Design-In Health and Safety Specification

Global Common

SD-012

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This specification supports the Lean Manufacturing initiative and is to be used by Nexteer Automotive Manufacturing Engineers worldwide as a specification for Manufacturing Equipment design. In addition, to ensure a safe work environment for all personnel, the following **Lean Vision** was used as a guiding principle in the development of this document.

Least complicated machine, process, and safety system that protects all personnel from injury and illness.

The intent is to use a common method and consistent implementation worldwide to prevent occupational injuries and illnesses while simplifying equipment. This shall be accomplished by using a Machine Risk Assessment analysis to identify equipment and process task-hazards. The "Hierarchy of Health and Safety Controls" shall be followed to eliminate exposure to these task-hazards.

The Manufacturing Engineering Leadership Team supports the Lean Manufacturing initiatives. They result in reduced cost, increased customer satisfaction, and our being a stronger company, while at the same time ensuring a safe work environment for our personnel.

The Equipment Engineer is identified throughout this Specification and is defined as the Manufacturing Engineer in charge of purchasing the equipment.

1. General

1.1 Scope

This specification contains Health and Safety principles, guidelines, and requirements for the design and redesign of Industrial Equipment and systems used in processing or manufacturing at Nexteer Automotive. This specification applies, but is not limited to, assembly workstations / cells, standard / custom build machines, conveyors, spray booths, ovens, process equipment, material handling equipment, robotic systems, and all related manufacturing systems. This document should be considered a guideline for development, prototype, validation, or lab equipment.

This specification is organized into four segments:

- Manufacturing Equipment System Designs and Design-In Safety Process
- Human Interface Applications
- Specific Hardware Applications
- Specific Manufacturing Process Applications

1.2 Purpose

The purpose of this specification is to provide the Nexteer Automotive Manufacturing community (including Engineers, Skilled Trades, Safety Personnel, and Equipment Suppliers) with the knowledge, tools, and methods to achieve a safe operating environment for all personnel.

1.3 Informative References

See Annex E for a list of informative references. Users of this document shall consult applicable Federal, State, and Local laws, regulations, and standards in addition to those listed.

1.4 Application

The requirements of this specification shall be applied to all new manufacturing equipment systems as defined in Section 1.4.1. Compliance to this specification for existing Manufacturing Equipment Systems undergoing modifications shall be applied as defined per Section 1.4.2.

The table below defines the safety, ergonomic, sound level, electrical and fluid power specifications required to be followed based on the scope of work being performed on the equipment:

New Equipment	Remanufactured (Rebuilt)	Retooled	Redeployed (Intra-Plant)	Redployed (Inter-Plant)	Modified (Safeguarding)
H&S Checklist	H&S Checklist	H&S Checklist	H&S Checklist	H&S Checklist	H&S Checklist
Machine Risk Assessment	Machine Risk Assessment	Machine Risk Assessment			Machine Risk Assessment
Regional Requirements	Regional Requirements	Regional Requirements	Regional Requirements	Regional Requirements	Regional Requirements
Machinery / Equipment Sign Off Procedure	Machinery / Equipment Sign Off Procedure	Machinery / Equipment Sign Off Procedure	Machinery / Equipment Sign Off Procedure	Machinery / Equipment Sign Off Procedure	Machinery / Equipment Sign Off Procedure
Lockout Placard	Lockout Placard	Lockout Placard	Lockout Placard	Lockout Placard	Lockout Placard
SD-000 / SD-010	SD-000 / SD-010	SD-000 / SD-010			SD-000 / SD-010
SD-011	SD-011	SD-011			SD-011
SD-012	SD-012	SD-012	SD-012	SD-012	SD-012
SD-017	SD-017	SD-017	SD-017	SD-017	SD-017
SD-018	SD-018	SD-018	SD-018	SD-018	SD-018

1.4.1 New Manufacturing Equipment Systems

New Manufacturing Equipment Systems includes the design, engineering, construction, and functional testing of the equipment. These new Systems shall follow the Design-In Safety Process outlined in this specification.

1.4.2 Existing Manufacturing Equipment Systems

Existing Manufacturing Equipment Systems are equipment that have been previously used in manufacturing and is being modified. Any equipment that is remanufactured, retooled, redeployed, or modified shall meet the job safety requirements according to applicable Health and Safety Standards, and regulations followed by the global Machinery/Equipment Sign Off Procedure. There are 4 types of existing equipment modifications listed below:

1. Remanufactured (Rebuilt) Manufacturing Equipment Systems

   Remanufactured Manufacturing Equipment Systems is equipment that is being mechanically, electrically, or fluid power rebuilt to an as-new state. These Manufacturing Equipment Systems shall follow the Design-In Safety Process and meet the requirements of this specification. A Machine Risk Assessment for the remanufactured system shall be completed.

2. Retooled Manufacturing Equipment Systems

   Retooled Manufacturing Equipment Systems is equipment where only the tooling is modified without impacting the existing safeguarding of the equipment. It shall be the responsibility of the Equipment Engineer to work with Health and Safety to complete the Plant's H&S Checklist. Where H&S issues exist, this document should be used as a guideline to update the safeguarding. A Machine Risk Assessment for the modified portion of the tooling shall be completed.

3. Redeployed (Intra-Plant and Inter-Plant) Manufacturing Systems

   Redeployed Manufacturing Equipment Systems is equipment that is moved from its existing location to another location without undergoing any modifications. It shall be the responsibility of the Equipment Engineer to work with Health and Safety to complete the Plant's H&S Checklist. This checklist is available on the H&S website. Where H&S issues exist, this document should be used as a guideline to update the safeguarding. Intra-Plant redeployment is defined as moving equipment within the same plant, Inter-Plant redeployment is defined as moving equipment between different plants.

4. Modifications to Manufacturing Equipment Systems

   When making modifications to existing Manufacturing Equipment Systems that impact the safeguarding of the equipment. These Manufacturing Equipment Systems shall follow the Design-In Safety Process and meet the requirements of this specification. The Equipment Engineer and Controls Engineer are to work with H&S to identify the tasks and hazards impacted by this change. A Machine Risk Assessment for these task-hazard combinations shall be completed and the safeguarding upgraded consistent with the agreed upon risk reduction method.

1.5 Deviations

Any deviations from this specification shall be addressed during Safety Design Reviews and Machine Risk Assessment creation with alternative solutions documented and approved by the Equipment Engineer, Controls Engineer, and H&S Representative. Any approved deviations shall only apply to that specific instance and shall not be considered a change to this specification or acceptable for future M&E purchases.

1.6 Design-In Safety Process and Associated Tools

1.6.1 Definition and Purpose

The Design-In Safety process is an engineering based, closed loop communication process using the Bill of Process (BOP), Best Practice database information, Machine Risk Assessment, Safety Design Reviews, and Validation information to procure Manufacturing Equipment Systems. This process will ensure a common approach for designing best practice safety systems into new and existing Manufacturing Equipment Systems.

1.6.2 Design-In Safety Process

The Process uses Design Reviews for safety, including both Machine Risk Assessment and Validation, as shown in Figure 1. The process incorporates existing efforts for Safety Designs that engineering groups are currently performing (Example: MSD, DFM, PFMEA, Safety Run-Offs, and Safety Sign-Off Tag procedures).

The Design-In Safety Process shall be integrated with the PDP / equipment procurement process. It is the responsibility of the Equipment Engineer to ensure compliance to this process.

1. Concept / Specifications

   At the start of a new program, develop the process / equipment concept consistent with the Global Bill of Process (BOP) and the Manufacturing System Design (MSD). Each type of equipment is to have a section in the Manufacturing Equipment Systems purchase specification outlining any appropriate Design-In Safety requirements for equipment to be purchased for this process. Feedback from Health & Safety on similar types of equipment, new program implementation, safety design reviews, and Machine Risk Assessment data will be vital input for continuously improving these Manufacturing Equipment Systems purchase specifications.

   Where the equipment is well defined, a Machine Risk Assessment should be conducted at this stage to ensure the safeguarding approach is appropriate.

   This is the responsibility of the Equipment Engineer (ME) in Charge and the assigned Controls Engineer (CE).

2. Pre-Award – Quote Review

   This review occurs after all Equipment Supplier's quotes have been reviewed, and a preliminary Equipment Supplier selection has been made. The design concept is to be reviewed for consistency with Design-In Safety requirements outlined in the Manufacturing Equipment Systems purchase specification and is considered the initial safety design review. If the Equipment Supplier has presented an alternative design approach, the Design-In Safety requirements may need to be revisited.

   NOTE: Where Equipment Suppliers indicate their equipment meets national / international standards, a Machine Risk Assessment shall be completed to verify the safeguarding has been appropriately implemented.

   This is the responsibility of the Equipment Engineer, the assigned Controls Engineer, and Purchasing.

3. New Equipment Machine Risk Assessment

   A "New Equipment" Machine Risk Assessment is a joint activity conducted on new Manufacturing Equipment System designs that have proceeded through the initial safety design review, the purchase order has been issued, and the Equipment Supplier has provided a detailed design concept for review (refer to Section 3, Machine Risk Assessment). The Machine Risk Assessment shall be conducted prior to the Equipment Supplier moving to the detailed design phase completion. The Machine Risk Assessment shall be stored in the MQ Workflow within TeamCenter Manufacturing.

The two main objectives for the Machine Risk Assessment are to identify hazards to design them out, and to allow Plant personnel who will operate and maintain the equipment an opportunity to provide valuable input into the safety systems of the new design. The team should consist of engineers from Nexteer Automotive and the Equipment Supplier, Plant hourly personnel (Example: Operator, Job Setter, Skilled Trades), and local joint Health & Safety Representatives.

It is the responsibility of the Equipment Engineer to ensure the Machine Risk Assessment is completed.

The joint training activities, from the technical, safety, and job-related fields, will become involved in the Machine Risk Assessment as needed.

4. Design Review / Design Approval

After the detailed design is submitted for approval, a second safety design review is to take place. This is to ensure the design is consistent with the Design-In Safety requirements, the Machine Risk Assessment for the equipment, and the Design-In concepts outlined in this document.

5. Safety Buy-Off

The third and final safety design review should occur during or prior to equipment runoff at the Equipment Supplier or Integrator's site, or as specified in the purchase order. Equipment Engineer and Health & Safety personnel are to ensure the M&E Safety Checklist, all safety elements outlined in the safety design revises, and the Machine Risk Assessment have been implemented appropriately.

6. Validation

The validation process is conducted at the Plant to validate the key safety deliverables have been completed. Validation activities shall be conducted and passed prior to the equipment or system is released for production. The Machine Risk Assessment outputs, such as Lockout, Elimination and Substitution, and Safeguarding (Engineering Controls), will be used in the validation process to ensure all safety items meet their intended use related to a specific task. The ME, and local Health & Safety personnel, will complete the Equipment Safety Sign-Off (red tag) procedure, review the M&E Safety Checklist, and validate the final placards.

To assist in the evaluation of safety components and circuits, reference SD-011. The information listed in Annex C can be used for Preventative Maintenance verification of safety components and circuits, or for annual safety system checks. In addition, the information listed can be used for verification of the safety system after safety components are replaced.

1.6.3 Feedback & Design Improvements

The application of the best safety practices for new equipment design is essential to the Design-In Safety process.

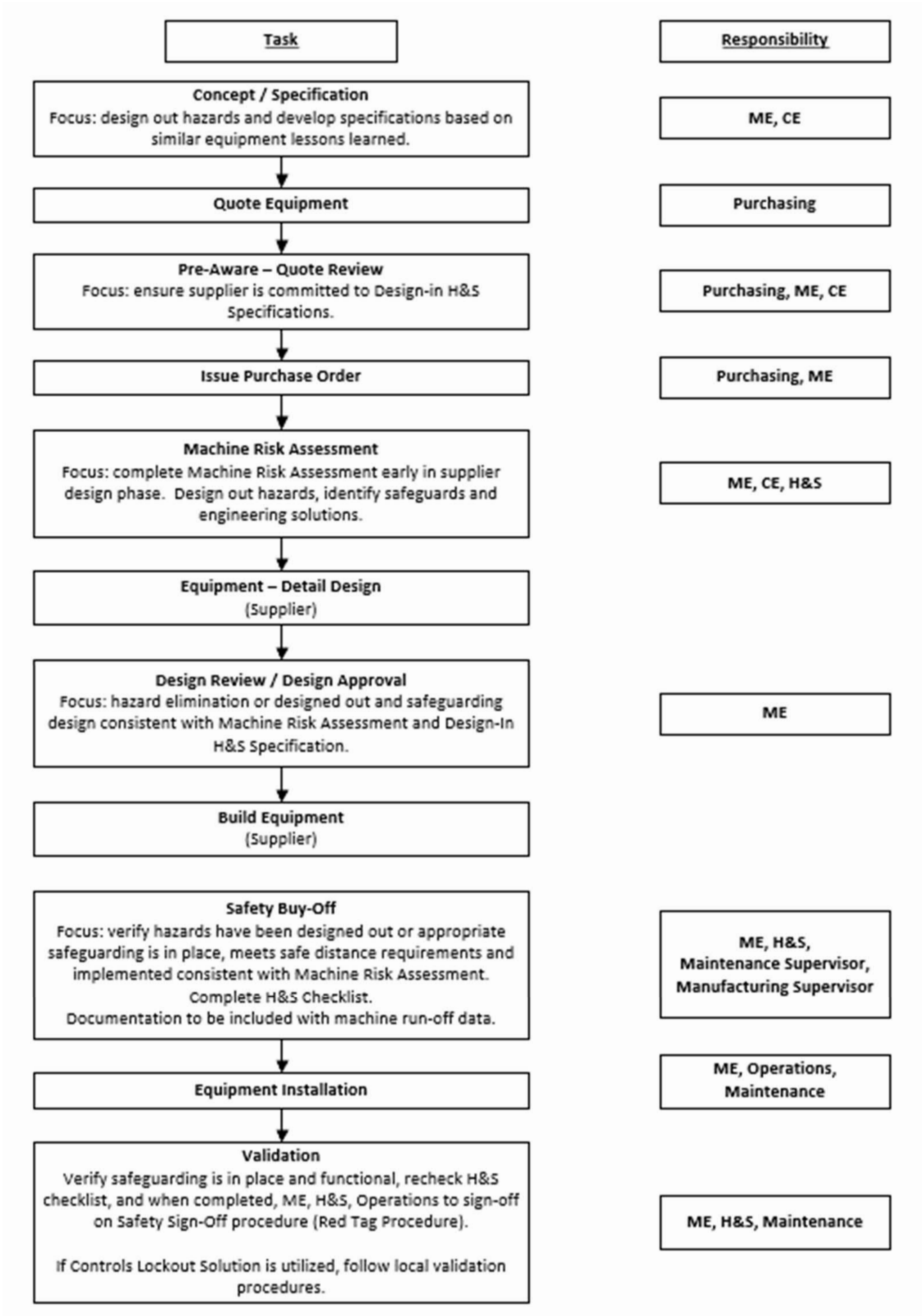


Figure 1: Design-In Safety Process

2. Hierarchy of Health and Safety Controls

The Hierarchy of Health and Safety Controls represents the fundamental principles that govern the application of safety designs, which eliminate or reduce risk caused by exposure to hazards based on specific tasks performed. This specification is based on these hierarchy principles.

The hierarchy consists of five levels – arranged in order of most effective to least effective – as shown below. The preferred method of controlling hazards is via Level 1 or Level 2 control.

Figure 2: Hierarchy of Health & Safety Controls

The table below indicates the effectiveness of Health & Safety Controls, the associated value and cost.

Effectiveness	Levels of Control	Value	Cost
Most	Elimination or Substitution	Hazards are eliminated or reduced.	Long-term cost reduced or eliminated.
⇩	Safeguarding (Engineering Controls)	Exposure to hazards is controlled.	Potential for higher initial cost, however, offset by reduced long term cost.
⇩	Warnings	Alerts people that hazards exist.	Cost to maintain and implement
⇩	Training and Procedures	Only trained personnel operate and maintain equipment. Safe operating practices and procedures are established.	Cost associated with training / retraining. Resources to establish Safe Operating Practices.
Least	Personal Protective Equipment	Provides a personal / last resort barrier to the hazard	Recurring operating cost associated with the use and maintenance of personal protective equipment.

Figure 3: Effectiveness of Health & Safety Controls

2.1 Applying the Hierarchy of Health and Safety Controls

The basic thought process must recognize the work to be done, evaluate the hazards and exposures associated with the tasks, and provide the most effective H&S control solution.

Safety for all processes, cells, and machines shall be addressed through the Hierarchy of Health and Safety Controls. The following examples are intended to provide a better understanding of the hierarchical approach. Refer to Annex E for illustrations of these examples.

2.1.1 Example Elimination or Substitution Methods:

- Eliminate equipment
- Simplify equipment
- Improve initial equipment design
- Remove / minimize human interaction with equipment
- Eliminate pinch points
- Eliminate or simplify material handling
- Place adjusting devices and other requirements for human interaction outside the hazard area
- Substitute less hazardous processes or chemicals
- Reduce energy (lower speed, force, amperage, pressure, temperature, volume or noise)

2.1.2 Example Safeguarding (Engineering Controls) Methods:

- Guards
- Light curtains
- Two-Hand Control Devices
- Enable Devices
- Safety mats
- Interlocks
- Safety controls and logic (safety relays, safety controllers, and other control devices
- Ventilation, local or point of operation exhaust
- Automatic / manual material handling (Example: lift for ergonomic issues)

2.1.3 Example Warning Methods:

- Lights, beacons, and strobes
- Awareness barriers
- Computer warnings
- Signs, placards, markings, or labels
- Markings indicating a restricted space on the floor
- Equipment start-up alarms, beepers, and horns

2.1.4 Example Training and Procedure (Administrative Control) Methods:

- Safe Operating Practices and Procedures
- Standardized Work Instruction
- Job rotation
- Written training programs
- Confined Space
- Lockout
- Equipment Safety Inspections

NOTE: Written training, procedures, and administrative controls are used when higher-level alternatives are not feasible, and when the risk adequately controlled. Personnel must be properly trained before operating and maintaining equipment. This includes being provided with up-to-date and accurate written instructions (Safe Operating Practices and Procedures, Standardized Work Instructions, Set-Up, Start-Up, Run, Stop, etc.). The training and instructions must be implemented, enforced, and followed.

2.1.5 Example Personal Protective Equipment (PPE) Methods:

- Face shields
- Safety glasses
- Hearing protection
- Gloves
- Safety Toe Shoes
- Protective sleeves
- Respirators
- Welding screens
- Expendable tools
- Hard Hats
- Safety Harnesses
- FR Clothing

3. Machine Risk Assessment

A task-based Machine Risk Assessment is a systematic process for evaluation of all operation and maintenance tasks, and their associated hazards. Task-hazard pairs are analyzed for risks in the hazardous area where environmental (work area) conditions (Example: equipment motion paths and speed, blind spots, fumes, mists, etc.) could potentially cause harm to the person performing the task. Group recommendations are then captured based on the analysis. Nexteer's Machine Risk Assessment process applies to the machine design and is within the scope of in-production use of the machine. Construction practices, such as conductor and hose sizing / ratings, installation, or machine de-commissioning, fall outside the scope of the Machine Risk Assessment process.

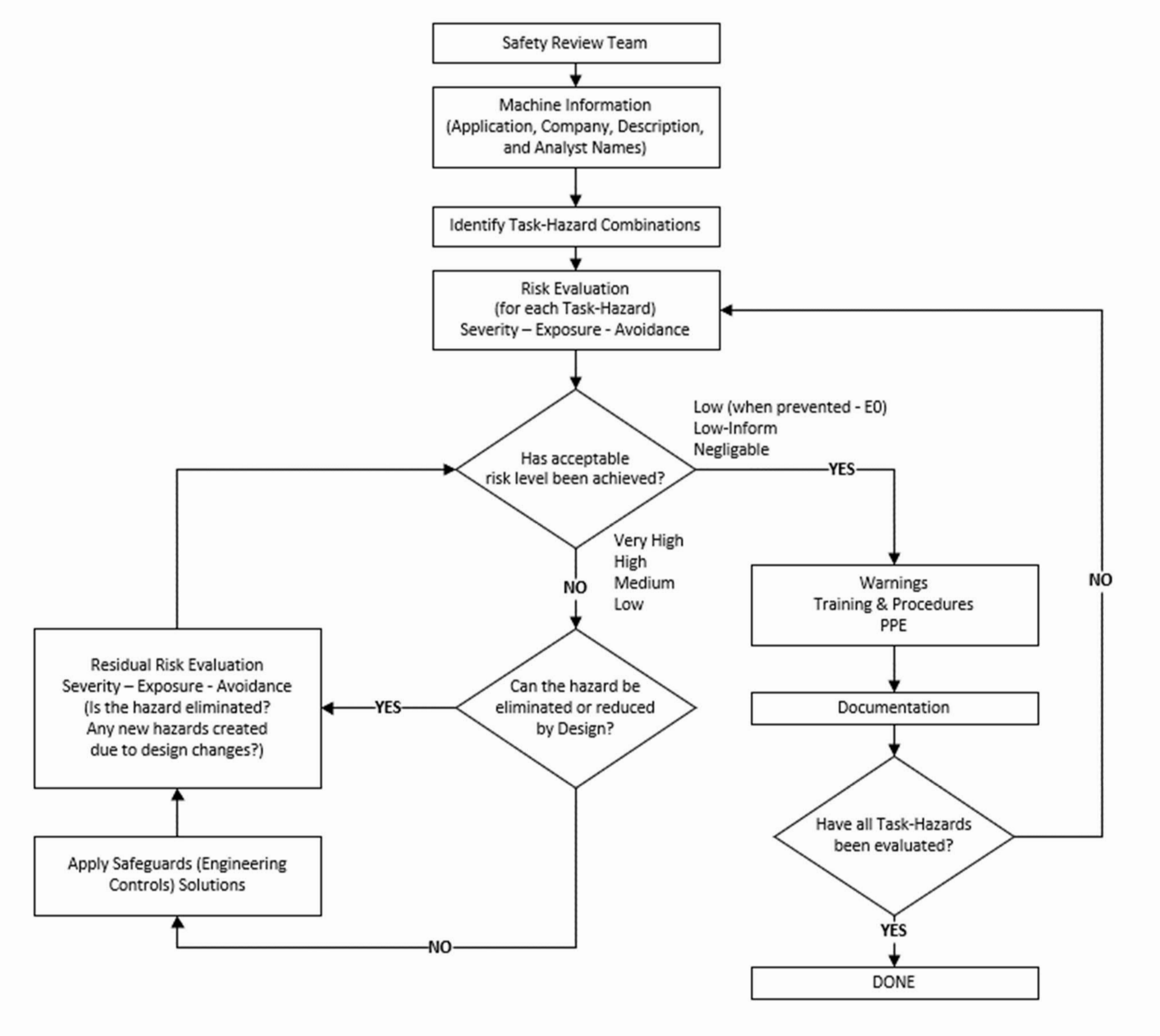


Figure 4: Machine Risk Assessment Process

3.1 Requirements

Several methodologies are available to perform a Machine Risk Assessment. The following process is one methodology that meets the requirements for an accurate and thorough Machine Risk Assessment. This process is consistent with, and based upon, ISO12100, ISO14121, ISO13849, ANSI B11.0, ANSI B11.TR3, and RIA TR 15.306.

The requirements for the Machine Risk Assessment are:

3.1.1 Nexteer Automotive personnel, and the Equipment Supplier, shall perform the Machine Risk Assessment early in the design process. Every effort shall be made to design-out hazards and design-in safety.

3.1.2 Nexteer Automotive and the Equipment Supplier shall ensure the Machine Risk Assessment accurately represents the equipment as delivered to Nexteer Automotive. Where the Equipment Supplier deviates from the original Machine Risk Assessment, Nexteer Automotive approval is required.

3.1.3 The steps in a Machine Risk Assessment include the following:

1. Assume that no safeguards are installed and identify all task-hazard combinations per Section 3.2.
2. Determine the level of risk for each task-hazard combination per Section 3.3 and 3.4.
3. Determine the safeguard solution / risk reduction method for each task-hazard combination per Section 3.5.
4. Design-out the hazard and if not possible, select the safeguard to meet the circuit performance level per Section 3.6.
5. Determine the level of residual risk for each task-hazard combination per Section 3.7.
6. Document the Machine Risk Assessment per Section 3.8.
7. Verify the proper implementation of the risk reduction method per Section 3.9

3.2 Task and Hazard Identification

The requirements for the task and hazard identification are:

3.2.1 Identify all reasonably foreseeable tasks associated with the equipment or process (User: Material Handler, Operator, Set-Up Person, Skilled Trades, or Passers-by).

3.2.2 Identify all reasonably foreseeable hazards associated with each task. Hazards shall be identified in all aspects of equipment operation including, but not limited to:

1. Equipment motions (Example: advance, raise, close, rotate, etc.) that the user is exposed to, if the motion creates a bump, pinch, crush, cut, sever, puncture, entanglement, etc.
2. Example Material handling tasks where the user is exposed to:
   - Ergonomics
   - Thermal – hot parts, hot surface
   - Part handling – sharp edge or burr, oil on part, coolant on part
   - Slips / trips / falls / egress
3. Example Process Hazards
   - Chemical / toxicity – oil, coolant, mist, grease, hydraulic fluid, RTV, etc.
   - Noise
   - Projectile – flying chips, weld splatter, parts, tools, hot plastic, etc.
   - Weld flash, lasers, x-ray (radiation), etc.
   - Fluid Injection
   - Heat
4. Skilled Trades Hazards
   - Vertical Loads
   - Stored Energy (Electrical, Hydraulic, Pneumatic, Mechanical)
   - Major Repair / Component Replacement

3.3 Risk Estimation

For each task-hazard combination, determine the level of risk using severity, exposure, and avoidance factors per the table below. Where multiple criteria can apply, use the most restrictive criteria.

FACTOR	CATEGORY	CRITERIA
Severity	S3 CATASTROPHIC	Normally non-reversible; likely will not return to the same job after recovering from the incident: • Fatality • Limb amputation • Thumb amputation • Long term disability • Chronic illness If **any** of the above are applicable, the rating is **CATASTROPHIC**.
	S2 SERIOUS	Normally reversible; likely will return to the same job after recovering from the incident. Note: The injury remains severe and significant. • Broken bones • Severe laceration • Finger amputation (not thumb) • Short hospitalization • Short term disability • Lost time (multiple day) If **any** of the above are applicable, the rating is **SERIOUS**.
	S1 SLIGHT	No recovery required before returning to the job: • Bruising / contusion • Small cuts • First Aid / No lost time (less than a single day) • Does not require attention by a medical doctor (physician) If **any** of the above are applicable, the rating is **SLIGHT**.
	S0 NO INJURY	No injury occurs.

FACTOR	CATEGORY	CRITERIA
Exposure	E2 FREQUENT	• Exposure of multiple short durations (> once per hour). • Time of Exposure > 15 continuous minutes. If **either** of the above are applicable, the rating is **FREQUENT**.
	E1 INFREQUENT	• Exposure < once per hour. • Time of Exposure < 15 continuous minutes If **both** above are applicable, the rating is **INFREQUENT**.
	E0 PREVENTED	• Exposure is eliminated / limited by inherently safe design measures. • Use of safety device prevents exposure or access to the hazard(s). Controls Solution is selected, and the implemented functional safety performance level (PL) meets or exceeds required functional safety performance level (PL_r). If **either** of the above are applicable, the rating is **PREVENTED**. E0 is only allowed to be used on initial risk evaluation if an inherently safe design is used.
Avoidance	A3 NOT POSSIBLE	• Safeguarding is not expected to offer protection from the process hazard (Example: explosion or eruption hazard). • Insufficient clearance to move out of the way of the hazard or significantly reduce its effect. • The system or cell layout causes the Operator to be trapped, with the escape route toward the hazard. If **any** of the above are applicable, the rating is **NOT POSSIBLE**.
	A2 NOT LIKELY	• Hazard can move fast enough to make avoidance unlikely (> 250mm/sec). • Inadequate warning / reaction time. • The hazard is unnoticeable, cannot be seen, or is unrecognizable. • Insufficient clearance to move out of the way even with safety-rated reduced speed control in use. • Obstructed path to move to safe area. If **any** of the above are applicable, the rating is **NOT LIKELY**.
	A1 LIKELY	• Hazard is noticeable, can be seen, or is recognizable. • Realistic chance of avoiding the hazard or significantly reducing its effect, such as through: · Adequate warning / reaction time. · Exposed personnel are familiar with the hazard · Sufficient clearance to move out of the way. · Hazard moves slow enough to make avoidance likely (< 250mm/sec). · Person is positioned in a safe location away from the hazard. · Task location is a safe distance away from the hazard origin. If **both** of the above main items are applicable, the rating is **LIKELY**.

