UNIVERSITY OF TWENTE

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SAFETY BY DESIGN PROJECT

PROJECT TITLE: DESIGN GUIDELINES FOR HAZARDS OF ANNEXE B OF ISO 12100

1)Introduction

A hazard is a potential source of harm, it can be found everywhere and at any time. Not all hazards can be prevented, but most of them can be, if necessary precaution steps are taken into account and applied. In this report the list of hazards in Annexe B of ISO 12100 (safety of machinery) [1] is analyzed and countermeasures for these hazards were created. A risk is the chance of something happening that will have a negative effect. In order to reduce the risks, we must eliminate hazards or minimize them into an acceptable amount. According to [1], there are three steps that can be used to reduce the risk, which include making inherently safe design measures; to safeguard and/or take complementary protective measures; and inform the user of the risks. According to Annexe B of ISO 12100 there are 10 hazard families which will be analyzed. Within these categories origins of hazards are found in [1], and countermeasures are created.
As per the structure of this report, the report by Q.J. Mooij titled "Design guidelines for hazards" on January 23 2022 was taken into account and its main scope and differences are presented as follows:

The report which was conducted by Q.J. Mooij titled "Design guidelines for hazards" on January 23 2022, main scope was to analyze and find countermeasures for the hazards from ISO 12100 (safety of machinery). In addition, the author describes methods that can be used during for making a machine and the operation of it safe for the user and environment. Furthermore, safe design measures were created by focusing more on the responsibility of the employer and proposing solutions the employer can take in order to prevent hazards. Finally, the author cites that there are many situations in the life cycle of a machine where hazards can occur, and he proposes countermeasures the employer can apply in order to prevent the hazards.

In this assignment we will focus more on countermeasures where the machinery is programmed to deal and to prevent the hazards of ISO 12100 by considering safety methods that can be used to ensure that the machine is safe for the environment and for the employer.

2) Safety Design

In order to make sure that a machine and the operation is safe for it to be used by the employer, there are some methods which can be applied to ensure the safety of the former. During this course, the Safety Cube Method was introduced which describes the process to increase project integral safety. This method identifies the risks in the whole life cycle of the machine, from the beginning to the end. The Safety Cube Method uses the safety by design method: perform a risk assessment for the functional, technical and operational aspects; design to sufficiently address the system objectives and meet technical, functional and operational requirements through the 'safety by design philosophy'; control the risk: if the risk is not acceptable, redesign and return to step 1 [2]. The Safety Cube Method works with a 15-step process, in 3 phases. The details of this method can be found at [3].

Another method to reduce the risk is the Plan-Do-Check-Act method which was introduced in New-Zealand. This framework was designed to ensure that hazards and risks were identified, reported, assessed and mitigated as part of daily operations. The first step is to identify hazards, which can be done by any member who identifies them, or by being identified during a routine safety inspection. To identify the risks and hazards, the workplace areas which are more prone to cause an immediate threat should be analyzed and checked regularly. The following step is to rank each risk to its level of severity and the likelihood of it occurring. To accomplish this step, the safety engineer should use the Risk Assessment Table and then assign the risk to a Risk Manager who will control the identified risks. The following step consists of the Risk Manager, who is now is aware of the identified and assessed risks, to eliminate or if not possible mitigate the risk in a practical manner. Once controls are put in place to eliminate or minimize the risks the Hazard and Safety Coordinator will review their effectiveness and approve of the

solutions and results. If some controls are not effective the flow will go back a step, until all controls are found to be effective. The final step is to update the risk register which is a central datasheet for the organization's risks and controls and it is important to keep the risk register updated and to find ways to continuously improve Hazard and Safety in the workplace. Figure 1 shows the process of Plan-Do-Check-Act Method.

