safety device disabled. **6.8 Muting during Slide Opening**
				Stopped at the planned stop position	(○)					–		Photo-electric safety device disabled. **6.8 Muting during Slide Opening**
			Reversal fault detected	Upstroking		○	○			0		**6.4.3 Protective Stop Function** **6.8 Muting during Slide Opening**
			Personnel detected inside the hazard zone	First starting	(○)	○	○			0		**6.4.3 Protective Stop Function** **6.7 Presence sensing before initiation**
		Emergency Stop	E-Stop button is pushed	In operation		○	○			0		**6.4.2 Emergency Stop Function**
				Stopped at the planned stop position	(○)	○	○			0		
			Safety block plug is pulled	In operation		○	○		○	0		Fault operation
				Stopped at the planned stop position	(○)	○	○		○	0		**6.11.3 Safety Blocks**
Trials and Maintenance	"Inching Stroke" during Die Trials	Temporal Stop	When RUN buttons are released	In operation: From the planned stop position to BDC	○ →	○ ←→	○			0		**6.12.3 Inching Stroke**
				Upstroking beyond BDC	○ →	○ ←→	○			0		**6.12.3 Inching Stroke**
		Protective Stop	Photo-electric safety device interrupted	In operation: From the planned stop position to BDC		○	○			0		**6.4.3 Protective Stop Function**
				Upstroking beyond BDC		○	○			0		**6.4.3 Protective Stop Function**
				Stopped at the planned stop position	(○)	○	○			0		
			Reversal fault detected	Upstroking		○	○			0		**6.4.3 Protective Stop Function** **6.8 Muting during Slide Opening**
			Personnel detected inside the hazard zone	First starting	(○)	○	○			0		**6.4.3 Protective Stop Function** **6.7 Presence sensing before initiation**
		Emergency Stop	E-Stop button is pushed	In operation		○	○			0		**6.4.2 Emergency Stop Function**
				Stopped at the planned stop position	(○)	○	○			0		
			Safety block plug is pulled	In operation		○	○		○	0		Fault operation
				Stopped at the planned stop position	(○)	○	○		○	0		
	"OFF" during Maintenance Work	Protective Stop	Mode selector switch set to OFF	In operation		○	○			0		**6.12 Operation Modes** **Fault operation**
				Stopped	(○)	○	○			0		**6.11 Slide Restraint Means** **6.12 Operation Modes**
		Emergency Stop	E-Stop button is pushed	Stopped	(○)	○	○			0		
			Safety block plug is pulled	Stopped	(○)	○	○		○	0		**6.1 Slide Restraint Means**
	Power outage					○Note 2	○		○	0		

Note 1: Table symbol definitions: Stopping: In the stopping process; Stopped: In a stopped condition; →: Shows passage of time; ○: Is actuated;
(○): Is not actuated by the applicable stopping device; —: Does not stop

Note 2: The main power source is shut down at the time of a power outage.

Table 8.3.2:The Relationship between Stop Functions and Methodology
(When Performing a Stop Category 0 or 1 Stop)