Figure 5: Hazard Severity / Exposure / Avoidance Categories

3.3.1 Severity of Injury

The injury severity is an estimation of harm due to each hazard while performing the associated task, slight injuries (no recovery time required), serious injuries (normally reversible), and catastrophic injuries (normally non-reversible, including death) are considered.

Estimations of severity of harm can be challenging. The most severe estimation can be unlikely, and the most likely severity can be insignificant (or negligible). Using either could lead to an inappropriate estimation of risk. Severity estimation should focus on the most severe harm that can realistically occur rather than the worst possible consequence."

To determine hazard severity, the usual consequences of accidents and normal healing processes should be considered in determining S3, S2, S1, and S0. For example, death would be classified as S3 (Catastrophic), whereas a finger amputation would be classified as S2 (Severe), and bruising or lacerations without complication would be classified as S1 (slight). An S0 is to be classified when there is no injury or consequence related to the hazard.

3.3.2 Exposure to a Hazard

The period of exposure to the hazard should be evaluated based on an average value, which can be seen in relation to the total period of time in which the equipment is used. For example, if it is necessary to reach regularly between the tools of the machine during cyclic operation to load / unload parts, E2 (Frequent) should be selected. If exposure is occasionally required and duration is less than 15 continuous minutes, E1 (Infrequent) should be selected.

E2 (Frequent) should be selected if a person is frequently or continuously exposed to the hazards. It is irrelevant whether the same or different persons are exposed to the hazard on successive exposures, for example, a machine loaded and unloaded by different operators. The exposure parameter should be chosen according to the frequency and duration of exposure to the hazard.

For Operator tasks, such as part load / unload, that are in the direct path of the motion or hazard including the programmed path of a robot, are considered E2 (Frequent) (when more than once per hour). A reach that is not in the direct path of the motion or hazard, should be considered E1 (Infrequent).

Ergonomic hazards are referenced in SD-017.

E0 is only allowed to be used on initial risk evaluation if an inherently safe design is used.

An inherently safe design measure either eliminates hazards, or reduces the risks associated with hazards, by changing the design or operating characteristics of the machine without the use of safeguarding and SRP/CS (safety related part of the control system). Inherently safe designs, or safety devices implemented to the required functional safety circuit performance level, are two methods to Prevent (E0) exposure.

3.3.3 Avoiding the Hazard or Limiting the Harm

When a hazardous situation occurs, A3 (Not Possible) should be selected if it is both impossible to avoid the hazard and impossible to significantly reduce its effect. A2 (Unlikely) should be selected if avoiding the hazard, or if significantly reducing its effect, is possible yet not realistic. A1 (Likely) should be selected if there is a realistic possibility of avoiding the hazard, or significantly reducing its effect.

It is important to know whether a hazardous situation can be recognized and avoided before leading to an accident. For example, an important consideration is whether the hazard can be directly identified by its physical characteristics or recognized only by technical means (such as indicators). Other examples which influence the selection of the Avoidance parameter include:

- Operation with or without supervision
- Operation by experts or non-professionals
- Speed of the hazard (>250mm/sec, or<250mm/sec)
- Possibilities for hazard avoidance (escapement, clearance)
- Practical safety experiences relating to the process

NOTE: A3 (Not Possible) is to be selected when working in a robotic cell and facing away from the robot, since exposure to the hazard is not in plain view.

When loading to the point of operation, the tooling design and part handling determine if the Operator is likely to avoid exposure to hazardous motions. The tooling should be designed to reduce exposure to the hazardous motions and the Operator trained to handle the parts such that it is likely to avoid hazardous motions (A1) or significantly reduce their effect.

3.4 Risk Level Determination

Using the Severity, Exposure, and Avoidance factors for each task-hazard combination, the table below should be used to determine the associated risk level and circuit performance reliability level.

SEVERITY	EXPOSURE	AVOIDANCE	RISK LEVEL	CIRCUIT PERFORMANCE RELIABILITY LEVEL
S3 – Catastrophic	E2 – Frequent	A3 – Not Possible	VERY HIGH	e
		A2 – Not Likely	HIGH	d
		A1 - Likely		
	E1 – Infrequent	A3 – Not Possible		
		A2 – Not Likely		
		A1 - Likely		
	E0 – Prevented	(NA)	LOW	c
S2 – Serious	E2 – Frequent	A3 – Not Possible	HIGH	d
		A2 – Not Likely		
		A1 - Likely		
	E1 – Infrequent	A3 – Not Possible		
		A2 – Not Likely	MEDIUM	c
		A1 - Likely		
	E0 – Prevented	(NA)	LOW	
S1 – Slight	E2 – Frequent	A3 – Not Possible		
		A2 – Not Likely		
		A1 - Likely		
	E1 – Infrequent	A3 – Not Possible	LOW - INFORM	b
		A2 – Not Likely		
		A1 - Likely	NEGLIGIBLE	
	E0 – Prevented	(NA)		

Figure 6: Risk Level Decision Matrix

3.5 Safeguard Solution / Risk Reduction Method

All effort shall be made to eliminate or reduce hazards to the lowest possible risk level. If hazard elimination or substitution through equipment design is not possible, use the risk level determined from Figure 6 to determine the required minimum risk reduction method.

Risk Level	Minimum Risk Reduction Method
Very High	Hazard elimination or substitution (Section 3.5.1)
High Medium Low	Safeguards (Engineering Controls) preventing access to the hazard or stopping the hazard (Section 3.5.2): • Preventing access – fixed barrier or interlocked guard / door. • Stop the hazard – two-hand control, light curtains, safety mats, or other presence sensing devices
Low-Inform	Non-interlocked barriers, clearance, warnings, and training & procedures (Section 3.5.3).
Negligible	Personal Protective Equipment (Section 3.5.4).

Figure 7: Minimum Risk Reduction Matrix

NOTE: Application of the Minimum Risk Reduction Matrix is primarily intended for machinery and equipment related task-hazard combinations. Certain task-hazard combinations, such as material related tasks that include exposure to sharp parts, thermal, and ergonomic hazards, require the application of the most effective level of feasible safeguarding based on the Hierarchy of Health & Safety Controls (Figure 2). Appropriate standards and regulations should also be consulted. The most effective means of addressing hazards is through elimination / substitution. If a hazard cannot be addressed through elimination / substitution, then safeguards (engineering controls) shall be considered.

3.5.1 Risk Level – VERY HIGH

Risk reduction shall be accomplished by hazard elimination or hazard substitution that does not create an equal or greater hazard.

3.5.2 Risk Level – HIGH, MEDIUM and LOW

Risk reduction shall be accomplished by means that prevent access to the hazard or cause the hazard to cease. Provisions of levels LOW – INFORM and NEGLIGIBLE may be used for safeguarding residual risk.

3.5.3 Risk Level – LOW - INFORM

Risk reduction, at a minimum, shall be by means of non-interlocked barriers, clearance from the hazard, warnings (audio / visual), and administrative controls (training and procedures). If the residual risk from implementing safeguarding or SRP/CS measures preventing exposure or access to the hazard is NEGLIGIBLE, additional risk reduction is not required.

3.5.4 Risk Level – NEGLIGIBLE

Risk reduction, at a minimum, shall be by personal protective equipment, if applicable.

3.6 Circuit Performance Level / Circuit Structure Category

When Engineering-Controls are part of the risk reduction method, the risk level is used to determine the minimum circuit performance level required (PLr) and circuit category structure, are consistent with ISO 13849-1. Safety circuits shall be implemented per SD-011, Specification for Safety Circuits. A task-hazard with a higher risk level require a higher circuit performance level and circuit structure rating than those task-hazard with a lower risk level. The required circuit performance level and circuit structure ratings as a function of the risk level is shown in Figure 8 – Minimum Circuit Performance Level & Circuit Structure.

<table>
<tr><th>Risk Level</th><th>PL_r</th><th>Structure Category</th></tr>
<tr><td>Very High</td><td>e</td><td>4</td></tr>
<tr><td>High</td><td>d</td><td>3</td></tr>
<tr><td>Medium</td><td rowspan="2">c</td><td rowspan="2">2</td></tr>
<tr><td>Low</td></tr>
<tr><td>Low - Inform</td><td rowspan="2">b</td><td rowspan="2">B</td></tr>
<tr><td>Negligible</td></tr>
</table>

Figure 8: Minimum Circuit Performance Level & Circuit Structure

3.7 Acceptable Residual Risk Level

Once all risk reduction methods have been identified and selected, the methods shall be reviewed to determine whether the risk level will be reduced to an acceptable level. Acceptable risk level is fundamentally a decision made during each machine risk assessment process and is based on each application. The following guidelines should be used when evaluating acceptable risk:

3.7.1 HIGH Residual Risk – Not acceptable. The group performing the Machine Risk Assessment must identify additional reduction methods to reduce the residual risk to an acceptable level.

3.7.2 MEDIUM Residual Risk – Not acceptable. The group performing the Machine Risk Assessment must identify additional reduction methods to reduce the residual risk to an acceptable level.

3.7.3 LOW Residual Risk – Acceptable if exposure is prevented (E0) or severity of injury is slight (S1).

3.7.4 LOW-INFORM Residual Risk – Acceptable.

3.7.5 NEGLIGIBLE Residual Risk - Acceptable.

3.8 Documentation

The Machine Risk Assessment shall be documented and updated as required during the equipment design, build, and safety run-off. At a minimum, the file must contain lists of tasks, hazards, risk reduction methods, and safeguard solutions selected to validate and record the Machine Risk Assessment requirements of Sections 3.1 through Section 3.5 of this document. The Machine Risk Assessment shall be retained in Team Center Manufacturing.

3.9 Verification

All risk reduction methods shall be verified to:

- Be designed and implemented on the machine according to the Machine Risk Assessment
- Perform the intended risk reduction according to the Machine Risk Assessment

Verification is an activity that takes place during the machine design reviews, safety checklist reviews, and physical testing of each risk reduction method as part of the machine purchase and qualification process.

4. Workstation Design / Operator Interface

Ergonomics related injury / illness are a significant percentage of all Health & Safety incidents, especially realized in industrial and manufacturing environments. A key strategy for reducing the number of ergonomics related injuries / illnesses is to integrate ergonomics guidelines early in the design stages of equipment and processes. Not only will the early integration of ergonomics guidelines minimize injury risk factors, it will also improve the performance factors of all those who operate or interact (Maintenance, skilled trades, and material handlers) with the equipment / process.

To provide a standardized approach for all Nexteer Automotive locations worldwide, a requirements document, implementation tools, and training have been developed and are documented on the Nexteer Data Exchange Website under SD-017, Design-In & Ergonomics Integration Requirements.

4.1 Two Steps to Safe and Efficient Ergonomic Designs

4.1.1 Knowing the Requirements

The Design-In & Ergonomics Integration Requirements document outlines the activity that standardizes the integration of ergonomic specific activity. The required document also defines the roles and responsibilities of all parties involved. Documentation is located on the Nexteer Automotive Ergonomics website. Design-In Ergonomics Guidelines, SD-017, and appropriate checklists for Equipment Suppliers can be found on the Nexteer Data Exchange Website.

4.1.2 Use the Tools

The Design-In Ergonomics Guidelines (SD-017) quantify the basic ergonomic design criteria for new products, processes, and equipment. The tool that corresponds to SD-017 is the Design-In Ergonomics Checklist. The intent of the checklist is to address commonly missed ergonomics concerns and to function as a 'thought-starter' for unique or special circumstances that may exist. The detailed steps of the Design-In Ergonomics Checklist are in SD-017.

Finally, the ergonomics analysis of 'what-if' scenarios is recommended during the design stage. For this activity, second-level analysis tools are available. These second-level tools are computer-aided programs that are quick and easy to use and provide data outputs to specific data inputs. These tools are located on the Nexteer Automotive Ergonomics website. Types of activities that can be analyzed include: one and two-handed lifting / lowering, material handler routes, push/pull/carry activity, forceful exertion and awkward posture analysis, and energy expenditure.

4.2 Suspended Vertical Loads

Suspended vertical loads shall be supported in the raised position by a secondary load holding device where both the vertical load is greater than 16 kg (35 pounds) and the Machine Risk Assessment indicates Frequent exposure (E2), as defined in Section 3.3.2.

Suspended vertical loads are all machine components that could drop causing a pinch point or hazard including tooling, fixtures, and fluid power cylinder rods.

Secondary load holding device requirement details are defined in SD-011 Specification for Safety Circuits Section 3.22.

5. Maintenance

This section provides design guidelines to enhance safety as it pertains to the maintenance of machinery and equipment. The focus is on providing safe, easy, and quick access for Operators, Skilled Trades, and other personnel who may perform machine maintenance.

5.1 Requirements

The following requirements enhance safety while performing maintenance on work cell equipment. The Equipment Supplier shall work with the Equipment Engineer to ensure the following requirements are met:

5.1.1 All energy-isolating devices on each piece of equipment shall be placed at the access points outside the hazardous area to minimize the time and travel required for a proper system / safety lockout and restart. Pneumatic lockouts shall be placed as close as possible to the electrical disconnect and at approximately the same height.

NOTE: These devices shall be located between 0.4 m (16 in) and 1.6 m (63 in) from the working surface. International references include ISO11226 and ISO11428.

5.1.2 Provide safe access and working space as well as clear visibility within and around all control panels. A minimum of 1.0 m (42 in) of clear space is required in front of all control panels containing voltage more than 50V. For specific clearance requirements, refer to the Electrical Safe Work Practices requirements for your facility.

NOTE: Safe access should apply to all controls including electrical, pneumatic, hydraulic, and mechanical.

5.1.3 Locate and mount machine control devices outside the hazardous area whenever possible. When it is not possible the machine control devices shall be clearly visible from outside the hazardous area. Reference the Lean equipment Design Specification SD-015 for further guidance on component placement. Ergonomic factors regarding posture and visual requirements shall be considered, reference SD-017.

Examples of machine control devices to be mounted outside the hazardous area are:

- Main electrical enclosures
- Human Machine Interface – HMI's
- Diagnostic equipment
- Main system pneumatic regulator
- Filters
- Lubrication - Reservoir and pump or fill point
- Lubrication – Manually filled grease zerc's
- Hydraulic power units

NOTE: Recommended mounting heights are between 0.4 m and 1.6 m (16 in to 63 in).

1. Equipment design shall consider the following mechanical safety issues:

   a. Eliminate the potential for stored energy, such as:

      - Hydraulic
        - Accumulators. Automatic and manual means of removing the stored energy are required.
      - Pneumatic
        - Pilot operated checks. Require a manual override to relieve trapped pressure.
        - Blocked center valves. Are not allowed.
        - Standard ball valves. Shall not be used downstream of the safety lockout valve.
      - Spring Loads (coil, torsional, etc.)
      - Vertical Loads
        - Counterbalance valves
        - Pilot operated checks. Require a manual override to relieve trapped pressure.
        - Rod brakes. Must be rated for static holding and dynamic braking.
        - Shot pins. Shall have a 4:1 safety ratio.

b. Eliminate sharp edges on all surfaces except where required (Example: tooling)
c. Counter-balance weights and cables
d. Design machine tooling fixtures, workpiece fixtures, rest cradles, pallets, transfer systems, etc. such that all production parts shall be secured at all times.

2. Eliminate or control exposure to hazardous motion for tasks that require the equipment to be in automatic mode to perform the task (Example: vibration analysis requires either safe access for measurement or permanently mounted transducers, infrared diagnosis, etc.).

   NOTE: By eliminating or controlling personnel exposure to hazardous motion, analysis, troubleshooting or planned maintenance procedures can be safely performed.

3. Design to eliminate maintenance tasks that require climbing to or working at an elevated location. If this is not possible, other fall prevention or protection measures must be provided. Reference the specifications listed in Section 6, Falls and Working Surfaces.

4. Provisions shall be made for direct or task (maintenance) lighting as part of a system to provide greater visibility during routine maintenance and service (reference SD-017).

5. Identify hazard zones (Example: areas that are not completely enclosed within safeguards) by using the following methods, as applicable:
   a. Painted floor markings
   b. Column markings
   c. Flashing lights to indicate the unsafe area

   This identification reduces the potential for injury in areas of risk outside the normal traffic patterns.

6. Specify the detailed training for proper maintenance and service techniques on all equipment or systems. In the interest of both safety and efficiency, proper preventive maintenance and repair training are necessary.

7. Provide a detailed list of preventive maintenance tasks including specific safety precautions to be added to the site Preventative Maintenance record keeping system.

8. To ensure that maintenance and service tasks can be safely performed, training shall be provided for all new manufacturing systems. Specific equipment training shall be identified by the Equipment Supplier or the Machine Risk Assessment Team during the design-in Machine Risk Assessment.

5.2 Design for Electrical Safe Work Practices (ESWP)

To enhance safety while performing maintenance on electrical equipment, the design shall include hazard control for identified electrical maintenance and troubleshooting tasks. These hazards typically include electrical shock or arc flash / blast. All local and regional requirements shall be followed for Electrical Safe Work Practices.

6. Falls and Working Surfaces

This section identifies the design requirements for the prevention of falls from heights as well as slips, trips and falls due to potential hazards due to walking and working surfaces.

Historical data indicates falls are a leading cause of occupational fatalities and serious injuries. These incidents occurred while employees were climbing or working at elevations. Consideration of potential fall hazards during the design stage, with a focus on fall prevention versus fall protection, will eliminate or reduce hazards and future retrofit costs. It will also facilitate quick preventive maintenance task completion. The Hierarchy of Health & Safety Controls must be leveraged for the design in phase for fall prevention.

6.1 Fall Prevention and Protection from Elevations

Each site must identify and comply with applicable regional regulations and requirements related to fall hazards and walking working surfaces. Whenever performing a task that would place a worker at risk to fall at a distance of 1.2 m (48 in) or greater, fall prevention or protection measures shall be included in the machine / process design. Tasks that expose a worker to a fall hazard from 0.4 m (16 in) up to 1.8 m (70 in) shall use fall prevention techniques, such as handrails, to eliminate the potential for a fall unless otherwise specified in the M&E purchase specification. Work platforms that are 0.4 m and higher must have appropriate means of access. Stairs are the preferred means of access.

NOTE: Consult Nexteer Automotive's Facilities Group Fall Prevention Program Requirements & Safety Systems for additional specific requirements.

The following shall be considered during the fall prevention design-in process:

6.1.1 The shutoff valves, controls, monitoring equipment, maintenance service apparatus, and similar items should be located at readily accessible floor or grade levels.

If this is not possible, fall arrest systems, including approved anchorage points, shall be established in order to protect personnel working at elevations.

6.1.2 Overhead equipment or machinery on rails shall be designed so it can be positioned for maintenance or repair in an area where fall hazards are controlled.

6.1.3 A means of access / egress shall be designed for maintenance and service that cannot be performed at readily accessible floor or grade levels. The design shall provide a means for safe access that reflects an anticipation of unplanned maintenance events and engineering of fall prevention measures.

6.1.4 Self-closing guard doors with self-latching mechanism that prevents outward opening into the fall hazard will be provided for all access openings designed for material movement and must open into the platform. Chains across such openings are prohibited.

6.1.5 The following climbing devices shall be used in the order listed below. These devices shall meet all regional regulations and requirements:

1. Fixed stairs
2. Alternating tread-type stairs

   These stairs should be used in limited space applications. They are designed at inclines of 50° - 70° and equipped with handrails.

3. Vertical ladders

   These ladders are the least desirable devices. They should only be used for infrequently (once or twice per week) accessed maintenance locations where floor space for fixed or alternating tread-type stairs are not available.

   Stairways, guarded platforms, and ramps provide safer access than portable lifting devices and ladders. All steps, ladder rungs, ramps, and working surfaces shall have a "non-slip" surface.

   When ladders are included in the design, all tasks performed shall provide the capability for a worker to continuously maintain three-point contact.

Methods for moving tools and equipment to elevated areas shall be a part of the design.

6.1.6 Approved anchorage points shall be designed for personal fall arrest systems when fall hazards cannot be eliminated or controlled.

1. Proper anchorage / attachment points must be on the "anticipated" tasks list of things to be performed.
2. A qualified person, who is knowledgeable of the design requirements for fall protection equipment, shall determine the proper equipment and appropriate anchorage. Designed and installed anchorage points are the responsibility of the Equipment Supplier. Anchorage points must be clearly labeled per the Nexteer Automotive Facilities Group Fall Prevention Program Requirements & Safety System.

6.2 Fall Prevention and Protection from Same Grade or Floor Level

6.2.1 All equipment shall be manufactured with the expectation it will not leak equipment and process fluids.

6.2.2 Provisions shall be made to capture, contain, or eliminate any coolant fluids or mists that might contribute to slips and fire hazards.

6.2.3 All equipment / machine installations shall minimize tripping hazards. All walking surfaces shall be free of elevated or protruding objects and should be considered potential hazards. Consideration shall be given to covering cables, pipes, and conduits, or routing them overhead. Flexible drops shall be installed neatly per Nexteer Automotive' s Best Practice - Flexible Utilities Connections, CEBP9801.

6.2.4 Newly poured or painted floors must have a coefficient of friction that will provide a safe walking and working surface.

6.2.5 Holes in floors and platforms shall be properly marked and guarded appropriately for the severity of the hazard. Proper guardrails (1.06 m guard rail with mid rail) or load rated covers shall be provided in industrial vehicle traffic areas. Floor covers must be rated to support the weight of the heaviest industrial vehicle, including any load the vehicle may carry. Floor covers must be marked with the maximum floor load rating.

6.3 Fall Hazard Control on Roofs

Consideration shall be given to reducing the number of equipment installations and stand-alone enclosures on the roof. Where roof-mounted equipment is necessary, the following requirements shall be followed:

6.3.1 Equipment shall be located at least 3 m (9 ft) from the edge of the roof. A warning system (Example: visible control, rope, plastic chain) is required at 1.8 m (6 ft) to serve as a warning the worker is approaching an unprotected edge.

6.3.2 Perimeter guarding of roofs shall be used for new buildings, additions, or major renovations.

6.3.3 Fixed ladders used to access roofs shall have perimeter guard railing for fall prevention on either side of the roof access point of the ladder. Perimeter guarding shall extend 1.8m (6 ft) on either side of the ladder. Fixed ladders that extend more than 7.3 m (24 ft) above a lower level shall be equipped with a personal fall arrest or ladder safety system.

Figure 9: Fixed Ladder Perimeter Fall Protection Examples

6.3.4 The need for skylights, heat-release vents, and other roof openings shall be eliminated whenever possible.

6.3.5 Heat-release vents and skylights shall have guarding installed under the vent capable of withstanding 18 g (40 lbs.) per square foot, or 454 Kg (1000 lbs.) concentrated load for personnel fall protection and be labeled to indicate presence of guarding and allowed loads. This guarding shall not impede airflow for heat-release vents.

6.3.6 Guarding shall be provided at all hoisting areas.

6.3.7 Roof areas shall be designed to eliminate the need for a worker to step across roof openings.

6.3.8 Access / egress to the roofs shall be provided by fixed stairs and properly marked doors.

6.3.9 Safeguarding shall be designed to protect workers from exposure to electrical shock from wires alongside or near the building.

6.3.10 Training shall be completed for all workers authorized to conduct work tasks associated with the roofs of the facilities.

6.3.11 All local and regional requirements shall be followed while accessing the roofs in accordance with the regional Roof Authorization Procedure.

7. Industrial Hygiene

This section provides the Equipment Engineer with basic information on new chemical approval and usage. If design questions arise, contact your Global Industrial Hygienist. Contact the appropriate Nexteer Local Hazardous Material Control Committee (HMCC) for questions regarding chemical approval.

7.1 Chemical Management

Requirements associated with bringing chemical materials onto a Nexteer Automotive site are covered in Nexteer Global Hazardous Materials Control Procedure 07-1-4-7 (previously G-1126). A summary of those requirements as they pertain to equipment designs are listed below. All chemical materials proposed for use in production, research, or maintenance activities shall be approved prior to their purchase and use.

7.1.1 Discuss the lubrication requirements of the equipment with the local Materials Laboratory or equivalent to determine if a product already approved for the site may be substituted for the manufacturer-recommended lubricant.

7.1.2 Review the use and exposure requirements of the product to be used (reference the Safety Data Sheet) to eliminate the use of chemical materials that required atmospheric controls, personal protective equipment, or costly disposal measures whenever possible.

7.1.3 During the equipment design phase, attempt to implement design attributes that minimize the potential for employee exposure to chemical materials (Example: through inhalation, ingestion, or through skin contact).

7.1.4 If a chemical material will be used that does not have current approval in place for the Plant of intended use, obtain the locally compliant SDS from the Manufacturer / Equipment Supplier.

7.1.5 Complete an X2953 Request for Approval (or local language equivalent) and submit, along with the SDS, to the Local HMCC for review. New Chemical reviews for US based operations shall follow procedure 07-3-4-6. This shall be completed prior to shipment of the equipment to the Nexteer Facility so the chemical material approval is in place when the equipment arrives.

7.1.6 Upon completion of the HMCC review, the requestor will be notified in writing of the review and approval status. For chemical materials that are approved, the HMCC will specify the necessary measures to be taken to control any hazards associated with the material handling, but not limited to, personal protective equipment (PPE), ventilation, and disposal.

7.1.7 Hazardous material information and precautionary measures must be communicated to the user(s) prior to using the material. This includes non-hazardous materials, which can release hazardous materials when used (Example: grinding, welding).

7.1.8 Process changes requiring the introduction of new chemical materials or having a reasonable chance of increasing the potential for exposure to existing chemical materials, shall be approved in advance of implementation. The user(s) shall be informed of such changes along with any additional control measures necessary to insure safe use.

7.2 Process Ventilation

This section provides guidance on the proper design, installation, and operation of process ventilation systems.

All new operations or processes that include potential sources of airborne contaminants shall be thoroughly reviewed by the lead ME to determine the need for exhaust ventilation. Contact your Facility Engineer or the Global Industrial Hygienist for assistance.

The type of ventilation equipment to be used shall depend on the type of air contaminant, such as but not limited to the following:

- Dust
- Gaseous Fumes
- Dry smoke
- Oily smoke
- Oil Mist
- Coolant Mist

If a review affirms the need, local exhaust ventilation shall be the preferred method for the removal of airborne contaminants.

The final step in the installation process must include testing and documentation. Verification is required to ensure the ventilation system is functioning as intended, and operating parameters such as airflow, static pressure, fan amps, and filter differential pressure are recorded for future reference. Drawings, depicting the entire installation, are required. The drawing must show how and where all measurements were taken.

When controlling contaminants through process ventilation, personal exposures shall be reduced to a maximum of 1/10th of the applicable permissible exposure limit as defined by applicable Regional, Federal, State, and Local laws, regulations and standards.

Process ventilation systems should be located in a convenient location to allow for ease of maintenance access. Units that are mounted in an overhead location should have platforms and stairways for access in order to reduce exposure to fall hazards.

Preventive maintenance plans shall be developed for process ventilation systems that collect flammable dust, liquids, or particulates in order to prevent a fire or any other hazards.

Process ventilation shall be designed in accordance with established principles of air flow following a recognized method, such as found in "Industrial Ventilation: A Manual of Recommended Practice," published by the American Conference of Governmental Industrial Hygienists (ACGIH) or local equivalent. Canopy exhaust hoods are not appropriate at employee workstations because of their tendency to draw contaminants through a worker's breathing zone. Exhaust stack height, location, and exit velocity shall be designed to minimize the reintroduction of exhaust emissions into the facility.

