ASSESSING SAFETY ANALYSIS AT FKM'S LABORATORY (GENERAL MACHINE LAB) UNIVERSITY MALAYSIA PAHANG BY USING ENERGY ANALYSIS METHOD

SUYANI BINTI ARIFIN

UNIVERSITI MALAYSIA PAHANG

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BORANG PENGESAHAN STATUS TESIS ♦

JUDUL **ASSESSING SAFETY ANALYIS AT FKM'S LABORATORY (GENERAL MACHINE LAB) UNIVERSITI MALAYSIA PAHANG BY USING ENERGY ANALYSIS METHOD**

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SUYANI BINTI ARIFIN

A report submitted in partial fulfillment
of the requirements for the award of the degree of
Bachelor of Mechanical Engineering with Manufacturing Engineering

Faculty of Mechanical Engineering
Universiti Malaysia Pahang

OCTOBER 2008

SUPERVISOR'S DECLARATION

We hereby declare that we have checked this project and in our opinion this project is satisfactory in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering with Manufacturing

Signature :
Name of Supervisor : En. Rosdi bin Daud
Position : Lecturer
Date : 5th November 2008

Signature :
Name of Panel : En. Mohamed Reza Zalani bin Mohamed Suffian
Position : Lecturer
Date : 5th November 2008

STUDENT'S DECLARATION

I hereby declare that the work in this thesis is my own except for quotations and summaries which have been duly acknowledged. The thesis has not been accepted for any degree and is not concurently submitted for award of other degree..

Signature : ………………….

Name : Suyani binti Arifin

ID Number : ME 05051

Date : 5 November 2008

“To my beloved mother and father. You are everything to me and always be there whenever I need you”

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ABSTRACT

Safety analysis by using energy analysis m ethod has been applied to laboratory Mechanical Engineering Faculty (FKM) of Universiti Malaysia Pahang. This analysis was applied on FKM 3A in FKM's laboratory which consist general machine such as universal milling machine and conventional lathe machine. The purpose of this analysis is to identify and evaluate hazard occurs at FKM's Laboratory by applying energy analysis. The approach to this study based on energy concept and straightforward method called Energy Analysis. This method is suitable for obtaining a quick overview of existing hazard. The methods are described step - by-step to show how analysis is practically done. The energy analysis methods for safety analysis seem to have been efficient in identifying hazards occurs at FKM 3A laboratory. The hazard was identified by survey, observation and interview that have been done. By analyzing the identified hazard, safety measure has been proposed. The suggestion also was proposed to improve the safety at the workplace.

ABSTRAK

Analisis keselamatan dengan menggunakan cara menganalisis tenaga telah digunakan ke atas makmal Fakulti Kejuruteraan Mekanikal (FKM) Universiti Malaysia Pahang. Analisis ini di aplikasikan dalam makmal FKM 3A yang merangkumi mesin umum seperti mesin kisar (milling) dan mesin larik konvensional. Tujuan analisis ini adalah untuk mengenalpasti dan menilai bahaya berlaku di makmal FKM menggunakan kaedah analisis tenaga. Pendekatan untuk kajian ini berdasarkan konsep tenaga dan kaedah langsung yang bernama Analisis Tenaga. Cara ini adalah sesuai untuk mendapat satu gambaran keseluruhan dengan cepat tentang bahaya yang sedia atau telah wujud dalam bentuk tenaga. Proses yang teratur dan sistematik dilakukan untuk menunjukkan bagaimana analisis ini boleh dijalankan. Analisis tenaga merupakan kaedah yang efisen dalam mengenal pasti bahaya yang wujud di makmal FKM 3A. Bahaya telah dikenalpasti melalui kaji selidik, permerhatiah dan temu ramah yang telah dilakukan. Dengan menganalisis semua bahaya yang telah dikenalpasti, pelbagai langkah-langkah keselamatan dicadangkan. Cadangan ini juga adalah untuk meningkatkan keselamatan di tempat kerja.

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CHAPTER 1

INTRODUCTION

1.1 BACKGROUND OF STUDY

Faculty of Mechanical Engineering (FKM) at Universiti Malaysia Pahang has a laboratory for students. The laboratory consist various kind of machines for student purpose. Some of the machine can be found in FKM's laboratory such as punching machine, conventional lathe machine, conventional milling machine, grinding machine, conventional drilling machine, CNC lathe machine, CNC milling machine and EDM machine. Hazard and accident could be occurred while con ducting the machine if the safety precaution was neglected since many students and staffs were using the machines everyday.

Hazard can be defined as anything that has potential to cause harm. Most hazards are dormant or potential, with only a theoretica l risk of harm, however, once a hazard becomes 'active', it can create an emergency situation [1]. This present paper purposed to identify hazard at FKM laboratory, analysis the hazard a nd suggest the idea in improving hazard control.

The data was collected and analyzed to trace where the hazard or accident potentially and was occur. Then, then possible solution to control or avoid the hazard suggested to FKM's laboratory management. This paper is concerned on how the hazard at FKM's laborat ory was identified, analyzed to control the hazard. The method called Energy Analysis was applied.

1.2 PROBLEM STATEMENT

(i) To identify hazard occurs at FKM's Laboratory (General Machine Lab, FKM 3A) by applying energy analysis

(ii) To improve safety at FKM's Laboratory by proposes the suggestions to control and reduce hazard.

1.3 OBJECTIVE

Objectives of this research are as follows:

(i) To assess whether it is possible or not to identify hazard by using energy analysis method at FKM's Laboratory (General Machine lab, FKM 3A).

(ii) To analyze the hazard occur using energy analysis method.

(iii) To propose improvements on safety at FKM's laboratory (General Machine lab, FKM 3A).

1.4 SCOPE

(i) Identify hazard occur at workplace in FKM's laboratory (General Machine lab, FKM 3A).

(ii) Propose the suggestions to control and reduce hazard.

CHAPTER 2

LITERATURE REVIEW

2.1 GENERAL

The safety analysis is tools that can be apply in safety work. By utilizing appropriate methods, the knowledge that is available in a workplace can be supplemented and applied more systematically. Good result can be obtained from the suitable designed analysis. Systematic safety work has economic benefits and risks can be reduced. Safety analysis has become methodology that is applied to a growing extent, often providing the basis for safety activities at plan level [2].