Work Classifi-cation	Operation Mode	Stop Type	Stop Device・Interlock Device	Slide Status	Servo Stop	Power Shutdown	Brake System	Electrical Braking	Restraint Means	Stop Category JIS B 9960-1	Muting	Referenced Items
Production	"Operational Single Stroke" during Production	Temporal Stop	When RUN buttons are released	In operation: From the planned stop position to BDC	○					2		
		Normal Stop		Upstroking beyond BDC						–	○	**6.8 Muting during Slide Opening**
				Stopped (upon arrival)	○			○		1		**6.4.5 Normal Stop Functions** When Feeding & removing
				Stopped (being held)	(○)	○	○				○	
			While RUN buttons are not released	Stopped (upon arrival)	○					2		Restart prevention system Fault operation Single stroke function
		Protective Stop	Photo-electric safety device interrupted	In operation: From the planned stop position to BDC		○	○	○		1		**6.4.3 Protective Stop Function**
				Upstroking beyond BDC						–	○	Photo-electric safety device disabled. **6.8 Muting during Slide Opening**
				When stopped at the planned stop positionp	(○)	○	○			–		Photo-electric safety device disabled. **6.8 Muting during Slide Opening**
			Reversal fault detected	When upstroking		○	○			0		**6.4.3 Protective Stop Function** **6.8 Muting during Slide Opening**
			Personnel detected inside the hazard zone	When first starting	(○)	○	○			0		**6.4.3 Protective Stop Function** **6.7 Presence sensing before initiation**
		Emergency Stop	E-Stop button is pushed	In operation		○	○	○		1		**6.4.2 Emergency Stop Function**
				When stopped at the planned stop position	(○)	○	○			0		
			Safety block plug is pulled	In operation		○	○	○	○	1		Fault operation
				When stopped at the planned stop position	(○)	○	○		○	0		**6.11.3 Safety Blocks**
Trials and Maintenance	"Inching Stroke" during Die Trials	Temporal Stop	When RUN buttons are released	In operation: From the planned stop position to BDC	○					2		**6.12.3 Inching Stroke**
				Upstroking beyond BDC	○					2		**6.12.3 Inching Stroke**
		Protective Stop	Photo-electric safety device interrupted	In operation: From the planned stop position to BDC		○	○	○		1		**6.4.3 Protective Stop Function**
				Upstroking beyond BDC		○	○	○		1		**6.4.3 Protective Stop Function**
				When stopped at the planned stop position	(○)	○	○			0		
			Reversal fault detected	When upstroking		○	○			0		**6.4.3 Protective Stop Function** **6.8 Muting during Slide Opening**
			Personnel detected inside the hazard zone	When first starting	(○)	○	○			0		**6.4.3 Protective Stop Function** **6.7 Presence sensing before initiation**
		Emergency Stop	E-Stop button is pushed	In operation		○	○	○		1		**6.4.2 Emergency Stop Function**
				When stopped at the planned stop position	(○)	○	○			0		
			Safety block plug is pulled	In operation		○	○	○	○	1		Fault operation
				When stopped at the planned stop position	(○)	○	○		○	0		
	"OFF"during Maintenance Work	Protective Stop	Mode selector switch set to OFF	In operation		○	○	○		1		**6.12 Operation Modes** Fault operation
				While stopped	(○)	○	○			0		**6.11 Slide Restraint Means** **6.12 Operation Modes**
		Emergency Stop	E-Stop button is pushed	While stopped	(○)	○	○			0		
			Safety block plug is pulled	While stopped	(○)	○	○		○	0		**6.1 Slide Restraint Means**
	Power outage					○Note 2	○		○	0		

Note 1: Table symbol definitions: Stopping: In the stopping process; Stopped: In a stopped condition; ○: Is actuated; (○): Is not actuated by the applicable stopping device; –: Does not stop.

Note 2: The main power source is shut down at the time of a power outage.

Table 8.3.3: The Relationship between Stop Functions and Methodology
(When Performing a Stop Category 2 Stop Under Conditions That Assure Sufficient Clearance)