A system performance monitor, such as a static pressure gauge shall be installed and should be located at or near the Operator's workstation. This gauge shall be color-coded to indicate the following:

- Normal operating condition (recommended color – green)
- Change filter condition (recommended color – yellow)
- Immediate service condition (recommended color – red)

In general, all process ventilation exhaust should be exhausted to the outside. Air that is re-circulated from process ventilation shall meet the criteria described in ANSI Z9.2, Fundamentals Governing the Design and Operation of Local Exhaust Ventilation Systems. Ventilation systems shall be designed and installed to reduce or eliminate additional Health and Safety hazards that may be created, for example, during periodic maintenance (falls, confined spaces, etc.).

7.3 Mist Control

For all wet machining equipment, new or rebuilt, that will generate mist/particulate exceeding 1 milligram per cubic meter (mg/m3) based on a Time Weighted Average (TWA). An appropriate mist collection device shall be purchased and installed as part of the acquisition. For US operations, the requirement is 0.5 mg/m3 based on a Time Weighted Average (TWA). Every effort should be made to enclose the tooling area of each machine to minimize both the mist expelled from the operation and the mist collector size required to control such mist. (Note: Mist collectors shall not be used in place of appropriately sized dust collectors for dry machining operations.) As a minimum, the following criteria shall be followed:

- The oil mist collector shall be a multi-stage, draw-through type.
- Exhaust the area in sufficient volume to prevent mist from escaping into the worker's air space. The air flow shall be pulled away from the worker's air space.
- Centrifugal, electrostatic precipitator or HVAC filter collector units are not permitted.

For induction heat treating equipment, new or rebuilt, that will generate mist/particulate exceeding 10 milligrams per cubic meter (mg/m3) for short term exposure (15 min) and exceeding 1 milligram per cubic meter (mg/m3) based on a Time Weighted Average (TWA). An appropriate mist collection device shall be purchased and installed as part of the acquisition. Every effort should be made to enclose the tooling area of each machine to minimize both the mist expelled from the operation and the mist collector size required to control such mist.

Refer to OSHA 1926.55, Appendix A or OSHA 1910, table Z, limits for air contaminants for the 8 hour (TWA) time weighted average (PEL) permissible exposure limits for the material(s) in use.

Significant respiratory effects have been associated with worker exposure to the mist / aerosols generated by production machining operations. These effects include symptom complaints such as cough, sinus, shortness of breath, cross shift lung function drop, occupational asthma, and hypersensitivity pneumonitis.

To minimize worker exposure, the following design issues should be addressed and considered in order to reduce mist generated by production machining operations:

7.3.1 Fluid Delivery

1. Select intrinsically safe fluids with low misting characteristics.
2. Cycle coolant on and off as required for machining or flushing chips.
3. Minimize fluid delivery pressure (velocity) and flow rate (GPM).
4. Minimize and remove contaminants to preserve tool life.
5. Cover coolant tanks.

7.3.2 Machine Tool Design

1. Employ efficient chip shedding and control methods.
2. The following machine design parameters correlate directly with increased misting levels: tool speed, wheel speed, and worn tooling.
3. Consider alternatives to metalworking methods that require high pressure fluids or mist.

7.3.3 Machine Enclosure Design

1. The machine enclosure must contain mist and vapor produced within the work envelope while operating under the design airflow.
2. Enclose the process as completely as possible to minimize exhaust requirements while allowing for easy access to maintain the machine and provide tool changes.
3. Automatic opening and closing doors shall be considered, where possible, for loading and unloading parts.
4. Make-up air inlets, if required, shall be strategically placed and below the point of metal cutting with a minimum in-draft velocity of 76m/min. Inlet location and design should not allow coolant to splash out or become obstructed with chips. Exhaust volume requirements should be determined to ensure all cracks and un-sealable openings have an in-draft velocity of 76 m/min.

7.3.4 Ductwork Design

1. Design the system to be leak-free (no spiral duct or duct with mechanical seams).
2. Employ industrial construction (~16-18 gauge) should the duct fill with liquid. All gasket and seal materials should be compatible with the metal working fluids.
3. Ductwork should be sloped toward the mist collector, where possible, to minimize the use of traps or airlocks. If traps are required, design with consideration for easy sludge and chip removal.
4. Airflow and air velocity should be designed for mist control, not chip removal. Duct transport velocity between the machine tool / equipment and main branch should be maintained at or below 610 m/min (2,000 FPM). Main branch velocities can be increased, as necessary, for system balance.
5. Only use flexible duct at the machine tool / equipment connection and keep as short as possible.
6. Fire suppression requirements shall be evaluated based on the fluid flash point(s) and be provided as needed.

7.3.5 Mist Collector Design

1. Only collectors providing a minimum of 95% filtration efficiency at 0.3 micron, or greater, shall be specified (equivalent to MERV-16).
2. The most efficient collector designs are, typically, multiple-stage. The collector design, however, should not permit the re-entrainment of mist between filtering stages.
3. The collector housing / plenums should be designed for equal airflow across each filter element.
4. Only collectors requiring minimal manual maintenance shall be specified. First stage separators shall be self-cleaning and designed for cleaning while in operation. Maintenance on the final stage shall be performed from the exterior of the unit (not requiring housing entry).
5. The collector housing design shall:
   - Be air and watertight
   - Withstand a differential static pressure of 4000 Pa (about 10 inches of water column)
   - Contain a sloped bottom with drains and airlock to facilitate removal of liquids and solids.
6. Fire suppression requirements shall be evaluated based on the fluid flash point(s) and be provided as needed.

7.3.6 Mist Collector Sizing

1. Open areas in the machine enclosure (gaps, cracks, chutes, doors that open during cycles, etc.) shall be accounted for. The total area is required to determine the mist collector size requirement.
2. For typical operations, the exhaust rate shall provide a minimum in-draft velocity of 76m/min (250FPM).
3. For non-typical, high-energy processes, the exhaust rate shall provide a minimum in-draft velocity of 152m/min (500FPM). High energy processes include:
   a. High coolant temperatures
   b. High coolant pressures
   c. High machining or grinding speeds
   d. High spindle horsepower
4. The total area shall be multiplied by 76m/min (250FPM) for typical operations or 152m/min (500FPM) for high energy processes to determine the mist collector size.
5. For machining processes that are not adequately enclosed, source capture hoods shall be used and design per the Industrial Ventilation Manual.
6. Mist collection for heated part washers require special considerations. Contact the Global Industrial Hygienist for assistance on proper mist collector sizing and design.
7. Machining processes that include blow-offs (compressed air or blower), the mist collector exhaust rate shall be increased by the blow-off flow rate. For example: the exhaust rate determined in 7.3.6.4 above shall include the blow-off flow rate to determine the overall flow rate requirement.
8. Sizing calculations shall be approved by the Nexteer lead ME or Global Industrial Hygienist prior to designing, building or purchasing a mist collector.

7.4 Noise Control

Nexteer Automotive has developed a Sound Level Specification SD-018 for the purchase of new, rebuilt and relocated machinery, power tools, and equipment. This design-in specification establishes:

7.4.1 Sound level limits for all new, rebuilt and relocated machinery, power tools, and equipment.

7.4.2 Measurement procedures, measurement instrumentation requirements, machine operating conditions, and the format for reporting machine certification data.

7.4.3 Equipment Supplier and Purchaser responsibilities.

7.4.4 Procedures for approving equipment at variance with the specified limit.

It is the responsibility of the Equipment Engineer to ensure the SD-018 specification, and any supplemental local sound level specifications, are issued with the Request for Quotation for all machinery and equipment generating noise in its normal mode of operation.

Feasible noise controls, whether by elimination, substitution, or engineering, shall be provided as an integral part of the safety design and build of equipment. It is the responsibility of the equipment supplier to meet the requirements of the SD-018 specification.

A current version of the SD-018 specification can be found on the Nexteer Data Exchange website. A summary of the major requirements is provided here:

- Equipment Suppliers shall perform a runoff noise level check following the technical procedures outlined in the Specification.
- Using sound data forms and sheets included in the Specification, the Equipment Supplier shall certify acceptable noise levels have been met. It is expected that site Safety Representative or the Equipment Engineer shall use the Specification to confirm the noise levels during the equipment release / sign-off process.
- Unless specified elsewhere in the Specification, the 8-Hour Time Weighted Average (TWA) sound level shall not exceed 80 dB(A) at ANY of the designated measurement locations on the machine measurement envelope and in the Operator’s Hearing Zone, during the operating time of the machine. Tooling and material handling related noise must be included.
- Impulse sound pressure levels shall not exceed the un-weighted true peak value of 130 dB at any measurement location on the machine measurement envelope and in the Operator’s Hearing Zone, during the operating time of the machine.
- If noise levels cannot be engineered out to be less than 80 dB(A), a waiver must be signed by the Equipment Supplier, Manufacturing Engineering, and the Plant Manager before the equipment is shipped or accepted. This waiver indicates all safeguards (engineering controls) options have been explored and deemed not feasible. The Equipment Engineer shall provide a copy of the waiver to site Safety Representative, Global Industrial Hygienist and site Noise Control Committee.

7.5 Laser Equipment

Lasers are given hazard classifications in order of severity (Example: Class 1, 1M, 2, 2a, 2M, 3a, 3R, 3b, and 4). Class 2a is obsolete but is listed for possible existing equipment. All facilities using Class 3b or Class 4 laser, or laser systems having an embedded Class 3b or Class 4 laser, shall have a Laser Safety Officer (LSO) local to the facility.

Class 1 lasers systems are required within Nexteer facilities.

Class 1 laser systems are considered "light proof" (Example: prevent access to the area where the laser beam intensity poses a hazard to the eyes and skin). The Class 1 laser system is not the definition of the laser hazard classification, the laser hazard classification is defined below.

NOTE: Additional laser systems requirements are located at the Industrial Hygiene website.

7.5.1 Laser Classification

Class 1 through 3R are considered "lower powered" lasers. Class 3B and 4 are considered "high-powered" lasers. A Class 1 laser is incapable of producing damaging radiation levels. Class 3B Laser classifications are based on the ability of the primary laser beam or reflected primary laser beam to cause biological damage to the eye or skin during use. A Class 4 laser poses a hazard to the eyes and/or skin from a direct beam or a diffuse reflection.

NOTE: Additional detail is located at the Industrial Hygiene website.

Laser Class	Characteristics	Hazards	Examples
1 & 1M	Very low power or enclosed beam.	Incapable of causing injury during normal operation.	CD and DVD players, laser printers
2 & 2M	Low Power Visible CW power: < 1mW	Low probability of injury Possible hazard if eye is stable and focused for extended period Eye aversion response protects	Bar code scanners
3R	Visible and invisible CW power: 1mW < 5mW	Low probability of injury Possible hazard if eye is stable and focused for extended period Eye aversion response protects	Laser pointer, laser measuring, teaching / guide lasers
3B	Visible and invisible CW power: 5mW < 500mW	Exposure to direct beam or specular reflections are eye hazards Heat/burn hazard for extended period Diffuse reflection is not a hazard	Alignment, leveling, seam tracking lasers
4	Visible and invisible CW power: > 500mW	Exposure to direct beam or diffuse reflections are eye and skin hazards Instant fire/burn hazard Laser generated air contaminants (> 10W)	Welding, cutting, and marking process lasers. Research lasers
1 with embedded Class 3B or Class 4 Laser	Low power outside secured Class 1 enclosure. CW High power ≥ 500mW inside enclosure.	Incapable of causing injury during normal operation with safety systems in place Maintenance and service tasks may require Task Instruction Sheets (TIS) / Safe Operating Procedures (SOP)	Welding, cutting, and marking process lasers inside Class 1 enclosure

Figure 10: Laser Classification Table

7.5.2 Laser Safety Considerations for the Equipment Engineer

The Laser Safety Office (LSO) is Nexteer's resident subject matter expert for compliance with regulations to safety. The Laser Safety Officer (LSO) shall approve all new lasers, laser systems, and machines that contain lasers prior to purchase. The modification, relocation, or reinstallation of existing laser equipment shall have the same requirements as a new laser purchase.

Class 1 lasers systems are required within Nexteer facilities.

Manufacturing Engineering is to work with the LSO to:

1. Complete the requirements of the Laser Safety Minimum Program requirements (lsminprog.doc).
2. Complete the Laser Master Inventory spreadsheet (lsinv.xls).

   NOTE: Pictures should be taken for future reference.
3. Verify the laser classification with the manufacturer.
4. Ensure wording and location of laser safety signs, laser safety labels, and guarding labels are present.

   NOTE: Additional information available is located at the Industrial Hygiene website.

7.6 Radiation

This section provides the Equipment Engineer with basic information on possible sources of radiation that will need to be reviewed when developing new equipment and processes containing or generating radiation. Radiation can be separated into two categories, ionizing and non-ionizing radiation.

7.6.1 Ionizing Radiation

Ionizing radiation is a general term applied to both electromagnetic waves or particulate radiation capable of producing ions by interaction with matter. Gamma rays are photons produced from nuclear transition emission. Photons produced from electron transitions in high atomic mass nuclides are called x-rays.

Ionizing radiation can be produced by man-made devices (x-ray machines, nuclear reactors, accelerators, etc.) or by naturally occurring radioactive material (Co-60, C-14, Am-241, Sr-90, Po-210, etc.) used in exit signs, thickness gauges, and static eliminators. It is the responsibility of the Equipment Engineer to ensure that all country, state, or local regulations are applied to the design and registration / licensing of equipment capable of emitting radiation.

NOTE: Additional information available is located at the Industrial Hygiene website.

1. The Equipment Engineer and Equipment Supplier must develop Safe Operating Procedures for the proper installation, maintenance, and disposal of radiation sources.
2. All facilities using radioactive sources or radiation generating equipment must have a Radiation Safety Officer (RSO), or designee, before installation, use, or maintenance of radiation sources or generating equipment.
3. For application detail, the Equipment Engineer shall adhere to all country, state, local, and Nexteer Automotive policies governing the purchase, installation, and use of radiation generating equipment. A completed license or registration form may be required by the local governing body.
4. The Equipment Engineer or Equipment Supplier must notify the Nexteer Automotive Industrial Hygienist prior to receiving all naturally occurring and generating radiation. Completion of the X-Ray Equipment Inventory & Survey Data Sheet is required.
5. A "Notice to Employees" must be posted in the area where radiation sources are present. The Equipment Engineer or Equipment Supplier must provide proper posting of the area with the radiation symbol, and other appropriate information, to aid individuals in minimizing exposure to radiation.
6. A secured and controlled storage area must be established for radiation material not in use. The Equipment Engineer or Equipment Supplier must supply the proper SOP for handling and storage.

7. The Equipment Engineer or Equipment Supplier must conduct radiation surveys prior to start-up to ensure exposures are within acceptable levels. Personal monitoring may be required. Documentation of survey results must be supplied to Safety, Engineering, and the Global Industrial Hygienist.
8. The Equipment Engineer or Equipment Supplier must provide wipe samples as specified by the regulating authority on all naturally occurring radioactive sources. Documentation of the results of testing must be supplied to Safety, Engineering, and the Global Industrial Hygienist.
9. The Equipment Engineer or Equipment Supplier must work with the RSO to assure all items listed above have been completed prior to shipping or receiving radiation material.

7.6.2 Non-Ionizing Radiation

Non-ionizing radiation is electromagnetic radiation which is the propagation or transfer of energy through space and matter by time-varying electric and magnetic fields. Photons with energies less than 12.4 eV are considered to have insufficient energy to ionize matter, and therefore are non-ionizing in nature. Non-ionizing radiation ranges from sub-radiofrequency magnetic and electric fields (ELF), radiofrequency (RF) and microwave radiation, light and infrared (IR) radiation, ultraviolet (UV) radiation, and includes lasers. Sources of non-ionizing radiation may be found with the following operations: electric furnaces, induction heaters, power plants, arc lamps, Hg-HID lamps, welding operations, UV curing operations, heat sealers, microwave generating equipment, microwave ovens, and lasers, as examples.

The Equipment Engineer or Equipment Supplier must provide information on the following, which is specific to non-ionizing radiation:

NOTE: Additional information available is located at the Industrial Hygiene website.

1. The Equipment Engineer or Equipment Supplier must develop Safe Operating Procedures for the proper installation, maintenance, and disposal of non-ionizing radiation equipment.
2. All facilities using non-ionizing radiation equipment must have a designated person responsible for periodic review of the equipment before installation, use, or maintenance.
3. For application detail, the Equipment Engineer shall adhere to all country, state, local, and Nexteer Automotive policies governing the purchase, installation, and use of non-ionizing radiation generating equipment. A completed license or registration form may be required by the local governing body.
4. The Equipment Engineer or Equipment Supplier must notify the Nexteer Automotive Industrial Hygienist, prior to receiving all non-ionizing radiation generating equipment, for assistance.
5. A “Notice to Employees” must be posted in the area where radiation generating equipment is present. The Equipment Engineer or Equipment Supplier must provide proper posting of the area and other appropriate information to aid individuals in minimizing potential exposure to radiation.
6. The Equipment Engineer or Equipment Supplier must conduct radiation surveys prior to start-up to ensure exposures are within acceptable levels. Personal monitoring may be required. Documentation of survey results must be supplied to Safety, Engineering, and the Global Industrial Hygienist.
7. The Equipment Engineer or Equipment Supplier must work with the Health & Safety Department to assure all items listed above have been completed prior to shipping or receiving radiation equipment.

7.7 Water Quality

Nexteer Automotive processes use many different water systems, including water-cooling towers, water Chillers, humidification systems, domestic hot water systems, parts washers, and potable drinking systems. The primary importance of good water quality is to minimize bacterial contamination.

The following basic guidance is provided for new installations:

7.7.1 All equipment shall be designed to minimize the generation of aerosols.

7.7.2 Once systems are installed, regular monitoring of the water systems shall be scheduled based on information from the Global Industrial Hygienist and comply with applicable regional regulations and requirements.

7.7.3 Water sampling should be conducted annually in facilities with potable water.

7.7.4 A program for routine maintenance and cleaning of the specific systems shall be developed and provided to the facility.

7.7.5 Where applicable, local regulations for discharge of water to sanitary sewer or surface drainage must be adhered to.

The Equipment Engineer or Equipment Supplier shall review the best available methods for operation and treatment of water systems to ensure a cost-effective program to maintain systems and control bacterial growth levels.

Water Quality References:

- ANSI 53 Drinking Water Treatment Units, Health Effects
- ANSI 60 Drinking Water Treatment Chemicals, Health Effects
- ANSI 61 Drinking Water System Components
- Cross Connection Control Program ID13-4SW-4-28

7.8 Confined Space

One of Nexteer Automotive' s major health and safety concerns is the un-authorized entrance of employees into confined spaces. Each year un-authorized entries into un-safe confined spaces kill hundreds of workers worldwide. Although Nexteer Automotive has issued corporate guidelines to assist sites in the development of site-specific confined space programs, our primary goal is to design machinery, equipment, and facilities without confined spaces.

NOTE: Additional information available is located at the Health and Safety Common Core Element – Confined Space Entry.

By definition, a confined space is a space that:

- Is large enough for an employee to enter fully and perform the assigned work.
- Has limited or restricted means for entry or exit; and
- Is not designed for continuous employee occupancy, or
- All of the above and is an open-top tank or pit.

Based on the potential risks associated, the Equipment Engineer should consider the following with any future designs:

7.8.1 To the extent feasible / possible, design machinery, equipment, or the facility WITHOUT confined spaces.

7.8.2 Entrances and exits to confined spaces shall be designed to the maximum access size possible. The minimum access size shall allow:

1. Personnel to pass through while wearing any required support devices (Example: self-contained breathing apparatus), and
2. The transfer of rescue equipment through the access passage.

7.8.3 Specifying doors instead of access ports, and stairs instead of ladders will facilitate unrestricted egress. This will aid in not creating a confined space.

7.8.4 The entrances and exits to confined spaces should be designed to eliminate fall hazards. If fall hazards exist, anchorage points shall be provided and identified.

7.8.5 Hazardous conditions shall be designed out of the confined space to the extent possible (Example: designed-in forced air ventilation may lessen the requirements when confined space entry is required).

7.8.6 Energy control devices shall be located outside the confined space and located at floor level, where possible. For example, a hazardous material traversing a confined space through piping may create an immediate danger to life condition if the line ruptures. Provisions to control the hazardous material shall be located outside the confined space. Examples of these valve schemes are blank or blind, breaking line, or double block and bleed.

7.8.7 All potential hazards and hazardous conditions shall be identified, evaluated, and recorded on the facilities Confined Space Log and Hazard Analysis Form. It is the responsibility of the Equipment Engineer to notify the local Health & Safety Representative to ensure this is complete.

7.8.8 All communication, atmospheric monitoring equipment, lighting, and tools shall be intrinsically safe as defined by the confined space procedure.

7.8.9 Equipment shall be labeled, logged with an assigned number to identify it as a confined space.

8. Safeguarding

This section provides design-in fundamentals and general principles for safeguarding of manufacturing equipment.

8.1 Fundamentals for Safeguarding

Safeguarding refers to the protection of personnel from hazards by using guards, safeguarding or awareness devices, safeguarding methods, or Safe Operating Procedures (SOP's).

The safeguarding methods listed in this section shall only be used after efforts to eliminate the hazards have been considered. The safeguard requirements will be determined by the results of the Machine Risk Assessment. Reference Section 2 - Hierarchy of Health and Safety Controls and Section 3 – Machine Risk Assessment of this document for further information.

Guard refers to a physical barrier that prevents exposure to a hazard.

Safeguarding Device refers to a device that detects or prevents access to a hazard.

Awareness Device refers to a barrier, signal (Example: audio or visual), or sign that warns individuals of an impending, approaching, or present hazard.

Safeguarding Methods refers to the protection of individuals from hazards by the physical arrangement of the machine to ensure a person cannot reach over, under, around or through the guard and access the hazard. The method must ensure the hazard is contained within the safeguarded area.

Safe Operating Procedure (SOP) refers to formal written instructions developed for the user to describe how a task is to be performed safely.

8.2 Guard Design

8.2.1 Point-of-Operation / Machine Guarding

This section covers point-of-operation / machine guarding of hazards on all machinery and equipment (including transportation / material handling / conveyor safety) that are not contained in a perimeter guarded cell.

Guards shall be designed to meet the following:

1. Prevent reaching over, under, around, or through a barrier into the point of hazardous motion. Reference Annex B and ISO 13857 for additional guidance on allowed safety distances to prevent access.
2. When frequent access is required, the guard shall be interlocked as determined by the Machine Risk Assessment and meet the requirements of SD-011. Hinged guarding implies the need for frequent access and shall be interlocked
3. When infrequent access is required, a tool shall be required to install / remove the guard.
4. Designed in a way that minimizes the motivation to defeat and not result in a hindrance to production. If a guard were to be considered a hindrance, the result may be the guard is wrongly removed or defeated, placing employees at serious risk of injury. One solution is to "design-in" a window where a guard would otherwise obstruct visual access.
5. Contain hazardous process byproducts (Example: coolant spray, sparks, or chips). See Section 7 – Industrial Hygiene of this document for further information.
6. Provide adequate protection from tool breakage and ejected parts to prevent injury to personnel.
7. Presence Sensing Devices (PSD) are acceptable as Point of Operation Guarding, provided they are implemented per the circuit performance reliability level requirements determined by the Machine Risk Assessment. Examples of Presence Sensing Devices are: light curtains, area scanners, and safety mats.
    a. The PSD shall be located so the operator is always detected within the protected area.
    b. If the PSD is also to be used as a cycle initiation device, refer to the PSDI requirements in Section 8.3.3.

8.2.2 Perimeter Guarding

The purpose of perimeter guarding is to prevent inadvertent access to a hazardous work area, and to contain any material or equipment that has the potential to be ejected from or dropped outside the work area. Perimeter guarding shall be designed to maximize visibility into the cell. Floor standing cabinets that are 1525 mm (60 in) or greater in height shall be positioned to maximize the view of the cell. There are two types of perimeter guarding allowed – hard guarding (Example: fencing, walls, and safety interlocked guard doors) and Presence Sensing Device (PSD).

1. Perimeter Hard Guarding (Example: fencing, walls, and safety interlocked guard doors) shall prevent reaching over, under, around, or through a barrier to access a hazardous motion. Reference Annex B and ISO 13857 for additional guidance on allowed safety distances to prevent access.

   Floor mounted perimeter hard guarding shall be a maximum of 180 mm (7 in) above the walking surface to prevent access to hazards by reaching under the safeguard and have a minimum height of 1400 mm (55 in).

   Hard guarding shall be designed to:

   - Prevent inadvertent access,
   - Contain parts or equipment that may be ejected,
   - Contain hazardous light / radiation,
   - Allow cleaning of the floor at the perimeter,
   - Be of a height suitable to contain the hazard,
   - Allow visibility into the equipment or work areas,
   - Require a tool to install / remove the guard

   All work areas where a hazard exists due to the ejection of material or equipment—shall have hard mechanical barrier guarding.

   If a pinch point is created with the location of fixed hard guarding, then pivoting, hinged, or profile hard guarding should be used. This guarding shall be safety interlocked to stop hazardous motion when it is moved and must be returned to its correct position before motion can be re-initiated.

   When frequent access is required, movable safety guard doors shall be provided. These guard doors may require to be interlocked as determined by the Machine Risk Assessment.

   All access guard doors should be located to prevent direct entry into the path of hazardous motions. Guard doors shall swing outward or slide parallel to entrance, and not swing inward.

   All full body access guard doors shall be designed so that when opened, the locking mechanism shall be mechanically prevented from inadvertently locking or trapping an individual in the machine.

   All full body access guard doors should have the capability of being locked with a plant-approved personal lockout lock to prevent reset of the guard door safety interlock circuit.

   For safety interlock device requirements refer to Section 8.3.1.

2. Perimeter PSD Guarding

   For work areas containing no hazard from material, radiation, or equipment ejection, perimeter-guarding methods that use presence-sensing devices are acceptable. Refer to Section 8.3.2 of this document for more information on device requirements.

   When frequent access within the safeguarded area is required to perform standardized work and cyclical tasks supporting normal production, the PSD shall be located so the operator is always detected.

3. Shared Perimeter Guarding

   Work areas, stations or cells that share a common safeguard shall ensure that operators in a work area are not exposed to hazards from an adjacent work area. Work areas sharing a common safeguard shall meet the following requirements.

   a. Each work area shall have its own safety interlocked entrance guard door and Emergency stop push button.

b. Material passages between work areas shall be safeguarded to prevent personnel access to hazards in the adjacent cell. PSD's may be used to stop the hazardous motion in the adjacent cell if access is attempted.

c. When one work area is shut down to allow for personnel entry, the adjacent area may continue in automatic mode provided there are no hazards from the operating area, as determined by the machine risk assessment.

d. Light curtains shall be installed in a manner that prevents personnel entry into the adjacent work area as well as prevents hazards from the adjacent area from accessing the area where maintenance personnel are located.

4. Perimeter Guarding Reset Requirements

When it is possible for a person to completely pass-through perimeter guarding (safety interlocked guard doors or PSD's), placing their body between the guarding and the hazard (full body access), the following reset requirements shall apply:

a. A safety circuit reset device shall be provided. The safety circuit shall not be reset by the physical closure of the safety interlock switch, the clearing of a PSD, or by the return of line voltage (power-up).

b. Safety circuit reset devices are permitted to be reset devices that also perform other reset functions, such as the E-Stop Reset pushbutton, provided all the reset requirements of this section are met.

c. The reset device shall be positioned such that it cannot be reached from within the protected area without interrupting the perimeter guard.

d. The reset device shall be positioned such that the entire safeguarded area is visible, allowing the operator to view that no personnel are in the safeguarded area

e. If the entire protected area is not visible from the reset location, multiple hardwired-reset devices shall be installed. These reset locations shall be positioned collectively to allow the entire protected area to be viewed, preferably on the outside of the safeguarded area. The number of reset locations should be minimized. The reset devices shall be properly connected to the safety circuit. When a specific reset sequence is required, the control circuitry shall force this reset sequence, and shall be reset within a maximum specified time.

f. Multiple, independent reset devices are permitted, provided the entire area protected by the perimeter guard is visible from each reset location.

g. A reset device for the safety circuit shall be located near each PSD that is used as a perimeter guard. This requirement does not apply to a reset switch (provided by the device manufacturer) that requires a tool in order to open a cover to gain access.

