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Application of the Job Safety Analysis (JSA) Method to Assessment Occupational Risk at the Workplace of the Laser Cutter Operator

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Abstract
Occupational risk is closely related to work environment. For the same positions, but in different working conditions threats and level of risk can be different. For this also estimating the degree of damage hazard the largest possible should be adopted effects. However, when estimating probability occurrence of threats should include, among others: working conditions, events from the past, or possible employee behavior (in particular those that may be the cause of an accident at work). The source of the above information may be data from statistics or observations of work stations.
The article presents the assessment of occupational risk at the position of the laser cutter operator, which was carried out using the Job Safety Analysis (JSA) method. According to this method, occupational risk is determined on the basis of two parameters, i.e.: consequences of C and probability of consequences P. In turn, the probability of consequences is the sum of three factors: frequency of hazard F, probability of event O and avoidability or damage limitation A.

Keywords
work environment, threats, occupational risk, occupational health and safety, laser cutout operator, JSA method, matrix methods for occupational risk assessment.

Introduction. The essence of occupational risk assessment

According to the definition contained in the Regulation (Regulation of the Minister of Labor and Social Policy of 26 September 1997 on general health and safety regulations), occupational risk is the probability of occurrence of adverse events related to the work performed, and in particular the occurrence of adverse health effects of the employee as a result of exposure to occupational hazards occurring in the work environment or due to the way work is performed.

Occupational risk means the occurrence of threats in the work environment that are mainly associated with the work performed in a given workplace, under certain conditions. When considering the essence of occupational risk, one should also pay attention not only to the possibility of damage, but also to its consequences (Glendon and Stanton, 2000; Fuller and Vassie 2004; Mol, 2003; Lingard and Rowlinson, 2005; Lingard, 2013; Gallagher et al., 2001; Hopkins, 2011; Montero et al., 2009). Because this risk will always be borne by the employee in connection with his professional activity (Pinto et al., 2011; Glendon et al., 2006; Reese, 2008; Romanowska-Slomka and Slomka, 2018).

Occupational risk assessment is a process that focuses on analyzing this risk as well as determining its acceptable level. Based on the occupational risk assessment, the employer is able to verify whether sufficient measures have been implemented in the workplace to reduce or eliminate the negative impact of work environment factors on humans (Aven, 2016; Oliver et al., 2002; Azadeh-Fard et al., 2015; Zanko and Dawson, 2012). The results of the risk assessment carried out also indicate which actions should be taken to reduce the possibility of accident and disease hazards (Marhavilas et al., 2011; Vogt et al., 2010; Krause, 2017; Hayes et al., 1998).

Occupational risk assessment should always be carried out when in the workplace (Zanko and Dawson,

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2012; Krause, 2017; Quinlan et al., 2010; Uzarczyk, 2006; Leso et al., 2018):

- new jobs are created;
- changes are implemented at existing work stations;
- changes were introduced in terms of the acceptable level of factors of the working environment, risk assessment, etc.;
- new protection measures have been applied;
- works are performed by employees of other companies, and this work affects the threat to employees of the organization.

The JSA (Occupational Safety Analysis) method used in this article to assess occupational risk in the position of a laser cutter operator belongs to the group of induction methods. In this case, the occupational risk is a function of the consequences of the event and the probability of the event. In the JSA method, the probability of the consequences (effects) of an event defined in the risk definition is detailed and presented by three risk parameters, ie the frequency of occurrence of threats, the possibility of avoiding or limiting the damage and the probability of the occurrence of the event. These parameters are described later in the article.

At this point, the author of the article would like to draw attention to the review of studies that indicate the practical application of the JSA method in the identification of hazards and occupational risk assessment at workplaces.

The literature on the subject presents the use of the JSA method to assess occupational risk in many different workplaces. Examples include: works and construction projects (Rozenfelda et al., 2010; Albrechtsen et al., 2019), the implementation of assembly tasks (Gopinath and Johansen, 2016), woodworking (working in a sawmill) (Thepaksorn et al., 2017), and even uranium mining (Ebrahimzadih et al., 2015).

The issues discussed in this article fill the research and literature gap in the field of occupational risk assessment in the position of a laser cutter operator, taking into account the use of the Job Safety Analysis (JSA) method.