Work Classification	Operation Mode	Stop Type	Stop Device, Interlock Device	Slide Status	Servo Stop	Power Shutdown	Brake System	Electrical Braking	Restraint Means	Stop Category JIS B 9960-1	Muting	Referenced Items
Production	"Operational Single Stroke" during Production	Temporal Stop	When RUN buttons are released	In operation: From the planned stop position to BDC	○					2		
		Normal Stop		Upstroking beyond BDC						–	○	**6.8 Muting during Slide Opening**
				Stopping (at destination)	○					2		**6.4.5 Normal Stop Functions**
				Stopping (at destination)	(○)						○	When Feeding & removing
			While RUN buttons are not released	Planned stopping (at arrival)	○					2		Restart prevention system Fault operation Single stroke function
		Protective Stop	Photo-electric safety device interrupted	In operation: From the planned stop position to BDC		○	○	○		1		**6.4.3 Protective Stop Function**
				Upstroking beyond BDC						–	○	Photo-electric safety device disabled. **6.8 Muting during Slide Opening**
				Stopped at the planned stop position	(○)						○	Photo-electric safety device disabled. **6.8 Muting during Slide Opening**
			Reversal fault detected	Upstroking		○	○			0		**6.4.3 Protective Stop Function** **6.8 Muting during Slide Opening**
			Personnel detected inside the hazard zone	First starting	(○)	○	○			0		**6.4.3 Protective Stop Function** **6.7 Presence sensing before initiation**
		Emergency Stop	E-Stop button is pushed	In operation		○	○	○		1		**6.4.2 Emergency Stop Function**
				Stopped at the planned stop position	(○)	○	○			0		
			Safety block plug is pulled	In operation		○	○	○	○	1		Fault operation
				Stopped at the planned stop position	(○)	○	○		○	0		**6.11.3 Safety Blocks**
Trials and Maintenance	"Inching Stroke" during Die Trials	Normal Stop	When RUN buttons are released	In operation: From the planned stop position to BDC	○					2		**6.12.3 Inching Stroke**
				Upstroking beyond BDC	○					2		**6.12.3 Inching Stroke**
		Protective Stop	Photo-electric safety device interrupted	In operation: From the planned stop position to BDC		○	○	○		1		**6.4.3 Protective Stop Function**
				Upstroking beyond BDC		○	○	○		1		**6.4.3 Protective Stop Function**
				Stopped at the planned stop position	(○)	○	○			0		
			Reversal fault detected	Upstroking		○	○			0		**6.4.3 Protective Stop Function** **6.8 Muting during Slide Opening**
			Personnel detected inside the hazard zone	First starting	(○)	○	○			0		**6.4.3 Protective Stop Function** **6.7 Presence sensing before initiation**
		Emergency Stop	E-Stop button is pushed	In operation		○	○	○		1		**6.4.2 Emergency Stop Function**
				Stopped at the planned stop position	(○)	○	○			0		
			Safety block plug is pulled	In operation		○	○	○	○	1		Fault operation
				Stopped at the planned stop position	(○)	○	○		○	0		
	"OFF" during Maintenance Work	Protective Stop	Mode selector switch set to OFF	In operation		○	○	○		1		**6.12 Operation Modes** Fault operation
				Stopped	(○)	○	○			0		**6.11 Slide Restraint Means** **6.12 Operation Modes**
		Emergency Stop	E-Stop button is pushed	Stopped	(○)	○	○			0		
			Safety block plug is pulled	Stopped	(○)	○	○		○	0		**6.1 Slide Restraint Means**
	Power outage					○Note 2	○		○	0		

Note 1: Table symbol definitions: Stopping: In the stopping process; Stopped: In a stopped condition; ○: Is actuated; (○): Is not actuated by the applicable stopping device; –: Does not stop.

Note 2: The main power source is shut down at the time of a power outage.

8.4 Classification of Power Shutdown Methods and Examples of Redundant Designs

Annex 8.4 is a supplement to this standard and Annex 8.1, and is not part of this standard.

8.4.1 Classification of Power Shutdown Methods

Functions that shut down the electrical power supply (power shutdown) to a servo motor come in many diverse systems and methods that are installed/implemented on each servo amplifier model, and they are also referred to by a variety of names. However, in this standard it is necessary to deal with these stop functions in a comprehensive manner as one function of a servo system, and thus they are defined and classified in 4.5. A more detailed explanation of this classification scheme is presented in Figure 8.4.1 and Table 8.4.1.

As shown in Figure 8.4.1, functions that disable servo amplifier (inverter circuit) inversions (AC generation) generally include systems that transmit external equipment signals (OFF signals) from the signal input area to the inverter circuit without involving programmable electronic circuit parts (control circuits) and systems that process such by means of the control circuit in the servo amplifier (referred to as 'servo OFF' or 'enable,' etc.). In this standard, the latter is considered to be a control function that is normally provided in a servo amplifier, and only the former is considered to be an 'electronic shutdown,' which is one type of power shutdown.

Also, the 'control circuit shutdown' shown in Figure 8.4.1 denotes a system that cuts the electrical power supply to the control circuit of the servo amplifier by means of an externally provided switch circuit, which results in the disabling of the energy output of the inverter circuit, but whether this applies to an 'electronic shutdown' or a 'servo OFF' is an issue that is determined based on the results of detailed failure analyses of the servo drive and the switch circuit, and this standard does not go so far as to give such guidance.