The implementation of the risk analysis regulations gives rise to a number of questions concerning the consistency between risk acceptance criteria and the available risk analysis methods and the feasibility of estimating the risk of accidents on a theoretical basis. There is a long tradition in the area of major accidents in addressing these questions (Versteeg, 1991; Allen et al., 1992; Niehaus, 1989). In the area of occupational accidents, questions concerning measures of risk, primarily based on historical data, have been thorough studied (Tarrants, 1980). Comprehensive literature exists on risk analysis methods and their application during design in this area (Harms-Ringdahl, 1987; Harms-Ringdahl, 1993; Kjellen, 1990; Reunanen, 1993; Soukas and Rouhiainen, 1993). However, there is a general lack of integration of these fields concerning the application of risk analysis in conjunction with risk acceptance criteria based on measures of risk as input to the decision making process. The paper addresses this integration.

2.1.1 Definition of safety analysis

Safety analysis is analysis of risk that is conducted within a variety of professional area and in various ways. There are standard that define part of the terminology for certain application area. One attempt at definition refers to a "safe system" as one that is free form obvious factors that might lead to injury of a person or damage to property or surroundings (SCRATCH, 1984). In sense, safety is the opposite of risk and can be regarded as inversely proportional to the risk (Kumamoto and Henley, 1996). Safety analysis is a systematic procedure for analyzing systems to identify and evaluate hazards and safety characteristics [2]. This definition is wide. The analyses are conducted within variety of professional area and in various ways. There are standards that define parts of the terminology for certain application area. Safety analysis usually has three main elements which is identification of hazards, assessment of the risk that arises and the generation of measures that can increase the level of safety [2].

2.1.2 Definition of risk analysis

Definition of Within the area of dependability and reliability there is an international standard (IEC, 1995) that defines " risk analysis" and a number of related terms. According this standard,

> *Risk analysis is the systematic use of available information to identify hazards and to estimate the risk to individual or population, property or environment.*

Risk analysis is also sometimes referred to as probability safety analysis (PSA), probability risk analysis (PRA), quantitative safety analysis and quantitative risk analysis (QRA).

2.1.3 The systematic approach

The analysis might apply to an existing installation or to production facilities that are still at planning stage. According to Lars Harms -Ringdahl, 2001 [2], there are several different aspects to a systematic approach:

- Gathering of information on the system provides the basis for the analysis and must be carried out systematically.
- The entire system and the activities within it should be included in the analysis. The analysis need to be designed so those important ele ments are not overlooked. A main thread must be identified and followed.
- A systematic specified methodology is required for the identification of hazards.
- The risk to which these hazards give rise need to be assessed in a consistent manner.
- A systematic approach is required when safety proposals are to be generated and evaluated.

A method for safety analysis can also be seen as a compressed account of previous experiences. The developments of analysis and safety activities are much “accident-driven”. Or, as Reason (1990) put it, “events drive fashions”. People have been forced to rethink, in one way or another, by their own experiences. Perspectives on accidents and strategies for the analysis of risks have been governed to a considerable extent by accide nts that have already occurred.

2.2 CLASSIFICATION OF HAZARDS

2.2.1 Respiratory Hazard

OSHA does not permit anyone to enter or occupy a space containing less than 95% oxygen. Even though human may be able to hold their breath for a couple of minutes, a single breath of an atmosphere without oxygen will result immediate unconsciousness and death if the victim is not remov ed to fresh air within minutes.

OSHA standard 29 C.F.R 1910.146 requires monitoring of these space to ensure that at least 19.5% oxygen is available prior to and during any confined space entry.

2.2.2 Corrosive Hazard

Corrosive atmosphere have the ability to cause damage to the skin or any other human tissue they contact. Strong acids and alkali materials are used in many industrial processes and are by-products generated in others. These atmospheres also have the ability to damage or destroy personal protective equipment (PPE). All PPE selected for use in corrosive atmosphere should be compatible with the materials in space.

2.2.3 Energy Hazard

These same hazards often conceal other deadly hazards such as energized electrical components, high pressure gas, and liquid transmission lines, and pneumatic or hydraulic equipment and component. The only way to protect entrants from these hazards is to educate them about the entire hazard in the workplace by isolating and de-energizing every component in the space before allowing them to enter.

2.2.4 Engulfment (contents) Hazard

Failure to isolate valves that direct contents into vessels is one of the problems. Unauthorized entry into open-top container with sloping sides and containing grain or other similar materials has also results in fatalities. One of the primary ways to guard against unauthorized entry and improperly compensated risk is trough effective education. Every employee must be taught to appreciate the dangers and they must understand the company policies that will not tolerate unauthorized entry.

2.2.5 Fire and Explosive Hazard

Flammable atmosphere pose serious fire and explosion threats to w orkplace. The permit system requires the space to be monitored before entry and continually to ensure that flammable vapors do not accumulate whole while the entrants inside the space. If reading of 10% or greater of the lower flammable limit of the gas is reached according to the combustible–gas monitoring instrument, the entrants must exit the space. The probe of the monitoring instrument should be located in the space where the vapor is most likely to be located.

2.2.6 Mechanical Equipment Hazard

Mechanical devices are design to mix, chop, and stir products. If primary energy to derive the devices is not properly locked out, according to 29 C.F.R 1910.147, and if energy stored in devices such as accumulators, capacitors, compressed air tanks, etc. is not bl ed off, equipment may activate and injure or kill the entrance. It is worth nothing that a single machine may have several different energy sources.

2.2.7 Fall Hazard

The OSHA requires all employees to be protected from falling from any surface 4 feet (29 C.F.R. 1910.23) to 6 feet (29 C.F.R. 1926.501) above adjacent surface. Each employee o walking or working (horizontal or vertical surface) with an unprotected side or edge that is 6 feet (1.8 meters) or more above a lower level must be protected from falling by the use of guardrail systems, safety net system, or personal fall arrest systems.

2.2.8 Environmental Condition Hazard

Other factors such as extreme temperature may compound the hazard to present. Any condition that has the potential to distract the ent rant from focusing on the other safety hazards could contribute to an accident or injury. The workplaces are dark, tiny space, encountering reptiles, rodent, or insects are another potential hazard. In such situation thermal imagers could possibly be used, as any living animal will give off heat and be visible even in low or no light condition. Noise and vibration are environmental conditions that complicate work to rescue. The machinery near the workplace should be stopped to reduce noise and vibration whe n ever possible. Psychological hazard of working in restricted space can adversely affect worker. Individuals who are susceptible to claustrophobia could have problems before or during entry into confined spaces. Employers should attempt to uncover this tendency through training prior to working in actual hazardous condition. People with minor or moderate claustrophobia anxiety in these working condition can often slowly acclimated through training and can learn to overcome the anxiety. Individuals who cannot do so should not be forced to work because they could create dangerous conditions for all the entrants.