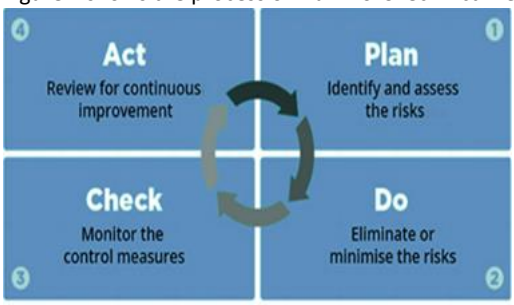

Figure 1

3) Hazard identification of 12100

3.1) Design guideline (countermeasures, improve existing hazards)

To make a safe system the safety should be taken into account during the whole design phase. Beginning with the concept, all materials, working principles, the lifetime of the product, but also maintainability and usability. The employer has a big responsibility when it comes to risks, and they can prevent hazards up to a certain amount. The risk reduction starts with a list of hazards at the workplace, and implementing appropriate risk control measures. These risks can be prioritized and consequently eliminated, substituted or controlled. Risks can be reduced by training employees properly; put warning signs at areas where hazards can happen; ensure all machines are properly guarded; educate the employees on the risks; and provide proper personal protection equipment (PPE) [5]. The employees can do a lot to prevent risks on themselves as well. For example they can visually check the machine before operation, perform a LMRA (last minute risk analysis). Or ensure all guards are in place before starting operation. Stop the machine when it operates abnormally. Do not work under unsafe conditions, adhere to all rules and safety regulations and wear correct PPE's [5]. Possible hazards can be grouped in 10 categories:

3.2)Possible hazards and measures to countermeasure/tackle them

The possible hazards according to the Appendix B of ISO 12100 are listed and categorized in the following groups:

Mechanical hazards:

Mechanical hazards are created from relative movements between parts of the human body and objects such as work equipment or work objects, which lead to their contact and this result can lead to accidents and injuries. According to accident statistics of the German Social Accident Insurance (DGUV), the accidents which are caused by mechanical hazards as well as accidents that can be caused by slipping , falling and tripping, account for the highest proportion of all occupational accidents and more specifically 25%.

The employer has a big responsibility when it comes to risks, and they can prevent hazards up to a certain amount. For this reason, in order to achieve risk reduction this report will focus on how the machine can prevent hazards and eliminate risk. The risk reduction starts with a list of hazards at the workplace and implementing appropriate risk control measures. These risks can be prioritized and consequently eliminated, substituted or controlled. The origins of mechanical hazards and the potential countermeasures for these hazards can be found in figure 2.

Figure 2:

Name	New solutions
Acceleration-Deceleration	• The machine is designed in a way that when it accelerates up to predetermined maximum speed , it immediately shuts down to eliminate any possibilities of any engineer being injured • If the machinery accelerates uncontrollably an automatic message will be sent to all engineers in near proximity to stay at a safety distance

Angular parts	• Design the radius of the angular parts to have an obtuse angle • Ensure that the angular parts have safety covers to ensure that the engineers will not be injured
Approach of a moving element to a fixed part	○ Implement sensors on the moving element and program it to stop when a fixed part is detected beyond a predetermined safety radius ○ Make sure that there is sufficient space between each product
Cutting parts	○ Make sure that the cutting machinery is stable and it is not vibrating ○ Program the robot to be as precise as possible to cut the parts, to avoid any sharp edges which could lead to injuries
Elastic elements	○ All the machinery that have elastic elements need to make sure that they have sufficient space between other machineries ○ All the machinery that have elastic elements need to make sure that they do not accelerate uncontrollably, because the elastic element can break and can injure the engineer
Falling objects	○ Before the use of a machinery, they should make sure that there are not any objects that are unstable ○ In case there are objects that have a possibility of falling, the operator must operate/or program the machinery to not accelerate over a predetermined maximum speed
Gravity	○ Before the use of a machinery, they should make sure that there are not any objects that are unstable
Height from the ground	○ Before the use of a machinery, they should make sure that there are not any objects that are unstable ○ Frequent inspections
High-pressure	○ Program the machinery to work with pressure which is within appropriate limits