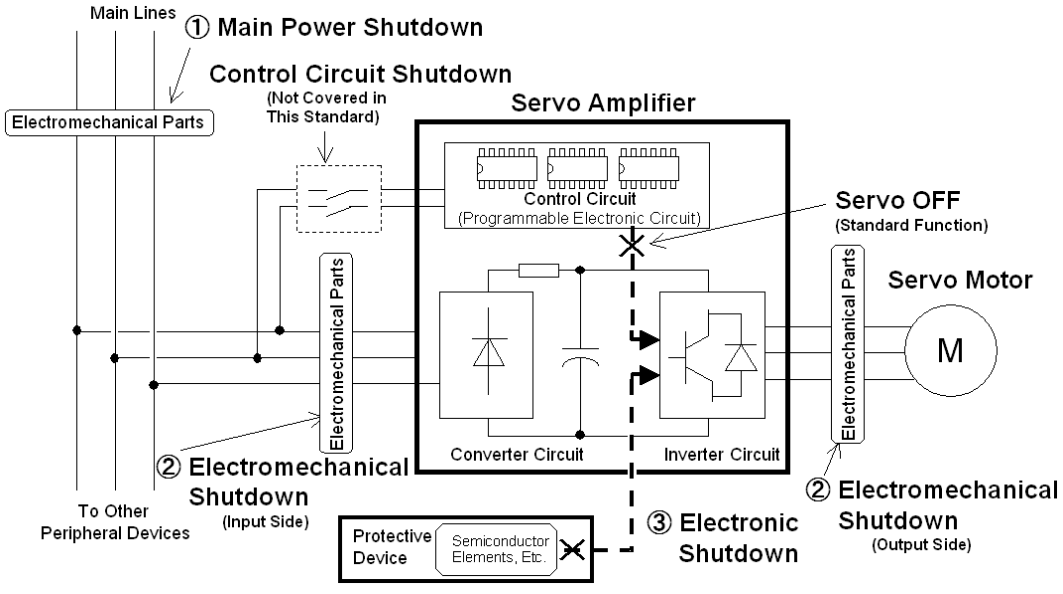


Figure 8.4.1: Classification of Power Shutdown Methods

In this standard, the 'main power shutdown' that accompanies the electrical power supply shutdown to the servo amplifier control circuit is, strictly speaking, just one method for attaining a 'power shutdown,' and there is no special stipulation that requires a 'main power shutdown.'

In contrast, Table 8.4.1 is provided as a guideline for determining which of the power shutdown methods defined in this standard—main power shutdowns, electro-mechanical shutdowns, and

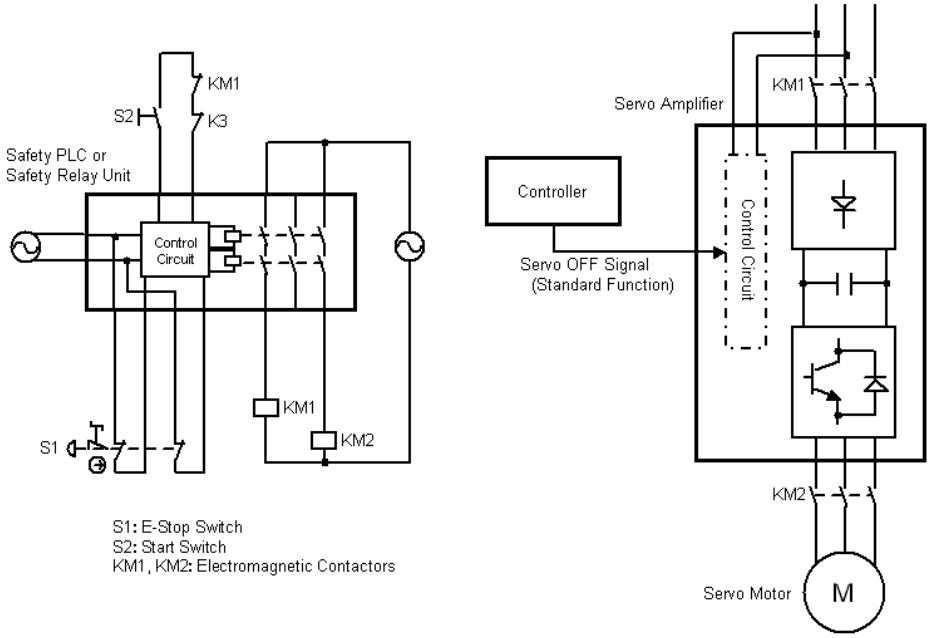
electronic shutdowns—will be applicable, and methods, functions, and means not presented in Table 8.4.1 that can guarantee equivalent safety performance with respect to the content presented as structural requirements are allowed.