The article presents synthetically the risk assessment methodology using the JSA method and the results of own research. The necessary research material was obtained by the author of the work as a result of observing the workplace, interviewing employees and analyzing the internal documentation of the company. It should also be noted that the impact on the final result of the occupational risk assessment will depend not only on organizational factors, but also on the technological advancement of the device and the safety measures applied. In the analyzed case, the laser cutter is equipped with a number of protective mechanisms.

Materials and methods. Occupational risk assessment using the JSA method

According to the Job Safety Analysis (JSA) method, the risk level is estimated on the basis of two parameters: the consequences (consequences) of the event and the probability of the consequences of the event (P), which is expressed by the following function: (Romanowska-Slomka and Slomka, 2018)

$$\mathrm{P} = \mathrm{F} + \mathrm{O} + \mathrm{A}, \tag{1}$$

where:

F – frequency of threat occurrence;
O – probability of occurrence;
A – the ability to avoid or limit damage.

The criteria related to the estimation of individual parameters are summarized in the Tables 1–3.

Table 1
Assessment of hazard frequency – F (JSA)

Value F	Characteristic
1	< Once a year
2	Once a year
3	Once a month
4	Once a week
5	Daily

Source: (Romanowska-Slomka and Slomka, 2018)

Table 2
Assessment of event probability – O (JSA)

Value O	Characteristic
1	Irrelevant
2	Unlikely
3	Imaginable
4	Likely
5	Usually

Source: (Romanowska-Slomka and Slomka, 2018)

Table 3
Assessment of the possibility of avoiding or reducing damage – A (JSA)

Value A	Characteristic
1	Obvious
2	Likely
3	Possible
4	Not possible
5	Impossible

Source: (Romanowska-Slomka and Slomka, 2018)

According to the presented method, the consequences of the event (C) are determined in four classes, which are presented in Table 4.

Table 4
Event consequence classes – C

Class	Description	Characteristic
C1	Slight	Non-incapable of work
C2	Marginal	Short inability to work
C3	Serious	Prolonged inability to work
C4	Very serious	Death

Source: (Romanowska-Slomka and Slomka, 2018)

Then, after estimating all risk parameters, the risk level should be read from the matrix (Table 5) and its category should be determined from three possible variants: negligible, acceptable and unacceptable risk (Reese, 2008).

Table 5
Risk Valuation (JSA)

Class C	P – probability of consequences				
	3–4	5–7	8–10	11–13	14–15
C1	1	2	3	4	5
C2	2	3	4	5	6
C3	3	4	5	6	7
C4	4	5	6	7	8

1–2	negligible risk
3–5	risk acceptable
6–8	risk not acceptable

Source: (Romanowska-Slomka and Slomka, 2018)

Characteristics of the selected enterprise

For the purposes of this work, a company operating since 2003 and providing water jet and laser cutting services was selected for the author's own research. Its offer also includes a bending service performed on a press brake as well as a service of cutting, cutting rollers and profiles on a band saw. Since 2016, the Company has also been involved in business activities in the field of production and marketing of products and technology for military or police purposes, based on the Ministry of the Interior and Administration License granted to it in this respect (Internal materials of the examined enterprise).

The indicated cutting methods (i.e. with a water jet, laser) are intended for unit, short series production and for machining difficult-to-cut materials with other technologies. The service is dedicated to a wide audience, including manufacturers of machinery and technological lines in the food industry, producers of machinery and equipment for mining and energy, fittings manufacturers, manufacturers of laboratories, as well as in the advertising industry, defense, construction, etc.

The priority of the surveyed enterprise is to provide its potential and current clients with the highest quality of services provided. Therefore, since July 2007, the Company has a certified quality system according to EN-ISO 9001: 2009 (nowadays PN-EN ISO 9001:2015) standards and successfully passes audits performed by TÜV Nord Cert GmbH every year. The analyzed company performs orders for both small and large business entities, as well as individual (retail) customers (Internal materials of the examined enterprise).