	○ Performing periodic inspections to machinery ○ Secure cylinders ○ Use appropriate material
Instability	○ Make sure that there is sufficient space between each machine ○ Make sure that there is a safety distance between the machine and the employees
Kinetic energy	○ Inspect and audit programs and controls
Machinery mobility	○ Ensure machine guards are in place before the machinery is operated ○ Conduct visual check on the machine before starting operation
Rotating elements	○ Make sure that there is sufficient space between each machine ○ Make sure that there is a safety distance between the machine and the employees
Rough-slippery surface	○ Make sure that the surface is dry ○ Have signs in case it is slippery
Moving elements	○ Have regular maintenance routine checks ○ Program the machine to stop functioning in case it is at a high speed
Sharp edges	○ Make sure that there are protective equipment for the sharp edges
Stored energy	○ Train engineers to know how to handle the stored energy ○ Program the machine to stop its function if there is a leakage of the stored energy.
Vacuum	○ Have regular maintenance routine checks

Electrical hazards

The main hazards of working with electricity are electric shock and burns from contact with live parts, explosion caused by unsuitable electrical apparatus or static electricity igniting flammable vapors or dusts such as spray paint booth. It is also very dangerous to work in an environment with water or high humidity, because the risks of an electrical shock is higher and due to the good conductivity of water. In order to prevent electrical hazards from occurring these general guidelines should be considered [6]:

• Keep away from loaded or energized circuits
• Sources of electricity must be guarded
• Disconnect devices from the source during maintenance or repairing the electrical item
• All handling equipment should be dry, including hands, or wear insulated soles or non-conducting gloves.

• Take electrical risk assessments
• Train safe workers

The origins of electrical hazards and the potential countermeasures for these hazards can be found in figure 3

Figure 3:

Name	New Solutions
Arc	○ Automatic shut down of the machinery to avoid any injuries to the engineers ○ The engineers should use protective clothes and gear ○ There should be a predetermined safety distance between the engineer and the machinery to avoid any injuries
Electromagnetic phenomena	○ Automatic shut down of the machinery to avoid any injuries to the engineers ○ The engineers should use protective clothes and gear ○ There should be a predetermined safety distance between the engineer and the machinery to avoid any injuries
Electrostatic phenomena	○ Automatic shut down of the machinery to avoid any injuries to the engineers ○ The engineers should use protective clothes and gear ○ There should be a predetermined safety distance between the engineer and the machinery to avoid any injuries
Live parts	○ Automatic shut down of the machinery to avoid any injuries to the engineers ○ The engineers should use protective clothes and gear ○ There should be a predetermined safety distance between the engineer and the machinery to avoid any injuries
Not enough distance to live parts under high voltage	○ To prevent any injuries, the engineers should use protective clothes and gear ○ Automatic shutdown of the machinery, if it surpasses a permitted maximum voltage to avoid any injuries to the engineers ○ There should be a predetermined safety distance between the

	engineer and the machinery to avoid any injuries
Overload	○ Implement energy-saving appliances ○ Unplug major energy-draining appliances ○ To prevent any injuries, the engineers should use protective clothes and gear ○ There should be a predetermined safety distance between the engineer and the machinery to avoid any injuries
Parts which have become live under fault conditions.	○ Automatic shut down of the machinery to avoid any injuries to the engineers ○ The engineers should use protective clothes and gear ○ There should be a predetermined safety distance between the engineer and the machinery to avoid any injuries
Short-circuit	○ The engineer should check appliances before the use ○ Before the use of the machinery, the maintenance engineer should perform a Basic Circuit Breaker Maintenance ○ There should be a scheduled Electrical Inspection at Least once a year
Thermal radiation	○ Implementing and using a reflective insulation barrier that reflects electromagnetic radiation away from its surface

Thermal Hazards

Thermal hazards are created when heat is dissipated, and they include amongst others explosion, flames or heat radiation. In order to prevent these hazards a number of precautions can be taken. First of all, the workers can wear appropriate clothing such as PPE'S clothes. In addition, removing items that can generate, inflect or radiate a lot of heat from the work environment. In case of a heat wave workstations should have cooling areas and fans to circulate air. Workers should be educated on how to handle thermal hazards and the proper PPE's. The origins of thermal hazards and the potential countermeasures for these hazards can be found in figure 4.