Table 8.4.1: Structural Requirements of Power Shutdown Methods

Terminology	Fig. 8.4.1	Structural Requirements	Remarks
4.5.1 Main Power Shutdown	①	The shutdown (disconnection) of the electrical power supply from the main line to the entire servo system using electro-mechanical components. However, it is permissible not to disconnect the power supply going to the 'exempted circuits' stipulated in JIS B 9960-1, 5.3.5 and to the display equipment that provides necessary information during inspections or repairs as long as the equipment conforms with the relevant requirements given in JIS B 9960-1.	In the case of work where it is not necessary to continue to supply electrical power to the servo system (e.g., installation, electrical work, repair work, parts replacement, maintenance, disassembly, etc.), the power shutdown and residual energy release performed using this method will be subject to the highest protective level (refer to JIS B 9700-2, 5.2.4).
4.5.2 Electro-Mechanical Shutdown (Input Side, Output Side)	②	The electrical power (motive energy) related to the motor drive is shut off between either the main line and the amplifier (input side) or the amplifier and the motor (output side) using electro-mechanical parts.	
4.5.3 Electronic Shutdown	③	Inverter circuit inversions (AC generation) are disabled by means of signals (off signals) from external devices such as sensing protective devices that are transmitted from the signal input area to the inverter circuit without involving programmable electronic circuit parts (control circuits).	
Servo OFF (This is assumed in this standard)	—	The base current OFF operation performed by the amplifier control circuit.	In this standard, this is considered to be a standard function incorporated in the amplifier (but it is not considered a safety function).
Control Circuit Shutdown (Not covered in this standard)	—	Usage of an external switch circuit to shut down the electrical power supply to the amplifier control circuits, which serves to disable the energy output of the inverter circuit.	A determination of whether this applies to an 'electronic shutdown' or to a 'servo OFF' is made based on a detailed failure analysis of the servo amplifier and the switch circuit.

8.4.2 Examples of Redundant Power Shutdown System Designs

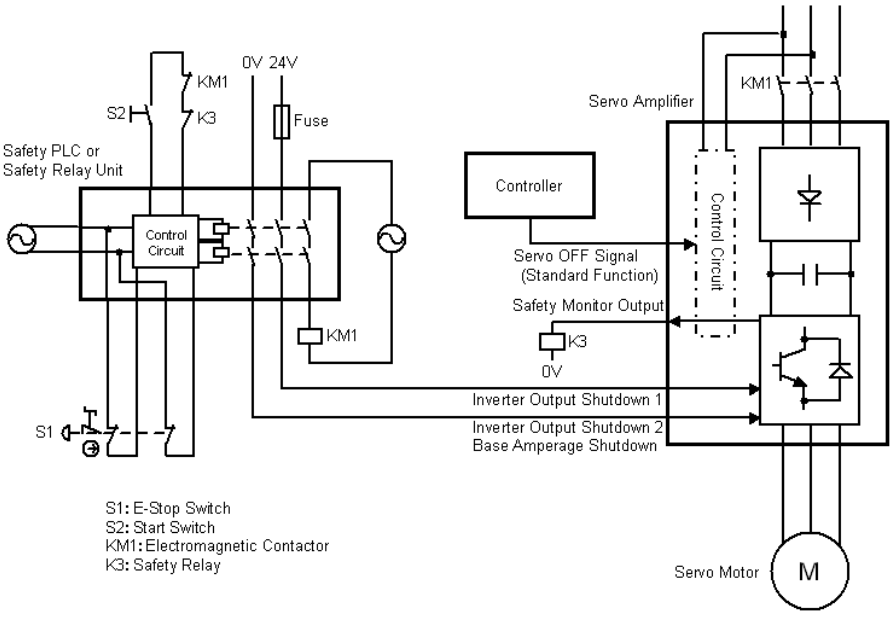
Figures 8.4.2—8.4.4 present examples of redundant power shutdown system designs intended to comply with the Category 4 requirements stipulated in 6.3. However, even if power shutdown systems are constructed using the structures shown in these examples, it does not necessarily guarantee that Category 4 has been immediately attained. The appropriateness of a design with respect to the selected category shall be separately and thoroughly confirmed based on safety-related parts failure analyses and safety function testing.