2.3 SELECTION METHOD

There are many method are referred to safety analysis, each with different field of application [3]. In general that any one specific method will only cover a limited part of the risk panorama. Extensive descriptions, references and evaluations of the methods are given by CCPS (1989) Harms-Ringdahl (1993), Lees (1980) Rausand (1991), Suokas (1985) and Suokas and Rouhiainen (1993). The Energy analysis method is relatively simple and risk analysis expert participation is not required (Harms-Ringdahl, 1993). Energy analysis is also called Preliminary Hazard Analysis. A further advantage of Energy analysis is that it is linked to a philosophy for the development of safety measures (Haddon, 1980). Often an Energy/Coarse analysis is the first step in a risk analysis process. Job safety analysis is primarily intended for analyses of well structured activities. Also this method is straight forward and relatively easy to apply. According to Suokas (1985) the quality of the results (validity and reliability) obtained by Job safety analysis can be impaired by such factors as inadequate boundary definition, work steps unintentionally omitted, and variety in the analysis object (e.g. different working methods or auxiliary equipment may be applied). Some of the criteria that might be used in choice of method are:

- That the method provides the support necessary to sustain systematic approach
- The method easy to understand and apply
- The analysis can be conducted even when information on a system is incomplete.
- The analysis can be conducted with a reasonable amount of effort, taking anything from part of a day to one or several week.

Four of the methods have a similar analytical procedure. They are Deviation Analysis, Energy Analysis, HAZOP and Job Safety Analysis. The different steps are taken in a planned sequence. This facilitates undertaking the analysis and also makes it easier to plan. The key steps that these methods have in common are:

1. A system is divided into several components, which involves the construction of simplified model of the system. This step is called " *structuring*".
2. The sources of risk (hazards) or other factors related to the risk of accidents are identified for each component of the system.
3. Some form of risk assessment is carried out.
4. A stage at which safety measures are proposed is included.

2.4 ENERGY ANALYSIS

2.4.1 Principles

The concept of energy is treated in a wide sense. Energy is something that can damage a person physically or chemically in connection with particular event. The purpose of this method is to obtain an overview of all the harmful energies in an installation. The approach of seeing energy as cause of injury was first developed by Gibson (1961) and Haddon (1963). The concept has proved useful and as been further developed and discussed in several books and reports as example Hammer (1972), Haddon (1980) and Johnson (1980). An additional feature of the account presented by Harms-Ringdahl (2001) is the way in which the analytical procedure is broken down in a number of defined steps (Harms -Ringdahl,1982).

Thinking in energy terms is based on a model of systems that contains three main components:

(i) That which might be harmed, usually a person but it could be equipment or industrial plant.

(ii) Energies which can caused harm

(iii) Barriers which prevent harm from being caused such as safeguards for machinery

Harmful energy can take on many forms such as an object comes at a height from which it may fall or electrical voltage. By adding acutely poisonous and corrosive substance, a fairly comprehensive picture of the injuries that might affect a human being is obtained. One essential part of the energy model is the c oncept of barriers. These will prevent the energy from coming into contact with the person and/or cause injury.

From the journal [4], this method is simple and suitable for obtaining quick overview of existing hazard. This method has been use for a long time ([Haddon, 1980 and Johnson, 1980]). A person must be exposed to an injurious influence which is a form of energy for an injury to occur. This is could be a moving part of the machine or slippery of the floor. Energy analysis procedure by Harms - Ringdahl, 2001[2]:

(i) PREPARE

Obtain information about the installation that being considered. This is definition of limits of the study object which may be only a single machine, some section or whole factory.

(ii) STRUCTURE

Dividing the system into suitable pa rts to be analyzed one at a time.

(iii) IDENTIFIY ENERGY

Identify source and stores of energy for each parts.

(iv) ASSESS RISKS

In the assessment, identifying the presence and efficiency of barriers is essential. They will affect seriousness and like hood of in juries.

Table 2.1: Example of a direct risk acceptance scale applied in Energy Analysis

Code	Description	Comment
0	Negligible risk	Energy cannot cause any significant injury
1	Acceptable risk, no safety measured required	Energy can cause injury, but barriers are adequate
2	Safety measure recommended	Barriers should be improved
3	Safety measure essential	Serious consequences and inadequate barriers

(v) PROPOSE SAFETY MEASURES

Questions are raised concerning whether and how risk can be reduced. It is good to be able to suggest a variety of solution, since it is not certain that the first will be the most effective. Then, the most suitable solutions can be selected.

(vi) SUMMARY

Summary the analysis and the result.

2.5 EXAMPLE OF APPLICATION ANALYSIS

According to journal [3], safety object such as operating procedure, alarms, sensors and barriers are mapped to model elements to avoid the hazards and keep the workplace safety. Without hazardous energy, harm or damage will not occur. This journal shows the steps to design plant safety model components:

1. Safety procedures - safety regulations and jobs are explained and attached to plant object, action, or state transition
2. Safety specifications - describes the plant objects characteristics and attributes
3. Safety historical data - capture historical data in standard format that is readable to plant systems
4. Safety common data- includes all common data that can be shared and exchanged among different plants and components/systems
5. Safety scenarios - an intelligent component to envision the safety level by building different scenarios with its safety level ranking
6. Safety devices - safety control systems component

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

An Energy Analysis contains four main stages as well as making preparations and concluding the analysis. It is usually best fully to comp lete each stage before moving on to the next. As an aid to analysis, a specially designed record sheet can be used.

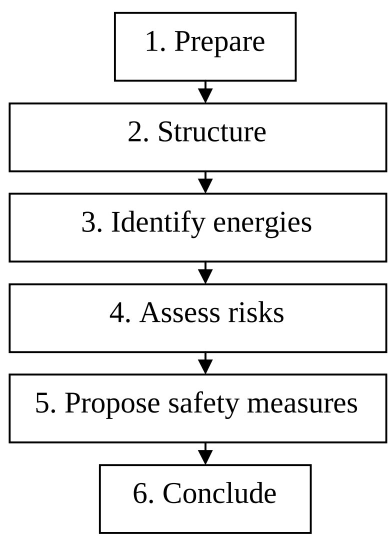

Figure 3.1: Main stages of procedure in energy Analysis

1. Preparation

Before embarking on the analysis itself, a certain amount of preparation is required. This concerns a definition of the limit of the object study which may be a single machine, a workplace or a whole factory. This paper only focuses on FKM 3A in FKM's laboratory which consist general machine such as milling machine and conventional lathe machine.

One essential aspect is to obtain information about the installation being considered. For Energy Analysis, this can consist of technical drawing and photographs.

2. Structure

The purpose of the structuring stage of the analysis is to divide the system into suitable parts which are then analysed one at time.