Figure 4:

Name	New Solutions
Explosion	○ Provide training to engineers to learn how to properly manage equipment and their temperature ○ Reduce exposure of the used equipment to the sun

	○ Let the used equipment rest after many years being used
Flame	○ Make a preliminary check of the used materials, to check if they are flammable or not, in case they are flammable reduce their exposure to the sun ○ Make a preliminary check for any wires that are in not a good shape (e.g., broken, etc) ○ In case there is a flame make sure that there are not any flammable material close by to prevent any bigger fires
Objects of material with a high or low temperature	○ By using and implementing equipment that ensure that the temperature will remain far below the flash point. ○ The engineers should use protective clothes and gear such as gloves, overalls etc.
Radiation from heat sources	○ By using protective clothes and gear to protect the engineers and employees from the radiation ○ In case these heat sources produce radiation , there should be a predetermined safety distance between the employees and the heat sources to prevent any radiation transmission from the heat source to the employees

Noise hazards

Hazardous noise is any sound that's frequency (e.g., high pitch), intensity (loudness), and duration (length of time) can cause permanent hearing loss. In most cases the approach is to eliminate the source of the noise, if this is impossible the noise source could be replaced by a quieter type of equipment and low-noise tools[8]. Furthermore, to reduce noise hazards vibration should be reduced wherever is possible. According to NIOSH Recommended Exposure Limit exposures above or at the level of 8-hour time-weighted average (85 dBA as an 8-hr TWA) using a 3-dB exchange rate is considered hazardous. The origins of noise hazards and the potential countermeasures for these hazards can be found in figure 5.

Figure 5:

Name	New Solutions
Cavitation phenomena	○ By implementing insulation to the parts of the machinery that can cause the cavitation phenomena
Exhausting system	○ Purchase machines and equipment that don't produce a lot of noise ○ Employers to use protective gear and ear-plugs.

Gas leaking at a high speed	○ The machine and equipment should have a safety system which can detect leakage , which would result in the machine reducing speed.
Manufacturing process	○ Employers to use protective gear and ear-plugs. ○ Purchase machines and equipment that don't produce a lot of noise
moving parts	○ Employers to use protective gear and ear-plugs. ○ Have regular maintenance routine checks
scraping surfaces	○ Employers to use protective gear and ear-plugs ○ Have regular maintenance routine checks
unbalanced rotating parts	○ Have regular maintenance routine checks ○ Program the machine to stop functioning in case it is at a high speed
whistling pneumatics	○ The machine and equipment should have a safety system which can detect leakage in the pneumatics, which would result in the machine reducing speed ○ Have regular maintenance routine checks ○ Employees to wear protective gear
worn parts	○ Have regular maintenance routine checks ○ Employees to wear protective gear

Vibration hazards

Vibration can cause changes in tendons, muscles, bones and joints, and can affect the nervous system. It can originate from various sources and prior to using the equipment there should be a risk assessment. The effects of vibration is influenced by how long it is used, how tight the device is gripped, how it is used and in what type of conditions it is used. The vibration level can be calculated to know the influence of the vibration on the worker. The employer and employee should both comply with the rules and regulations for vibrations.

The origins of vibration hazards and the potential countermeasures for these hazards can be found in figure 6

Figure 6

Name	New Solutions
cavitation phenomena	○ The machine should have pressure control systems and in case it goes above a limit, the machine will immediately stop working ○ The employee should wear protective gear and clothes.

misalignment of moving parts	○ The employee should wear protective gear and clothes ○ The machine should be programmed to stop functioning if the moving parts are in danger of injuring an employee.
mobile equipment	○ The employee should wear protective gear and clothes ○ The machine should be programmed to stop functioning if the moving parts are in danger of injuring an employee.
scraping surfaces	○ Employers to use protective gear ○ Have regular maintenance routine checks
unbalanced rotating parts	○ The employee should wear protective gear and clothes ○ The machine should be programmed to stop functioning if the moving parts are in danger of injuring an employee.
vibrating equipment	○ The employee should wear protective gear and clothes ○ The machine should be programmed to stop functioning if the moving parts are in danger of injuring an employee.
worn parts	○ Have regular maintenance routine checks ○ Employees to wear protective gear

Radiation hazards

Radiation hazards can cause very serious health issues to workers who are exposed to radiation. The most important way to protect the people who are in danger of being exposed to radiation, is to decrease as much as possible the amount of radiation, and by decreasing the exposure time and increasing the distance between the worker and the source that is exposing radiation. In the following figure the hazards and their countermeasures are presented.