Note: The following components are used in this example:

- Electromagnetic contactor : Equipped with a forced open B contact for feedback purposes.
- Safety PLC or safety relay unit : Complies with Category 4.

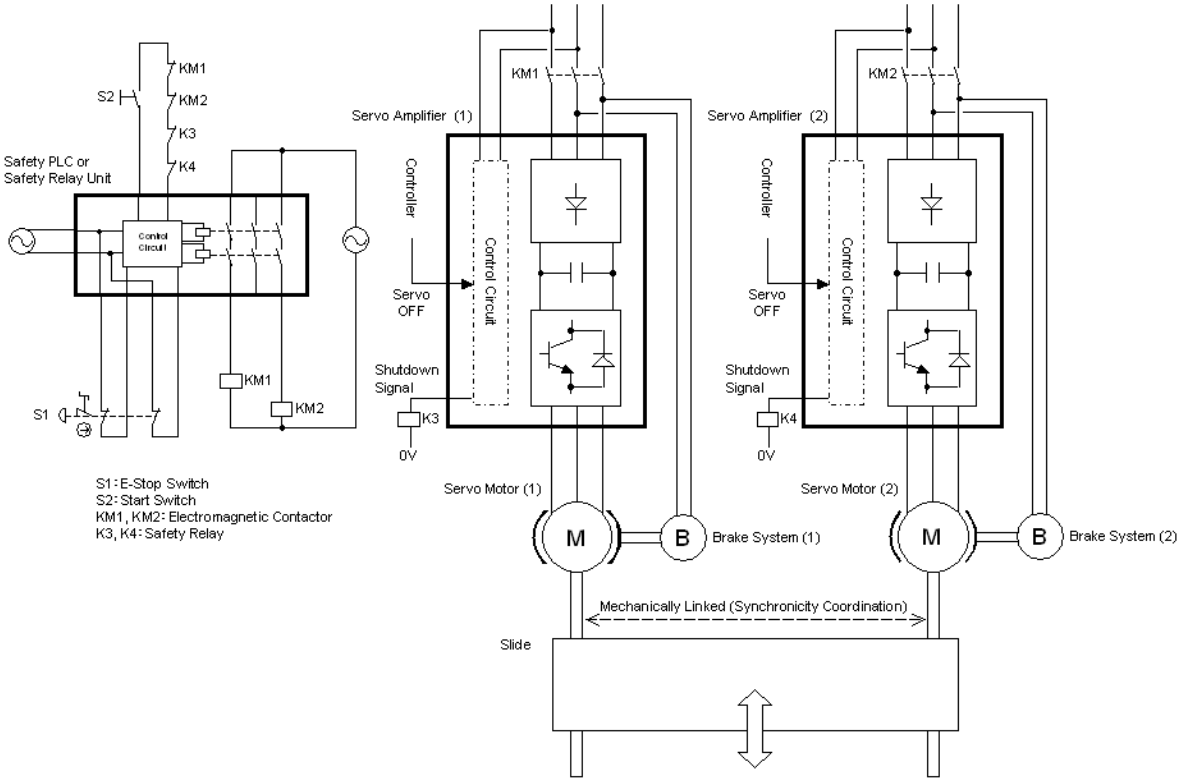
Figure 8.4.2: Redundant Power Shutdown System Design Example 1
(An Example Using 2 Electromagnetic Contactors)



Note: The following components are used in this example:

- Electromagnetic contactor : Equipped with a forced open B contact for feedback purposes.
- Safety PLC or safety relay unit : Complies with Category 4.
- Servo amplifier: Equipped with a Category 3 compliant power shutdown function (electronic power shutdown function)

Figure 8.4.3: Redundant Power Shutdown System Design Example 2
(An Example Using Electromagnetic Contactors and Electronic Shutdown)



Note: This is an example of a redundant system on a servo press with multiple mechanically linked servo drive shafts (shown as being linked by the slide in this figure), where as long as one of the two servo systems is able to perform a power shutdown and decelerate the slide by means of the brake system even if a failure were to occur in the other servo system, any hazardous slide motion would in the end be prevented by the mechanical structure, such as a structure where the slide becomes fully locked. However, the intended safety performance shown here cannot be attained in the case of systems that allow disagreement between the motions of the 2 shafts, such as in a master-slave system where one side is the master and the other is the slave. Moreover, analyses and evaluations are necessary in cases where stop function redundancy would be lost due to a single fault, such as a fault caused by a defect in the mechanical element parts that link the two shafts (e.g., the link becomes damaged).

