



Vaporizing foil actuator welding prototype manufacturing and applications risk analysis

Buharlaştırılmış folyo aktüatör kaynağı prototip imalatı ve uygulamaları risk analizi

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Abstract

This study was conducted to examine risk levels for Vaporizing Foil Actuator Welding (VFAW) prototype manufacturing and applications. A risk analysis was carried out by using the L-type matrix method to detect hazards and risks in newly developing VFAW applications. 60 risks were identified for VFAW, 37 of which were high and 23 were moderate. To reduce the risk and occupational accidents to the lowest possible level; a measuring instrument that can continuously monitor current and voltage values, a remote detonation system and a discharge mechanism have been added to the prototype system. Thanks to the measures taken the situations that may result in serious accidents, fire, explosion, loss of limb, and even death that may occur during the experiment have been brought under control and VFAW applications have been made safer.

Keywords: Occupational safety and health, Vaporizing Foil Actuator Welding, Risk Assessment, L-Type Matrix

1 Introduction

Many studies and applications are carried out to ensure the continuity of manufacturing processes and to meet the needs of the industry [1-4]. Increasing needs and technological developments necessitate different manufacturing techniques [5, 6]. Employees are faced with many health and safety problems during manufacturing processes [7-9], and the issue of occupational health and safety is gaining more importance every day [10-14]. When the occupational accidents in the welding sector and related business lines are examined; It is observed that occupational accidents occur at a rate of 44% as a result of not using personal protective equipment, 37% due to lack of attention, and 17% due to equipment that does not take adequate safety precautions [9, 15-17].

The lack of education and knowledge of the employees in the occupational fields and the poor analysis of the working conditions constitute the basis for occupational accidents. Occupational safety analysis is a safety tool that can be used to identify and control hazards associated with a

Öz

Bu çalışma, Buharlaştırılmış Folyo Aktüatör Kaynağı (VFAW) prototip üretimi ve uygulamaları için risk düzeylerini incelemek amacıyla gerçekleştirilmiştir. Yeni geliştirilen VFAW uygulamalarında tehlike ve risklerin tespiti için L tipi matris yöntemi kullanılarak risk analizi yapılmıştır. VFAW için 37'si yüksek ve 23'ü orta olmak üzere 60 risk belirlendi. Riski ve iş kazalarını mümkün olan en düşük seviyeye indirmek için; prototip sisteme akım ve gerilim değerlerini sürekli takip edebilen ölçü aleti, uzaktan patlatma sistemi ve deşarj mekanizması eklenmiştir. Alınan önlemler sayesinde deney sırasında oluşabilecek ciddi kaza, yangın, patlama, uzuv kaybı ve hatta ölümlerle sonuçlanabilecek durumlar kontrol altına alınmış ve VFAW uygulamaları daha güvenli hale getirilmiştir.

Anahtar kelimeler: İş güvenliği ve sağlığı, Buharlaştırılmış folyo aktüatör kaynağı, Risk değerlendirmesi, L-Tipi Matris

particular process, job, or procedure [18]. Risk assessment analyses are of great importance in areas where applications such as workshops and laboratories are carried out. Workshops and laboratories have serious hazards due to their working environments and many risks arising from these hazards. Specific studies should be conducted to identify the existing risks and levels for these areas [19-22]. In order to protect against the dangers and risks in the working environment, hazards should be determined, the risks should be analyzed systematically and necessary precautions should be taken in a timely manner [23-26]. In this way, occupational safety conditions will be provided and a healthy working environment will be achieved.

Vaporizing foil actuator welding (VFAW), based on electric explosion [27] and shock wave [28] of conductors, was first used for welding by Vivek et al. [29]. VFAW is a new and promising type of pulse welding for the increasing demand for alternative joining methods [29-31]. It belongs to the solid state welding group and uses a high pressure pulse produced by vaporizing an aluminum foil [32-34]. It is an ideal technique for welding materials that are difficult to

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weld with each other using conventional methods, as they have different mechanical and thermal (e.g. melting point) properties such as Fe, Al, Cu, Ni and Ti [35-38]. It creates a pulse and creates a high-speed production technology by enabling the rapid evaporation of thin conductors with electricity. It has various applications such as forming, cutting, embossing, collision welding, powder compression, and spring-back calibration [39, 40].

In this welding process; By using the impact effect of electrical discharge, metal materials are superiorly joined between welding fixtures by means of the supporting steel blocks and the standoff sheet that separates the welding materials. Figure 1 shows the general application scheme of the VFAW process [29, 41, 42].

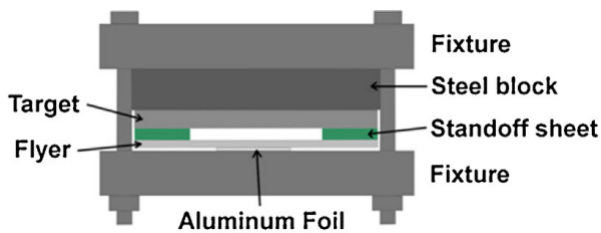


Figure 1. Scheme of the vaporizing foil welding apparatus [29].

This study is for VFAW, which is newly developed and in search of industrial applications in the industrial market; During the implementation, it was carried out in order to identify possible risks that may occur in terms of work and employees, and to make preventive suggestions to solve these risks. During the study, a prototype machine was developed and manufactured and all experiments were carried out on this machine to produce welded joints with VFAW.

The prototype produced allows studies on the welding process and parameters of different materials. In addition, the study has enabled the practical determination of the potential hazards that may occur during the "Vaporizing Foil Actuator Welding Prototype Device and Applications" activities and the risks that may arise as a result of these. The step-by-step manufacturing and application studies for welding methods provide a systematic description of the methods and principles regarding the control of expected or potential risks. The ultimate goal is to reduce VFAW-specific, high-probability work accidents, occupational diseases, and environmental damage to acceptable levels. This study is also considered to be a guide in the applications and experimental studies during the production of welding equipment.