Non full body access perimeter guard applications are allowed to automatically reset the safety circuit upon closure of the safety interlocked guard door or clearing of the PSD.

8.2.3 Thermal Hazard Guarding

Thermal hazard guards should be designed to:

1. Keep personnel from contacting components in their normal work areas, which could cause burns.
2. Prevent personnel from contacting surfaces that could cause a reaction, which could result in injury.

Temperature Requirements

Charts from ISO 13732 provide when an injury can occur based upon touching a hot object, with respect to time.

All material (solid or liquid) above 52 degrees C (125 degrees F) shall be evaluated on the machine risk assessment. Temperatures below this threshold falls within the low side of a reversible injury and requires an exposure of approximately 10 seconds before injury could occur. Safeguarding, PPE, warning signs and other administrative controls (Example: floor markings, training, SOPs) can be determined during the machine risk assessment.

8.2.4 Machine Coolant Guarding

Consideration should be given to guarding designs for high-pressure coolant applications to ensure removable access hatches / doors are completely sealed or allow leaks / drips to drain back into the machine and not on the

Plant floor. All hydraulic and lubrication oil systems on the machine shall be totally contained and connections sealed.

Safeguards shall contain the coolant from splashing or running onto plant walkways. It is critical the guarding and containment system be designed to ensure long term effectiveness.

8.3 Safeguarding Devices

The following fundamentals shall be used when designing safeguarding devices into systems. These devices shall be used at a position that meets the safe distance formulas (located in Annex A).

8.3.1 Safety Interlocks

Safety interlocks shall be designed, constructed, and installed using the following requirements:

1. Safety interlocks are to be designed into guard and safety guard door approaches as determined by the Machine Risk Assessment.
2. Safety interlock systems for guards and safety guard doors shall meet the following requirements. Safety guard door interlocks for specific applications are covered in more detail in Section 10 - Robotic Cells and Section 11 - Servo Controlled Equipment and Machining Cells of this document.
   a. Be a safety rated device and implemented as specified by the Machine Risk Assessment required circuit performance level (PL r). Reference SD-011 for safety interlock requirements.
   b. Be tested or cycled per plant procedures, global work instructions and Manufacturer recommendations.
   c. Prevent the use of unauthorized and / or unintentional bypass devices on applications with motivations and likelihood for using bypass cheater keys. Example: utilizing safety guard door interlocks with encoded devices.

      NOTE: A manual override may be required for Power-ON to release guard locking safety interlock switches based on the defined task (Example: solenoid override for cell access in a power off condition).
   d. Be used where hinged or sliding doors provide access to hazards as determined by the Machine Risk Assessment, and any applicable standards.

      NOTE: Where interlocks are utilized for other than safety reasons, the requirements of this section do not apply.
   e. Be located and mounted to prevent damage and to minimize tampering.
   f. Be installed in accordance with the device manufacturer instructions.
3. Non-locking Safety Interlocks
   a. Non-locking safety interlock switches should be used on equipment where all hazardous motion stops upon safety circuit interruption and an immediate stop does not create another hazard or create a problem with machine cycle interruption. (Example: No concern for broken tools or flying parts if the system is stopped at any moment in time).
   b. The stop times of machine hazards shall prevent personnel from accessing the hazard when opening an interlocked safety guard door.
4. Guard Locking Safety Interlocks

   Guard locking safety interlock switches shall be provided for the protection of personnel based on the following:
   a. Prevent guards from opening until all hazardous motion has stopped, due to lack of adequate safe distance (Examples: high inertia, spinning down grinding wheels, cooling of parts).
   b. Prevent access when safety circuit interruption and an immediate stop may create another hazard (Examples: broken tools, flying parts or machine damage).
   c. Shall be Power-ON to release.

   Guard locking safety interlock switches shall be provided for process protection when inadvertent interruption of a machine or cell may create a problem with the process or machine cycle.

Power-OFF to release safety interlock switches may be used on applications where guard locking has not been included for the safety of personnel and used solely for the protection of a process, as noted on the Machine Risk Assessment.

An escape release shall be provided with all guard locking safety interlocks where full body access is possible. The escape release shall only be accessible from inside the safeguarded area.

Request to enter push buttons shall be readily accessible, and typically provided at each guard locking interlock switch location as a minimum. A single request to enter push button may control multiple guard locking interlock switches.

5. Request to Enter Push Button Requirements for Guard Locking / Unlocking

The typical functional requirements for a request to enter push button are as follows:

a. Shall initiate a cycle stop request, stopping the system at the next logical stopping position of the current cycle, and flash the Yellow PB indicator light.

b. Shall unlock all appropriate guard locking interlock switches once the cycle and all hazardous motions have stopped. At this point the Yellow PB indicator light shall be solid on (not flashing) indicating clear to enter.

c. Closing of the guard door and pressing the safety reset PB, locks the guard locking interlock switches and cancels the request to enter function.

8.3.2 Presences Sensing Devices (PSD's)

1. A PSD (Example: light curtain, safety laser scanner or safety mat) shall meet the requirements as specified by the Machine Risk Assessment circuit performance level. Light curtains are preferred over safety mats and safety laser scanners. Visual aids (Example: floor markings, posted layouts) shall be provided to indicate safeguarded areas when using safety laser scanners.

2. The PSD shall be capable of being incorporated into the machinery and equipment control system, and shall initiate a stop, or prevent hazardous operation of the machine, when any object is detected in the sensing field.

3. The PSD shall be installed to prevent personnel from going over, under, or around to get into the hazardous area, or be trapped. Reference Annex A and ISO 13855 for additional guidance on allowed safety distances to prevent access.

   Vertical PSD detection zones (Example: light curtain) shall be a maximum of 300 mm (12 in) above the walking surface to prevent access under the detection zone and have a minimum height of 900 mm (36 in). Detection zones located higher than 300 mm (12 in) above the walking surface require additional safeguard measures to be provided.

   Horizontal PSD detection zones (Example: safety laser scanner) shall be a maximum of 800 mm (32 in) above the walking surface. Detection zones 300 mm (12 in) above the walking surface create a risk of undetected access beneath the detection zone. This shall be considered in the machine risk assessment and additional safeguard measures applied.

4. The supports shall be substantial enough to resist deflection and shall be mounted to avoid a pinch point where material, or a material carrier, enters or exits a cell.

5. Various PSD's employ different sensing and adjustment techniques. The point at which a device responds to an intrusion may vary. The devices shall be located, or adjusted, per the safe distance formula; ensuring any hazard is controlled upon intrusion. Multiple devices may be required to accomplish a "protected area."

6. The effective sensing field shall be of adequate height, width, and depth to guard the area.

7. The response time of the PSD used in the safe distance formula shall be the maximum response time considering the impact of object sensitivity adjustments and environmental changes.

8. The PSD resolution shall be appropriate to the design application. Example: light curtains shall be 14 mm (finger-safe), safety laser scanners shall be 30 mm (hand-safe). Refer to SD-007 for device requirements.

9. The PSD may be muted or bypassed at times when no hazards exist for the Operator, however, it must be muted or bypassed with an equally reliable safety circuit. Refer to SD-011 (Specifications for Safety Circuits) for further details on PSD devices and safety circuit requirements.
10. The PSD shall not be affected by ambient conditions (Example: smoke, dust, haze, or vibration) or light sources decay such that an increase in response time or object sensitivity occurs.
11. If there is a loss of power to the PSD, the device shall initiate an immediate stop command to the machinery and equipment control system.
12. The PSD shall be appropriately rated per the safety standard requirements detailed in SD-007 and SD-011.
13. The resetting of the PSD safety circuit shall meet the requirements in 8.2.2.4.

8.3.3 Presence Sensing Device Initiation (PSDI)

PSDI provides cycle initiation on manual load/unload single cycle operating systems where a PSD is the primary safeguard device. PSDI initiates the machine cycle once a new part is sensed to be properly loaded and the operator exits the PSD.

Refer to SD-011 Specification for Safety Circuits and SD-1032 (Programmable Logic Controller Application Specification) for PSDI implementation requirements. All local regulations and regional requirements shall be applied when PSDI is implemented.

8.3.4 Two-Hand Control Devices

When using two-hand control devices in safeguarding design, the devices shall meet the following requirements. Refer to SD-011 (Specifications for Safety Circuits) for two-hand control safety circuit requirements.

1. Be protected against unintentional operation. Example: Pre-installed field cover or guards protect the device and prevent inadvertent activation
2. Be arranged by design using either construction or minimum separation of 550 mm (should not exceed 600 mm) to require the concurrent use of both hands to initiate and maintain the machine cycle. Minimum separation of 550 mm required if no other means of preventing defeat are provided.
3. Be maintained until the hazardous motion has been eliminated.
4. Require the release of both hands and the reactivation of both control devices before a machine cycle can be reinitiated (anti-tie down).
5. Be located and anchored at least the minimum safe distance from the nearest point-of-operation hazard in order to prevent the Operator from reaching the hazard zone either with a hand or another body part. Reference Annex A and ISO 13855 for additional guidance.
6. Stop normal cycle action or retract hazardous motion if one or both of the Operator's hands are removed at any point in the cycle where a reach-in hazard exists.

   NOTE: Two-Hand Control is not to be confused with Two-Hand Cycle Start Initiation. While using Two-Hand Cycle Start Initiation, the PSD is the primary safeguard.

8.4 Operator Interface Devices

The following parameters shall be included in the design, construction, and installation of the Operator interface control panels. These devices shall:

8.4.1 Be readily identifiable and appropriately marked or labeled as to their function.

8.4.2 Be located near the Operator and properly placed in order to keep the Operator clear of all machine hazards.

8.4.3 Be mounted in a location that does not require the interruption of a safeguard to access the interface device.

8.4.4 Be protected from unintentional operation by normal movement of the Operator or flow of work pieces, material, or tooling through the manufacturing process.

8.4.5 Not initiate any motion unrelated to its designation.

NOTE: Stopping devices shall be clearly marked and require only momentary actuation to stop machine motion.

8.4.6 Cycle Initiation

1. Cycle initiation devices shall be designed and located so that all parts of the body are clear of machine hazards.
2. Equipment that is being initiated by an operator every cycle shall have a cycle initiation device that is rated for the application. See SD-007 for cycle initiation device requirements.
3. Zero-Force buttons, cycle start limit switches (wobble / whisker) require anti-tie down features.
4. For the use of two-hand controls for cycle initiation, see the Two-Hand Control section 8.3.4 for requirements.
5. For the use of PSDs for cycle initiation, see the PSDI section 8.3.3 for requirements.

8.5 Emergency Stop Function and Devices

Each machine shall be provided with one or more emergency stop (E-STOP) devices. The devices shall be located at all operator interface control panels, such as HMI's, as well as other locations where an emergency shutdown may be needed.

NOTE: An emergency stop device may not be required only if the machine risk assessment documents one is not necessary. Other risk reduction methods, such as training and safe operating procedures, may be a suitable replacement where hazards exist.

Emergency stops shall:

- Override all other functions and modes of operation.
- Remove power to the machine actuators as quickly as possible without creating other hazards.
- Be reset at the point of interrupt.
- Not initiate restart when reset.

8.5.1 Emergency Stop Functional Requirements

Emergency Stop functions, circuits, and devices perform an auxiliary stop function typically provided in addition to the machine's safeguarding system. The emergency stop function shall be implemented consistent with the safeguard circuit performance level and be operational at all times.

The activation of the emergency stop function shall stop all hazardous motions within a clearly defined area of control. The emergency stop function shall not affect adjacent equipment that is not posing a hazard.

The activation of the emergency stop function shall not require a decision by the Operator regarding the effects of the emergency stop signal. The emergency stop function should be easily accessible, and visible to the Operator.

Resetting an emergency stop function shall be a deliberate action.

A manually operated E-Stop device shall:

1. Be provided at each operator station.
2. Be hardwired into the emergency stop safety circuit.
3. Function independently from the system controller.
4. Be mounted between 0.9 m (35 inches) and 1.65m (65 inches) above service level.

8.5.2 Emergency Stop Device Design Requirements.

1. Be clearly identified.
2. Be readily accessible.
3. Be easy to operate.
4. Be pushbuttons or pull-cords.
5. Not capable of being locked.

8.5.3 Emergency Stop Pushbutton Requirements.

1. Be red in color.
2. Have a yellow background.
3. Be palm type or mushroom shaped and larger than other stop controls.
4. Be unguarded, not shrouded and not recessed.
5. Maintained (latching) contact-type buttons that require deliberate action in order to reset (disengage / release).
6. Text labelling for the emergency stop button is not required.
   a. Labels are required for localized emergency stop buttons that have a different span of control than other E-Stop buttons in the same span of control. (Example: chip conveyors or pump-back units behind a machine).

8.5.4 Emergency Stop Pull Cord Requirements.

1. The cables or ropes shall be red in color.
2. The cables or ropes shall be clearly marked and visible.
3. In the event of cable or rope breakage, loss of tension or disengagement, the E-Stop command shall be initiated.
4. The points of reset should be located, where possible, such that the entire length of the cable or rope is visible from that location.
5. The E-Stop shall be activated from any part of the cable. (The application may require switches at both ends of the cable.)
6. Pull cords shall be accessible on each side of the equipment where a person may be exposed to a hazard.
7. The cables or ropes should be as close to the equipment as possible to avoid accidental actuation while still accounting for deflection required to generate the emergency stop command.
8. Design consideration should be given to the following:
   a. The amount of deflection required to generate the E-Stop command and the maximum deflection possible.
   b. The minimum clearance between the cable(s) or rope(s) and the nearest component.
   c. The force required to activate the E-Stop device.

8.5.5 Emergency Stop Span of Control

The emergency stop function for a guarded area or cell shall remove all motion power to all equipment within that guarded area and remove other hazardous motion as required. An emergency stop should shut down other guarded areas or equipment that is adjacent to the local guarded area, unless stopping of that equipment creates additional hazards or unnecessarily affects production.

All emergency stop devices for a guarded area must have the same span of control.

Each span of control may cover sections of a machine, an entire machine or a group of machines. The spans of control shall be clearly defined and identifiable at the emergency stop device.

8.6 Awareness Barriers

Awareness barriers are a less effective level of control as described in Section 2 - Hierarchy of Health & Safety Controls of this document. Awareness barriers may include but are not limited to, guardrails, chains on posts, and retractable tapes or ropes. Awareness barriers shall meet the following requirements:

8.6.1 Make personnel aware they are entering or reaching into a hazardous area.

8.6.2 Provide a point of physical contact before entering the hazardous area.

8.6.3 Create no pinch points between themselves and other stationary or moving parts of machinery or tooling.

8.7 Awareness Devices / Signals

Awareness devices or signals shall be designed, constructed, and located to provide a recognized signal (audible, visual, or a combination of both) of an approaching or present hazard. Consideration shall be given to the following:

8.7.1 Lamp failure.

8.7.2 Color blindness.

8.7.3 Hearing ability.

8.7.4 Distinction from paging systems.

8.7.5 Sufficient number of lights for large areas for proper visibility of potential hazards.

8.7.6 Distinctive and intense enough sound to rise above ambient noise level.

8.7.7 Annoyance level, as it relates to the likelihood of disconnection.

9. Lockout / Hazardous Energy Control

The principles of lockout, as applied to hazardous energy control, are included in this section.

Hazardous energy control is a key consideration in system concept and design (see Health and Safety Common Core Element – Machine / Equipment Energy Control).

9.1 General Principles

9.1.1 Energy-Isolation Devices

1. The control circuit and energy-isolating devices shall be designed and installed to provide safe system access for service and maintenance tasks. Energy-isolating devices shall not be mounted inside the hazardous area.
    a. The devices shall be located for easy access.
    b. The devices should be in plain view and identified with defined abbreviations and color as per Section 9.2.4.
2. For stand-alone equipment, the primary energy-isolating control devices should be designed and installed in proximity to each other (Example: electrical disconnect, air shutoff valve, and hydraulic shutoff valve all located in the same area of the machine).
3. When cells or transfer lines are used, the primary energy-isolating control devices should be designed and installed in proximity to each other.
4. Lockout / energy control placards that identify the stored energy sources and the safeguards against their release shall be provided per Section 9.2.4.
5. On systems with stored energy, where isolation does not guarantee energy control when the system is initially locked out, special warnings (Example: placards / signs) shall be provided at all key lockout points per Section 9.2.4.

    NOTE: Detailed steps for controlling the stored energy condition shall be part of the system's operation manual. If stored energy is needed to perform a task, additional safeguarding (engineering controls) shall be included to safeguard all personnel.

9.2 Hazardous Energy Control-Lockout

The main lockable disconnects for all hazardous energy sources shall be located outside the safeguarded area. Through-the-door electrical disconnect switches with rod actuators that allow the operating handle to become disengaged from the switch when the panel door is open are not preferred. All electrical enclosures with through-the-door rotary disconnect switches, with the handle mounted on the door shall be labeled with the designated Health & Safety Rotary Disconnect lockout labels.

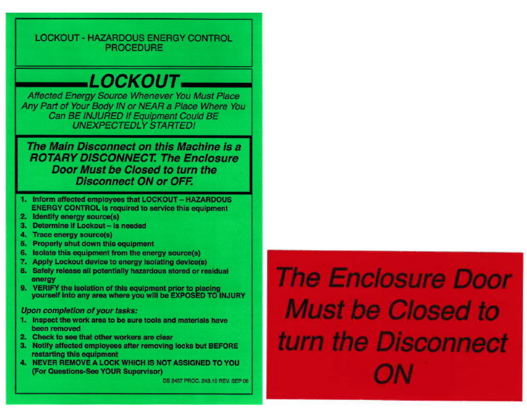


Figure 11: Through-the-door disconnect identification maintained by the Environmental Health & Safety Team.

Equipment using 115-volts or 220-volt (dependent on region) as the primary power source that use plug-socket combinations as the disconnecting means, shall use a lockable plug-enclosing device for equipment lockout (Example: Hubbell Lockout Device).

Periodically, Equipment Suppliers will provide lockable disconnects on the equipment to control minor motion. These disconnects shall be connected in series with the primary disconnects and used per the Machine Risk Assessment.

NOTE: Secondary auxiliary lockable disconnects (Example: motor safety switches) are allowed inside the cell when required to perform specific tasks. These disconnects must be wired in series with the primary disconnect. An auxiliary contact on the safety switch to de-energize the motor starter for under-voltage protection shall be provided. Refer to Electrical Equipment of Industrial Machines – General Requirements IEC 60204-1.

Primary lockable shut-off valves (Example: pneumatic and hydraulic) shall be installed on the service side, outside of the cell. Lockable shutoff valves must also be self-relieving type to bleed all air / hydraulic in the system.

In some cases, additional auxiliary shut-off valves may be desired inside the cell to perform a specific service function as described in a Safe Operating Procedure (SOP). Their use is permitted as long as they are connected in series to a main shut-off that is located outside the cell. These valves must also be lockable and self-relieving. Reference the Nexteer Automotive Lockout / Energy Control Program.

9.2.1 Motion Power Source

Motion Power Source is defined as that power source that results in motion on a machine (Example: electrical power for motors, pneumatic power for cylinders, or hydraulic power for cylinders).

1. The primary motion power system shall be fed through mechanically interrupted disconnect switches or valves.
2. When disengaging an electrical disconnect could result in restart problems, the designer shall add an early break auxiliary contact on the disconnect switch to provide an orderly shutdown.
3. In applications where the station / cell extends to both sides of a conveyance system, consideration shall be given to locating power disconnects on both sides of the line, based on station / line size. When using a second set of disconnects, the set shall be wired in series with the main disconnect.
4. The motion power of a part conveyance system that is not integrated into (not powered from) the part processing equipment (Example: buffering or accumulating systems) shall have independent lockout provisions.

NOTE: Items 2-4 pertain to existing legacy equipment, not required for new equipment purchases.

9.2.2 Stored Energy

Where stored energy exists, a warning sign shall be posted on the machine / equipment.

1. Gravity

Wherever dropping or drifting of equipment / parts presents a hazard, devices shall be installed to prevent the hazard. Examples of gravity drifting prevention devices may include, but are not limited to the following:

- Cylinder Rod Brakes
- Rail Locks
- Piloted Check Valves (for light loads)
- Shot Pins
- Safety Pins
- Blocks

a. The machine risk assessment shall identify task hazard combinations involving suspended vertical loads or gravity related hazards.

b. The control and monitoring of these devices shall be implemented to meet the requirements of the machine risk assessment and SD-011, Specification for Safety Circuits

c. A yellow label with black lettering indicating "Caution" shall be provided near each piloted check valve on the machine to identify a potential for trapped air in the equipment. PO checks shall be documented on the lockout placard. The label is shown in Annex E.

Suspended vertical load requirements for operator load / unload applications are listed in Section 4.2.

2. Mechanical

Tension or pressure that can cause a hazard (Example: springs on a mechanism, brakes, check valves on pneumatic / hydraulic lines, blocks, or auto shot pin systems) shall be capable of being released or controlled.

3. Electrical

Provisions must be provided to discharge all stored electrical energy (Example: capacitors, static electricity, uninterruptable power supplies).

9.2.3 Kinetic Energy

If hazards exist due to kinetic energy (Example: momentum of a grinding wheel) after lockout, those hazards shall be guarded to prevent inadvertent contact.

Devices (Example: cylinder rod brakes, guard locking safety interlocked guard doors with delays, and guards) may be used to control kinetic energy hazards.

9.2.4 Lockout Placards

Lockout Placards are required for each piece of equipment within Nexteer Automotive. These placards identify each energy source, their location, the means to lock out the source, and how verification is performed. All placarding shall be in accordance with Nexteer Automotive' s Lockout Energy Control Procedure (reference Procedure 243.10). The Equipment Supplier shall provide all necessary electronic files to the Equipment Engineer, including the location of all lockout points and details for appropriate safe operating practices, at Machine Qualification 1 (MQ1).

- Lockout Placards shall be created using the Nexteer Lockout Placard Toolkit, located on the ME Website link.

Lockout Placards shall be developed in parallel with the equipment design and build. Temporary lockout placards shall be displayed on the equipment at the time of Machine Qualification 1 (MQ1). Full-color laminated lockout placards, with appropriate Safe Operating Procedures (SOP's), shall be affixed to the equipment prior to Machine Qualification 2 (MQ2). Placards must be verified through the Global Safety Red Tag Procedure (G1245) prior to equipment use.

All lockout placards created shall contain the following information:

- A **header** which identifies the equipment / machine, location, department, and the total number of lockout points identified.
- A **graphic** which shows the equipment / machine layout and each energy isolation point location.
- An **information grid** which identifies each energy source and provides the necessary instructions to isolate and verify lockout.
- A **footer** which identifies the number of locks required to achieve zero-energy state, a unique placard identification, date created, number of pages included, and procedural reminders.

1. Zone and Zone Isolation

A zone is an area of the equipment / machinery whose energy source(s) can be secured independently of any adjacent or opposite area. A piece of equipment can be divided into zones if it consists of many separate energy control devices which allows for area isolation; that is, no other zones will be affected if the energy controls to a zone are isolated. An example of this would be asynchronous conveyors containing separate electrical, hydraulic, pneumatic, or other system lockouts that allow one area to be isolated independently from others.

Equipment cannot be divided into zones if it consists of a single energy source that, when secured, affects all functions of the equipment.

NOTE: If a piece of equipment is not designed to have separate energy control devices which allow for area isolation, manufacturing facilities are not required to retrofit the equipment for zone area isolation.

2. The Lockout Placard Header

TOTAL LOCKOUT POINTS IDENTIFIED	NEXTEER AUTOMOTIVE PLANT #99	LOCATION COLUMN #H-8
4	SD654321 - CARTRIDGE ASSEMBLY MACHINE	DEPT #89
BEFORE SERVICING THIS MACHINE, NOTIFY AFFECTED PERSONNEL.		

Figure 12: Lockout Placard Header

The placard header shall include the following information:

- The Nexteer Automotive Plant number.
- The machine Asset Tag Number (SD Number) and description.
- The number of lockout points identified in the placard.

NOTE: The number of lockout points identified does not necessarily reflect the number of locks required to reach zero-energy state.

- The location of the machine, such as the column number or bay location.
- The department number or area the machine is located, where applicable.
- The specific zone the placard applies, where applicable.
- Procedural reminder to notify affected personnel before servicing the machine.

3. The Lockout Placard Graphic

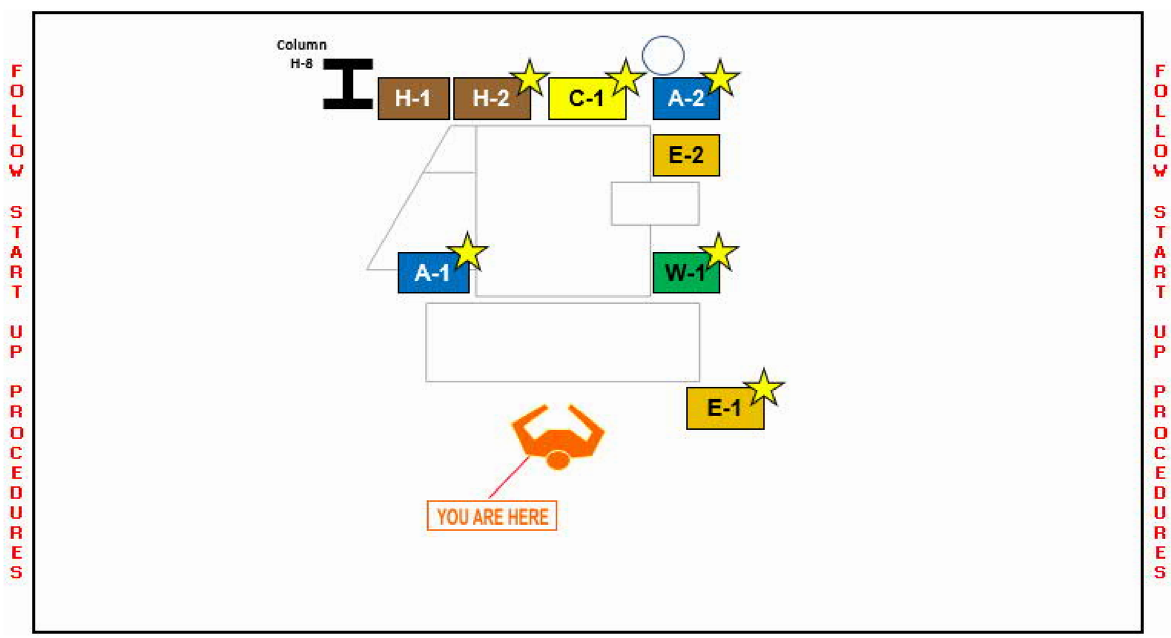


Figure 13: The Lockout Placard Graphic

The placard shall contain a graphic representation of the machine with all lockout points identified. Where zoning is applicable, the graphic shall highlight adjacent zone(s) for energy isolation in the event a task performed may place the worker in the adjacent or opposite zone(s). The graphic shall include the following information:

- A graphical representation of the machine.
- All energy isolation devices and locations.
  - Electrical panels
  - Pneumatic shutoffs
  - Hydraulic tanks
  - Other energy sources (including special sources)
  - Lockout points
  - Isolation and control methods (block and pin)
- Primary energy source identification (star).
- An indication of present position, “You are here.”
- Relative location of the machine (Example: column number).
- Zone highlights, where applicable.