Laser cutter operator – scope of duties. Threats at the workplace

The work of the laser cutter operator consists in performing activities related to cutting a wide range of materials, such as (Internal materials of the examined enterprise):

- steel (e.g. carbon, alloy, construction, quality, quality, tool, wear-resistant, galvanized);
- stainless steel (e.g. stainless, heat-resistant, acid-resistant);
- non-ferrous metals and their alloys (e.g. aluminum, copper, titanium, brass);
- stone (granite, marble, conglomerate, sandstone);
- ceramics (ceramic and porcelain tiles, conglomerates);
- gum;
- plastics;
- glass;
- wood-based panels, wood-like panels;
- special materials, thermal insulation, electrical insulation, glass epoxy, delmat, vetrotherm, vetronite, textolite, canavasit, micanite, lightherm, deltherm, aramid and others.

In the studied enterprise, the laser cutting machine operator programs, operates and maintains the machine in good condition. The basic tasks of the laser cutout operator include: (Internal materials of the examined enterprise).

- preparing the workplace (familiarizing with the technical drawing or template, preparing tools for work);
- setting parameters and supervising the work of the machine tool;
- transport to the workplace of the processed elements / objects and their mounting on the machine table;
- starting and stopping the machine;
- detection of machine work irregularities and removal of minor defects;
- operating measuring instruments and apparatus to check the quality of the machining performed (accuracy of shapes, dimensions, etc.);
- cleaning and maintenance of supported machines, devices and instruments;
- compliance with health and safety regulations when operating machinery and equipment;
- conducting inter-operational control of the machining process.

Work on the position takes place in a shift cycle, 8 hours per work shift. The employee performs activities in accordance with the established process, usually in a standing or walking position.

There are a number of occupational threats at the position of the laser cutter operator, which are detailed and described in the Table 6.

Table 6
Hazards identification at the workplace of the laser cutter operator

Hazard symbol	Hazard	Source of danger	Effects
TH-1	Capture by moving machine parts	Moving machine parts and equipment (cutting plotter work tables)	Injuries, injuries, limb amputations, death
TH-2	Injury from sharp or rough edges and surfaces	Workpiece, waste mesh, machine table	Bruises, bumps, skin abrasions, cuts, cut limb wounds and heads
TH-3	Dump by the machine	Other machines moving around the production hall	Severe injuries, sprains and fractures of limbs, crushing, head and spine injuries, concussion, internal organ injuries, disability, death
TH-4	Crushing, by machine (crushing)	Machine transport, tilting the outer support casing, closing clamping jaws	Severe injuries, sprains and limb fractures, crushing head and spine injuries, concussion, internal organ injuries, disability, death
TH-5	Hit by falling objects	Objects stored on racks, fall of moved material	Bruises, bumps, bruises, head injuries, concussion,
TH-6	Fall at the same level	Spilled fluids (water, oils, greases), cables, left behind tools and materials in the wrong place, general disorder, obstructed communication routes, improper footwear worn by the employee	Bruises, bumps, skin abrasions, bruises, sprains and fractures of the limbs, head injury and spine
TH-7	Fall to a lower level	Climbing the roof (e.g. to open), climbing machine pallets, using stairs, using ladders and landings	Bruises, bumps, skin abrasions, bruises, sprains and fractures of the limbs, head injuries and spine, internal organ injuries, disability, death
TH-8	Noise	Noise generated by laser cutting plotter or other machines and devices located in the production hall	Fatigue, headache, trouble concentrating, feeling unwell, hearing damage
TH-9	High pressure spray	Cutting gas, hydraulic oil	Bruises, abrasions, cuts, wounds

Table 6 [cont.]