2 Material and method

In this study, the L-type matrix method was used, and each of the listed hazards was evaluated separately by using the hazard/risk assessment form for each defined activity area. The L-type matrix method is generally used in the evaluation of cause-effect relationships; It is used to analyze the relationship between two or more variables or to determine (scoring) the degree of risk and the effect of risk. This method is a computable and quantitative risk

assessment method as well as being fast and easy to implement [36, 43, 44]. The flow chart followed for the hazard identification and risk assessment program consists of the steps in Figure 2 [30].

While calculating the risk value of each of the identified hazards, the probability and impact (severity) of the hazard are classified and scored. The risk value is calculated from the combination of probability and effect. Hazard classification is determined by examining the risk value of the hazard and whether there is a sanction related to the consequences of the risk, and a priority rating (score) is given to each identified risk [30].

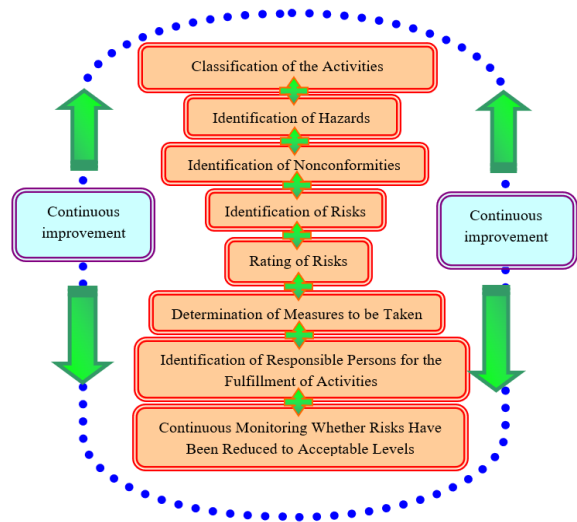


Figure 2. Hazard identification and risk assessment program flow chart [30].

While performing the VFAW risk assessment, the hazards and risks related to both health and safety were handled one by one. Examples: noise, combustion, explosion, etc. For each classification and situation, the score was determined according to the frequency of occurrence of the risk defined by the L-type matrix probability score sheet in Table 1. In line with the L-type matrix effect (intensity) table given in Table 2; The severity of the scenario that may occur in case of the realization of the defined risk is scored. These values are written in the probability and severity columns of the table given in Appendix A Table A1. The risk value was calculated with the formula given in Equation 1, and the risk scores were determined by using the L-type decision matrix given in Table 3. This risk score is written in the current score section of the table given in Appendix A Table A1. With the measures taken, a new risk score was obtained by reducing the probability and severity values, and this score was recorded in the target score column in Table A1 of Appendix A.

$$\text{Risk} = \text{Impact (Severity)} \times \text{Probability} \quad (1)$$

Table1. L-Type matrix probability score table [30]

Probability	Frequency
5: Very High	Every day
4:High	Once a week
3: Medium	Once every three months
2: Low	Once a year
1:Very Low	Every five years or more

Table 2. L-Type matrix effect (intensity) table [30]

Value	Ratings
5: Catastrophic	Death
4: Major	Serious Injury, Limb Loss, Occupational Disease, Permanent Incapacity for Work
3: Moderate	Injuries requiring treatment, Inpatient Treatment, Short Term Incapacity for Work Situations that may require first aid,
2: Minor	Outpatient treatment, Loss of workforce during the day
1: Insignificant	No job loss, no need for first aid

For the scoring to be objective, it was prepared by taking the opinions of the occupational safety experts of the joint health and safety unit and the risk assessment team members, the coordinating officer of the risk assessment studies, as well as the opinions of those present in the experiment area.

After taking the average of the scoring results, the final scores are determined as whole numbers; By multiplying the final scores, a basis was established for an objective evaluation of the priority level. Here the scoring was done by different people. The data obtained were reviewed by the risk assessment team and the coordinator of risk assessment studies, and the final priority level was determined [30].

According to the priority level determined and the resources that the study owners can allocate, the evaluation of the priority among the hazards was decided in line with the method given in Table 4. It is continuously checked and investigated whether the planned activities are realized or not. The risk assessment was made according to the risks discovered during the manufacturing activities and VFAW experiments in the workshop while the VFAW prototype was being manufactured.

Table 3. L-Type decision matrix [30]

Risk Score = Possibility x Severity	Severity				
	1- Very Low	2- Low	3- Moderate	4- Severe	5- Critical
PROBABİLİTY					
1 - Very Low	Negligible 1	Low 2	Low 3	Low 4	Low 5
2- Low	Low 2	Low 4	Low 6	Medium 8	Medium 10
3- Medium	Low 3	Low 6	Medium 9	Medium 12	High 15
4- High	Low 4	Medium 8	Medium 12	High 16	High 20
5- Very High	Low 5	Medium 10	High 15	High 20	Unacceptable 25

Table 4. Result and action table [30]

Conclusion	Action	Importance level
Unacceptable Risks (25)	Work should not be started until the identified risk is reduced to an acceptable level, if there is an ongoing activity, it should be stopped immediately. If it is not possible to reduce the risk despite the actions taken, the activity should be blocked.	1
Significant Risks (15,16,20)	Work should not be started until the identified risk is reduced, if there is an ongoing activity, it should be stopped immediately. If the risk is related to the continuation of the work, urgent action should be taken and as a result of these measures, the continuation of the activity should be decided.	2
Moderate Risks (8,9,10,12)	Actions should be initiated to reduce the identified risks. Risk reduction measures can take time.	3
Acceptable Risks (2,3,4,5,6)	Additional control processes may not be needed to eliminate identified risks. However, existing controls should be maintained and it should be audited that these controls are maintained.	4
Insignificant Risks (1)	It may not be necessary to plan control processes and keep records of activities to be performed to eliminate identified risks.	5

Considering the date of the study, it was found appropriate to make revisions for VFAW prototype manufacturing and applications, if necessary, based on the risks that could not be seen or discovered, and the risks that occurred or may occur later. Additions to the system used for this study and modification of the test site should take this into account as the conditions for the risks listed will be changed.