The following components are used in this example:

- Electromagnetic Contactors : Equipped with a forced open B contact for feedback purposes.
- Safety PLC or safety relay unit : Complies with Category 4.
- Brake System : A normally closed type mechanical brake.

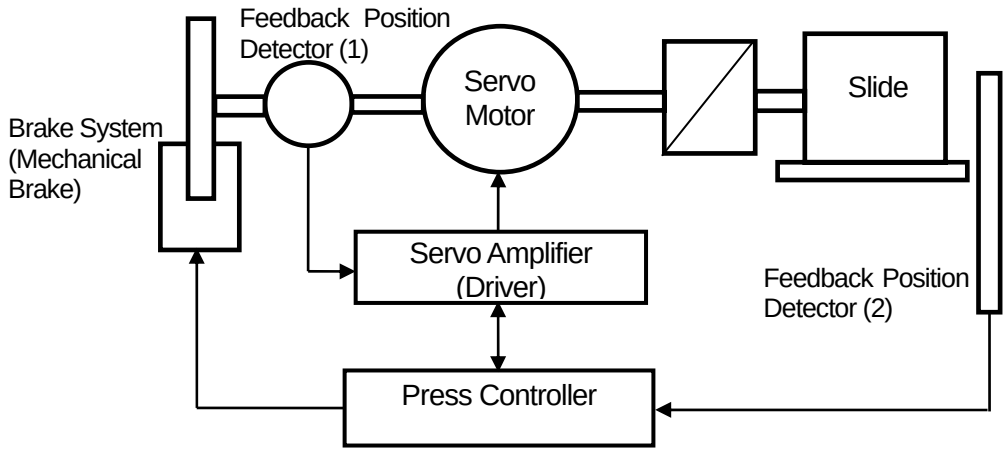
Figure 8.4.4: Redundant Power Shutdown System Design Example 3
(An Example Using Multiple Servo Systems to Assure Redundancy)

8.5 Implementation Examples of Static Brake Performance Monitoring Functions

Annex 8.5 is a supplement to this standard and Annex 8.1, and is not part of this standard.

8.5.1 Implementation Examples of Static Brake Performance Monitoring of Mechanical Brake Systems

Envisioning a servo press that executes static brake performance monitoring of mechanical brake systems, Figure 8.5.1 presents a function block diagram of a specific implementation example. However, this figure is primarily provided for explanatory purposes in order to show the components and those actuations related to the static brake performance monitoring function, and even if a subsystem is constructed with the same structure and actuation shown in this example, it does not necessarily guarantee that the required safety function (category) has been immediately attained. The appropriateness of a design with respect to the selected category shall be separately and thoroughly confirmed based on a detailed hardware failure analysis, a press controller software quality evaluation, and post-implementation safety function testing.



- The signal from feedback position detector (1) is processed in the servo amplifier.
- The processed signal is sent from the servo amplifier to the press controller.
- The signal from feedback position detector (2) is received by the press controller.
- The values of feedback position detector (1) and feedback position detector (2) are compared in the press controller, and if there is no disagreement, the value becomes the detection value of the slide position before the monitoring test.
- The press controller actuates the mechanical brake system (mechanical brake).
- The press controller commands the servo amplifier to operate at the torque value used for brake performance monitoring.
- Power is supplied from the servo amplifier and the motor generates torque.
- The signal from feedback position detector (1) is processed in the servo amplifier.
- The processed signal is sent from the servo amplifier to the press controller.
- The signal from feedback position detector (2) is received by the press controller.
- The values of feedback position detector (1) and feedback position detector (2) are compared in the press controller, and if there is no disagreement, the value becomes the detection value of the slide position after the monitoring test.
- The position detection values before and after the monitoring test are compared in the press controller, and if there are changes in the values this is judged as performance degradation of the brake system , and the starting of the slide is disabled and a fault message is displayed.