Hazard symbol	Hazard	Source of danger	Effects
TH-10	Electromagnetic radiation	Electromagnetic field caused by permanent magnets (linear drives, magnetic sheet metal splitters)	Danger to life for people with a pacemaker
TH-11	High magnetic attraction	Linear drives, magnetic plate distributors	Injuries, cuts
TH-12	Laser radiation	Class 4 laser radiation during service, calibration or improper use of guards	Permanent damage to the retina, thermal damage to the skin, erythema
TH-13	Laser radiation (secondary)	Intense, visible radiation at the treatment site by plasma formation	Permanent damage to the retina, thermal damage to the skin, erythema
TH-14	Electric shock	Main axis servo converter (control cabinet), faulty electrical installation, use of faulty devices and power tools,	Burns, paralysis, disorders of the organs of the nervous, respiratory, circulatory systems, unconsciousness, death
TH-15	Thermal radiation or splashing molten substances	Splashing slag pieces	Irritation and skin burns, eye damage
TH-16	Thermal burns	Hot workpiece parts	Skin irritation and burns
TH-17	Pollination	Dust and dust escaping during the work process by transporting and / or processing materials	Respiratory diseases, pollinosis
TH-18	Influenza virus (type A, B, C)	Direct contact with flu patients	Influenza of various types, complications e.g. pneumonia
TH-19	Changing atmospheric conditions	Unloading or loading of materials, objects outside the production hall	Colds, flu, pneumonia
TH-20	Fire	Fire, arson, short circuit, improper storage of flammable materials, non-compliance with smoking bans	Body burns, soaking, disability, death, disaster
TH-21	Contact or inhalation of toxic liquids, gases, mists, vapors and dusts	Cutting gas, dust, aerosols, cutting oils, polyethylene coated profiles	Poisoning, loss of health, damage to the respiratory tract, damage to internal organs
TH-22	Allergies	Means used to maintain laser machine tools (e.g. oil, grease, liquids for cooling workpieces)	Allergies, irritation of the mucous membranes of the eyes, throat, larynx, headache, malaise, intoxication
TH-23	Dynamic load on musculoskeletal system organs	Manual transport of materials, workpieces and waste, performing cleaning works	Muscle and joint pain, tendinitis, spinal degeneration, limb cramps
TH-24	Static load on musculoskeletal system organs	Embedding materials on the template, entering data into the control computer, supervision over the cutting process	Pain, musculoskeletal system diseases, flat feet, varicose veins, spinal curvatures
TH-25	Eye load	Work that requires accuracy, poor lighting	Visual impairment, pain, burning, tearing, conjunctivitis
TH-26	Load on the nervous system	Employee interpersonal relations with superiors and other colleagues	Somatic symptoms (e.g. headache, internal organs), depression, problems with concentration, dizziness, stomach upset, coronary artery disease

Source: own study

Analysis of results – occupational risk assessment as a laser cutter operator

Occupational risk assessment for the laser cutter operator was carried out using the matrix JSA (Job Safety Analysis) method. Based on the observation of the workplace, interview with employees and analysis of internal documents of the company, hazards were identified. Then, for each identified threat, the individual risk parameters were evaluated and the risk category was determined.

The basis for adopting specific values of individual risk parameters were the technical and organizational safeguards already implemented in the enterprise.

The analysis carried out in this respect showed that the machine tool thanks to the technical solutions used meets the highest safety standards. As an example we can point to various types of protection, locks, safety covers that prevent accidental starting of the machine, and thus it was possible to reduce the risk associated with even laser radiation (characteristic for this type of equipment) to an acceptable level. In addition, the employer has equipped each machine operator with specialized glasses and work clothes to protect his eyes and skin against possible damage (e.g. in the event of machine tool failure).

It should be emphasized that an element of health and safety in the case of the audited enterprise is the maintenance of the proper condition of the technical infrastructure, as well as compliance with all safety rules. Because disregarding any of these preventive measures may increase the risk to an unacceptable level.

The analysis of occupational risk at the position of the laser cutter operator shows that all identified occupational hazards are at an acceptable level. Maintaining such a level of risk, however, requires constant monitoring of preventive measures introduced and undertaking quick responses in the event of any deviation.

Analyzing individual parameters of risk assessment, it should be stated that for all threats the same occurrence frequency (F) was adopted, i.e. at level 5 – daily. Because these threats are typical for activities carried out by operators on each business day. Another estimated parameter in occupational risk assessment was the probability of occurrence of an event (O). In this case, the individual threats were assigned the values: 1 (irrelevant) or 2 (unlikely). Such values were determined, among others on the basis of the register of accidents at work. Because in the examined industrial plant no accidents have occurred so far at the indicated workplace. In addition, interviews with employees confirmed that so far none of the employees had an accident at work or work-related illness.

As part of the occupational risk assessment, the opportunity to avoid or reduce damage was also identified (A). Also in this case, individual threats are assigned the lowest values, i.e. 1 – obvious or 2 – likely. Based on the sum of these three parameters, the probability of consequences (P) was estimated. Given the consequence classes C (expressed in terms of severity of employee injuries), the risk value and its category were read from the matrix. The results of the risk assessment are presented in Table 7.

An important issue in the field of occupational risk assessment is the correctness and adequacy of the results. Therefore, attention should be paid to the requirements that guarantee the correct assessment of occupational risk.