3 Results and Discussion

The hazards and risk assessments identified for the Vaporizing Foil Actuator Welding prototype manufacturing and applications in the study performed are presented in Appendix A [Table A1](#). While the prototype is being manufactured, there are different manufacturing needs and studies in the workshop and in the experiment area. The risks listed in this study are based on the site of the experiment and the school fabrication workshop. Hazards are not listed here for cases where manufacturing support is received from industries and businesses for prototype manufacture.

The created hazards were graded using the matrix method, and suggestions were made for the precautions to be taken. For the measures determined at significant risks, the expiry date is 10-15 days after the first analysis; for medium-level risks, it was created and checked after 30 days. In order to ensure that the experimenters and the test place are suitable for safe operation, the test studies continued after the controls specified here.

With this risk analysis study, 9 for fire, pharmacy, emergency departments with a high probability of occurrence for newly developing VFAW, 9 for personal protective equipment materials, warning-warning and ergonomic sections, 12 for mechanical operations with the use of hand tools and compressors, and 60 risks were identified, 30 for the electrical departments.

The grading results of these risks are 37 high risk and 23 moderate risks numerically. For each risk situation, the risk score was determined by means of the tables and it was seen that the average risk score was 14. According to the method specified in [Table 3](#), this figure reveals that VFAW and its studies are high-risk studies. Due to the high risk of the work required for the prototype and welding produced for VFAW, it should be developed under constant control and supervision. In addition to manufacturing works that are described as mechanical, welding apparatus and tests must be operated with electrical support and precautions.

4 Conclusions and suggestions

One of the situations that is always neglected while producing prototypes is the work that needs to be carried out on occupational health and safety issues. The risk analysis application acts as a warning and mostly preventive for dangerous situations that may occur, accidents and even situations that may result in death. The realization of the planning in the process in harmony with the legislation will ensure the acquisition of the right road map. This study was conducted to examine the risk levels for "Vaporizing Foil Actuator Welding prototype fabrication and applications". In the study, hazards and risks for newly developing VFAW

applications were determined and risk analysis study was carried out with the L-type matrix method.

In order to reduce the identified risks to an acceptable level, based on the Occupational Health and Safety Law published in the Official Gazette dated 30.06.2012 and numbered 28339 of the Law No. 6331, in accordance with the Occupational Health and Safety Risk Assessment Regulation dated 29.12.2012 and numbered 28512, sustainable, effective control and measures have been determined.

As a result; 60 risks, 37 high risk and 23 medium risks, were determined in the workshop and field where this study was carried out. A risk score was determined for each risk, and the mean risk score for the study was 14. VFAW and its applications were found to be high risk. These identified high risks should be managed and kept under surveillance. Thanks to the measures taken, risk management activities were determined. The hazard and risk assessment results, which were created according to the identified risks, are presented graphically in [Figure 3](#). Here, it is seen that the current risk scores for VFAW have been reduced by the measures taken.

Current risk scores for VFAW; While the impact severity and probability scale were created using the L-type decision matrix, the target scores were created using the result and action table. A separate risk score was determined for each of the 60 risks. Thanks to the measures taken, sustainable and effective controls and measures were determined in accordance with the Occupational Health and Safety Risk Assessment Regulation, and target scores were achieved.

In [Figure 4](#), mechanical additions made to the prototype produced as a result of the risk analysis study are presented. An explosion button used for the remote explosion system, a control valve associated with the control of this button, a separate storage area for the compressor, and a second pneumatic switch for correct grounding have been added to the existing prototype system. These deficiencies, which protect the employees and the environment, were noticed and implemented through the risk analysis study.

Reducing the sources of high risk to an acceptable level in high-risk VFAW and applications will be ensured by the full implementation of the measures determined as a result of the analysis. In this regard, employees should show the necessary importance both at the production stage and at the place where the test is carried out. Before and after starting work, periodic trainings should be given about VFAW work and its risks. For the work to always remain in safe conditions, continuity should be ensured by the occupational safety specialist. Among the existing risks are serious risks of electric shock, explosion and burning to the experimenters.

For these risks, the following suggestions were made in general, aiming to eliminate the deficiencies in the measures taken in current situations, to correct the application errors and to provide a safe experimental environment;

- Personal protective equipment materials suitable for the work should be provided and used,
- An emergency plan should be created for emergencies,

- The numbers to be called in case of emergency should be hung in a visible place in the test area in the size and position in accordance with the safety and health signs regulation,
- At least one employee should receive first aid training,
- There should be 6kg dry chemical powder fire extinguishers in the work area against fire, they should be located within the test area, at easily accessible points,
- Measurement indicators, where current and voltage values can be observed continuously, should be added to the welding set up,
- In the welding prototype, a remotely controllable pneumatic switch should be added to the system in

order to ensure safe discharge while electrical discharge is being made and to prevent damage to the person and the physical environment in and around the experiment area.

- New tests should not be carried out before safe conditions are established,
- Occupational safety specialists should continue training and inspection with continuous controls,
- Risk assessment team members should periodically train everyone working on the fabrication and testing site to maintain due attention to work-specific risks.