In general, structuring is performed in accordance with the physical layout of the installation under study. In principle, the plant or equipment is divided into 'volumes' (spatial segment).

This means that the boundaries of the entire system to be analysed should also be thought of in volume terms. After structuring, a check should be made as to whether any component has been omitted or lost in some way. If the entire area to be analysed is not covered, supplementary volumes are needed. Sometimes, it may be wise to add an extra 'volume' to cover anything lying outside the area where the object in question is located.

3. Identify energies

For each volume, source and stores of energy are identified. One problem is to determine the level of energy. Energy should not be excluded just because it seems unlikely that a human being will be exposed to it.

4. Assess risk

Each identify source of energy is assess. The method itself does not prescribe what kind of assessment should be made. Each energy may have a variety of consequences. In the assessment identifying the presence and efficiency of barriers is essential. They will affect the seriousness and likelihood of injuries. In principle the choice is to accept the system as it is or determine the safety improvements are needed.

Table 3.1: Direct risk acceptance scale applied in Energy Analysis

Code	Description	Comment
0	Negligible risk	Energy cannot cause any significant injury
1	Acceptable risk, no safety measured required	Energy can cause injury, but barriers are adequate
2	Safety measure recommended	Barriers should be improved
3	Safety measure essential	Serious consequences and inadequate barriers

5. Propose safety measures

At the next stages, a study is made of the energies for which safety measures are requires. Questions are raised concerning whether and how risks can be reduced? Can safety devices be installed? At beginning, it is a matte r of generating and sifting through ideas. Then the most suitable solutions can be selected.

6. Conclusion

The analysis is concluded by preparing a report, which summarises the analysis and its results. It might contain descriptions of the limits and assump tions of the analysis.