4. The Lockout Placard Information Grid

	Energy Source			Location	Perform Action	You Must Verify
☆	E-1	Electric	Machine Main Disconnect	Main Electrical Panel	Turn Off & Lock Out Electrical Disconnect	PUSH MASTER START BUTTON ON MAIN PANEL. VERIFY MACHINE WILL NOT START. CHECK FOR MOTION.
	E-2	Electric	Infeed Conveyor Disconnect	Right Side of Machine	Turn Off & Lock Out Electrical Disconnect	ON HMI MANUAL SCREEN, PUSH CONVEYOR JOG. VERIFY CONVEYOR WILL NOT START.
	CAUTION	Electric	Battery of Uninterruptible Power System (UPS)	Main Electrical Panel (Inside)	Turn off Machine Main Disconnect and Wait for Battery to Discharge	CHECK THAT RESIDUAL POWER STORED IN BATTERY OF UPS HAS DISSIPATED.
☆	A-1	Air	Machine Main Air Disconnect	Left Side of Machine	Press Down Pneumatic Lockout Valve & Lock Out	LISTEN FOR EXHAUSTED AIR PRESSURE. MANUALLY ACTUATE PNEUMATIC VALVE(S) TO TEST FOR MOTION. NO MOTION SHOULD OCCUR
	CAUTION	AIR	Pilot Operated Check Valve	Various Locations - See PO Check Note Tags	Mechanically Support Load if Necessary & Depress Manual Override Before Servicing.	LISTEN FOR EXHAUSTED AIR PRESSURE WHILE MANUALLY SHIFTING DIRECTIONAL VALVE. CHECK FOR MOTION.
☆	A-2	Air	Grease Barrel Main Air Disconnect	Rear of Machine	Press Down Pneumatic Lockout Valve & Lock Out	LISTEN FOR EXHAUSTED AIR PRESSURE. MANUALLY ACTUATE PNEUMATIC VALVE(S) TO TEST FOR MOTION. NO MOTION SHOULD OCCUR
☆	W-1	Water	Machine Main Water Shutoff Valve	Right Side of Machine	Turn Handle Counter-Clockwise to Close Valve & Lock Out	CHECK FOR WATER FLOW INTO RINSE TANK.
☆	C-1	Chemical	Machine Main Grease Shutoff Valve	Rear of Machine	Turn shutoff valve to off position and Lock Out. Open grease purge valve(s) after shutoff. Turn off A1 removing air from dispense valves	MANUALLY ACTUATE PNEUMATIC VALVE(S) CONTROLLING THE DISPENSERS TO TEST FOR FLOW. NO FLOW SHOULD OCCUR
	H-1	Electric	Machine Main Disconnect	Main Electrical Panel	Turn Off & Lock Out Electrical Disconnect E-1	PUSH MASTER & HYD. PUMP START BUTTONS ON MAIN PB PANEL. VERIFY HYD PUMP MOTOR REMAINS OFF. MANUALLY SHIFT DIRECTIONAL VALVE. CHECK FOR MOVEMENT.
☆	H-2	Hydraulic	Hydraulic Accumulator	Rear of Machine	Turn Off & Lock Out Accumulator Dump Valve and Close Pump Isolation Valve	VERIFY ZERO PRESSURE ON THE ACCUMULATOR GAUGE. MANUALLY ACTUATE HYDRAULIC VALVE(S) TO TEST FOR MOTION. NO MOTION SHALL OCCUR.

Figure 14: The Lockout Placard Information Grid

The body of the lockout placard shall contain an information grid which includes the following:

- All energy sources identified and their location.
- Primary energy source identification (star).
- Action to be performed to isolate the energy source.
- Verification steps to be accomplished.
- Zone isolation, where appropriate.

Equipment that does not have zone capability shall have titled columns that contain four key points of lockout energy control. These columns are divided as follows:

- Energy Source
- Location
- Perform Action
- You Must Verify

Energy Sources include the following:

- Air / Pneumatic
- Chemical
- Electric
- Gravity
- Hydraulic
- Mechanical
- Natural Gas
- Radiation
- Steam
- Thermal (Hot / Cold)
- Water
- Non-Potable Water
- Tower Water

Each type of energy source is to be identified by color and letter, as well as uniquely identified within the source by number. As an example, if multiple electrical disconnects are present, each one shall be labeled appropriately as E-1, E-2, E-3, etc. A star shall be placed next to an energy source that is the primary source of isolation. As shown in the example figure above, locking out E-1 results in the energy isolation of E-2.

Each energy source shall be uniquely identified by color. The following standards apply:

A	Air / Pneumatic (blue - RGB 0, 12, 112)
C	Chemical (yellow - RGB 255, 255, 0)
E	Electric (orange - RGB 238, 193, 0)
G	Gravity (black - RGB 0, 0, 0)
H	Hydraulic (brown - RGB 153, 102, 51)
M	Mechanical (tan - RGB 204, 153, 0)
NG	Natural Gas (pink - RGB 255, 102, 255)
R	Radiation (purple - RGB 112, 48, 160)
S	Steam (grey - RGB 166, 166, 166)
T	Thermal - Hot / Cold (green - RGB 0, 176, 80)
W	Water (green - RGB 0, 176, 80)
W	Water, Non-Potable (yellow - RGB 255, 255, 0)
W	Tower Water (orange - RGB 255, 102, 0)

Figure 15: Lockout Placard Energy Source Standard Colors

5. The Lockout Placard Footer

STOP (3) LOCKS REQURED TO ACHIEVE ZERO-ENERGY STATE. NOTE: ADDITIONAL NON-LOCKABLE HAZARDOUS ENERGY LISTED ABOVE MAY REQUIRE OTHER CONTROL DEVICES / METHODS. STOP		
Placard ID SD654321	IF LOCKOUT ENERGY CONTROL CANNOT BE PERFORMED / VERIFIED - STOP - CONTACT YOUR SUPERVISOR.	11/25/2017 Page 1 of 1

Figure 16: The Lockout Placard Footer

The Lockout Placard Footer shall contain the following information:

- The number of locks required to achieve zero-energy state.
- The Placard ID Number.
- The date and number of pages.
- Procedural reminder to contact Supervision if lockout cannot be performed or verified.

6. Energy Source Identification Tags

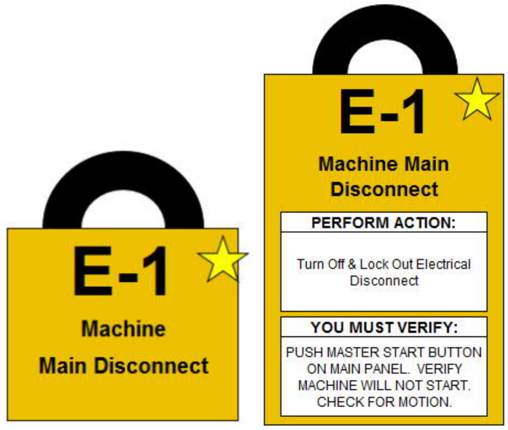


Figure 17: Example Energy Source Identification Tags

An energy source identification tag shall be affixed to each lockout point identified in the Lockout Placard. Each identification tag represents a specific energy source by color and lettering and shall be secured to the energy source isolation device according to the placard.

7. Validating the Placard

Before a lockout energy control placard can be posted, it must be verified that, when the procedure is followed, the energy sources have been isolated and controlled for the purpose of maintenance repair or servicing. The validation process consists of authorized employee(s), the area supervisor of authorized workers, and the designer of the placard at the location to be posted. Together they shall perform the step-by-step process of neutralizing all energy sources as identified on the placard.

Following completion of this process, if it is determined to be effective, the placard shall be posted along with each energy isolation device tag. If, after completing the placard, verification of all energy sources cannot be locked out or controlled for the equipment, a reevaluation of the lockout placard and lockout system must occur.

9.3 Hazardous Energy Control – Part Transfer Systems

Hazardous motion from part transfer or conveyance systems that are an integral part of the work cell shall be stopped by the energy control system. This requirement ensures no motion may occur which could cause injury to anyone servicing part of the production system. Reference ANSI/ASME B20.1, Safety Standard for Conveyors and Related Equipment.

9.4 Controls Lockout Solutions (CLS) in Lieu of Lockout

Established CLS procedures for entering a cell are only allowed for equipment existing in the plant prior to January 1, 2022. CLS is not allowed for new equipment purchases or retooled equipment as of January 1, 2022.

The term Controls Lockout Solutions refers to a Hazardous Energy Control system used on **rare and specific equipment / processes**. This concept is used on processes having multiple pieces of equipment arranged in a cell. To perform a simple task, such as changing a weld tip on a robot weld gun, would require locking out multiple energy isolating devices prior to entering the cell. Locking out each piece of equipment requires **significant** Operator / Maintenance effort, and the productivity loss is significantly longer than the time required to perform the change / repair task. This type of cell typically involves design and implementation of additional energy isolating control systems to effectively isolate all equipment without having to independently lockout all pieces of equipment. The intent of a Controls Lockout Solution is to provide a control reliable safety system for personnel to enter a work cell when it is **not practical to lockout the equipment** (for example, robotic cells without robot disable capabilities).

NOTE: 3rd Party machine or system validation may be required in certain US facilities.

9.4.1 Elements

Controls Lockout Solution (CLS) is a system designed approach that removes energy to hazardous motion devices / equipment / machinery in a designated area (Example: zone or cell) as protected by the safety circuit design and implementation. CLS is **not a substitution** for lockout.

NOTE: Properly designed CLS implementation removes power to the robot through the use of safety circuit hardware; it does not isolate power such as lockout devices.

CLS shall be implemented consistent with performance levels as determined through the Machine Risk Assessment process.

NOTE: The design of the system shall consider all energy sources (Example: electrical, mechanical, hydraulic, gravity, and pneumatic).

CLS uses safety devices that are designed to:

- Stop and remove power to specific machines / equipment.
- Control the hazardous motion energy to the machine.
- Take precedence over other machine control hardware and software.

9.4.2 Circuit Design Requirements

CLS designs shall meet all requirements identified in this section.

1. In CLS applications where electrical energy controls the motion identified as hazardous by the Machine Risk Assessment, safety circuits shall be used to remove electrical power to all hazardous motion.

   These devices shall be:

   - Duplicated to ensure the equipment stops safely.
   - Monitored so further operation is prevented when a failure of any device in the CLS application is detected.

   NOTE: For electrical applications, redundant contactors or relays are required. Redundancy can be accomplished through one of the following:

   - Redundant master contactors / relays in series.
   - A combination of one master contactor / relay in series with the process control contactors / relays.
   - Redundant contactors / relays (Example: safety relays).

2. Where hydraulic or pneumatic energy controls the motion identified as hazardous by a Machine Risk Assessment, the fluid power shall be controlled by either:

   - Removing the energy by removing power to the equipment generating the fluid power (Example: hydraulic pump or air compressor).
   - Using fluid power devices to remove and block fluid power to all hazardous motion.

   These devices shall be:

   - Duplicated to ensure that the equipment stops safely.
   - Monitored so further operation is prevented when a failure of any device in the CLS application is detected.

   NOTE: For applications where the energy is not removed by removing power to the equipment generating the fluid power, redundant valves are required. Redundancy can be accomplished through:

   - Redundant master valves in series.
   - A combination of one master valve in series with the process control valves.
   - Redundant valves (Example: safety valves).

3. The CLS circuit shall be hardware-based. The hardware shall take priority over any software signals used to control the manufacturing process. CLS cannot rely on software-controlled inputs or outputs to safely stop hazardous motion, however, software inputs can be used to monitor the status of the CLS activity.

4. Power devices shall be rated for the maximum-switched load available at any time. The devices controlling the primary energy must be sized to handle the maximum-switched load. Power factor, duty cycle, and switch load vs. life shall be considered when selecting safety components. In an electrical circuit, the protective devices (Example: fuses or circuit breakers) determine the maximum loads that can exist at any time. In a hydraulic circuit, consult ISO 4413, Hydraulic Fluid Power - General Rules Relating to Systems, or the applicable standard. In a pneumatic circuit, consult ISO 4414, Pneumatic Fluid Power - General Rules Relating to Systems, or the applicable standard.

5. The contacts used in the CLS application (Example: hardwired circuits) to monitor power devices shall be positive-opening contacts. They shall be either integral to the device, or on a screw-on (not snap-on) contact block. Switches used to monitor valve spool position shall change state each time the valve is operated (Example: each switch shall cycle on-off-on or cycle off-on-off). Switches monitoring valves must be wired in such a manner to make and break each cycle. Monitoring each state change will detect if the switch becomes detached from the device it is monitoring.

6. Every start and reset circuit used in the CLS application shall be designed to prevent tie-down. Push buttons with one Normally Open (NO) and one Normally Closed (NC) contact can be used if they are wired so the NO contact must close, and NC contact must open to obtain reset. Single contact push buttons can be used when wired in such a manner to be pushed to make contact and released to open the contact before a reset is obtained.

7. All safety status indicators for the CLS application shall be fail-to-safe. The CLS indicator shall be green in color and labeled “CLS Active – OK to Enter”. The label requirement prevents lamp failure, temporary power loss, cable faults, fuse faults, or other faults in the signaling system from indicating CLS is active.

   NOTE: If the indicator is ON, the equipment is under CLS control. If the indicator is NOT ON, the equipment is not under CLS control. Entering the protected area with the CLS indicator in the OFF state is a violation of Nexteer Automotive’s Lockout Policy.

8. Safety status indicators for CLS shall be controlled by hardwired devices (Example: auxiliary contacts of contactors, safety relays, or valve position sensors). Hardwired devices must take priority over any software driven outputs. Software outputs in series and overridden by the hardware devices are acceptable.

   NOTE: The power devices cannot be in two states (Example: “on” and “off”) at the same time. The “true” status of the power source will be indicated only when all power devices are “off.”

9. Audible start-up signals shall not sound if CLS has disabled any equipment. There should be input from the CLS application to the system controller that inhibits any “equipment start-up” warning signals (Example: horns) when the circuit has disabled any equipment.

10. The control circuit shall not indicate AUTO if CLS has disabled any equipment. If the CLS application has been used to disable equipment, there must be an input from the CLS application to the system controller to inhibit AUTO mode.

11. All CLS mode control devices shall have the capability to be locked in position or be housed in a lockable enclosure. These mode control devices that disable / enable motion when the guard door is open must be able to be locked in position or be located behind a cover that can be locked to prevent access. This requirement will prevent changing the mode (allowing motion) of the equipment until all personnel have removed their locks.

9.4.3 CLS Task Placards

A CLS task placards shall be posted at each entry guard door into the cell or equipment. Each placard has three major sections showing the tasks that can be performed under CLS control, tasks to be performed under Lockout Energy Control, and the hazards that may be encountered when inside the safeguarded area. For an example CLS placard, see Annex C.

10. Robotic Cell

A robotic cell is the safeguarded area defined by safeguarding that surrounds the robot(s), the end-effector(s), and other associated machinery and equipment.

Any robot(s) that is an integral part of a machining cell shall meet the additional requirements for a machining cell as outlined in Section 11, Servo Controlled Equipment and Machining Cells.

Reference, ISO 10218: Robots and robotic devices – Safety requirements for industrial robots and ANSI/RIA R15.06: American National Standard for Industrial Robots and Robot Systems - Safety Requirements.

10.1 Safety Design Requirements for Robotic Cells

10.1.1 General Layout Requirements

The robotic cell layout shall include all facility features and equipment intended for use, including, but not limited to, the following:

1. Perimeter guarding.
2. Cell entrances.
3. Operating spaces (including path of the end-of-arm tooling and any carried parts and materials).
4. Restricted spaces at Operator Load / Unload Stations and for cell safeguarding (perimeter guarding and PSD's).
5. Auxiliary equipment located within the cell guarding.
6. Location of the Plant floor facility equipment or obstructions in the cell (Example: building columns).
7. Tooling and transfer systems.

Potential pinch points shall be identified and eliminated as practicable. If not practicable, appropriate safeguarding (engineering controls) shall be implemented as determined by the Machine Risk Assessment.

The robot's restricted space shall be established using a combination of safety-rated soft axis limits (DCS) and hard stops, limiting the robot's reach to all anticipated operating and maintenance positions. Basic soft axis limits shall be incorporated to prevent collision with the hard stops.

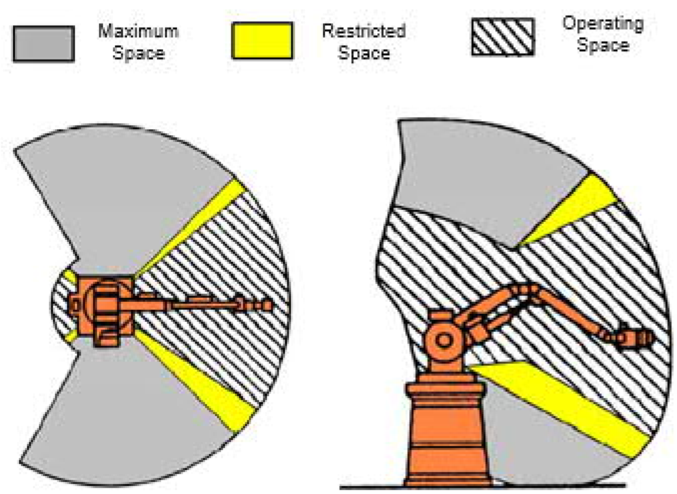


Figure 18: Robot Space Definition

10.1.2 Energy Control and Lockout

To maintain control of the safe state of all hazards within the robot cell, entry into the cell shall use the following energy methods at a minimum:

1. Total lockout (electrical disconnect, main air shut off, robot controller), or
2. Robot disable switch, or
3. Robot teach pendant, or
4. For multi-person entry into a robot cell where power has not been isolated through total lockout, the first person shall use the robot teach pendant and each additional person shall use a separate enabling device. Multi-person entry requirements shall be defined in the machine risk assessment.

10.1.3 Personnel Access Guard Door

Provide safe access to equipment requiring service and to facilitate the use of energy control and lockout. Interlocked safety guard doors shall be used.

1. Robot Cell Entrance Guard Door

   At least one entrance guard door shall be provided for a cell. Each entrance guard door location shall be provided with the following at a minimum:

   a. Safety interlock switch with guard locking.
   b. Escape release for full body access robot cells.
   c. Robot disable switch for full body access robot cells.

   When the robot cell occupies both sides of an assembly line and access across the assembly line is hazardous (as determined by the Machine Risk Assessment), or access to the cell based on layout is difficult, additional entrance guard door(s) shall be provided. In these instances, the guard door(s) should be provided with a request to enter pushbutton in addition to requirements above.

2. Cell Entrance and Exit Procedures

   The typical entrance and restart procedures for robotic cells are as follows:

   a. Stop the system at the next logical stopping position of the current cycle by actuating a control device (Example: end-of-cycle stop pushbutton, request to enter pushbutton, cell run out request pushbutton). Pushbuttons may be hardwired or on the HMI screen. Reference section 8.3.1.5 for additional guidance.
   b. Follow lockout and energy control procedures.
   c. Turning off and locking the robot disable switch is required when entering the full body access cell. The use of the robot disable switch is not required when the robot is in teach mode and a robot enabling device is in hand (Example: robot teach pendant and/or separate enabling device). These shall be the conditions to allow unlocking of the safety interlocked guard door.
   d. Verify a de-energized / neutral energy state.

      NOTE: Use of robot disable switch only, instead of complete lockout and energy isolation, is allowed when performing routine minor servicing tasks required to support normal production operations.

      NOTE: Established CLS procedures for entering a cell are only allowed for equipment existing in the plant prior to January 1, 2022. CLS is not allowed for new equipment purchases or retooled equipment as of Jan 1, 2022.
   e. Open the safety interlocked guard door and enter the cell. Reference Section 8.3 for design requirement.
   f. Entry from one cell into an adjacent cell through a PSD is not a normal entrance and violates lockout and energy control procedures.

g. To reactivate automatic operation, the following actions shall occur within normal start-up procedures:
- Removal of all service equipment and tools,
- Notification of affected and authorized personnel,
- Closure of all guard doors,
- Resetting of the guard door interlock circuits,
- Restoration of all the other safeguards required for automatic operations, and
- Deliberate cell restart action

10.2 Robot Manual Mode Speed Requirements

10.2.1 Manual Reduced Speed Mode

Manual reduced speed mode (T1) shall be provided to limit the speed of the robot for jogging, teaching, and programming activities. The speed shall be limited to a maximum of 250 mm/sec (10 in/sec) when in teach mode.

All cell control systems shall be designed to provide each person in the cell with the capability to stop hazardous motion while motion power is available. This requirement can be met using a robot teach pendant, or an enabling device.

10.2.2 Manual High-Speed Mode

Manual high-speed mode (T2) is defined as the robot speed of greater than 250 mm/sec (10 in/sec). Manual high-speed mode (T2) is **not allowed.**

NOTE: Manual high-speed mode (T2) shall not be provided for new or retool equipment purchases as of Jan 1, 2022.

10.2.3 Cells with Multiple Robots

For robotic cells with multiple robots, a lockable teach selection function shall be provided and used to only allow a single robot to be moved in teach mode at one time when the robots have overlapping restricted space. This shall be defined on the Machine Risk Assessment.

Refer to SD-011 Specification for Safety Circuits and SD-1040 Specification for Fanuc Robots implementation requirements.

10.3 Cell Safeguarding

The safeguarded space shall be established using perimeter guarding. Perimeter guarding shall be located outside of the robots restricted space, unless the perimeter guarding is designed to be the limiting device establishing the restricted space.

10.3.1 Outside the Cell Safeguarding

Hard guarding (Example: fences, guard doors, walls, and doors) and presence sensing device (PSD) guarding are approved methods for cell perimeter guarding, reference Section 8.2.2 Perimeter Guarding. The positioning or openings in any fixed guarding must not allow a person to reach over, under, around or through the guard and access a hazard.

Perimeter hard guarding (with openings, typically 40 mm x 40 mm square or less) shall be:

- Located a minimum of 200 mm (8 in) outside of the robots' operating space, when DCS is not the limiting device.
- Located a minimum of 300 mm (12 in) outside of the robots' defined DCS zones.

Perimeter hard guarding (with no openings, Example: solid plexiglass or metal panels) shall be:

- Located outside of the robots' operating space, when DCS is not the limiting device.
- Located a minimum distance of 200 mm (8 in) outside of the robots' defined DCS zones.

Light Curtain PSD Perimeter guarding shall be:

- Located a minimum distance of 300 mm (12 in) outside of the robots' defined DCS zones.
- Located a minimum distance of 600 mm (24 in) outside of the robots' operating space. Minimum distance is to prevent operator from accessing hazards when reaching through PSD.

Limiting the speed of the robot by a safety rated system (DCS) may be considered for reducing the distances above, based on safe distance calculations. Reference Annex A and ISO 13855 for additional guidance on safe distance calculations.

The height of the cell perimeter safeguarding shall be a minimum of 1850 mm (72 in) and prevent the access to a hazard by reaching over the safeguard. The height requirement does not apply to totally enclosed robot stations or cells. An example of a totally enclosed robot cell is a tabletop robot surrounded by solid plexiglass.

If the above requirements cannot be met, an alternative safeguarding method shall be determined by the Machine Risk Assessment.

PSD Perimeter guarding devices shall meet the requirements of Section 8.3.2. In case of conflict, the requirements detailed in Section 10 take precedence.

10.3.2 Inside the Cell Safeguarding

If a person is not required to be inside the safeguarded area to teach a robot, no additional safeguarding is required other than the cell perimeter guarding. However, this requires safeguarding preventing all hazardous robot motion when any personnel enters the cell.

If a person is required to be inside the safeguarding area to teach a robot, the individual must avoid potential pinch point hazard between the robot and process related obstructions. Single-point control of the robot is required to perform all manual robot operations (teach pendant or live-man switch). Refer to Section 10.2 for Teach and speed requirements.

10.4 Shared Workspace Safeguarding

A shared workspace is defined as the space or work area the robot reaches during normal automatic operation. It is also the space or work area that, at a different time, individuals can access as part of the normal production operation.

The operator PSD in a shared workspace shall maintain the presence detection of an operator at all times.

Shared workspaces shall be designed such that operators are prevented from evading, avoiding, or clearing the operator PSD by climbing on or over parts of the machinery.

10.5 Axis Limiting and Sensing Devices

Limiting devices that establish the restricted space for a robot shall be used as defined below.

10.5.1 Mechanical and Electro-Mechanical Limiting Devices

The robot-restricted space is defined based on the placement of the mechanical (Example: hard stops) or non-mechanical (Example: PSD or DLD) limiting devices. Building columns and other physical barriers (Example: equipment, tooling) may also define the restricted space, per the Machine Risk Assessment. The cell designs shall allow the Operator to remain safe after the cycle start device has been activated. The non-mechanical limiting devices shall be implemented as specified by the Machine Risk Assessment circuit performance level requirements.

10.5.2 Safety-Rated Soft Axis (DCS) and Space Limiting

Safety-rated axis limits (DCS) can be used to create both working and restricted zones of the robot operation. Safety-rated soft axis limits can define any geometric shape as a restricted space, but the restricted space shall be defined at the actual physical stopping position of the robot.

Safety-rated soft axis limits can be dynamically controlled as part of the automatic cycle (Example: based on Operator PSD feedback) but shall not be reconfigured during automatic cycle. Safety limit configuration signatures shall be annunciated to the PLC.

10.5.3 Dynamic Limiting Devices (DLD)

When the loading and unloading operation cannot be designed to completely remove the operator from a shared workspace, the space or work area shall be safeguarded to prevent a robot and person occupying the same space simultaneously. Typically, a DLD is used to prevent the robot from entering the shared workspace and safeguard the operator. Moveable safety interlock guards (Example: part drawer or door) may be used. Examples of DLDs include light curtains, safety scanners, Dual Check Safety (DCS) functions.

The DLD shall be positioned to meet the following requirements:

1. The robot-restricted space shall not extend beyond the Operator PSD.
2. The location of the Operator PSD shall comply with the safe distance formula to the nearest point-of-operation hazard for the Operator, implemented consistent with the Machine Risk Assessment. Reference robot hazard mitigation Section 10.8 and Annex B for additional guidance.

When an Operator is present (the Operator PSD is tripped / interrupted), the robot end-of-arm tooling, or the part being carried, shall be prevented from entering the shared workspace. Other associated hazardous motion (Example: tool clamps, weld guns) shall be controlled. One of the following methods shall be used based on the Machine Risk Assessment:

- A DLD for detecting the position of the robot shall stop the robot from entering the shared workspace when a person is in the shared workspace.
- Switches or sensors that detect robot position shall be implemented consistent with the machine risk assessment circuit performance level requirements and shall stop the robot from entering the shared workspace.

The Operator PSD may be muted by a hardware-based safety circuit or a safety rated software and/or firmware based controller when another safeguarding device (Example: robot DLD) indicates there is no hazard from the robot. This circuit allows the Operator to reach inside the shared workspace when the robot is in a safe position within the robotic cycle. If the robot approaches the shared workspace while the Operator is present, or the Operator attempts to enter the shared workspace when the robot is present, the robot shall stop immediately.

During the machine cycle, a dedicated green indicator light that is visible from the Operator's workstation shall indicate the point in the process cycle when the Operator can reach into the shared workspace without stopping the process.

The location of the safeguarding devices on the robot side of the shared workspace shall be installed in a manner that stops the robot before any part of its tooling, or the part being carried enters the shared workspace.

10.5.4 Robot Restricted Space and Dynamic Limiting Devices (DLD's)

Using DLD's (including DCS), the robot's restricted space can be automatically changed during a portion of the robots' cycle to allow manual loading / unloading tasks performed while the robot is clear from the Operator's work area. Control devices may be used to limit robot movement when the Operator is interrupting the Operator PSD while the robot performs its task program. Devices including, but are not limited to:

- Cam operated / safe limit switches
- Light curtains
- Safety interlock switches
- Safety rated axis limits (DCS)

The device(s) shall be positioned so the robot stops before entering the shared workspace. DLD's shall be integrated as specified by the Machine Risk Assessment circuit performance level requirements. The DLD shall not be used as the Operator PSD.

When teaching the robot, the Operator PSD or DLD may be bypassed in a control reliable manner to allow the programmer to stand close to the equipment or tooling to perform the task.