First, such an assessment should be carried out by company employees or external specialists. However, it is important that the person (or a team of employees) has knowledge in the field of technical safety and labor law, and shows knowledge of the workplace (e.g. employment structure, machines, devices, processes, technology). Employee involvement in the risk assessment process very often reveals a lot of informal information about inconvenience at the workplace or employee behavior. It should also be emphasized that reliable identification and assessment of threats will also be influenced by consultations with the employer and employees. Hence, the person performing the occupational risk assessment should have analytical and interpersonal skills.

In view of the above, the author of this work, as part of his research, he used not only the source documents of the company, but also carried out observation of the workplace and formal and informal talks with a health and safety specialist and employees of the company. Additionally, the prepared initial version of the occupational risk assessment card was also consulted with the management and employees of the enterprise. The author's assumption was to make the results of the risk assessment as objective as possible.

Moreover, the occupational risk assessment was carried out using two methods in parallel: the JSA method (described in this paper) and the Risk Score method. When comparing the obtained results, it should be noted that they do not differ significantly. The conducted analysis showed that the identified threats are characterized by a very low or low risk value and it is at an acceptable level. The detailed methodology of the research as well as the results and conclusions of the evaluation are presented in the paper (Palega and Krauze, 2020).

Table 7
Occupational risk assessment card for the laser cutter operator

Hazard symbol	Hazard	Preventive measures	Risk assessment					
			F	O	A	P [F+O+A]	C	Risk
TH-1	Capture by moving machine parts	Designation of a zone for moving machine elements, motion sensors, blockade	5	1	1	7	C4 Death	5 risk acceptable
TH-2	Injury from sharp or rough edges and surfaces	Use of protective clothing, use protective gloves and tools when inserting and removing workpieces	5	2	2	9	C2 Short inability to work	4 risk acceptable
TH-3	Dump by the machine	Designation of machine moving zones, compliance with the prohibition of staying in the danger zone	5	1	1	7	C4 Death	5 risk acceptable
TH-4	Crushing, by machine	Designation of machine movement zones, marking of passages, caution	5	1	1	7	C4 Death	5 risk acceptable
TH-5	Hit by falling objects	Securing the object against falling from a height, securing the displaced load, prohibiting being in and crossing the danger zone	5	1	1	7	C3 Prolonged inability to work	4 risk acceptable
TH-6	Fall at the same level	Keeping order in the workplace, wiping up spilled liquids, use of shoes with non-slip soles, unfolding mats and non-slip floor coverings, caution	5	1	2	8	C3 Prolonged inability to work	5 risk acceptable
TH-7	Fall to a lower level	Maintaining order at the workplace, using a functional ladder and platforms, marking platforms and any possible inequalities	5	1	1	7	C4 Death	5 risk acceptable
TH-8	Noise	Wearing hearing protectors, repair (or replacement) and maintenance of equipment that generates excessive noise, conducting periodic checks and measurements of noise values	5	1	1	7	C2 Short inability to work	3 risk acceptable
TH-9	High pressure spray	Observe the deadlines for maintenance work, disconnect the power supply safely before starting the maintenance of the cutting gas supply system, carry out maintenance work on the hydraulic supply with the machine switched off	5	1	1	7	C2 Short inability to work	3 risk acceptable
TH-10	Electromagnetic radiation	People with pacemakers should keep the required distance from the source of danger, inform employees, visitors and foreign personnel about the danger to people with a pacemaker	5	1	1	7	C4 Death	5 risk acceptable

Table 7 [cont.]