3.2 FLOW CHART

3.2.1 Final Year Project 1

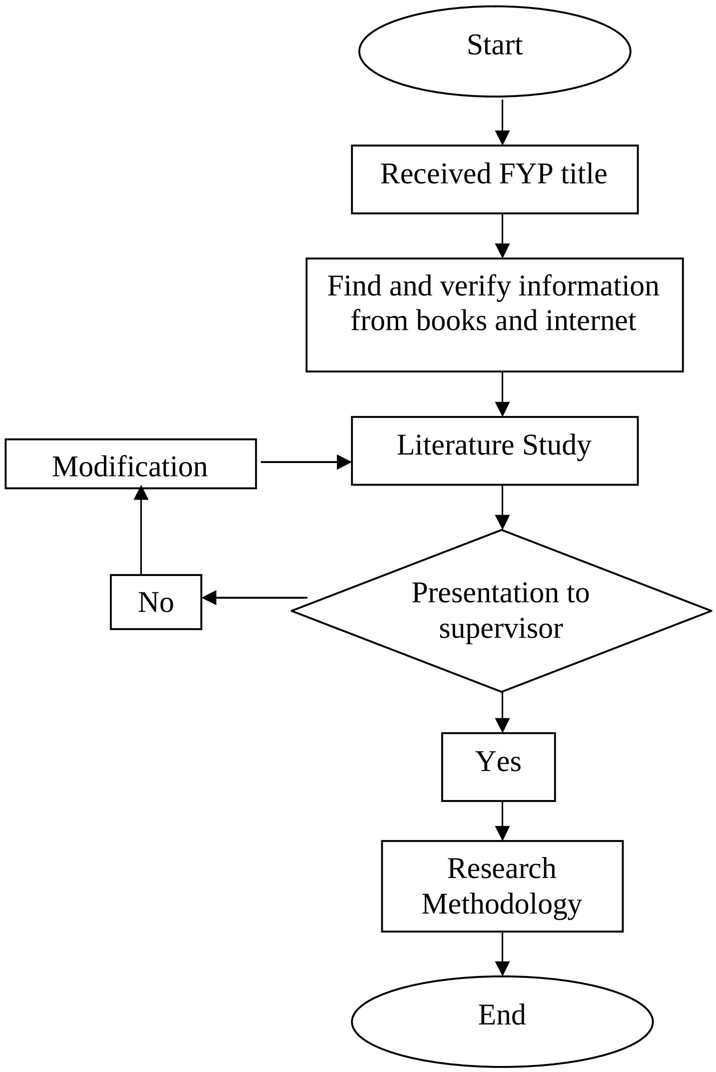

Figure 3.2: Flow chart for FYP I

3.2.2 Final Year Project 2

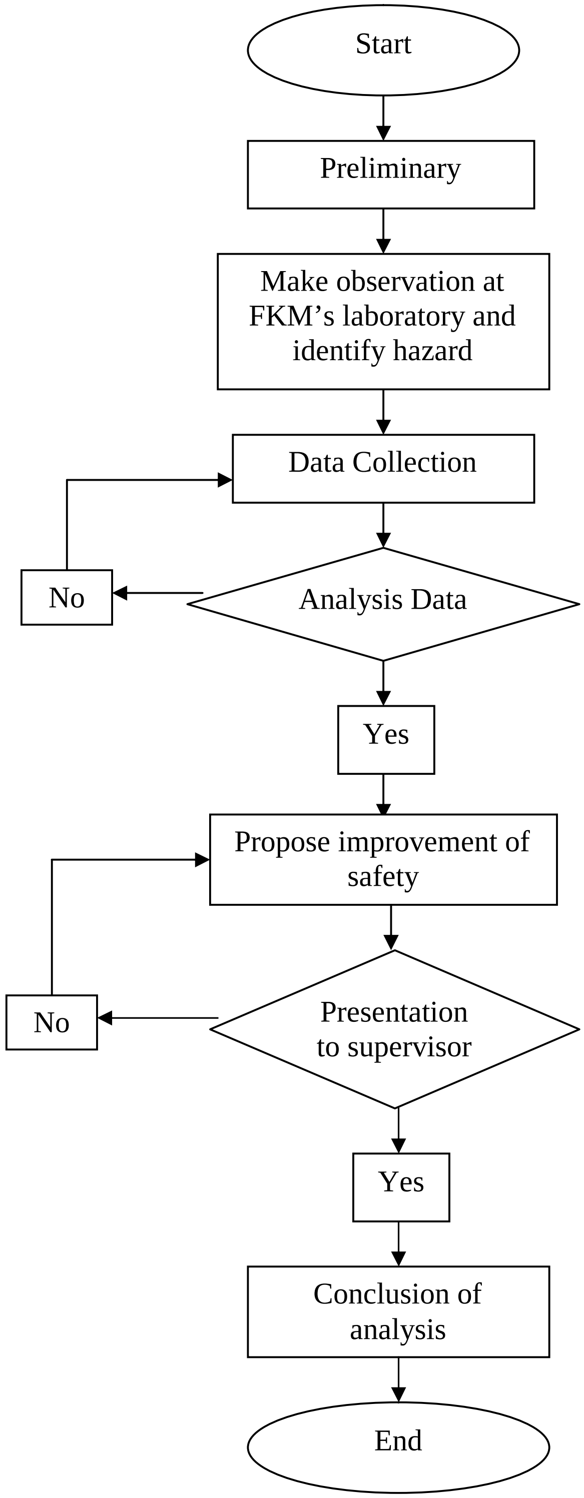

Figure 3.3: Flow chart for FYP 2

3.3 FLOW CHART EXPLAINATION

Methodology is an important element in a project where it specifically describes the method to be used in the project. It is also can be a guideline to ensure we are following the project flow that we have planned at the beginning. Methodology also will help in order to make sure that the research run smoothly until we get the result and achieve the project objective. Here is the flow of project procedures from both of flow chart that have been taken to achieve the project objectives. The activities are listed below:

(i) After receiving the project title, see supervisor to discuss details about the project title including scope and objectives. It is important to understand them clearly. Besides that, set the time with supervisor to meet for follow-up the project progress. It is important to lecturer guide the progress work each students and will discuss more about the project

(ii) Get and finding information which related with title and studies the information to give a clear understand on the project itself. The information gain from read book, surfing the internet, discussion with supervisor and get explanation from JP. All information is useful for the project.

(iii) Understand what safety analysis all about. A systematic procedure for analysing systems to identify and evaluate hazard and safety characteristic. Understand how to conduct safety analysis at FKM's laboratory by using energy analysis method.

(iv) First of all obtain information about the installation that being considered. This is definition of limits of the study object which may be only a single machine, some section or whole factory. Then, dividing the system into suitable parts to be analyzed one at a time. Third step is identifying source and stores of energy for each part.

After that, in the assessment, identifying the presence and efficiency of barriers is essential. They will affect seriousness and likehood of injuries. Next, questions are raised concerning whether and how risk can be reduced. It is good to be able to suggest a variety of solution, since it is not certain that the first will be the most effective. Then, the most suitable solutions can be selected. Last but not list, summaries the analysis and the result.

3.4 DATA COLLECTION

All the information regarding to the installation place to analyse gained by observation and interview. This study focus on area FKM 3A. This area consists of 18 conventional lathe machines and 18 vertical milling machines.

3.4.1 Survey (questionnaire)

Survey had been done in order to collect the data and gain additional information and opinion from users. The questionnaire which is consist 11 questions are given randomly to the 50 respondents. In this case, the targeted respondents are mechanical engineering student from various batches and course. The important of this surveys is to find out and identify hazard occur in FKM laboratory especially laboratory FKM 3A. The questions in this survey are selected from Delaware safety program [9]. This safety program conducted by insurance commissioner of the state Delaware, US since year 1989.

3.4.2 Observation

The observation has been done to this workplace area (General Machine, FKM 3A). The task is to observe the user's safety precautions and hazard could obtain while conducting the conventional lathe machine and vertical milling machines. This activity is conducted almost without user awareness whiles their conducting the machine. This is because to make sure the authentic of the data. There are few pictures have been taking while the observation at the workplace.

3.4.3 Interview

The interview has been conducted in the workplace during the user conducting the machine. The randomly interview has been conducted to elicit information from the user of the machine abo ut their awareness on safety precaution while conducting the conventional lathe machine and milling machines in this General Machine laboratory, FKM 3A. The questions guided from reference Occupational Safety and Health Association (OSHA) standards 1910.21 1-2.19. This checklist is actually intended to assist supervisors and workers to determine if machinery and machine guarding are required, if such protection readily available and is it properly used. The lists of questions are presented on appendix A1. The questions approach was suited to the research and analysis purpose in that it is useful in ensuring to collect the data and enabled the identification of hazard occur. The interview was conducted after observation taken place.

3.5 ANALYSIS PROCEDURE

3.5.1 Preparation

Safety analysis by using energy analysis method will be conducted on area FKM 3A at FKM's laboratory. This area consists of 18 conventional lathe machine and 18 milling machines. The systematic procedures are:

3.5.2 Structure

The area will be divided into two volumes which are volumes for conventional lathe machine and two volumes for milling machines:

3.5.2.1 Conventional lathe machine

i. Conventional lathe machine (former)
   - consist 8 machines

Figure 3.4: Conventional Lathe Machine (formal)

ii. Conventional lathe machine (new)
   - consist 10 machines

Figure 3.5: Conventional Lathe Machine (new)

3.5.2.2. Milling machine

i. Milling machine (former)
   - consist 8 machines

Figure 3.6: Milling Machine (formal)

ii. Milling machine (new)
   - consist 10 machines

Figure 3.7: Milling Machine (new**)**

3.5.3 Identify energies

Identify stores and sources of energy that can cause harm or hazard for each volume. For most categories, the link between energy and injury i s obvious. Table 3.2 show the checklist of different types of energies.

Table 3.2: Checklist for Energy Analysis

1. POTENTIAL ENERGY Person at a high Object at a high Collapsing structure Handling, lifting 2. KINETIC ENERGY Moving machine part Flying object, spray, etc. Handled material Vehicle 3. ROTATIONAL MOVEMENT Machine part Power transmission Roller/cylinder 4. STORED PRESSURE Gas Steam Liquid Pressure different Coiled spring Material under tension 5. ELECTRIC Voltage Condenser Battery Current (inductive storage and heating Magnetic field	6. HEAT & COLD Hot or cold object Liquid or molten substance Steam or gas Chemical reaction Condensed gas (cooled) 7. FIRE & EXPLOSION Flammable substance Explosive: - material -steam or gas - dust Chemical reaction, e.g: -exothermic combinations - impurities 8. CHEMICAL INFLUENCE Poisonous Corrosive Asphyxiating Contagious 9. RADIATION Acoustic Electromagnetic Light, incl. infra and ultra Ionized 10. MISCELLANEOUS Human movement Static load on an operator Sharp edges Danger point, e.g. between rotation rollers Enclosed space

3.5.4 Assess risk

By using direct risk acceptance scale applied in Energy Analysis from table 3.1, assess and record the sources of energy that have been identify before.