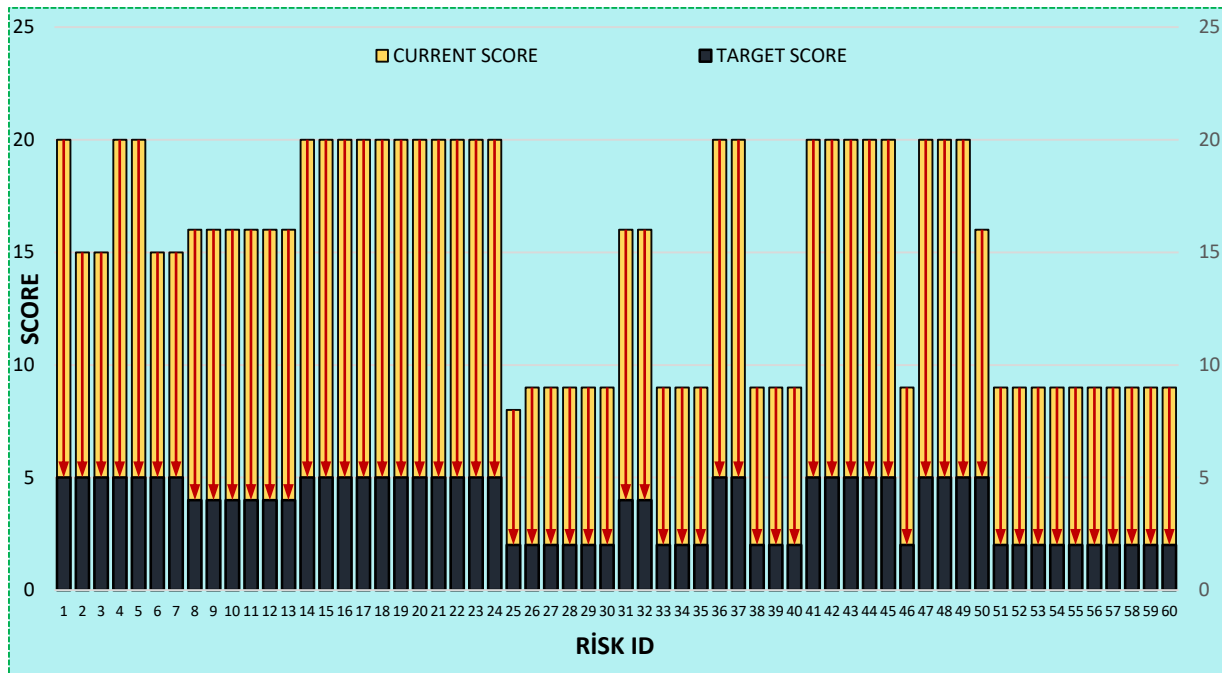


Figure 3. Hazard and risk assessment result graph

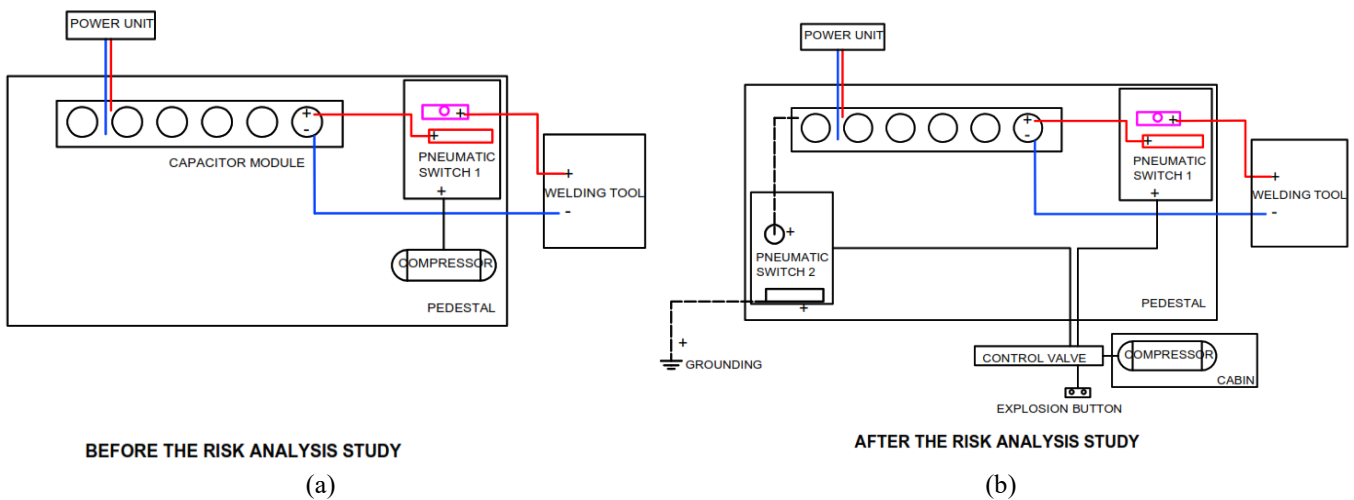


Figure 4. Mechanical attachments to the vaporizing foil actuator welding by risk analysis study

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Conflict of interest

The author declares that there is no conflict of interest.