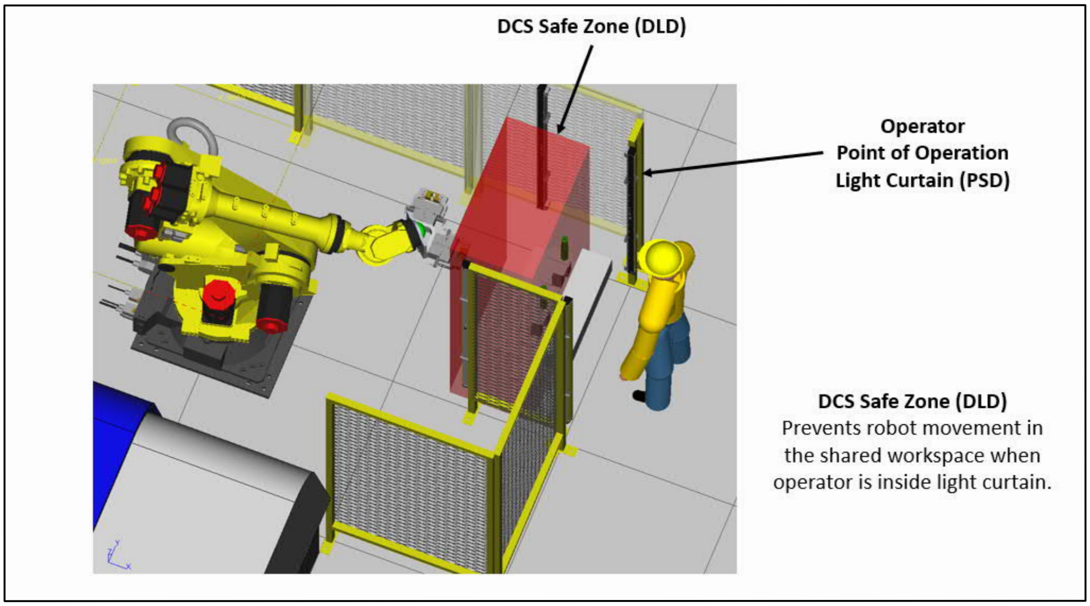


Figure 19: Operator Loading / Unloading Task (Shared Workspace)

10.6 Material Handling Applications

For a gravity hazard concern, a material handling robot shall retain the material in its end-effector in the event of a loss of energy to the robot servos. For a vacuum cup application, end-effector part retention (Example: a vacuum lock) shall be provided when personnel enter the safeguarded area. The plant shall have an ongoing maintenance procedure in place for end-effector tooling.

Material handling robotic cells shall use perimeter hard guarding when material or equipment has a potential to be ejected from or dropped outside the work area creating a hazard. Refer to Section 8.2.2 for additional Perimeter Guarding requirements.

10.7 Adjacent Robotic Cells

Robotic cells or stations that share common safeguarding between them shall meet the requirements of section 8.2.2.3 Shared Perimeter Guarding. This includes shared perimeter hard guarding and PSDs.

10.8 Robot Hazard Mitigation

The information in this section summarizes Nexteer's minimum standards for protecting personnel in operator stations and outside the perimeter of robotic cells. Not all examples will be applicable to every robotic application. Each robotic application must be reviewed to ensure the proper hazard mitigation is applied based on the machine risk assessment.

Operator and perimeter guard hazard mitigation for robotic cells must be verified utilizing the latest machine run off safety checklist.

10.8.1 Preferred Order of Hazard Mitigation for Cell Perimeter:

1. Place perimeter guarding outside of robot maximum reach (including path of the end-of-arm tooling and any carried parts and materials).
2. Use hard stops (J1, J2, & J3) to restrict robot movement within perimeter guarding. This may require reorientation of the robot to enable the use of hard stops.
3. Use safety-rated soft axis limits (DCS zones) as documented below.

All robot non-hard stops are defined as Category 0 Power-off stop in DCS.

DCS zones must extend vertically to cover the entire robot operating space unless otherwise noted as shown in the following figures.

10.8.2 Robot Workspace Restrictions Within Perimeter Guarding

1. All examples shown below include the robot end effector and part movement.
2. All perimeter guarding shall meet the requirements defined in Section 10.3.1.

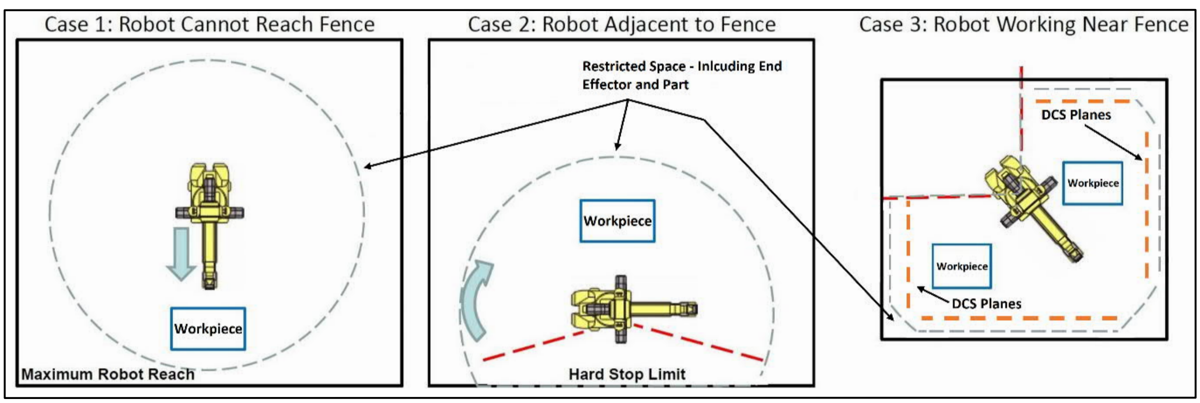


Figure 20: Robot Envelope Restriction Within Perimeter Guarding

- Case 1 Mitigation: None required.
- Case 2 Mitigation: Install J1 & J3 hard stops.
- Case 3 Mitigation: Install J1 & J3 hard stops and apply DCS zones.

10.8.3 Perimeter DCS Requirements – Robot Working Near Perimeter Guarding

1. Perimeter hard guarding shall meet the requirements of Section 10.3.1 to prevent access to hazards.
2. DCS zones are required for cell perimeters only where the robot can reach the perimeter.
3. DCS zones shall meet the requirements of Section 10.3.1.
4. Operator PSD mounting shall meet the requirements of Section 8.3.2 and 10.3.1.
5. If the robot can only reach the perimeter by flipping over on J3, DCS is not required.

10.8.4 Operator Station Light Screen and DCS Setup

1. Operator light screen installation shall meet the requirements of Section 8.3.2 and 10.3.1.
2. Operator light screen(s) shall detect the operator at all times.
3. DCS Zones may be replaced by robot light screens with Nexteer prior approval.

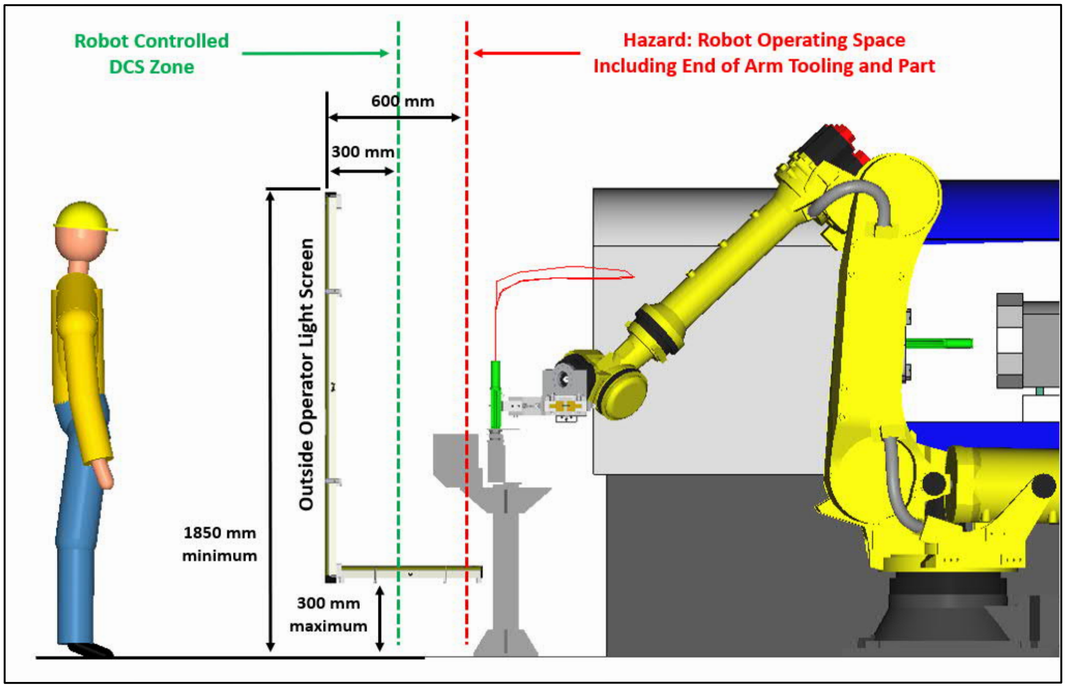


Figure 21: Operator Station Light Screen and DCS Zone Setup

11. Servo Controlled Equipment and Machining Cells

This section lists the specific safety requirements for individual Servo Controlled Equipment and machining cells.

Servo Controlled Equipment is defined as any machine that uses servo systems for machine motion, including multi-axis assembly machines and individual Computer Numerically Controlled (CNC) metal removing equipment.

A machining cell is defined as a group of equipment that incorporates the following:

- Industrial machines
- Gauges and related devices used to process a workpiece
- Devices used to process a workpiece or group material through a series of manufacturing or assembly operations
- Material handling devices controlled by programmable devices

Reference ANSI B11.20, Safety Requirements for Integrated Manufacturing Systems.

11.1 Safety Design Requirements for Servo Controlled Equipment

11.1.1 All servo-controlled machines shall be designed to not create hazardous condition(s) if the following scenarios occur:

1. Loss of electrical power
2. Voltage surges
3. Changes in either oil or air pressure

11.1.2 All equipment shall provide means for isolating all power sources. Reference Section 9 - Lockout / Hazardous Energy Control for energy isolation device requirements.

11.1.3 The location and access to any energy isolating device shall not be inhibited by other hardware associated with the servo-controlled equipment (Example: electrical panel mounted directly above a self-contained coolant system). If it is not possible to provide direct access to the energy isolating device, (Example: a movable platform). Reference Section 9.1.1 for energy isolation device requirements.

11.1.4 Control systems that initiate motion shall be located to prevent inadvertent operator interaction. Control and equipment devices requiring access during normal automatic machine operation shall be located outside the safeguarded area. Reference Section 8.4 for requirements.

11.1.5 Every effort shall be made to eliminate or reduce hazards to the lowest possible risk level. If hazard elimination or substitution through equipment design is not possible, safeguarding devices shall be used and applied as required by the Machine Risk Assessment circuit performance level. Reference Section 3.5 & 3.6 of this document for requirements. Reference Section 8 Safeguarding for requirements of selecting and implementing appropriate safeguarding.

11.1.6 All Operator or maintenance stations, including remote enabling devices (pendants and enabling pendant stations), shall have Emergency Stop devices installed. Reference Section 8.5 for Emergency Stop device and functionality requirements.

11.1.7 Software and firmware-based safety control systems, used in place of hardware-based safety control systems shall require approval by the Controls Engineer. The system shall meet the following requirements at a minimum:

1. Be designed such that any safety related component or firmware failure shall:
   a. Lead to the shutdown of the system in a safe state.
   b. Prevent subsequent automatic operation until the component failure has been corrected.
2. Shall be designed and constructed to meet the Machine Risk Assessment circuit performance level requirements. Reference Section 3.6 for Circuit Performance Level & Circuit Structure Category requirements.

11.1.8 Electrical connectors intended to be connected or disconnected shall be a switch rated plug socket combinations and meet the requirements of SD-004 Section 13.4.5 – Plug Socket Combinations.

11.2 Operator Workstation Safety Requirements for Servo Controlled Equipment

11.2.1 Load / Unload Devices

1. Every effort shall be made to eliminate the operator from the servo-controlled piece of equipment's load / unload station by using turntables, shuttles, as well as other types of part transfer mechanisms.
2. All workpiece loading and unloading devices shall meet the Machine Risk Assessment circuit performance level requirements.
3. When access is required for the adjustment or maintenance of a workpiece transfer device requiring the equipment's hazardous motions enabled with the safeguarding open, all hazardous motion shall be controlled with an enabling device. The enabling device shall be connected as part of the main operator console or a remote operator pendant (Reference Section 11.3). The enabling device shall be defined in the Machine Risk Assessment

11.2.2 Presence Sensing Devices (PSD's)

1. When loading and unloading operations cannot be designed to completely remove the Operator from the servo-controlled equipment hazard, the equipment shall use one of the following to prevent any motion while the operator is in the shared workspace:
   a. A PSD to detect the operator while in the shared workspace
   b. A movable interlocked barrier guard
2. The PSD and movable interlocked barrier guard shall be implemented as specified by the Machine Risk Assessment Circuit Performance Level requirements in Section 3.6.

11.2.3 Automatic Tool Changers

1. Access to hazardous movements of the tool changer shall be prevented by fixed and interlocked movable guards. The safeguarding shall be de as specified by the Machine Risk Assessment Circuit Performance Level requirements in Section 3.6.
2. When the safety interlocked movable guard is open, the tool magazine's drive power shall be disconnected.
3. The ability to view the movement of the tool changer while the guard is closed shall be provided.

11.3 Maintenance Personnel Safety Requirements for Servo Controlled Equipment

11.3.1 Maintenance activities for servo-controlled equipment shall be done following the Lockout / Hazardous Energy Control requirements defined in Section 9.

11.3.2 Maintenance tasks, such as, spindle alignment, tool changer alignment, clearing part jams, and qualifying fixtures may require servo power to remain in an energized. For these tasks, maintenance shall have a single point of control of the servo-controlled equipment to maintain control of the safe state of all hazards while performing these tasks with drive power enabled. Single point control shall include the following:

1. Use of an enabling device which, when held in an actuated position, shall allow motion to occur. Motion shall be disabled upon release.
2. Move a single axis at a time at a reduced speed not to exceed 2m/min.
3. Automatic Operation of the servo-controlled equipment shall be disabled when single point of control is activated.

11.3.3 Single point of control shall be provided by the following methods:

1. If the maintenance person can safely perform their task with the equipment's drive power enabled while standing at the main Operator's station, the single point controls can be provided in the main machine console.
2. If the maintenance person cannot safely perform their task with equipment's drive power enabled while standing at the main Operator's station, an enabling device shall be provided for single point of control. The enabling device shall include the following functional requirements:
   a. Physically disable the main Operator's console when the remote pendant enabling device is actuated. The disabling of the main Operators' console shall be accomplished via hardwiring and not through simple software techniques.
   b. An Emergency Stop device implemented in accordance with Section 8.5 of this document.
   c. The remote pendant enabling device shall be implemented as specified by the Machine Risk Assessment Circuit Performance Level. Refer to Section 3.6 for requirements.

11.4 Safety Design Requirements for Machining Cells

11.4.1 Process Layout Analysis

The process's equipment layout shall include all facility features and equipment that that will be included in the machining cell. This process analysis shall be performed by the Equipment Engineer and, if applicable, by the Machine Tool Builder / Integrator.

The process layout shall be provided for creating the Machine Risk Assessment. The process layout shall include the following features at a minimum:

1. Actual location of the equipment on the Nexteer plant floor.
2. All process equipment
3. All tooling access points
4. All auxiliary equipment (Example: measurement / gauging systems, transfer systems)
5. Material stock bins or containers
6. The location of operator and maintenance tasks
7. All hazardous zones
8. Guarding that encloses the equipment perimeter
9. Cell entrances that lead into hazardous zones
10. The location of all energy control devices
11. All presence sensing devices.
12. Locations of both the Operator and maintenance tasks.
13. When multi-axis machines are used in the process, simulation may be required to ensure the system has a safety system to meet the requirements of the Machine Risk Assessment

11.4.2 Servo Equipment Cell Entrance Procedures

The typical entrance and restart procedures for servo equipment cells are as follows:

1. Stop the system at the next logical stopping position of the current cycle by actuating a control device (Example: end-of-cycle stop pushbutton, request to enter pushbutton, or manual mode selection). Pushbuttons may be hardwired or on the HMI screen.
2. Follow lockout and energy control procedures. Turning off and locking of the robot disable switch is required when entering the full body access cell without a robot enabling device in hand (Example: robot teach pendant and/or separate enabling device). Verify a de-energized / neutral energy state.
3. Open the safety interlocked guard door and enter the cell. Reference Section 8.3 Safeguarding Devices for design requirement. The safety interlocked guard door shall prevent the guard door from opening until all hazardous motion has stopped.
4. Entry from one cell into an adjacent cell through a PSD is not a normal entrance and violates lockout and energy control procedures.
5. To reactivate automatic operation, the following actions shall occur within normal start-up procedures:
   a. Removal of all service equipment and tools,
   b. Notification of affected and authorized personnel,
   c. Closure of all guard doors,
   d. Resetting of the guard door interlock circuits,
   e. Restoration of all the other safeguards required for automatic operations, and
   f. Deliberate cell restart action

11.4.3 Robots Within Machining Cells

When robots are used within a machining cell, the Machine Risk Assessment shall be performed. Robot cell requirements shall be applied from Section 10 of this specification.

12. Driverless Industrial Vehicles and Systems

This section lists requirements for driverless industrial vehicle systems. These types of vehicles include but are not limited to the following common references:

- Autonomous Mobile Robots (AMR)
- Automated Guided Vehicles (AGV)
- Automatic Guided Industrial Vehicle (AIV)

The driverless vehicle shall comply with the safety requirements and protective measures detailed in ISO 3691-4 or ANSI/TSDF B56.5. These standards shall be referenced for additional requirements on all driverless industrial vehicle system installations.

12.1 Layout Requirements

12.1.1 It is critical to allocate appropriate aisle widths and consider safety clearances to identify and resolve hazardous conditions early in the layout design process.

12.1.2 A minimum clearance of 500 mm (20 in) shall be maintained on both sides of the vehicle path or on one side of the path if the clearance on the other side is 100 mm (4 in) or less to a continuous fixed structure (example: a wall). The clearance shall be measured between the path and adjacent fixed structures along the path.

12.1.3 Passing driverless vehicles shall maintain a minimum of 200 mm (8 in) clearance between the maximum width of the vehicles and their payloads.

12.1.4 The driverless vehicle may travel anywhere inside the main vehicle aisles or any defined paths outside of the main vehicle aisle.

12.1.5 The surfaces where the vehicle will be operating shall be maintained to ensure that the traction required for travel, steering, and braking performance can be met under the expected environmental conditions for that surface.

12.1.6 The system layout and vehicle safety systems shall consider the physical environment, including temperature, humidity, ambient weather (example: exposed or outdoor vehicle route) and air quality.

12.2 Vehicle Safeguarding

12.2.1 A Machine Risk Assessment is required for all driverless vehicle installations.

12.2.2 Prior to any driverless vehicle movement an optical signal or alarm shall sound for at least 2 seconds. The start-up speed shall be limited to 0.3 m/s for 500 mm on applications where the vehicle is towing a trailer behind the vehicle.

12.2.3 The safety-related parts of all safeguarding functions listed below shall meet PL d requirements per ISO 3691-4. This includes the Emergency Stop, Presence Sensing, Presence Sensing Muting, Braking, and Speed Monitoring safety functions. Reference ISO 3691-4 for minimum PL requirements for safety functions that are not listed.

12.2.4 **Emergency Stop Safety Function:** Each driverless vehicle shall be provided with an emergency stop function that stops all vehicle movement in an appropriate manner without creating additional hazards. The emergency stop devices shall be clearly visible and readily accessible from all sides of the vehicle and its payload. Readily accessible does not necessarily require the devices to be on all sides of the vehicle unless the application requires it. Each trailer / cart being pulled behind the vehicle shall include a minimum of two emergency stop pushbuttons (one on each side) electrically connected to the vehicle's emergency stop safety circuit.

1. The vehicle's emergency stop device shall be locally reset. Automatic restart of the vehicle motion is not permitted after the reset of the emergency stop function.
2. An emergency stop shall occur if the vehicle moves off the intended path or there is a loss of speed control.

Refer to Section 8.5 of this document for Emergency Stop pushbutton requirements.

12.2.5 **Presence Sensing Safety Function:** Each driverless vehicle shall be provided with presence sensing devices (PSDs) for the detection of personnel and obstructions in all directions of vehicle travel. This may require multiple PSD devices per vehicle.

1. The PSD detection field shall extend beyond the maximum width of the vehicle and payload by 100 mm (4 in) at a minimum.
2. The height of the detection zone shall be equal to or less than 300 mm (12 in) above the traveling surface to prevent undetected access beneath the detection zone.
3. The detection capability or resolution of the PSD device shall be set to 50 mm to allow for the detection zone of the PSD to be below 300 mm (12 in) above the traveling surface.
4. The vehicle shall stop before contact between the parts of the vehicle or payload and a stationary person (not a person stepping into the vehicle path or moving toward the vehicle) or obstruction. A safe stopping distance calculation shall be performed for the vehicle and its payload based on Annex A. This determination depends on many factors, such as other vehicle and pedestrian traffic, clearances, condition of the floor, and the stability and retention requirements of load(s).
5. The vehicle movement may restart automatically in the event of a stop due to personnel detection in its path after the person has moved outside of the detection zone of the PSD for a minimum of 2 seconds and following appropriate warnings (example: optical or sound).
6. The PSD function shall be active at all times unless muting is required for load transfer or specific equipment interaction. The PSD shall only be muted as late as possible ensuring the absence of personnel. It is recommended that the vehicle be less than 180 mm (7 in) from load transfer location before muting. While the PSD is muted, the maximum travel speed shall be 0.3 m/sec.

12.2.6 **Braking System Safety Function:** The braking system working with the object presence sensing system and the response time of the safety control system shall stop the vehicle prior to impacting personnel or an obstruction.

1. Changes in environments shall be considered, such as changes in weather, surface conditions, or applications that may affect the vehicle stopping distance.

12.2.7 **Speed Monitoring Safety Function:** Each driverless vehicle shall be provided with speed monitoring system to ensure the programmed speed of the vehicle meets the requirements of the application and location of the paths potential obstructions. Clearance requirements referenced below are detailed in section 12.1.2. Reference ISO 3691-4 Tables A.1 and A.2 or ANSI/TSDF B56.5 Table 1 for additional guidance on speed and clearance requirements.

1. In areas where clearance requirements are maintained (operating zone) and the distance to a fixed structure or object in line with the vehicles direction of travel is greater than 500 mm (20 in), the rated or full speed of the vehicle is allowed.
2. In areas where clearance requirements are not maintained (operating hazard zone) and the distance to a fixed structure or object in line with the vehicles direction of travel is greater than 500 mm (20 in), the maximum travel speed of the vehicle shall be 1.2 m/sec.
3. In areas where the distance to a fixed structure or object in line with the vehicles direction of travel is less than 0.5 m (20 in), the maximum travel speed of the vehicle shall be 0.7 m/sec.
4. In restricted zones the maximum travel speed of the vehicle shall be 0.3 m/sec.
5. The deceleration rate from full speed shall not cause additional hazards.

Clearance on One Side of Vehicle	Clearance on Other Side of Vehicle	Clearance in Direction of Travel	Personnel Detection Means	Maximum Vehicle Speed
≥500 mm	≥500 mm	≥500 mm	Active	Full or Rated Speed
≥500 mm	≤100 mm	≥500 mm	Active	Full or Rated Speed
≥500 mm	>100 mm and <500 mm	≥500 mm	Active	1.2 m/sec
≥500 mm	≥500 mm	<500 mm	Active	0.7 m/sec
N/A	N/A	N/A	Muted	0.3 m/sec

Figure 22: Maximum Vehicle Speed Based on Clearance and PSD

12.3 Conveyors Attached to a Driverless Vehicle

12.3.1 For applications where conveyors are mounted to a driverless vehicle, the following requirements shall be met.

1. The conveyor(s) shall be stopped prior to any movement of the vehicle.
2. Emergency stop device(s) mounted on the vehicle shall also stop the conveyor(s).
3. The conveyor(s) shall be designed so the load cannot move from the designated position while the vehicle is moving.
4. The conveyor(s) shall be provided with a means to prevent the vehicle from moving if the load is not in the designated position.

12.4 Floor Markings

12.4.1 Driverless vehicle paths outside of main vehicle aisles shall be identified anywhere the vehicle travels.

12.4.2 Driverless vehicle path lines are not required within defined main vehicle aisles and “orange crush” areas.

12.4.3 The path lines shall indicate the most extreme point of the vehicle and payload on both sides of the path.

12.4.4 Driverless vehicle path lines shall be 100 mm (4 in) wide painted or industrial tape lines and be blue in color. The paint or industrial tape shall be durable and suitable for the environment.

12.4.5 Driverless vehicle path lines shall be discontinued in areas where the clearance to a non-continuous fixed structure (example: column or stairway) will be less than 0.5 m (20 in) and be replaced by black and yellow hashed paint or striped tape and any awareness barriers deemed necessary.

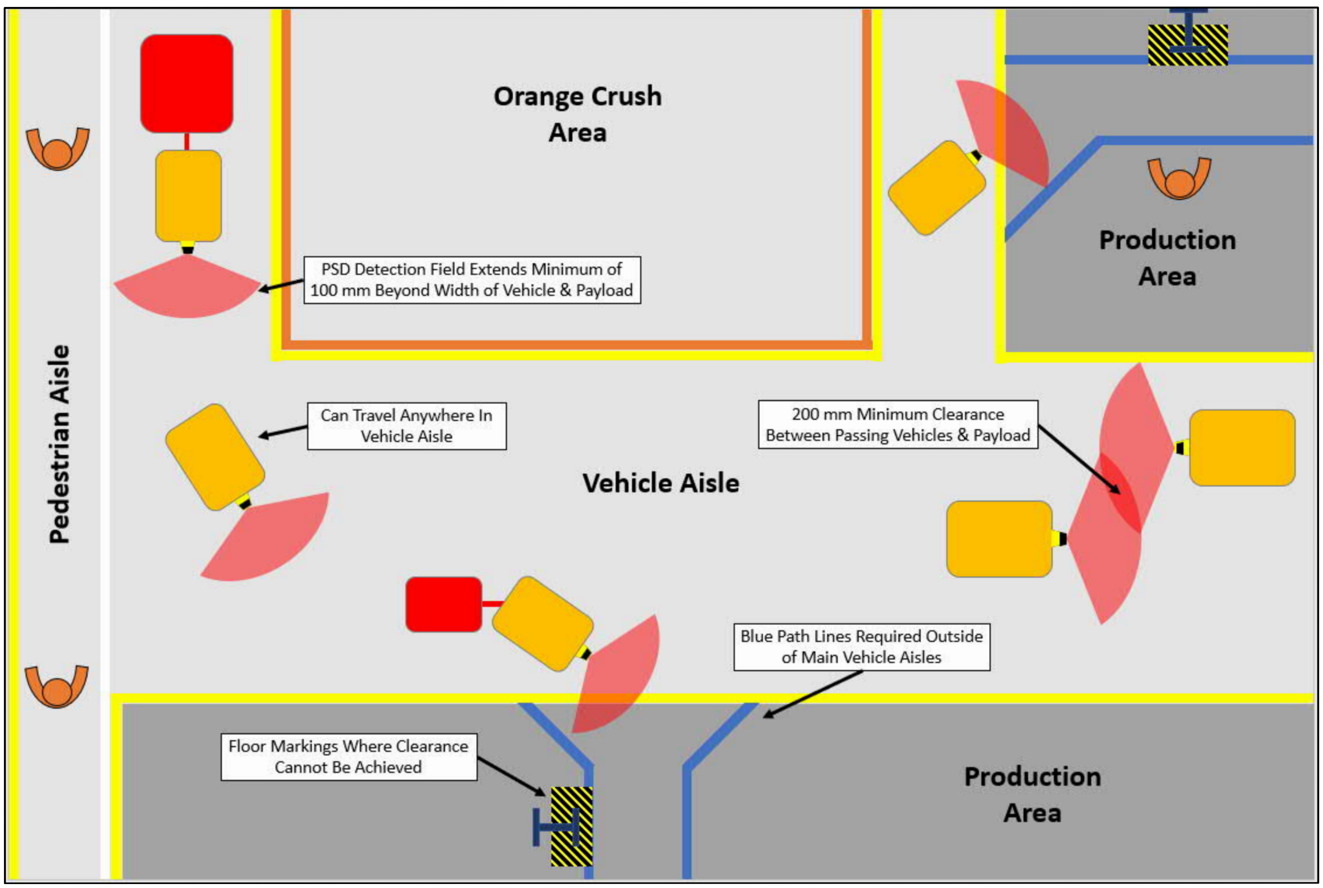


Figure 23: Floor Marking Examples

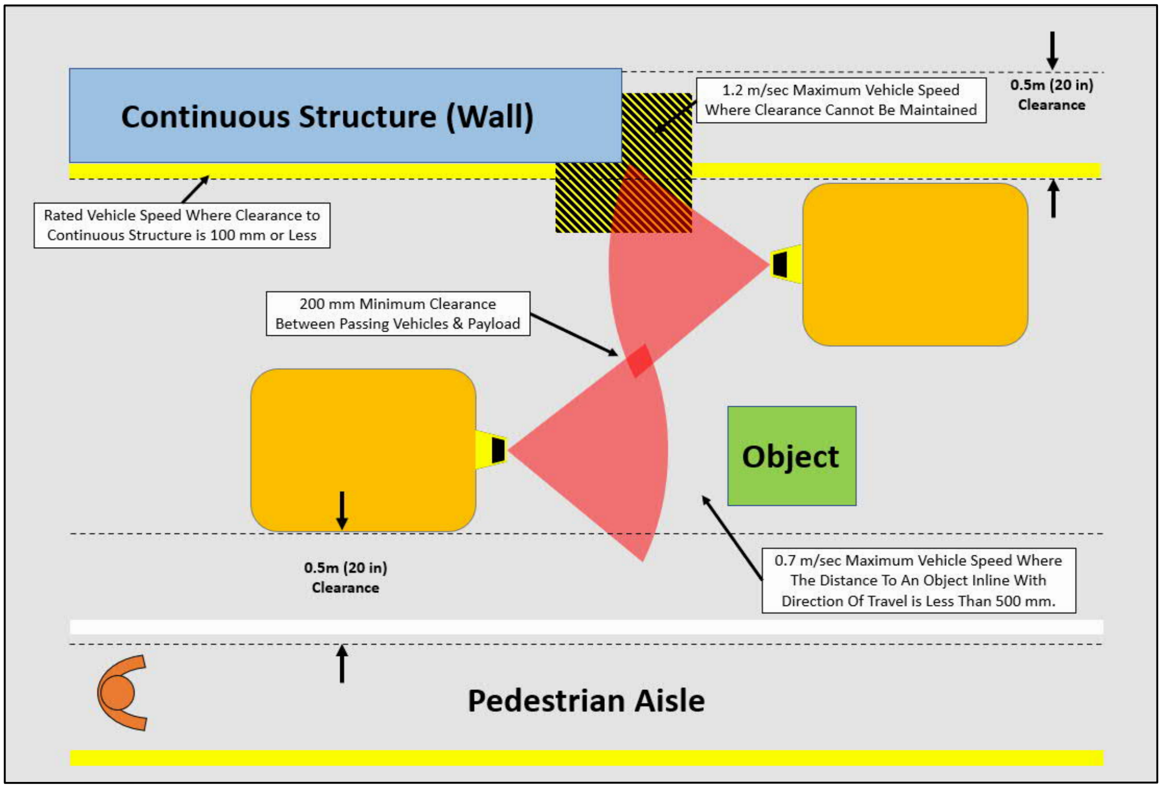


Figure 24: Vehicle Clearance and Speed Examples

Annex List

A. Safe Distance Formulas

A.1 General Formula

The following general safety distance formula calculates the minimum safe distance to mount the safety device from the hazardous motions (or hazardous situation). This formula shall be used as required in ISO 13855. Additional guidance in the use of this formula for typical Nexteer applications are included within this Annex. The safe distance to mount the safety device shall be verified during the completion of the safety checklist.