Table 3.3: Record sheet from energy analysis

Volume	Energy	Hazard / Comments	Evaluation
i. Conventional lathe machine (former) & Conventional lathe machine (new)			
ii. Horizontal milling machine (former) & Horizontal milling machine (new)			

3.5.5 Propose safety measures

Grouping the identify hazard into more general category to investigate conceiving safety measures.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 INTRODUCTION

This chapter will discuss the results and discussion of the study that have been done at faculty of mechanical engineering (FKM) University Malaysia Pahang. These results are based on the questionnaire, observation and interview to identify and analyze hazard occur during the staff and student conducting the machines in workplace FKM 3A by using energy analysis method.

4.2 SURVEY ANALYSIS

A survey consists of eleven questions had been done in order to gather information from users. In this case, the targeted respondent is 50 mechanical students from various course and batch. The important of this surveys is to find out and identify hazard occur in FKM laboratory especially laboratory FKM 3A. The questions in this survey are selected from Delaware safety program [9]. This safety program conducted by insurance commissioner of the state Delaware, US since year 1989. The questionnaire question that has been conducted is in appendix A2.

4.2.1 Question 1

This question asks whether the respondent ever had an injury during conducting milling or lathe machine. This is to identify the kind of injury that the respondent ever had. From the answer, the hazard occurs can be determined.

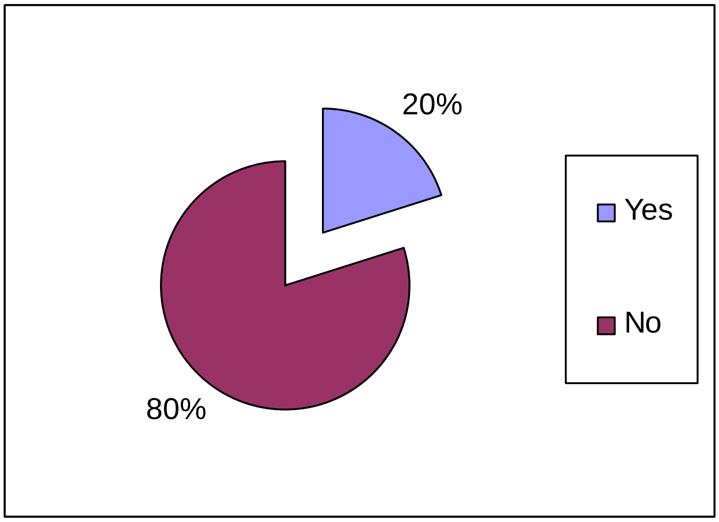

Figure 4.1: Pie Chart 1

The pie chart above show that 80% of the respondent says no and another 20% say yes. Majority of the respondent say they never had an injury during conducting the milling and lathe machine. But another 20% respondents say they ever had injury during conducting the milling and lathe machine. The kind of injury that the respondents ever had are minor injury such as wounded on their hand because of the sharp corner of the work piece and the flying chips to their face.

4.2.2 Question 2

Second question asks there are any false floors or platforms used to provide dry standing and walking surfaces at FKM 3A (lab milling and lathe machine). This is to know how much safety precaution that the FKM laboratory management has done to avoid hazard.

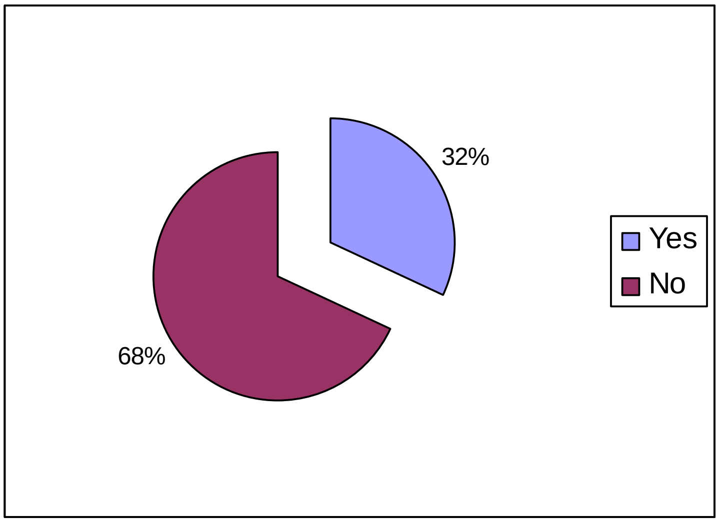

Figure 4.2: Pie Chart 2

The pie chart above shows that 68% of the respondents say there are no false floors or platforms used to provide dry standing and walking surface at l aboratory FKM 3A and another 32% of the respondents say yes. The finding shows that the floor at laboratory FKM 3A have no false floor or proper floor are provided from this survey. Without proper floor in this laboratory, the floor will become slippery and could incur the hazard and injury to the users. The FKM laboratory management should not take this problem easily.

4.3.3 Question 3

Third question asks whether the respondent wear any personal protective equipment (PPE) while conducting the milling and lathe machine. This question is to know what PPE that the respondent wears most during laboratory. This is important to prove whether the respondents are in enough protection of safety or not.

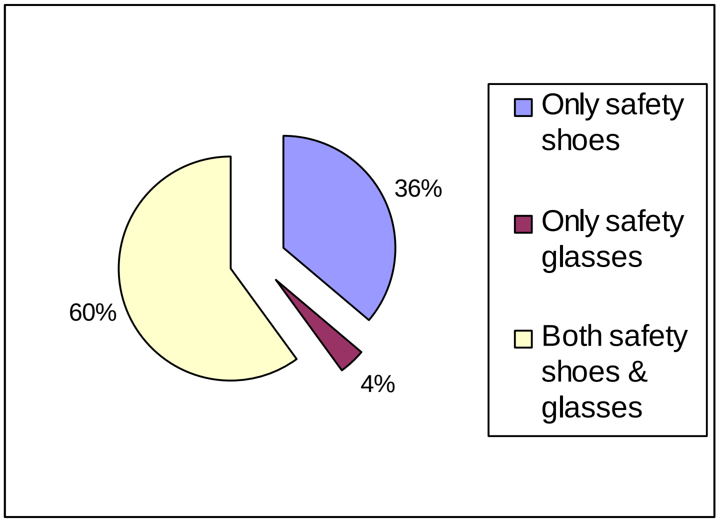

Figure 4.3: Pie Chart 3

As shown above, amounts of the respondent wear both safety shoes and safety glasses during conducting or operating the milling and lathe machine at FKM 3A are 60%. 36% of the respondents only wear safety shoes and another 4% wear only safety glasses. Other personal protective equip ment (PPE) such as safety helmet is not necessary to wear while conducting the milling and lathe machine. Majority of the respondent do not have a problem to follow the safety precaution to conduct milling and lathe machine. This 36% of the respondents who only safety shoe and 4% who only safety glass will incur the hazard to themselves and other persons in the laboratory. This finding shows that the behaviors of the user are not discipline enough to follow the safety precaution.