Figure 8.5.1: Function Block Diagram of the Static Brake Performance Monitoring Function of a Mechanical Brake System

8.6 Examples of Measures Applicable to Software

Annex 8.6 is a supplement to this standard and Annex 8.1, and is not part of this standard.

8.6.1 Overview

The software used for servo presses shall be reliable, and moreover, it shall be tested, evaluated, and proven that its behavior is acceptable when a failure occurs. In this standard, specific measures to attain this purpose are not stipulated, but as an example, the following measures based on ISO 13849-1:2006, 4.6 are presented. Now, if the same software is used for multiple safety functions, compliance with the strictest malfunction-related requirements is required.

8.6.2 Basic Measures

At a minimum, the following basic measures are to be applied to software related to safety functions:

a) The application of the V model that accompanies software development process verification and validation activities (refer to ISO 13849-1:2006, Figure 6).
b) Documentation of the functional requirement specifications, the safety level requirement specifications, and the design.
c) Modular and structured design, programming, and coding.
d) Control of systematic failures.
e) Verification of correct implementation.
f) Functional testing, for example, black box testing.
g) Implementation and management of appropriate software safety lifecycle activities related to software modifications.
h) Protections to prevent changes by users.

8.6.3 Embedded Software

Safety-related embedded software is to be designed, developed, attained, verified, and managed in accordance with safety integrity level 3 (SIL3) requirements stipulated in JIS C 0508-3 in the case of hand-in-die servo presses, and in accordance with the appropriate safety integrity levels in all other cases.

8.6.4 Application Software

Application software related to safety functionality is to be designed, developed, attained, verified, and managed in accordance with ISO 13849-1:2006, 4.6.3 when written in a limited variability language, and ISO 13849-1:2006, 4.6.2 when written in a full variability language.

8.6.5 Software Based Parameterization

Software based parameterization related to safety functions, such as the settings for the allowable values for a safety function start time, start position, or monitoring function, is only to be possible using the dedicated software tool supplied by the manufacturer, and unauthorized changes are to be prevented by means of a password, etc.

Additionally, it is necessary to maintain the integrity of all data related to parameterization, and compliance with ISO 13849-1:2006, 4.6.4 or IEC 62061, 6.11.2 is to be considered in order to achieve this.

9. Summary

Regarding safety measures for the servo presses, each servo press manufacturer had been independently developing protective measures until the previous TI103:2006 standard was issued in March, 2006. However, the rapid expansion and development of servo press functionality and technology since its first issuance has prompted the need for the consistency on an international level within their various regulations and standards and has recently led to the first revision. The recommended approach to servo press safety and the technology benchmarks/performance standards presented in the previous edition are all incorporated in this TI103:2008.

This revision addresses those hazards among all of the servo press hazards that are attributable to the unique characteristic of a servo press where slide motion is controlled by a programmable servo system, and a new list of hazards has been formulated. Regarding other hazards and those attributable risks that are not addressed in this standard, just as in the case of the ones already recognized for conventional power presses, they are to be adequately eliminated or reduced by adhering to the relevant laws and regulations (The Industrial Safety and Health Act, The Enforcement Order of the Industrial Safety and Health Act, The Ordinance on Industrial Safety and Health, The Construction Code for Power Press, and The Construction Code for Press Machine or Shearing Machine Safety Equipment).

In addition, this revised edition has been made to consider consistency with the ISO/IEC standards for machine safety that have been significantly augmented in recent years, and its correlation/equivalence with the technological content of these groups of standards has been clarified. Especially as it relates to requirements for servo system safety performance, the content of this standard has been reviewed from the perspective of international standards, and its content has also been revised to confirm with the concepts, standards, and terminology on functional safety stipulated in the most recent ISO/IEC standards.

Please be noted that now there are plans to have this TI103:2008 association standard become a Japanese Industrial Standards (JIS). In the event it becomes the JIS standard, this association standard will consequently become null and void.

Compiled by: The Japan Forming Machinery Association, Engineering Committee Secretariat