Hazard symbol	Hazard	Preventive measures	Risk assessment					
			F	O	A	P [F+O+A]	C	Risk
TH-11	High magnetic attraction	Do not keep heavy ferromagnetic objects (sheets, tools) in the hands of danger, keep watches and other magnetic data carriers (e.g. credit cards) away	5	1	1	7	C2 Short inability to work	3 risk acceptable
TH-12	Laser radiation	Use protective clothing, protective glasses for working with lasers and laser radiation shields	5	1	1	7	C3 Prolonged inability to work	4 risk acceptable
TH-13	Laser radiation (secondary)	Do not look directly at the place of processing, do not start the machine if the protective windows in the cabin are damaged	5	1	1	7	C3 Prolonged inability to work	4 risk acceptable
TH-14	Electric shock	Compliance with the principles of safe operation of machinery, equipment and power tools, conducting periodic inspections and measurements of electrical installation parameters	5	1	1	7	C4 Death	5 risk acceptable
TH-15	Thermal radiation or splashing molten substances	Wear protective clothing	5	1	2	8	C3 Prolonged inability to work	5 risk acceptable
TH-16	Thermal burns	The use of personal protection (if required), the use of special tools for removing hot workpieces	5	2	1	8	C2 Short inability to work	4 risk acceptable
TH-17	Pollination	Ensuring adequate air ventilation	5	1	1	7	C2 Short inability to work	3 risk acceptable
TH-18	Influenza virus (type A, B, C)	Prevention, voluntary, vaccination	5	2	4	11	C2 Short inability to work	5 risk acceptable
TH-19	Changing atmospheric conditions	Adaptation of clothing to the weather conditions outside	5	2	1	8	C2 Short inability to work	4 risk acceptable
TH-20	Fire	Implement fire protection measures (in accordance with regulations), keep snow extinguisher (class B) and powder extinguisher (class D) ready for use	5	1	1	7	C4 Death	5 risk acceptable
TH-21	Contact or inhalation of toxic liquids, gases, mists, vapors and dusts	Ensuring efficient suction installation, ensuring adequate air ventilation	5	1	1	7	C3 Prolonged inability to work	4 risk acceptable

Table 7 [cont.]

Hazard symbol	Hazard	Preventive measures	Risk assessment					
			F	O	A	P [F+O+A]	C	Risk
TH-22	Allergies	Ensuring adequate ventilation in the production hall, following the material safety data sheets	5	1	1	7	C2 Short inability to work	3 risk acceptable
TH-23	Dynamic load on musculoskeletal system organs	Adherence to the rules regarding manual transport work, the employee adopting the correct posture	5	1	1	7	C2 Short inability to work	3 risk acceptable
TH-24	Static load on musculoskeletal system organs	The employee adopting the correct body posture, providing breaks at work for rest or rotation of employees (in the case of permanent or frequent exposure)	5	1	1	7	C2 Short inability to work	3 risk acceptable
TH-25	Eye load	The use of appropriate lighting, cleaninand maintenance of lighting fittings, current replacement of used bulbs and fluorescent lamps	5	1	1	7	C2 Short inability to work	3 risk acceptable
TH-26	Load on the nervous system	Responding to conflict situations, leisure	5	1	2	8	C2 Short inability to work	4 risk acceptable

Source: own study

Conclusion

1. In order to identify threats, research was carried out consisting of observation of the workplace (using a checklist), interviews with the employer, employees and a health and safety specialist. In addition, the following company documentation was analyzed: disease record, accident documentation, measurements of harmful factors, workplace instructions, machine and device manufacturers' instructions, safety data sheets.
2. The working environment of the laser cutter operator is characterized by the occurrence of many factors hazardous and harmful to the health of the employee. However, the occupational risk assessment has shown that due to the preventive measures used they are at an acceptable (acceptable) level.
3. Maintaining an acceptable level of identified occupational hazards requires systematic monitoring of technical and organizational security measures applied. In this respect, it is also necessary to raise employees' awareness and to exercise caution in special situations. Because the lack or disregard of the preventive measures indicated in the risk assessment card will increase the likelihood of a work-related accident or illness and, consequently, increase the risk category, even to an unacceptable level.
4. Ensuring the safety of machine operation requires the use of a number of technical measures (e.g. covers, housings, light curtains, two-hand control devices, and undertaking organizational and procedural measures.
5. An important element of preventive measures is to inform employees about potential hazards associated with the operation of machinery in the workplace. Therefore, the employer is obliged to provide employees with current health and safety instructions. These instructions should contain information on hazards at the workplace and how to use machines and other technical devices.
6. The laser cutter analyzed in this work is equipped with many different types of technical protections, thus meeting the highest safety standards of its users. Thanks to the use of technical measures such as protection, blockades, safety covers pre-

venting the machine from starting, it was possible to reduce the risk associated with even laser radiation.

7. An important element of safety is also appropriate marking of danger zones with the help of safety signs. The markings used on the machine are intended to inform and warn the employee about situations directly threatening their safety and life.

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