Similarity rate (iThenticate): 7%

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APPENDICES

Appendix A Table A1

HAZARD AND RISK ASSESSMENT FORM																					
"VAPORISING FOIL ACTUATOR WELDING PROTOTYPE MANUFACTURING AND APPLICATIONS" RISK ANALYSIS																					
RISK ASSESSMENT TEAM		HAZARD CLASS: VERY DANGEROUS		DATE MADE		18.07.2022															
THESIS ADVISOR		PROF.DR.MUSTAFA KEMAL KÜLEKÇİ		DATE MADE		18.07.2022															
JOB SECURITY SPECIALIST		MEHMET ERGİN ÖNDER		DATE MADE		18.07.2022															
WORKPLACE DOCTOR		DR.SERDAR TAŞCI		DATE MADE		18.07.2022															
EMPLOYEE REPRESENTATIVE		LECTURER GANİME TUĞBA ÖNDER		DATE MADE		18.07.2022															
SUPPORT PERSONNEL		ORÇUN KÜÇÜKATAY		DATE MADE		18.07.2022															
RISK ID	DEPARTMENT	ACTIVITY	HAZARD LIST	RISK DESCRIPTION	CURRENT MEASURE	AFFECTED PEOPLE	Probability Score	Severity	Risk Score	Priority Degree	Planned Action Evaluation Mitigation Description	RESPONSIBLE	DATE	Probability Score	Severity	Risk Score	Finish Date	Probability Score	Severity	Risk Score	END SITUATION
1	FIRE	FIRE	Inability to respond to fire	Combustion, burns, material damage in the workplace	Fire extinguisher tube was provided to be used in the experiment area.	Persons in the experimental area	4	5	20	2	Appropriate type, size and number of fire extinguishing devices will be provided for each partitioned area.	Employer/ Employer's Attorney		1	5	5	1.08.2022	1	5	5	Continuous Control
2	FIRE	FIRE	The absence of fire fighting equipment in conditions suitable for use in the test room	Combustion, burns, material damage in the workplace	Since the fire extinguishers are mobile, they are in the open and easily accessible places.	Persons in the experimental area	3	5	15	2	1. Fire extinguishers will be placed at a maximum height of 90 cm from the ground in such a way that they can be easily taken. 2. The location will be indicated with signboards in accordance with the fire extinguisher safety and health signs regulation.	Employer/ Employer's Attorney		1	5	5	1.08.2022	1	5	5	Continuous Control
3	FIRE	FIRE	Lack of education	Combustion, burns, material damage in the workplace	Employees have fire training.	Persons in the experimental area	3	5	15	2	1. Training will be provided on the use of fire extinguisher tubes. 2. Employees will be informed about fire extinguishing procedures. 3. Instructions to use fire extinguishers will be placed on them.	Employer/ Employer's Attorney		1	5	5	1.08.2022	1	5	5	Continuous Control
4	FIRE	GENERAL	Firefighting equipment not working	Combustion, burns, material damage in the workplace	The expiration dates are checked and the expired ones are changed.	Persons in the experimental area	4	5	20	2	Periodic control of fire extinguishers once in 6 months, periodic control of pressure vessels every 5 years will be made by the manufacturer and the documents will be kept.	Employer/ Employer's Attorney		1	5	5	1.08.2022	1	5	5	Continuous Control
5	FIRE	GENERAL	Insufficient fire extinguishers	Late response to fire, increased damage, burning	There is one fire extinguisher.	Persons in the experimental area	4	5	20	2	1. Sufficient number of fire extinguishers will be taken 2. Fire tubes will be 90 cm above the ground 3. Fire tubes will be replaced every 6 months	Employer/ Employer's Attorney		1	5	5	1.08.2022	1	5	5	Continuous Control
6	EMERGENCY	GENERAL	Lack of a list of numbers to call in an emergency	Increasing severity of possible problem	It was hung in visible places.	Persons in the experimental area	3	5	15	2	Fire extinguishers will be maintained and the numbers will be called in case of emergency will be hung in a visible place in the experiment area in the school where the experiment is conducted, in the size and position in accordance with the safety and health signs regulation.	Employer/ Employer's Attorney		1	5	5	1.08.2022	1	5	5	Continuous Control
7	EMERGENCY	WARNING AND CAUTION MARKINGS	Failure to prepare an emergency plan	Injury, panic, escape or delay in response	There is no current measure	Persons in the experimental area	3	5	15	2	1. An emergency plan will be prepared 2. Employees will be informed about the emergency plan.	Employer/ Employer's Attorney		1	5	5	1.08.2022	1	5	5	Continuous Control
8	EMERGENCY	GENERAL	Lack of personnel with first aid knowledge	Accidents due to ignorance	Employees have basic first aid training.	Persons in the experimental area	4	4	16	2	At least one employee will be provided with first aid training.	Employer/ Employer's Attorney		1	4	4	1.08.2022	1	4	4	Continuous Control

Appendix A Table A1 (Continued)

9	MEDICINE CABINET	GENERAL	Lack of medicine cabinet in the working area	Insufficient first aid	There is a medicine cabinet in the school hallway.	Persons in the experimental area	4	4	16	2	1. A medicine cabinet will be provided to the working area. 2. The medicine cabinet will be checked at regular intervals	Employer/ Employer's Attorney	1	4	4	1	1.08.2022	1	4	4	Continuous Control
10	HAND TOOLS	EXPERIMENTAL AREA	Lack of cabinets for hand tools	Injury	There is no current measure	Persons in the experimental area	4	4	16	2	1. Hand tool cabinets will be provided 2. The finished tools shall not be in the active area or on the test setup during the test. 3. After each work, the tools will be placed in the cabinet.	Employer/ Employer's Attorney	1	4	4	1	1.08.2022	1	4	4	Continuous Control
11	HAND TOOLS	EXPERIMENTAL AREA	Hand tools not complying with CE standard	Injury	There is no current measure	Persons in the experimental area	4	4	16	2	Hand Tools will be CE marked	Employer/ Employer's Attorney	1	4	4	1	1.08.2022	1	4	4	Continuous Control
12	ELECTRIC	EXPERIMENTAL AREA	Contact with probes during electrical charging	Electrocution, fire, explosion, limb loss	The stages are carefully followed by the electrical and machine teacher.	Persons in the experimental area	4	4	16	2	1. Required PPE will be used 2. There will be a 6kg dry chemical powder fire extinguisher in the work area against fire.	Employer/ Employer's Attorney	1	4	4	1	1.08.2022	1	4	4	Continuous Control
13	ELECTRIC	EXPERIMENTAL AREA	Short circuit in the electrical terminal in the fixture area	Fire, explosion	There is a fire extinguisher	Persons in the experimental area	4	4	16	2	1. Required PPE will be used 2. There will be a 6kg dry chemical powder fire extinguisher in the work area against fire.	Employer/ Employer's Attorney	1	4	4	1	1.08.2022	1	4	4	Continuous Control
14	ELECTRIC	EXPERIMENTAL AREA	Incorrect polarity connections of voltage cables	Electrocution, limb loss, death	The stages are carefully followed by the electrical and machine teacher.	Persons in the experimental area	4	5	20	2	1. Required PPE will be used 2. There will be a 6kg dry chemical powder fire extinguisher in the work area against fire.	Employer/ Employer's Attorney	1	5	5	1	1.08.2022	1	5	5	Continuous Control
15	ELECTRIC	EXPERIMENTAL AREA	Incorrect connection of probes and terminal poles during capacitor charging	Electrocution, fire, explosion, limb loss, death	The stages are carefully followed by the electrical and machine teacher.	Persons in the experimental area	4	5	20	2	1. Required PPE will be used 2. There will be a 6kg dry chemical powder fire extinguisher in the work area against fire.	Employer/ Employer's Attorney	1	5	5	1	1.08.2022	1	5	5	Continuous Control
16	ELECTRIC	EXPERIMENTAL AREA	Short circuit on capacitor	Fire, explosion	The stages are carefully followed by the electrical and machine teacher.	Persons in the experimental area	4	5	20	2	1. Required PPE will be used 2. There will be a 6kg dry chemical powder fire extinguisher in the work area against fire.	Employer/ Employer's Attorney	1	5	5	1	1.08.2022	1	5	5	Continuous Control
17	ELECTRIC	EXPERIMENTAL AREA	Electric shock during capacitor discharge	Electrocution, fire, explosion, limb loss, death	In order not to be too close during the discharge, a 1 m long insulated metal is checked.	Persons in the experimental area	4	5	20	2	1. Required PPE (Insulation Gloves) will be used and attention will be at the forefront in the works. 2. The remote detonation distance for the system will be increased 3. Remote blasting system will be applied 4. There will be a 6kg dry chemical powder fire extinguisher in the work area against fire.	Employer/ Employer's Attorney	1	5	5	1	1.08.2022	1	5	5	Continuous Control
18	ELECTRIC	EXPERIMENTAL AREA	Electric shock when making measurements on a capacitor	Electrocution, fire, explosion, limb loss, death	The stages are carefully followed by the electrical and machine teacher.	Persons in the experimental area	4	5	20	2	1. Required PPE will be used 2. There will be a 6kg dry chemical powder fire extinguisher in the work area against fire.	Employer/ Employer's Attorney	1	5	5	1	1.08.2022	1	5	5	Continuous Control
19	ELECTRIC	EXPERIMENTAL AREA	Absence of grounding system	Electrocution, fire, explosion, limb loss, death	There is no current measure	Persons in the experimental area	4	5	20	2	The grounding of the test device will be done by the electrician.	Employer/ Employer's Attorney	1	5	5	1	1.08.2022	1	5	5	Continuous Control