4.2.4 Question 4

This question asks did the respondents have been enforcing to use the personal protective equipment (PPE) in FKM laboratory. The question is to know what PPE that the management of FKM laboratory enforces the respondent to wear during conduct the machine.

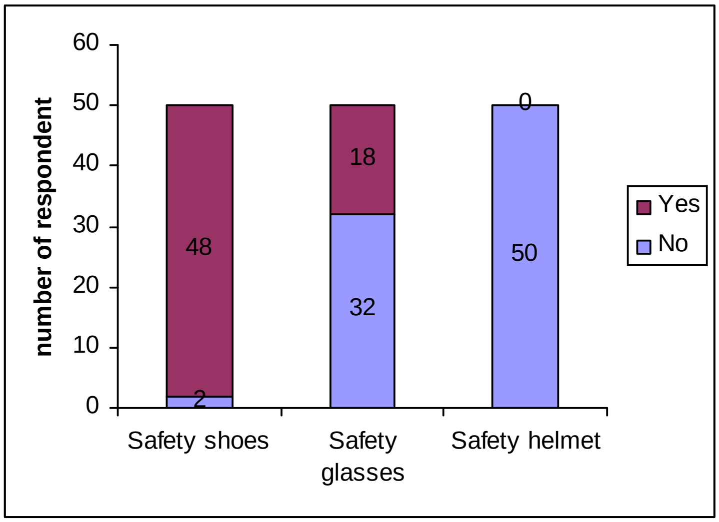

Figure 4.4: Histogram 4

As shown in the graph above, 48 respondents say they had been enforced to wear safety shoe and 18 say they had been enforced to wear safety glass while conducting the machine at FKM 3A. Only 2 respondents say they not be enforced to wear safety shoes and 32 say not be enforced to wear safety glass. This question obviously shows that the users are not being enforced to wear safety helmet in FKM laboratory. Majority of the respondent do not have problem to follow the safety regulation to wear the safety shoes during conducting the laboratory. Only few persons of respondent refuse to follow the regulation because of themselves attitude and lack awareness. Regarding to the responses on safety glasses, respondents are not seriously being enforce by FKM laboratory management to wear safety glasses while conducting the machine.

4.2.5 Question 5

Questions five asks the respondent whether safety glasses are provided by FKM laboratory or not. The important of this finding is to know whether the respondents are care about this PPE and whether FKM laboratory management is seriously care about the safety while conducting the machine.

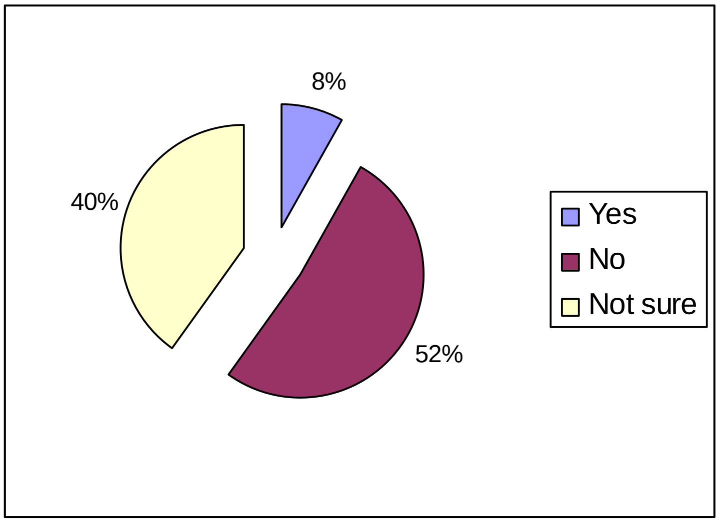

Figure 4.5: Pie Chart 5

The pie chart above show that 52% which majority of the respondents say the FKM laboratory are not provide safety glasses. Another 40% say not sure and 8% say FKM laboratory provided safety glasses to them. The respondents who say not sure might because of they did not wear the safety glasses or they have their own safety glasses while they conducting the machine.

4.2.6 Question 6

The question asks does the respondent personal protective equipment (PPE) are meet or exceed the ANSI/ OSHA standard. This finding is to know the safety of using the PPE is in order the standard.

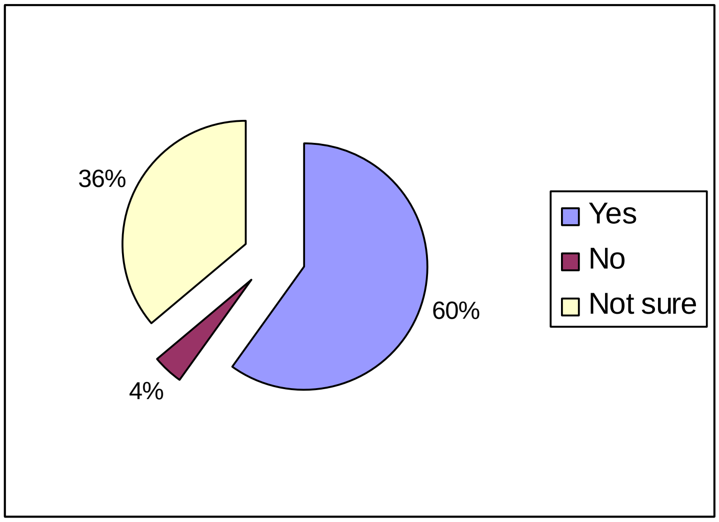

Figure 4.6: Pie Chart 6

From the pie chart above, majority of the respondents (60%) are confident with their PPE are exceed the ANSI or OSHA standard. 36% of the respondent are not sure with their PPE condition and only 4% say their PPE condition are not exceed with the standard. The finding can shows there are still many users are not enough information about the PPE standard for safety.

4.2.7 Question 7

This question ask the respondent own awareness on safety precaution when conducting the milling / lathe machine. The finding is to know how much the respondent's safety awareness on their self.