Figure 7

Name	New Solutions
ionizing radiation source	○ Employees to wear protective gear ○ The machine should be programmed to stop functioning in case there is a high chance of the radiation being elevated and been exposed.
low frequency electromagnetic radiation	○ Employees to wear protective gear ○ The machine should be programmed to stop functioning in case there is a

	high chance of the radiation being elevated and been exposed.
optical radiation (infrared, visible and ultraviolet), including laser	○ Employees to wear protective gear ○ The machine should be programmed to stop functioning in case there is a high chance of the radiation being elevated and been exposed.
radio frequency electromagnetic radiation	○ Employees to wear protective gear ○ The machine should be programmed to stop functioning in case there is a high chance of the radiation being elevated and been exposed.

Material-substance

Material choice can be crucial in designing any system. The material should provide the desired requirements for the system, but also safety should be taken into account in this process. But also properties like toxicity and flammability should be taken into account when designing a system. The origins of material/substance hazards and the possible countermeasures can be found in figure 8:

Figure 8

Name	New Solutions
Aerosol	○ Store in a safe place ○ Train and inform the employee for the proper use of the material
Biological and microbiological (viral or bacterial) agent	○ Store in a safe place ○ Train and inform the employee for the proper use of the material ○ The employee to wear suitable clothes
Combustible	○ Store in a safe place ○ Train and inform the employee for the proper use of the material ○ The employee to wear suitable clothes
Dust	○ Ensure the cleanliness of the workplace ○ The employee to wear suitable clothes
Explosive	○ Store in a safe place ○ Train and inform the employee for the proper use of the material
Fibre	○ Store in a safe place ○ Train and inform the employee for the proper use of the material
Flammable	○ Train and inform the employee for the proper use of the material ○ The employee to wear protective clothes ○ Store in a safe place
Fluid	○ Train and inform the employee for the proper use of the material ○ The employee to wear protective clothes ○ Store in a safe place
Fume	○ Keep away from fumes ○ The employee to wear protective clothes
Gas	○ Train and inform the employee for the proper use of the material

	○ The employee to wear protective clothes ○ Store in a safe place
Mist	○ Clean workspace ○ The employee to wear protective clothes
Oxidizer	○ Train and inform the employee for the proper use of the material ○ The employee to wear protective clothes ○ Store in a safe place

Ergonomic

The severity of an ergonomic hazard often depends on the level and time of the exposure. Ergonomic hazards can lead to sore muscles or long-term illness. The origins of ergonomic hazards and the possible countermeasures can be found in figure 9:

Figure 9

Name	New Solutions
Access	○ Ensure that there is enough space for engineers to move around each department of the workplace and restrict areas they can't go.
Design or location indicators and visual display units	○ Ensure that there are enough messages to inform the employee
Design, location or identification of control devices	○ There shouldn't be any disruptions during the path of the control devices and the employee
Effort	○ All efforts should be in safety guidelines
Flicker, dazzling shadow, stroboscopic effect	○ Use light-bulbs that do not flick ○ Reduce devices that provide stroboscopic effect
Local lighting	○ Ensure that there is sufficient lighting
Mental overload/underload	○ Collaborate with a psychologist so the employees can contact her in case there is any need
Posture	○ Have ergonomic chairs and equipment
Repetitive activity	○ Only do the same work for a short period time
Visibility	○ Ensure that there is enough visibility

Environment in which the machine is used

The environment of the workplace can greatly influence the efficiency of the work done, but also the safety and pleasure of the work. The origins of ergonomic hazards and the possible countermeasures can be found in figure 10:

Figure 10

Name	New Solutions
Dust and fog	○ Ensure the cleanliness of the workplace ○ The employee to wear suitable clothes
Electromagnetic disturbance	○ Store in a safe place ○ Train and inform the employee for the proper use of the material ○ The employee to wear suitable clothes
Lightning	○ Avoid going outdoors ○ Avoid electricity wires and fences ○ Avoid trees
Moisture	○ Ensure the cleanliness of the workplace ○ The employee to wear suitable clothes
Pollution	○ Avoid pollution as much as possible ○ Properly dispose materials that can harm the environment
Snow	○ The employee to wear suitable clothes ○ Avoid rushing
Temperature	○ The employee to wear suitable clothes

	○ Adapt and offer solutions when extreme weather conditions occur
Water	○ Train and inform the employee ○ The employee to wear protective clothes ○ Insulate machines and make sure there is no water close to open wires
Wind	○ Protect equipment from wind
Lack of oxygen	○ Train and inform the employee ○ The employee to wear protective clothes

4) Implementation of safety by design for the hazards of ISO B 12100

As per the chosen method Plan-Do-Check-Act, as previously mentioned, the method was introduced due to its design which allows employers on a daily basis to identify, report, assess and mitigate hazards and risks as part of their daily operations. The first step is to identify hazards, which can be done by any member who identifies them, or by being identified during a routine safety inspection. In order for the employer to be able to know how to identify the risks and the hazards by properly and regularly training them. The following step is to rank each risk to its level of severity and the likelihood of it occurring. Then, the safety engineer should use the Risk Assessment Table and then assign the risk to a Risk Manager who will control the identified risks. In order to accomplish this step the Risk Manager and safety engineer should be brought up to date with new risk assessment techniques by following regular training and sessions. The following step consists of the Risk Manager, who is now is aware of the identified and assessed risks, to eliminate or if not possible mitigate the risk in a practical manner. Once controls are put in place to eliminate or minimize the risks the Hazard and Safety Coordinator will review their effectiveness and approve of the solutions and results. If some controls are not effective the flow will go back a step, until all controls are found to be effective. In order to accomplish this step the Risk Manager and Hazard and Safety Coordinator should be brought up to date with new risk assessment techniques by following regular training and sessions The final step is to update the risk register which is a central datasheet for the organization's risks and controls and it is important to keep the risk register updated and to find ways to continuously improve Hazard and Safety in the workplace.

As per the Safety-By-Design To make a safe system the safety should be taken into account during the whole design phase. Beginning with the concept, all materials, working principles, the lifetime of the product, but also maintainability and usability. The employer has a big responsibility when it comes to risks, and they can prevent hazards up to a certain amount. The risk reduction starts with a list of hazards at the workplace and implementing appropriate risk control measures. These risks can be prioritized and consequently eliminated, substituted or controlled. Risks can be reduced by training employees properly; put warning signs at areas where hazards can happen; ensure all machines are properly guarded; educate the employees on the risks; and provide proper personal protection equipment (PPE) [5]. The employees can do a lot to prevent risks on themselves as well. For example they can visually check the machine before operation, perform a LMRA (last minute risk analysis). Or ensure all guards are in place before starting operation. Stop the machine when it operates abnormally AGAIN

5)Conclusion

In this report hazards and countermeasures were analyzed for various circumstances, based on annexe B of ISO 12100 [1].The Safety Cube Method and the Plan-Do-Check-Act method can both be of great value to employers and designers of systems. These methods can both be used in different stages of machinery. The Safety Cube Method is used in the design phase and looks at the whole life cycle of the machine. But the Plan-Do-Check-Act was designed to ensure that hazards and risks were identified, reported, assessed and mitigated as part of daily operations. The hazards treated in this report were separated in 9 categories and for each hazard there was a suggested countermeasure. Even though in this report the countermeasures main subject was to be a solution mostly accomplished by the machines, at some circumstances and the presence of the employee was necessary.

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