Appendix A Table A1 (Continued)

20	ELECTRIC	EXPERIMENTAL AREA	Discharge in the wrong place during the test	Fire, explosion	There is no current measure	Persons in the experimental area	4	5	20	2	1. Required PPE will be used 2. There will be a 6kg dry chemical powder fire extinguisher in the work area against fire.	Employer/ Employer's Attorney	1	5	5	1	5	1.08.2022	Continuous Control
21	ELECTRIC	EXPERIMENTAL AREA	Explosion/burning of capacitors during charging	Fire, explosion	There is no current measure	Persons in the experimental area	4	5	20	2	1. Required PPE will be used 2. There will be a 6kg dry chemical powder fire extinguisher in the work area against fire.	Employer/ Employer's Attorney	1	5	5	1	5	1.08.2022	Continuous Control
22	ELECTRIC	EXPERIMENTAL AREA	Explosion/burning of Capacitors during discharge	Fire, explosion	There is no current measure	Persons in the experimental area	4	5	20	2	1. Required PPE will be used 2. There will be a 6kg dry chemical powder fire extinguisher in the work area against fire.	Employer/ Employer's Attorney	1	5	5	1	5	1.08.2022	Continuous Control
23	ELECTRIC	EXPERIMENTAL AREA	Arc jump	Fire, explosion	Keeping the appropriate distance	Persons in the experimental area	4	5	20	2	1. Before each work, the areas where arc may occur will be checked and the appropriate arc distance will be left according to the current. 2. Zones that can be isolated will be isolated 3. Necessary PPE will be used 4. There will be a 6kg dry chemical powder fire extinguisher in the work area against fire.	Employer/ Employer's Attorney	1	5	5	1	5	1.08.2022	Continuous Control
24	MECHANICAL	EXPERIMENTAL AREA	Compressors close to workers	Explosion	There is no current measure	Persons in the experimental area	4	5	20	2	Compressor will be removed from the employees, a separate protective area will be created for the device.	Employer/ Employer's Attorney	1	5	5	1	5	1.08.2022	Continuous Control
25	MECHANICAL	EXPERIMENTAL AREA	Noise caused by blasting during the experiment	Loss of hearing	PPE is used	Persons in the experimental area	4	2	8	3	1. CE marked earplugs will be used by the people in the experiment area. 2. Noise measurements will be made and noise protectors will be provided and used according to the results.	Employer/ Employer's Attorney	1	2	2	1	2	1.08.2022	Continuous Control
26	MECHANICAL	EXPERIMENTAL AREA	Hand injuries during handling/cutting of test materials	Falling, crushing, pinching/cutting/loss of limb	Care is taken when working with parts and PPE is used	Persons in the experimental area	3	3	9	3	1. Care will be taken while transporting the test materials. 2. Care will be taken that the floor is not wet or slippery.	Employer/ Employer's Attorney	1	2	2	1	2	1.08.2022	Continuous Control
27	MECHANICAL	EXPERIMENTAL AREA	Absence of spirals and sander protective guards during cutting operations	Falling, crushing, pinching/cutting/loss of limb	There is no current measure	Persons in the experimental area	3	3	9	3	Machines will not be operated without protective covers.	Employer/ Employer's Attorney	1	2	2	1	2	1.08.2022	Continuous Control
28	MECHANICAL	EXPERIMENTAL AREA	Inadequate fixation of materials during drilling operations	Falling, crushing, pinching/cutting/loss of limb	There is no current measure	Persons in the experimental area	3	3	9	3	The materials to be drilled will be fixed with a vise and checked before the work.	Employer/ Employer's Attorney	1	2	2	1	2	1.08.2022	Continuous Control
29	MECHANICAL	EXPERIMENTAL AREA	Hand injuries during assembly and disassembly processes between experiments	Falling, crushing, pinching/cutting/loss of limb	There is no current measure	Persons in the experimental area	3	3	9	3	Necessary PPE (gloves) will be used and attention will be at the forefront in the works.	Employer/ Employer's Attorney	1	2	2	1	2	1.08.2022	Continuous Control
30	MECHANICAL	EXPERIMENTAL AREA	Pneumatic switches not being fixed to the floor	Injury, arc/burn/explosion due to undesired ground contact in the experimental setup	The pneumatic switch is fixed to the table edge	Persons in the experimental area	3	3	9	3	It will be ensured that the materials that are at risk of moving during the test are fixed to the floor in a place where there will be no falling and tipping problems and that their connections are fixed.	Employer/ Employer's Attorney	1	2	2	1	2	1.08.2022	Continuous Control
31	MECHANICAL	EXPERIMENTAL AREA	Not fixing the capacitor group to the ground	Injury, arc/burn/explosion	Capacitors are on the table.	Persons in the experimental area	4	4	16	2	The capacitor group will be fixed to the ground so that it will not fall and its connections will be checked before each operation.	Employer/ Employer's Attorney	1	4	4	1	4	1.08.2022	Continuous Control