S = (K x T) + C

- S = Minimum safety distance between the device and the nearest point of operation hazard (in millimeters).
- K = Approach speed constant of body, or parts of body (application specific).
- T = The total estimated time to stop hazardous motion which include various factors (in seconds).
- C = Added Intrusion Distance (in millimeters).

A.2 The total time (T) that it takes for that hazard to cease includes portions that vary by machine type and by the safeguarding device applied. The following affect the total stopping time:

- Response time of the safeguarding device, referred to as T_1.
- Response time of the safeguarding device interface, referred to as T_2.
- Response time of the machine control system, referred to as T_2.
- Stop time of the equipment including stopping capability of motors, drives, and the reaction time of valves, referred to as T_2.
- Note: $T_1 + T_2$ can be measured by a stop-time measurement device such as the Gemco Series 1999 Semelex II Safetimeter test set.
- The time to open an interlocked guard door for applications without guard locking. This time is typically subtracted (or entered as a negative value) from the stop and response times detailed above.
- Additional time is required for mechanical power press applications for the brake monitor to compensate for variations in normal stopping time. Refer to ANSI B11.1 for information on press brake monitors.

A.3 The intrusion distance (C) is added within the formula based on a distance that a part of the body (usually a hand) can move past the safeguard towards the hazard zone prior to actuation of the safeguard and varies by machine type and by the safeguarding device applied. The intrusion distance for typical Nexteer applications is detailed below.

General formula: S = (K x T) + C

A.4 Light Curtains

Approach speed constant K = 2000 mm per second for light curtains placed closer than 500 mm to the hazard.

Approach speed constant K = 1600 mm per second for light curtains placed further than 500 mm to the hazard.

Intrusion distance C = 8 x (d-14) in millimeters, where "d" is the safety device object sensitivity (also in millimeters), C shall never be less than 0. The intrusion distance formula estimates a distance a person's finger or hand must penetrate the light curtain sensing plane before being detected by the light curtain.

The minimum distance for S shall be 100 mm.

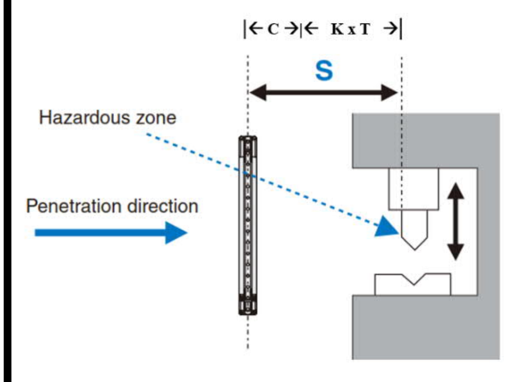


Figure A.4 Light curtain placement

A.5 Safety Laser Scanners or Horizontal Light Curtains:

Approach speed constant K = 1600 mm per second.

C = 1200 – (0.4 x H) in millimeters, where "H" is the height of the detection plane off of the floor (also in millimeters), C shall never be less than 850 mm.

It is recommended that H be between 800 > H > (15 x (d – 50)) in millimeters, where "d" is the safety device object sensitivity (also in millimeters). If H is greater than 300 mm there is a risk of inadvertent undetected access beneath the detection zone and requires additional safeguard measures to be applied.

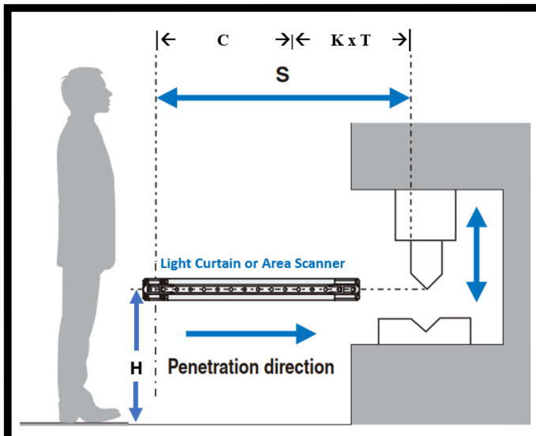


Figure A.5 Horizontal sensing ESPE placement

A.6 Safety Mats:

Approach speed constant K = 1600 mm per second.

Intrusion distance C = 1200 mm.

Height of the detection plane H = 0 mm.

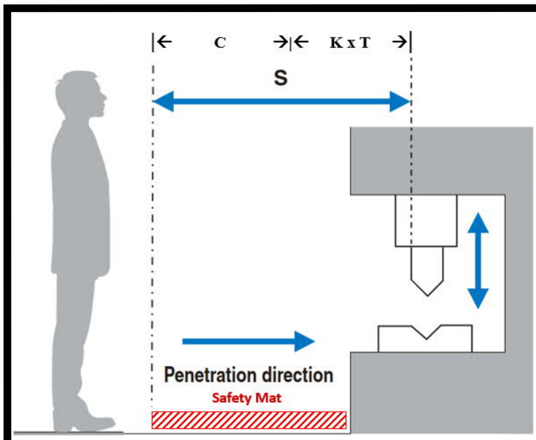


Figure A.6 Safety Mat placement

General formula: S = (K x T) + C

A.7 Shared Workspace

Placement of the Operator presence-sensing device at the operator entrance into a shared workspace (S1) is calculated using the safeguard specific formula listed above (such as the light curtain formula when a light curtain is used to detect operator entrance).

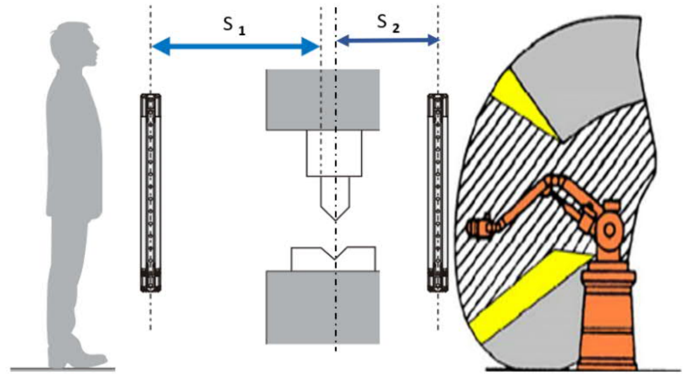


Figure A.7 Shared workspace

Placement of a Robot presence-sensing device at the robot entrance into a shared workspace (S2) is calculated using the safeguard specific formula listed above (such as the light curtain formula when a light curtain is used to detect the robot entrance)

Approach speed constant K = programmed robot speed

The total stop time T = stop time of the robot

Intrusion distance C is application specific, taking into account robot tooling dimensions and the minimum object sensitivity of the presence sensing device, calculating how far the robot must penetrate the light curtain sensing plane before being detected by the light curtain.

A.8 Interlocked guard door without guard locking:

Approach speed constant K = 1600 mm per second.

Intrusion distance C is a distance required to be included if, in the act of opening an interlocked guard, it is possible to push fingers or a hand through the opening towards the hazard before a stop signal is generated. C = 0 for typical Nexteer guarding applications.

The total stop time typically includes the time to open an interlocked guard door. This time is typically subtracted (or entered as a negative value) from all other system stop and response times.

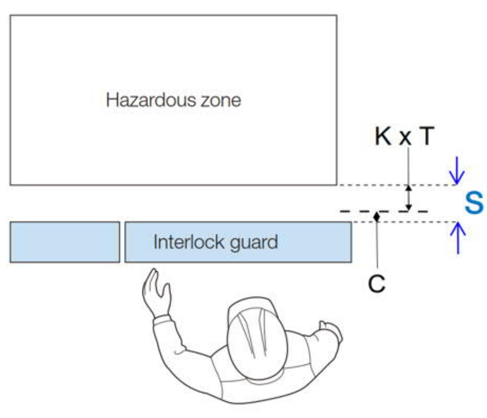


Figure A.8 Interlocked guard door without guard locking

A.9 Two-Hand Control Devices:

Approach speed constant K = 1600 mm per second.

Intrusion distance C = 250 mm.

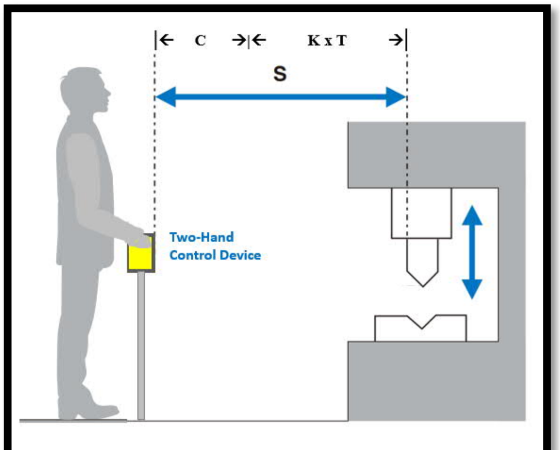


Figure A.9 Two-Hand Control Device placement

B. Safe Distances to Prevent Reaching Hazards

B.1 General

This annex provides requirements for the two most common applications for fixed safeguarding structures preventing the access of hazardous areas. These tables shall be referenced when designing and installing safeguarding to prevent reaching over or through the safeguards. Reference ISO 13857 for additional guidance related to these tables and requirements for less common applications.

The safeguarding structures in this annex are located in a single plane. Additional safeguard structures or surfaces can reduce the free movement of the body part, further preventing access to the hazardous area. Reference ISO 13857 for additional guidance related to these tables and requirements for less common applications.

B.2 Reaching Over Safeguarding

The following table provides the required horizontal safe distance from a hazard that can be classified as a severe injury and has a high probability of occurring. This is based on the height of the protective structure and of the hazardous area.

Reference Figure B.2

- Height of the nearest point to the hazard (a)
- Height of the protective structure or safeguard (b)
- Horizontal safety distance to hazard (c)
- Hazard zone – nearest point (1)

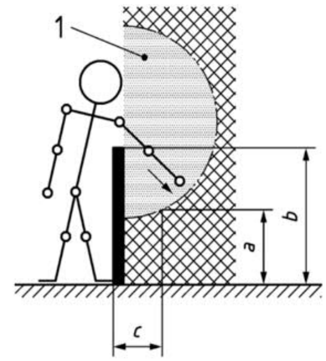


Figure B.2

Height of hazard zone [c] *a*	Height of protective structure [a, b] *b*									
	1 000	1 200	1 400	1 600	1 800	2 000	2 200	2 400	2 500	2 700
	Horizontal safety distance to hazard zone, *c*									
2 700	0	0	0	0	0	0	0	0	0	0
2 600	900	800	700	600	600	500	400	300	100	0
2 400	1 100	1 000	900	800	700	600	400	300	100	0
2 200	1 300	1 200	1 000	900	800	600	400	300	0	0
2 000	1 400	1 300	1 100	900	800	600	400	0	0	0
1 800	1 500	1 400	1 100	900	800	600	0	0	0	0
1 600	1 500	1 400	1 100	900	800	500	0	0	0	0
1 400	1 500	1 400	1 100	900	800	0	0	0	0	0
1 200	1 500	1 400	1 100	900	700	0	0	0	0	0
1 000	1 500	1 400	1 000	800	0	0	0	0	0	0
800	1 500	1 300	900	600	0	0	0	0	0	0
600	1 400	1 300	800	0	0	0	0	0	0	0
400	1 400	1 200	400	0	0	0	0	0	0	0
200	1 200	900	0	0	0	0	0	0	0	0
0	1 100	500	0	0	0	0	0	0	0	0

Table B.2

Protective structures less than 1400 mm (55 in) in height shall not be used, because they require additional protective measures. The protective structure shall be a maximum of 180 mm (7 in) above the walking surface.

B.3 Reaching Through Safeguarding

The following table provides the required horizontal safe distance from the hazardous area for safeguards that have regular openings. These requirements apply to openings between safeguards and the machine structure or framing as well.

The safe distance “Sr” is based on the body part and the “e” dimension of the shape opening. The “e” corresponds to the side of a square opening, the diameter of a round opening, and the narrowest dimension of a slot opening. The bold horizontal lines shown in the table delineate the part of the body that is restricted by the opening size.

Openings that are larger than 120 mm shall meet the requirements detailed in Section B.2 Reaching Over Safeguarding.

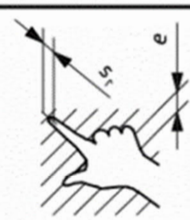
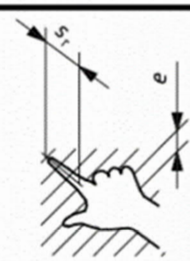
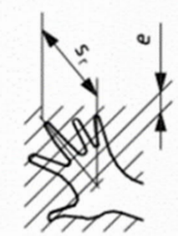
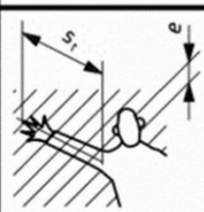
Part of body	Illustration	Opening	Safety distance, s_r		
			Slot	Square	Round
Fingertip		$e \leqslant 4$	$\geqslant 2$	$\geqslant 2$	$\geqslant 2$
		$4 < e \leqslant 6$	$\geqslant 10$	$\geqslant 5$	$\geqslant 5$
Finger up to knuckle joint		$6 < e \leqslant 8$	$\geqslant 20$	$\geqslant 15$	$\geqslant 5$
		$8 < e \leqslant 10$	$\geqslant 80$	$\geqslant 25$	$\geqslant 20$
Hand		$10 < e \leqslant 12$	$\geqslant 100$	$\geqslant 80$	$\geqslant 80$
		$12 < e \leqslant 20$	$\geqslant 120$	$\geqslant 120$	$\geqslant 120$
		$20 < e \leqslant 30$	$\geqslant 850$ [a]	$\geqslant 120$	$\geqslant 120$
Arm up to junction with shoulder		$30 < e \leqslant 40$	$\geqslant 850$	$\geqslant 200$	$\geqslant 120$
		$40 < e \leqslant 120$	$\geqslant 850$	$\geqslant 850$	$\geqslant 850$

Table B.3

C. Test Sequence Design Requirements

When a design is not Nexteer Automotive common (Example: SD-010), a new test sequence shall be developed at the component level. This new test sequence shall be developed by the Equipment Engineer and responsible Controls Engineer using the design requirements listed below.

C.1 Cell lockout

This test proves that the cell can be locked out.

- Referencing the posted placard, locate the lockout disconnects for each piece of equipment within the cell.
- Follow Nexteer Automotive lockout procedures in order to lock out the cell and verify that all live energy has been removed.

NOTE: Verify that all energy sources (Example: electrical, pneumatic, hydraulic) to each piece of equipment are disconnected and no energy is available at the equipment.

C.2 Perimeter guarding

This test determines the following:

- No access into the cell / work area via unauthorized routes can be attained
- Perimeter guarding is located at a safe distance from hazardous motion to prevent pinch points
- Visually inspect the cell to:
  - Verify that the perimeter guarding properly prevents access into the cell and that the guarding prevents persons from reaching into a hazardous area
  - Confirm that all access guard doors are equipped with safety interlocks and do not open into the cell
  - Verify that the perimeter guarding is located at a safe distance from all hazardous motion

NOTE: If there is not sufficient clearance and a pinch point exists, verify that other safeguarding devices (Example: safety mats, light curtains) prevent access or stop hazardous motion if someone is in the pinch point area. These devices shall be tested as outlined in Step 9 of this Annex.

- Verify that all material entrance points do not create pinch/crush areas or allow undetected access into the cell.

C.3 E-stop, reset and power on

This test ensures that all of the equipment can be stopped with an emergency stop device and the equipment will not re-start until it receives specific instructions to do so. The tests in this step shall be carried out on individual pieces of equipment in the cell before groups of equipment are tested, when applicable. All equipment that passes into, across, or out of the cell/work area shall pass this test before continuing the validation process.

- Every manual E-stop control device shall be tested to ensure it stops all hazardous motion within its span of control.

NOTE: Conduct this test in the manual, automatic and teach mode for each E-stop device. All of the equipment should be in motion in order to ensure that each E-stop affects every piece of equipment. For robots, the teach pendant E-stop shall function identically to all other E-stops in the cell.

- Each E-stop device shall be tested to ensure that no motion occurs when it is returned to its normal position (Example: E-stop push button is pulled out).
- No motion shall occur when each safety system is reset (Example: station reset push button is depressed).
- All safety system resets shall be tested for anti-tie down capability.

NOTE: This test is typically performed by holding the reset button in and trying to start the equipment. No motion should occur when the reset button is held in. Conduct this test in both the manual and automatic mode.

- All power on and start control devices that initiate hazardous motion shall be tested for anti-tie down capability.

NOTE: With all safety systems reset, operate the power on or start control device and hold in the depressed (on) state. No motion should occur. Conduct this test in both the manual and automatic mode. If the start device cannot be held "in" (Example: HMI input), skip this step.

C.4 Power device duplication and monitoring

This test proves that the power devices that are used to control the energy (which creates hazardous motion) are also duplicated and monitored. Also, this test shows that a failure of either device will remove hazardous motion and prevent further operation.

Use the Machine Risk Assessment data summary sheet for CLS as well as the final "as built" control circuit drawings to identify which power devices (Example: contactors and valves) control hazardous motion. All power devices that are part of CLS and are used to control the energy (which creates hazardous motion) shall be duplicated.

- To test for duplication, verify that the redundant devices control all hazardous motion during CLS and that both devices de-energize when a safety device (Example: E-stop, guard door switch) is actuated. If any equipment comes standard with redundant control devices (Example: a control reliable robot), check one of each model to ensure they meet this requirement.
- To test the monitoring of power devices, check each power device individually to ensure that when it is in a failed state the safety systems cannot be reset. This verification can be performed by holding each device in the failed state (Example: hold contactor "in") while trying to reset the safety systems.
- To test the monitoring of control devices, check each control device individually within each safety circuit to ensure that when it is in a failed state the safety systems cannot be reset. This verification can be performed by holding each single device in the failed state (Example: hold relay "in") while trying to reset the safety systems.
- To test the functionality of CLS circuit design status indicator, verify that it is not illuminated if any CLS controlled power device is in the failed state.

C.5 Perimeter guard interlock

This test verifies that the safety interlocks on the perimeter guarding stop all hazardous motion in the safeguarded area.

The following actions shall be taken to verify the perimeter guard interlock:

- Test each perimeter guard interlock device by opening each gate or tripping each perimeter guard light curtain with every piece of equipment in motion.
  NOTE: When actuated, each device (Example: gate switch or light curtain) shall stop and prevent a restart of all hazardous motion in the cell. Conduct this test for each perimeter guard interlock device in the automatic mode.
- Test that the automatic mode cannot be obtained under any condition while any gate is open or perimeter guard is tripped.
- Test that no motion occurs when the gate safety interlock system is reset.
- Review the functionality of the gate to determine under which conditions hazardous motion can continue when the gate is opened. For example, with the selector switches on the gate box in the correct position and either a teach or enabling pendant in use, hazardous motion may be allowed to continue when the gate is open.

- For conditions in which no hazardous motion is allowed in the cell, ensure that all hazardous motion stops when the gate is opened.
- Test each position of every selector switch to ensure it only enables the motion intended.
  NOTE: Conduct this test in both the manual and teach mode because when the gate is open, hazardous motion is only permitted in these modes.
- Test every safety device (Example: E-stop buttons, gate switches, and light curtains) that stops hazardous motion in the cell to ensure it causes the hazardous motion power devices to open (Example: de-energize) and remain open.

C.6 Teach pendant verification

This test verifies the robot teach pendant(s) or machine pendant cannot be overridden by any other control device. It also ensures that the teach pendant provides exclusive control of the equipment, and it does not unintentionally enable the equipment.

The following actions shall be taken to verify the robot teach pendant:

- With a gate open, verify that each teach pendant initiates servo motion only when the switches located on the gate box are in a position that permits robot servo motion.
- Test each teach pendant to ensure that no robot motion is allowed until the enabling (hold-to-run) switch is engaged.
- Test each teach pendant to ensure that all robot motion controlled by the teach pendant stops when the enabling (hold-to-run) switch is released.
- Test each teach pendant to ensure that no robot motion occurs when the hold-to-run switch is engaged until motion is initiated by a separate action (Example: joystick).
- In the teach mode, ensure that robot motion cannot be initiated by any other control device.

C.7 Enabling pendant

This test verifies that the enabling pendant(s) cannot be overridden by any other control device. It also ensures that the enabling pendant provides exclusive control of the equipment, does not unintentionally enable any piece of the equipment, and only enables the equipment in its intended span of control.

With the switches on the gate control console in the correct position, an enabling pendant permits motion in the safeguarded area while a gate is open.

- With a gate open, test that each enabling pendant only enables the motion indicated by the switches on the gate control console.
- Test each enabling pendant to ensure that no motion is allowed until the enabling (hold-to-run) switch is engaged.
- Test each enabling pendant to ensure that all motion enabled by the pendant stops when the enabling (hold-to-run) switch is either squeezed or released.
- Test each enabling pendant to ensure that no motion occurs when the enabling (hold-to-run) switch is engaged until motion is initiated by a separate action (Example: HMI input).

C.8 Point-of-operation safeguarding device

This test verifies that the point-of-operation safeguarding device(s) are mounted in the correct position, and that the equipment will safely stop before any person reaches the hazardous area.

- Verify that the safeguarded zone is sufficiently sized to prohibit any person from contacting the hazardous motion.
- Verify that barriers or other safeguarding devices prevent a person from passing through the safeguarded area into the hazardous area.
- Verify that no access (Example: reaching over, under, or around the safety device) to a danger point exists.
- Verify that the safety device is securely mounted and that it cannot be adjusted or removed without the use of tools.
- For all devices guarding hazardous motion, verify that the device is dual channel (Example: control reliable).
- Test that the hazardous motion (which the Operator may be exposed to) stops when the safeguarded area is entered and before the Operator is exposed to it (reference Annex A: Safe Distance Formulas).
  NOTE: Conduct this test only in the automatic mode.
- Test that no motion occurs when the safeguarding device is reset.

C.9 Pinch point safeguarding device

This test verifies that pinch point safeguarding devices inside the safeguarded area are mounted in the correct position and that no hazardous motion can be initiated when the devices are actuated.

- Verify that the safeguarded area is sufficiently sized so that the Operator cannot be present in the pinch point area without actuating the safeguarding device.
- Verify that the safety device is securely mounted and that it cannot be adjusted or removed without the use of tools.
- For all devices guarding hazardous motion, verify that the device is dual channel (Example: control reliable).
- Test that the hazardous motion creating the pinch point cannot be initiated when a person is in that pinch point area.

NOTE: Conduct this test only in the manual mode.

- Test that no motion occurs when the safeguarding device is reset.

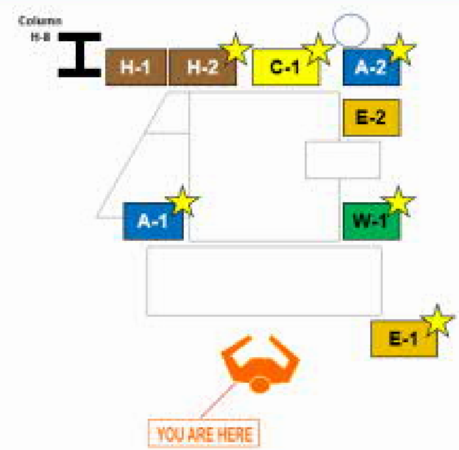
D. Placards

D.1 Example Lockout Placard

TOTAL LOCKOUT POINTS IDENTIFIED	NEXTEER AUTOMOTIVE PLANT #99	LOCATION COLUMN #H-8
8	SD654321 - CARTRIDGE ASSEMBLY MACHINE	DEPT #89

BEFORE SERVICING THIS MACHINE, NOTIFY AFFECTED PERSONNEL.