Appendix A Table A1 (Continued)

32	MECHANICAL	EXPERIMENTAL AREA	Welding fixture not fixed to the floor	Injury, arc/burn/explosion	The fixture is free on the table.	Persons in the experimental area	4	4	16	2	The welding fixture will be fixed to the floor and its connections will be checked before each work.	Employer/ Employer's Attorney	1	4	4	1	4	4	Continuous Control
33	MECHANICAL	EXPERIMENTAL AREA	Falling pieces	Falling, crushing, pinching/cutting/loss of limb	There is no current measure	Persons in the experimental area	3	3	9	3	Necessary PPE (steel-toed shoes) will be used and attention will be at the forefront in the works.	Employer/ Employer's Attorney	1	2	2	1	2	2	Continuous Control
34	WELDING	EXPERIMENTAL AREA	Welding fumes and vapors emitted into the environment	Occupational respiratory system diseases, poisoning	There is no current measure	Persons in the experimental area	3	3	9	3	1. There will be a ventilation system in the environment to prevent exposure to welding fumes. 2. In cases where ventilation is not possible, general ventilation will be provided by keeping doors and windows open in closed areas.	Employer/ Employer's Attorney	1	2	2	1	2	2	Continuous Control
35	WELDING	EXPERIMENTAL AREA	Welding beam	Eye diseases, occupational disease	There is no current measure	Persons in the experimental area	3	3	9	3	Welding glasses or screens will be used for welding.	Employer/ Employer's Attorney	1	2	2	1	2	2	Continuous Control
36	WELDING	EXPERIMENTAL AREA	Improper electrical connections of the welding assembly	Burning, explosion, death	There is no current measure	Persons in the experimental area	4	5	20	2	Cable connections will be made by an electrician and checked continuously.	Employer/ Employer's Attorney	1	5	5	1	5	5	Continuous Control
37	WELDING	EXPERIMENTAL AREA	The presence of flammable, combustible, explosive materials near the welding place	Burning, explosion, death	There is no current measure	Persons in the experimental area	4	5	20	2	1. There will be no flammable explosives and flammable materials in the welding area. 2. Necessary PPE will be used and attention will be at the forefront in the works. 3. There will be a 6kg dry chemical powder fire extinguisher in the work area against fire.	Employer/ Employer's Attorney	1	5	5	1	5	5	Continuous Control
38	WELDING	EXPERIMENTAL AREA	Hot spark splash	Burning	There is no current measure	Persons in the experimental area	3	3	9	3	The experimental setup will be located behind the protective screen.	Employer/ Employer's Attorney	1	2	2	1	2	2	Continuous Control
39	WELDING	EXPERIMENTAL AREA	Welding in narrow spaces	Poisoning, occupational respiratory disease	There is no current measure	Persons in the experimental area	3	3	9	3	1. There will be ventilation in the working area 2. It will be done with a remote blasting system so that no one is in the welding room. 3. No one will be in the room except when necessary.	Employer/ Employer's Attorney	1	2	2	1	2	2	Continuous Control
40	WELDING	EXPERIMENTAL AREA	Failure to periodically check the welding assembly	Electric shock, fire, explosion, death	Connection checks are made.	Persons in the experimental area	3	3	9	3	1. Connections will be checked before each experiment 2. As fixed elements may be loose, they will be checked in each test. 3. The parts that need to be cleaned will be cleaned with tools such as files, wire brushes, and sandpaper to prevent arc formation and burning.	Employer/ Employer's Attorney	1	2	2	1	2	2	Continuous Control
41	WELDING	EXPERIMENTAL AREA	Random connection of welding cable splices	Electric shock, fire, explosion, death	There is no current measure	Persons in the experimental area	4	5	20	2	Cable connections will be made by an electrician and checked continuously.	Employer/ Employer's Attorney	1	5	5	1	5	5	Continuous Control

Appendix A Table A1 (Continued)

42	WELDING	EXPERIMENTAL AREA	Setting the current settings to high	Electric shock, fire, explosion, death	Observation is made from the panel on the measuring instrument.	Persons in the experimental area	4	5	20	2	Employer/Attorney	1	5	5	1.08.2022	1	5	5	Continuous Control
43	WELDING	EXPERIMENTAL AREA	High voltage settings	Electric shock, fire, explosion, death	Observation is made from the panel on the measuring instrument.	Persons in the experimental area	4	5	20	2	Employer/Attorney	1	5	5	1.08.2022	1	5	5	Continuous Control
44	WELDING	EXPERIMENTAL AREA	Improper grounding	Electric shock, fire, explosion, death	There is no current measure	Persons in the experimental area	4	5	20	2	Employer/Attorney	1	5	5	1.08.2022	1	5	5	Continuous Control
45	WELDING	EXPERIMENTAL AREA	Incorrect connection of cables to the machine	Electric shock, fire, explosion, death	There is no current measure	Persons in the experimental area	4	5	20	2	Employer/Attorney	1	5	5	1.08.2022	1	5	5	Continuous Control
46	WELDING	EXPERIMENTAL AREA	Arc noise during welding	Hearing loss	Earplugs are used.	Persons in the experimental area	3	9	3	3	Employer/Attorney	1	2	2	1.08.2022	1	2	2	Continuous Control
47	WELDING	EXPERIMENTAL AREA	Not insulating the welding fixture	Electric shock, fire, explosion, death	Insulated with electrical tape	Persons in the experimental area	4	5	20	2	Employer/Attorney	1	5	5	1.08.2022	1	5	5	Continuous Control
48	WELDING	EXPERIMENTAL AREA	Contacting the welding fixture without system discharge	Electrocution, limb loss, death	The grounding piston is actuated and after measuring that the current is below 40 Amperes, contact is made.	Persons in the experimental area	4	5	20	2	Employer/Attorney	1	5	5	1.08.2022	1	5	5	Continuous Control
49	WELDING	EXPERIMENTAL AREA	Contacting the system during measurement operations	Electrocution, limb loss, death	Attention is paid	Persons in the experimental area	4	5	20	2	Employer/Attorney	1	5	5	1.08.2022	1	5	5	Continuous Control
50	WELDING	EXPERIMENTAL AREA	Shock wave generated during welding causes window panes to burst	Injury, environmental damage	Doors and windows are left open in the experiment room	Persons in the experimental area	4	4	16	2	Employer/Attorney	1	5	5	1.08.2022	1	5	5	Continuous Control
51	WELDING	EXPERIMENTAL AREA	Cleaning the test materials with chemical material	Poisoning by inhalation of chemical substance	There is no current measure	Persons in the experimental area	3	3	9	3	Employer/Attorney	1	2	2	1.08.2022	1	2	2	Continuous Control

Appendix A Table A1 (Continued)

52	WARNING AND CAUTION	GENERAL	Not using signs and plates when texting	Injury due to work accident	There is no current measure	Persons in the experimental area	3	3	9	3	Warning signs will be posted	Employer/ Employer's Attorney	1	2	2	1	2	2	1.08.2022	1	2	2	Continuous Control
53	ERGONOMICS	GENERAL	Employees standing up	Occupational diseases in advanced stages of musculoskeletal pain	There is no current measure	Persons in the experimental area	3	3	9	3	1. Employees will be given training on ergonomics 2. In order to prevent the employees from working standing up, there will be chairs where they can sit between the experiments. 3. Continuous position will be changed at regular intervals 4. It will be ensured that they take breaks 5. Exercises to relax the muscles will be done	Employer/ Employer's Attorney	1	2	2	1	2	2	1.08.2022	1	2	2	Continuous Control
54	ERGONOMICS	GENERAL	Employees' leaning work	Low back and neck pain, occupational diseases in advanced stages	There is no current measure	Persons in the experimental area	3	3	9	3	Measures will be taken to prevent employees from working in the same position all the time. 1. Employees will be given training on ergonomics 2. Technical support will be received regarding this situation 3. Employees will be prevented from working by bending over 4. Continuous position changes will be provided 5. It will be ensured that they take breaks at regular intervals	Employer/ Employer's Attorney	1	2	2	1	2	2	1.08.2022	1	2	2	Continuous Control
55	PERSONAL PROTECTIVE EQUIPMENT	GENERAL	Personal protective equipment does not have the CE mark and does not have a Turkish user manual	Injury due to work accident	Necessary warnings are made.	Persons in the experimental area	3	3	9	3	1. The personal protective equipment materials to be used will have the CE mark 2. They will have a Turkish user manual for the employees to understand easily	Employer/ Employer's Attorney	1	2	2	1	2	2	1.08.2022	1	2	2	Continuous Control
56	PERSONAL PROTECTIVE EQUIPMENT	GENERAL	Employees not wearing ear protection	Hearing loss	There is no current measure	Persons in the experimental area	3	3	9	3	1. During each experiment, everyone in the experiment area will wear ear protection. 2. Equipment shall bear CE mark	Employer/ Employer's Attorney	1	2	2	1	2	2	1.08.2022	1	2	2	Continuous Control
57	PERSONAL PROTECTIVE EQUIPMENT	GENERAL	Employees not using safety glasses	Eye diseases	There is no current measure	Persons in the experimental area	3	3	9	3	CE marked protective glasses will be provided and used	Employer/ Employer's Attorney	1	2	2	1	2	2	1.08.2022	1	2	2	Continuous Control
58	PERSONAL PROTECTIVE EQUIPMENT	GENERAL	Employees not using steel-toed shoes	Injury due to falling material	There is no current measure	Persons in the experimental area	3	3	9	3	Employees will be provided with shoes suitable for the job	Employer/ Employer's Attorney	1	2	2	1	2	2	1.08.2022	1	2	2	Continuous Control
59	PERSONAL PROTECTIVE EQUIPMENT	GENERAL	Employees not using isolated gloves	Electrocution, limb loss, death	There is no current measure	Persons in the experimental area	3	3	9	3	1. Everyone who will come into contact with the test device during each experiment will use insulated gloves. 2. Equipment shall bear CE mark	Employer/ Employer's Attorney	1	2	2	1	2	2	1.08.2022	1	2	2	Continuous Control
60	GENERAL	GENERAL	Disorganized work area	Accidents at work	The experiment area is arranged after the work is finished.	Persons in the experimental area	3	3	9	3	1. The work area will be arranged after the intermediate operations are done 2. Appropriate storage and stacking will be done in the working area. 3. The continuity of this situation will be ensured.	Employer/ Employer's Attorney	1	2	2	1	2	2	1.08.2022	1	2	2	Continuous Control