FOLLOW START UP PROCEDURES



FOLLOW START UP PROCEDURES

	Energy Source		Location	Perform Action	You Must Verify
☆ E-1	Electric	Machine Main Disconnect	Main Electrical Panel	Turn Off & Lock Out Electrical Disconnect	PUSH MASTER START BUTTON ON MAIN PANEL. VERIFY MACHINE WILL NOT START. CHECK FOR MOTION.
E-2	Electric	Infeed Conveyor Disconnect	Right Side of Machine	Turn Off & Lock Out Electrical Disconnect	ON HMI MANUAL SCREEN, PUSH CONVEYOR JOG. VERIFY CONVEYOR WILL NOT START.
CAUTION	Electric	Battery of Uninterruptible Power System (UPS)	Main Electrical Panel (inside)	Turn off Machine Main Disconnect and Wait for Battery to Discharge	CHECK THAT RESIDUAL POWER STORED IN BATTERY OF UPS HAS DISSIPATED.
☆ A-1	Air	Machine Main Air Disconnect	Left Side of Machine	Press Down Pneumatic Lockout Valve & Lock Out	LISTEN FOR EXHAUSTED AIR PRESSURE. MANUALLY ACTUATE PNEUMATIC VALVE(S) TO TEST FOR MOTION. NO MOTION SHOULD OCCUR
CAUTION	AIR	Pilot Operated Check Valve	Various Locations See PO Check Note Tags	Mechanically Support Load if Necessary & Depress Manual Override Before Servicing.	LISTEN FOR EXHAUSTED AIR PRESSURE WHILE MANUALLY SHIFTING DIRECTIONAL VALVE. CHECK FOR MOTION.
☆ A-2	Air	Grease Barrel Main Air Disconnect	Rear of Machine	Press Down Pneumatic Lockout Valve & Lock Out	LISTEN FOR EXHAUSTED AIR PRESSURE. MANUALLY ACTUATE PNEUMATIC VALVE(S) TO TEST FOR MOTION. NO MOTION SHOULD OCCUR
☆ W-1	Water	Machine Main Water Shutoff Valve	Right Side of Machine	Turn Handle Counter-Clockwise to Close Valve & Lock Out	CHECK FOR WATER FLOW INTO RINSE TANK.
☆ C-1	Chemical	Machine Main Grease Shutoff Valve	Rear of Machine	Turn shutoff valve to off position and Lock Out. Open grease purge valve(s) after shutoff. Turn off A1 removing air from dispense valves.	MANUALLY ACTUATE PNEUMATIC VALVE(S) CONTROLLING THE DISPENSERS TO TEST FOR FLOW. NO FLOW SHOULD OCCUR
H-1	Electric	Machine Main Disconnect	Main Electrical Panel	Turn Off & Lock Out Electrical Disconnect E-1	PUSH MASTER & HYD. PUMP START BUTTONS ON MAIN PB PANEL. VERIFY HYD PUMP MOTOR REMAINS OFF. MANUALLY SHIFT DIRECTIONAL VALVE. CHECK FOR MOVEMENT.
☆ H-2	Hydraulic	Hydraulic Accumulator	Rear of Machine	Turn Off & Lock Out Accumulator Dump Valve and Close Pump Isolation Valve	VERIFY ZERO PRESSURE ON THE ACCUMULATOR GAUGE. MANUALLY ACTUATE HYDRAULIC VALVE(S) TO TEST FOR MOTION. NO MOTION SHALL OCCUR.

STOP (6) LOCKS REQURED TO ACHIEVE ZERO-ENERGY STATE.
NOTE: ADDITIONAL NON-LOCKABLE HAZARDOUS ENERGY LISTED ABOVE MAY REQUIRE OTHER CONTROL DEVICES / METHODS. STOP

Placard ID SD654321	IF LOCKOUT ENERGY CONTROL CANNOT BE PERFORMED / VERIFIED - STOP - CONTACT YOUR SUPERVISOR.	08/04/2022 Page 1 of 1

D.2 Example CLS Placard

CLS Task Placard

Control Lockout Solution

CLS removes electrical power from devices that cause motion through control-reliabile safety circuits; it does not isolate electrical power.

The robot is the ONLY device within the cell that falls under CLS Guidelines; all other devices must be locked out prior to entry.

Enter the cell ONLY when the "*CLS ACTIVE - OK TO ENTER*" green indicator is illuminated.

The following tasks can be performed within this cell under CLS:

Lathes:
- Operate in Local Mode
- Startup Machinery
- Change Tools
- Push Chips
- Clear Run-Time Faults
- Cycle Lathe to bring parts to size
- Change Lathe Inserts
- Change Lathe Jaws - (with Lathe Power remove)
- Vibration Analysis
- Part Program Development

Parts Presenter:
- Operate in Local Mode
- Clear Miscellaneous Faults

Misc:
- 5S Activities

Robot:
- Jog / Program / Teach Robot
- Adjust Gripper Proxes

Lockout

When performing tasks not listed above, or when exposed to other motion hazards, LOCKOUT procedures must be followed.

Hazard Awareness

The following hazards may be encountered when working wthin this cell. Always remember safe work practices; visually assess the work area, identify any hazard, and use training received. Wear your personal protective equipment.

- Trips / Slips
- Sharp Edges / Cuts
- Head Obstructions
- Falls (use platform step ladders or areal lifts, wear fall protection equipment)
- Fires from Cutting and Welding
- Burns
- Chemical Reaction from Lubricants, Sealers, etc. (review Safe Use Instructions)
- Gravity (use saffety pins / blocks, follow rigging techniques)

If you have any questions, contact your Supervisor.

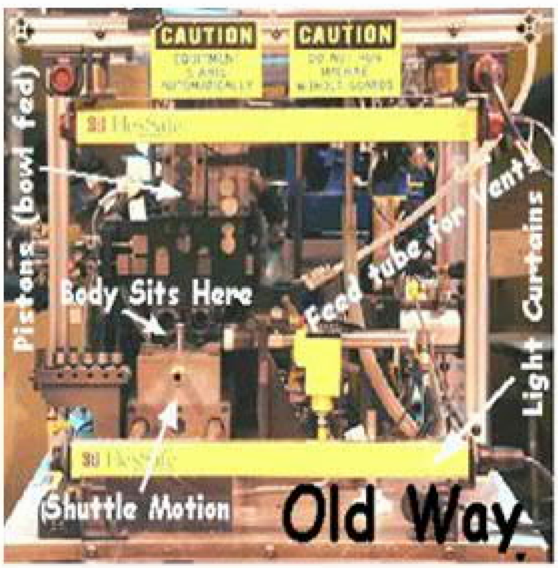
E. Hierarchy of Controls – Solutions Illustrations

The basic thought process must recognize the work to be done, evaluate the hazards and exposures associated with the tasks and provide the most effective H&S Control Solutions.

Safety for all processes, cells, and machines shall be addressed through the Hierarchy of Health and Safety Controls. The following examples are intended to provide a better understanding of the hierarchical approach.

E.1 Elimination or Substitution:

- Eliminate equipment
- Simplify equipment
- Improve initial equipment design
- Remove / minimize human interaction with equipment
- Eliminate pinch points
- Eliminate or simplify material handling
- Place adjusting devices and other requirements for human interaction outside the hazard area
- Substitute less hazardous processes or chemicals



E.2 Safeguards (Engineering Controls):

- Perimeter guards
- Light curtains
- Safety mats
- Safety Guard Interlocks
- Safety Guard Locking Switches
- Safety relays, switches and other control devices
- Ventilation, local or point of operation exhaust
- Automatic / Manual material handling (Example: lift for ergonomics issue)
- Movable interlocked guard

Light Curtains

Safety Interlock Switch

Safety Relay

Emergency Stop Pushbutton

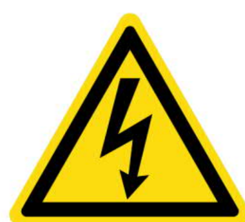
E.3 Warning, Caution, Danger Labels:

- Fall Hazard

- Confined Space

- Pinch Point

- Electrical Hazard

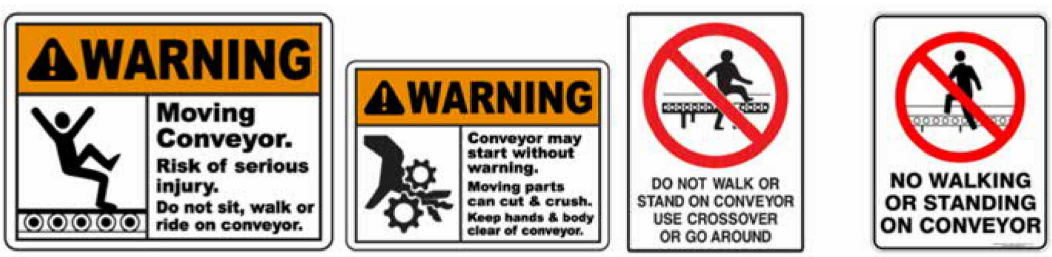


- Trapped Air

CAUTION
TRAPPED AIR MAY BE PRESENT AFTER TURNING OFF SAFETY EXHAUST VALVE. MECHANICALLY SUPPORT LOAD IF NECESSARY AND DEPRESS MANUAL OVER-RIDE BEFORE SERVICING.

- Authorized Personnel

- Conveyor Hazard

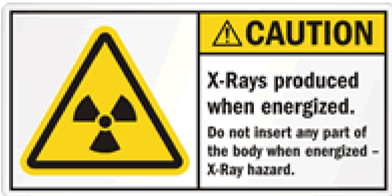


- Magnetic Hazard

- Hot Surface

- Fire Hazard

- X-Ray, Radiation Hazard

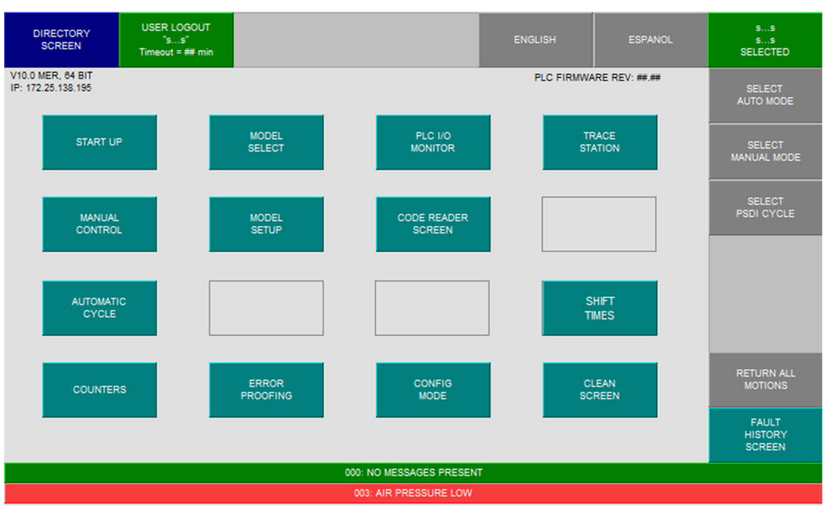


- Laser Beam Hazard

- Lights, beacons, and strobes



- Computer warnings



- Pedestrian Crossover Signs

- Markings indicating a restricted space on the floor



E.4 Training and Procedures (Administrative Controls):

- Safe operating practices and procedures
- Standardize Work Instructions
- Job rotation
- Written Training Programs

NOTE: Written training, procedures and administrative controls are used when higher-level alternatives are not feasible, and when the risk is adequately controlled. Personnel must be properly trained before operating and maintaining equipment. This includes being provided with up-to-date and accurate written instructions (Safety, Standardized Work, Set-up, Start-up, Run, Stop, etc.). The training and instructions must be implemented, enforced and followed.

E.5 Personal Protective Equipment (PPE)

The following PPE list are examples and not meant to be all inclusive list of PPE requirements. PPE shall meet local, regional and government requirements.

- Face shields
- Safety glasses
- Hearing protection
- Gloves
- Safety Toe Shoes
- Protective sleeves
- Respirators
- Welding screens
- Expendable tools
- Hard Hats
- Safety Harnesses
- FR Clothing

Welding Screen

F. References

The references used in the development of this specification are listed below.

NOTE: Users of this specification shall consult applicable Federal, State, Country, and Local laws, regulations, and standards in addition to those listed below. Reference the most current version of the specifications / standards listed below.

F.1 Nexteer Automotive Documents:

F.1.1 Manufacturing Engineering – Website: www.nexteerdataexchange.com:

- SD-004, Electrical Specification for Industrial Machinery, addendum to IEC 60204-1
- SD-007, Approved Components List
- SD-011, Specification for Safety Circuits
- SD-013, Hydraulic fluid power - General rules relating to systems, addendum to ISO 4413
- SD-014, Pneumatic fluid power - General rules relating to systems, addendum to ISO 4414
- SD-015 Lean Equipment Design
- SD-016, Lean Equipment Controls Design
- SD-017, Design-In Ergonomics Guidelines (DEG)
- SD-018, Sound Level Specification

F.1.2 Health & Safety – Nexteer Intranet Link: Health & Safety Homepage

- Industrial Hygiene Policies and Procedures
- Lockout / Energy Control Program
- SL2, Uniform Plant Sound Survey Procedure
- SL3, Program for Occupational Hearing Conservation and Noise Control
- Fall Prevention Program Requirements & Safety Systems

F.2 United States of America National Documents:

F.2.1 American National Standards Institute (ANSI):

- ANSI/ASME B20.1, Safety Standard for Conveyors and Related Equipment
- ANSI B11.1, Machine Tools – Mechanical Power Presses – Safety Requirements for Construction, Care, and Use
- ANSI B11.19, Machine Tools, safeguarding when referenced by the Other B11 Machine Tool Safety Standards - Performance Criteria for the Design, Construction, Care, and Operation
- ANSI B11.20, Manufacturing Systems/Cells-Safety Requirements for Construction, Care, and Use
- ANSI B11.23, Machining Centers - Safety Requirements for Construction, Care, and Use
- ANSI/ITSDF B56.5, Safety Standard for Driverless, Automatic Guided Industrial Vehicles and Automated Functions of Manned Industrial Vehicles
- ANSI/RIA R15.06, American National Standard for Industrial Robots and Systems – Safety Requirements
- ANSI Z136.1, American National Standard for the Safe Use of Lasers
- ANSI Z244.1, Lockout/Tagout of Energy Sources
- ANSI Z9.2 Fundamentals Governing the Design and Operation of Local Exhaust Ventilation Systems

F.2.2 National Fire Protection Association (NFPA):

- NFPA 79, Electrical Standard for Industrial Equipment
- NFPA 70E, Standard for Electrical Safety in the Workplace.

F.2.3 Occupational Safety & Health Administration (OSHA):

- OSHA 29 CFR 1910 (applicable provisions)
- OSHA 29 CFR 1910.147, The Control of Hazardous Energy (Lockout/Tagout); The Ontario Occupational Health & Safety Act; the Quebec Occupational Health & Safety Act; the Ontario Hydro Act.

F.3 Global Documents:

F.3.1 European Directives:

- 89/391/EEC – Health & Safety Framework Directive
- 92/58/ EEC – Safety and/or Health Signs Directive
- 2003/10/EC – Noise Directive regarding the exposure of workers
- 2006/42/EC – Machinery Directive
- 2014/30/EU – Electromagnetic Compatibility Directive (EMC)
- 2014/35/EU – Low Voltage Directive

F.3.2 International Standards Organization (ISO)

- ISO 1819 -- Safety code for continuous mechanical handling equipment
- ISO 3864-1, Graphical symbols – Safety colours and safety signs – Part 1: Design principles for safety signs and safety markings
- ISO 3691-4, Industrial Trucks – Safety requirements and verification – Part 4: Driverless industrial trucks and their systems
- ISO 4413, Hydraulic fluid power – General rules and safety requirements for systems and their components
- ISO 4414, Pneumatic fluid power – General rules and safety requirements for systems and their components
- ISO 9612, Acoustics – Guidelines for the measurement and assessment of noise in a working environment
- ISO 11014, Safety data sheets for chemical products
- ISO 10218, Robots and Robotic Devices – Safety requirements for industrial robots
- ISO 11226, Ergonomics – Evaluation of static working postures
- ISO 11428, Ergonomics – Visual danger signals – General requirements, design, and testing
- ISO 11553, Safety of Machinery – Laser processing safety requirements
- ISO 12100, Safety of Machinery – General principles for design – Risk assessment and risk reduction
- ISO 10218-1, Robots and Robotic Devices — Safety requirements for industrial robots — Part 1: Robots
- ISO 10218-2, Robots and Robotic Devices — Safety requirements for industrial robots — Part 2: Robot systems and integration
- ISO 13849-1, Safety of Machinery – Safety related parts of control systems – Part 1: General principles for design
- ISO 13851, Safety of Machinery – Two Hand control device
- ISO 13855, Safety of Machinery – The positioning of protective equipment in respect of approach speeds of parts of the human body.
- ISO 13856, Safety of Machinery – Pressure sensitive protective devices
- ISO 13857, Safety of Machinery – Safety distances to prevent danger zones being reached by the upper and lower limbs
- ISO 14119, Safety of Machinery – Interlocking devices associated with guards – Principles for design and selection
- ISO 14120, Safety of Machinery – Guards
- ISO 14122-2, Safety of Machinery – Permanent means of access to machinery – Part 2: Working platforms and walkways
- ISO 14122-3, Safety of Machinery – Permanent means of access to machinery – Part 3: Stairs, stepladders, and guard-r rails
- ISO 14159, Safety of Machinery – Hygiene requirements for the design of machinery
- ISO 15066, Robots and Robotic Devices - Collaborative robots
- ISO 45001, Occupational Health & Safety

F.3.3 International Electro-Technical Commission (IEC)

- IEC 60204-1, Electrical Equipment of Industrial Machines - General Requirements
- IEC 60034-9, Rotating Electrical Machines – Noise Limits

F.3.4 European Normative (EN)

- EN 12101-2, Specification for natural smoke and heat exhaust ventilators

- EN 61496, Safety of machinery – Electro-sensitive protective devices

International specifications are available from their respective publisher, and there are also general distributors who provide specifications from multiple publishers.

G. Definitions

actuators: A mechanical device for moving or controlling motion.

anti-repeat: The function of the control system that limits the machine to a single cycle with the actuating control(s) held in the operating mode.

anti-tie down: 1) With a two-hand control device, the function of the control system that requires the release of all actuators before the machine operation can be reinitiated. 2) With a safety circuit reset, the function of the safety circuit that requires the reset signal to cycle on and off with each circuit reset.

attended program verification (APV): The act of verifying the robot's programmed tasks at the programmed speed while within the safeguarded area.

automatic mode: Any operating mode that produces continuous cycling.

awareness barrier: An attachment that, by physical contact, warns personnel of a present or approaching hazard.

awareness device: A device or signal that, by means of audible sound or visible light, warns personnel of a present or approaching hazard.

barrier: A device or object that provides a physical boundary to a hazard.

braking system: The combination of parts that control a driverless vehicle's speed or bring the vehicle to a halt or hold it stationary.

cell: A collection of machines in a defined area.

chemical: Any element, chemical compound, or mixture of elements or compounds.

concurrent: Acting in conjunction, this term is used to describe a situation where two or more controls exist simultaneously in an operated condition but are not necessarily executed simultaneously.

control devices: Any piece of control hardware providing a means for human intervention in the control of a machine or system (Example: an emergency stop button, start button, or selector switch).

control reliability: A method of ensuring the integrity of performance of the safety devices or control systems. As a result, a single component failure within the device, interface, or system shall not prevent the normal stopping action from taking place but shall prevent a successive machine cycle.

control system: Sensors; manual input and mode selection elements; interlocking and decision-making circuitry; and output elements to the machine or robot operating devices and mechanisms comprise the control system.

cycle: A complete movement of the machine or robot from its initial start position back to that same start position. This may include feeding and removal of the material or workpiece(s).

diagnostic coverage (DC): Diagnostic coverage is the automatic detection of dangerous failures in the safety function. This represents the ratio of dangerous failures that can be detected to the total dangerous failures that could occur, expressed as a percentage.

design-in safety: The process by which health and safety processes, tools, methods, and requirements are integrated early in the design phase to improve safety, quality, cost and productivity.

disconnect (mechanically interrupted): An electrical-energy interrupting device that uses mechanical linkage to force a break in the power supply to an individual piece of equipment.

dynamic limiting device (DLD): A limiting device that may be activated or muted in the course of executing the application program of a robot; thereby, redefining the safeguarded space.

enabling device: A manually operated device that permits motion when continuously activated.

end-effector: An accessory device or tool specifically designed for attachment to the robot wrist or tool mounting plate to enable the robot to perform its intended task (Example: gripper, spot weld gun, arc weld gun, spray paint gun, or any other application tools).

emergency stop: The immediate or controlled stopping of all hazardous machine motion, which is usually accompanied by the removal of the source power to the machine.

ergonomics: The evaluation, design or redesign of facilities, environments, jobs, job tasks, training methods and equipment to match the capabilities of people.

exclusive control: A station or pendant control on any piece of equipment that allows an individual to operate it in a manual mode. In addition, the operation cannot be overridden from any other location.

firmware: The executive control program (Example: operating system) code provided by the manufacturer of the component in a non-volatile internal storage mode and is not changeable by the user.

guard: A barrier that prevents entry into the point-of-operation or any other hazardous area.

safety red tag procedure (G1245): The safety approval process to ensure powered equipment that is installed, moved, rearranged, redesigned, or rebuilt meets the job safety requirements according to the applicable health and safety standards and regulations before the equipment is released for production purposes.

hard stop: A mechanical device that restricts the robot's or machine tool's ability to move to its full capability.

hazard: A condition or set of circumstances that can cause physical harm to exposed personnel.

hazard area: An area or space that poses an immediate or impending physical hazard.

hazardous motion: Motion of the equipment or a release of energy that can pose as a hazard.

hazardous zone: See hazard area.

hierarchy of health and safety controls: Health and safety control solutions that are listed in the order of effectiveness from most to least (Example: elimination or substitution, safeguarding (engineering controls), warnings, training and procedures, and personal protective equipment).

incident: an unplanned, undesired event that adversely affects completion of a task. Incidents range in severity from near misses to fatal accidents.

industrial equipment and systems: A physical apparatus (Example: welder, conveyor, machine tool, fork truck, turn table, positioning table, or robot) that is used to perform industrial tasks.

industrial hygiene: The anticipation, recognition, evaluation, elimination, and control of chemical, biological and physical hazards.

inherently safe design: A design that either eliminates hazards, or reduces the risks associated with hazards, by changing the design or operating characteristics of the machine without the use of safeguarding and SRP/CS (safety related part of the control system).

interlock: A means or device that allows a hazardous condition to exist only when a predetermined set of conditions is met.

interlocked barrier guard: A barrier, or section of a barrier, interlocked with the [machine] control system to prevent inadvertent access to the point of operation during normal [machine] operation. Alternative terms include hinged guards, fencing, gates, hand-operated and auto-operated access doors, mechanical point-of-operation guarding, perimeter guarding, and interlocked mechanical components.

intrusion distance (C): Distance that a part of the body (usually a hand) can move past the safeguard towards the hazard zone prior to actuation of the safeguard.

light curtain: A device that creates a sensing field or plane to detect the presence of an individual or object.

limiting device: A device that prevents a machine or machine elements from exceeding a designed space limit.

lockout: A lock placed on an energy isolating device (Example: a disconnect switch or shut-off valve) in accordance with Union/Nexteer Automotive lockout energy control procedures.

machinery (equipment): an assembly equipped with or intended to be equipped with a drive system consisting of linked parts or components, at least one of which moves, with machine actuators, control and power circuits, joined together for a specific application. This includes an assembly of machines that are arranged and controlled so that they function as an integral system.

machine risk assessment (MRA): a systematic process for evaluation of all operation and maintenance tasks, and their associated hazards.

machine tool: A power-driven tool used for machining.

manual mode: Any operating mode of the machine or system that requires the Operator to initiate and maintain the motion of the machine or system during the cycle, or portion of the cycle, by use of the actuating control.

manufacturing equipment systems: An assembly of machines that are arranged and controlled so that they function as an integral system.

mean time to dangerous failure: Mean Time to Dangerous Failure ($MTTF_D$) of the components is the time in years over which the probability of failure is relatively constant.

muting: The automatic temporary bypassing of any safety related function(s) of the control system or safeguarding device.

operating modes: The systems of operating machines, robots, and other equipment for various operations generally consisting of automatic, manual, and jog / inch / set-up modes.

operating zone: The defined area in which a driverless vehicle operates with adequate clearances.

operating hazard zone: The area of a driverless vehicle's operating zone without adequate clearances OR cannot be protected by personnel detection devices. This can be found in low clearance and load transfer areas.

orange crush zones: Restricted areas with substantial mobile equipment traffic. Typical orange crush zones include rail docks, truck docks, material storage areas, and any other area where pedestrian hazards are present as determined by the PIV committee.

path: The area swept by a driverless vehicle with its payload including trailer(s).

perimeter guard: A barrier at the perimeter (or segment of the perimeter) of a machine or production system.

pinch point: Any point at which it is possible for a portion of the body to be caught between two moving physical devices or between one moving and one stationary physical device.

placard: A form of quick reference documentation placed on the equipment or at the entrances into the safeguarded areas.

point-of-operation: The location in the machine where the material or workpiece is positioned, and work is performed.

positive-guided relay: Relay designed to eliminate any springing of the contacts to ensure a true making and breaking of contacts and, in the case of a failure, to ensure that a minimum clearance of 0.5 mm between the open contacts is maintained. These relays are sometimes called guided-contact, captive-contact, direct-drive, force-guided-contact, or forced-contact relays.

positive-opening contacts: The achievement of contact separation as a direct result of a specified movement of the switch actuator through non-resilient members (Example: not dependent upon springs).

presence sensing device (PSD): A device (Example: light curtain, scanner, safety mat) that creates a sensing field, area, or plane that detects the presence of an individual or object.

programmable electronic system (PES): An electronic system that performs logical, decision-making or arithmetic functions by executing instructions in a specific manner. The system usually includes input and output elements (ports) and is usually re-programmable.

readily accessible: Capable of being reached quickly for operation, renewal, or inspections, without requiring those to whom ready access is requisite to climb over or remove obstacles or to resort to portable ladders, and so forth.

redundancy: Duplication or repetition of elements in electronic or mechanical equipment that provides alternative functional channels in case of a failure(s).

restricted space or area: a work area that is intended for authorized personnel only (not intended for continued occupancy) and contains potential hazards with physical restrictions that may impact the activities that can be performed.

restricted zone: The area in which a driverless vehicle operates without adequate clearances AND cannot be protected by personnel detection devices. Only authorized personnel are permitted to enter.

risk: The potential for injury based on exposure to a hazard(s) during a given task.

robot operating space: The space within the restricted space that is used by a robot, including the end of arm tooling and part, while performing all motions commanded by the task program.

robot restricted space: The maximum distance that a robot, including the end of arm tooling and part, can travel in all directions after a limiting device has been installed. The restricted space is defined by the space the robot physically stops, not where the stop command is initiated.

safe distance: A minimum distance from a hazard that safeguarding shall be located to prevent persons from exposure to the hazard.

safe operating procedure (SOP): A specific written procedure that must be followed when it is determined that the equipment design prohibits a particular task from being performed in accordance with either the plant lockout procedure or CLS procedure. (Reference Union/Nexteer Automotive lockout implementation guidelines.)

safeguarding: Methods of protecting personnel from hazards by using guards, safeguarding devices/methods or safe work procedures.

safeguarding device: A means (device) that detects or prevents inadvertent access to a hazard.

safety gate: See interlocked guard door

safety interlock: A means or device that prevents entry into a zone or cell while hazardous conditions exist. Entry can be attained only when a predetermined set of conditions is met.

safety data sheet (SDS): a document that lists information relating to occupational safety and health for the use of various substances and products.

SRP/CS: An acronym used in place of Safety Related Part of the Control System. Part of a control system that responds to safety-related input signals and generates safety-related output signals. (ISO 13849-1:2015) For ease and consistency the term safety circuit has been used throughout this document.

shall: Denotes a requirement that is to be strictly followed in order to conform to this specification.

should: Denotes a recommendation, practice, or condition among several alternatives or a preferred method or course of action.

single component failure: Relates to a redundant control system whereby the failure of any one component of the system will have no effect on the stopping action of the system.

single point of control: The ability to operate the machine or robot such that initiation of machine or robot motion from one source of control is only possible from that source and cannot be overridden from another source.

stop device: A part of the machine operating system (Example: emergency stop button, presence sensing device, pull cord, monitored power circuitry, or a cycle stop/hold button) that causes the cycle to stop when it is either automatically or manually activated.

stored energy: Any source of energy (Example: hydraulic systems, air cushions, springs under pressure, or gravity) that could still present a hazard after a piece of equipment or process has been stopped from performing its normal function.

two-hand control device: A device that requires the concurrent use of both Operator's hands to initiate and continue the machine cycle during the hazardous portion of that cycle.

RECORD OF REVISIONS

Revision No	Date	Section	Description
001	17DE10	ALL	Initial release of SD-012 – based on Delphi Design-In Health and Safety Specification.
002	28JU18	ALL	Reformatted document: highlighted changes made during revision.
003	27SE22	ALL	Complete review and update of entire document.
004	16OC23	12	Updated Driverless Vehicle Section
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