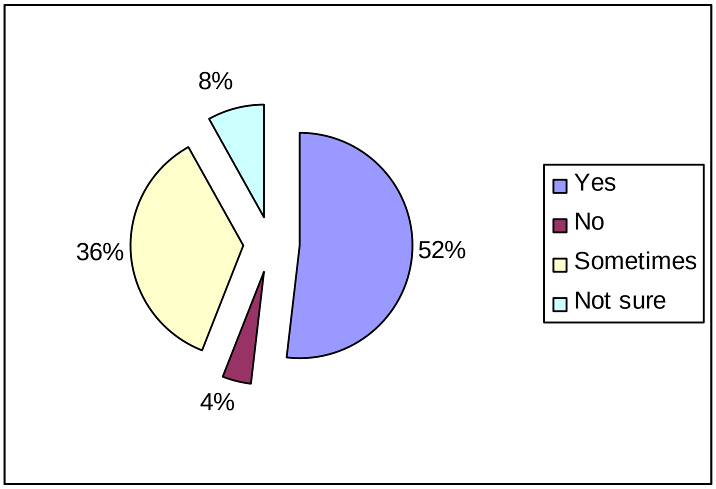

Figure 4.7: Pie Chart 7

As seen in pie chart above, majority of the respondents (52%) have their own awareness on safety while conducting the machi ne. But 36% of the respondents say sometimes they have their own awareness and 8% respondents say not sure about their awareness on safety. 4% of the respondents admit that they have no awareness on safety precaution during conducting the machine. Therefor e, the percentage of user have awareness must be increase to 100% to have safety environment at FKM laboratory.

4.2.8 Question 8

The question asks how many people usually operate or conducting one machine at one time. This is to know whether this situation is possible to produce hazard.

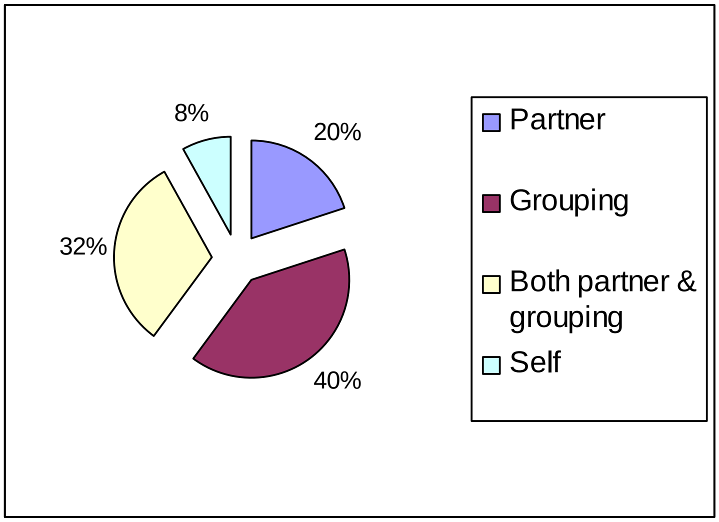

Figure 4.8: Pie Chart 8

As shown above, 40% of the respondents usually operates or conducting the machine by grouping. Majority the grouping consist 3 to 4 persons per machine. 32% respondents say they conduct the machine sometimes with their partner and sometimes by grouping. Another 20% say that they conducting the machine by partner only and 8% only by self. The percentage of this survey maybe depends on what purpose the respondent have to conduct the machin e.

4.2.9 Question 9

Question 9 asks do the respondents are practice consistent good housekeeping after use the machine. This is to know how much respondent awareness on housekeeping after using the machine to avoid hazard.

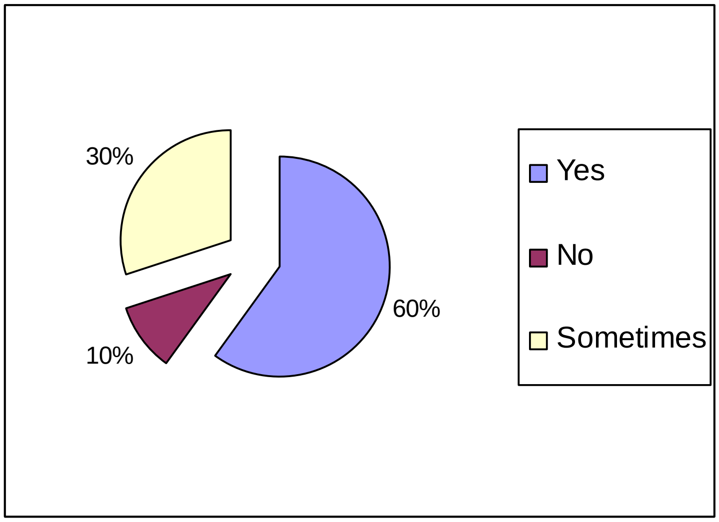

Figure 4.9: Pie Chart 9

As shown in pie chart above, 60% of the respondents are practice consistent good housekeeping after use the machines. 30% response only sometimes they are practice housekeeping and 10% respondents never practice good housekeeping at FKM laboratory. Therefore the finding shows that there are still many users are not practicing good housekeeping at laboratory to keep laboratory neat and tidy. If the laboratory is messy, it will incur the hazard.

4.2.10 Question 10

Question number 10 asks whether the lecturer, lab instructor or JP (Jurutera Pengajar) supervised during the respondent operating the machine. This is to know how much the FKM laboratory management care to control hazard.

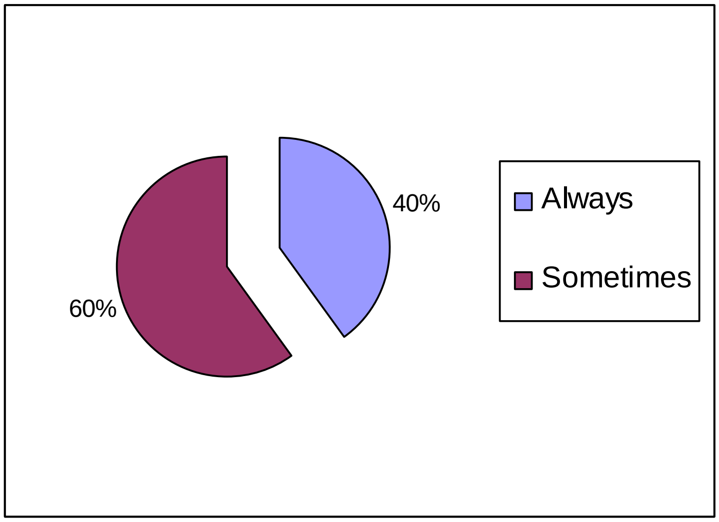

Figure 4.10: Pie Chart 10

The pie chart above shows that 60% of the respondents say the lecturer or JP (Jurutera Pengajar) is sometimes supervised the user conducting the machine. Another 40% respondents say the JP always supervised them during conducting the machine. Therefore, the finding shows that the JP is not around all the time during the user conducting the machine.

4.2.11 Question 11

This question asks opinions from respondent about their suggestion or recommendation on how to improve safety at FKM laboratory. From all suggestion and recommendation that the respondents give, what and how hazard occur will be identify.

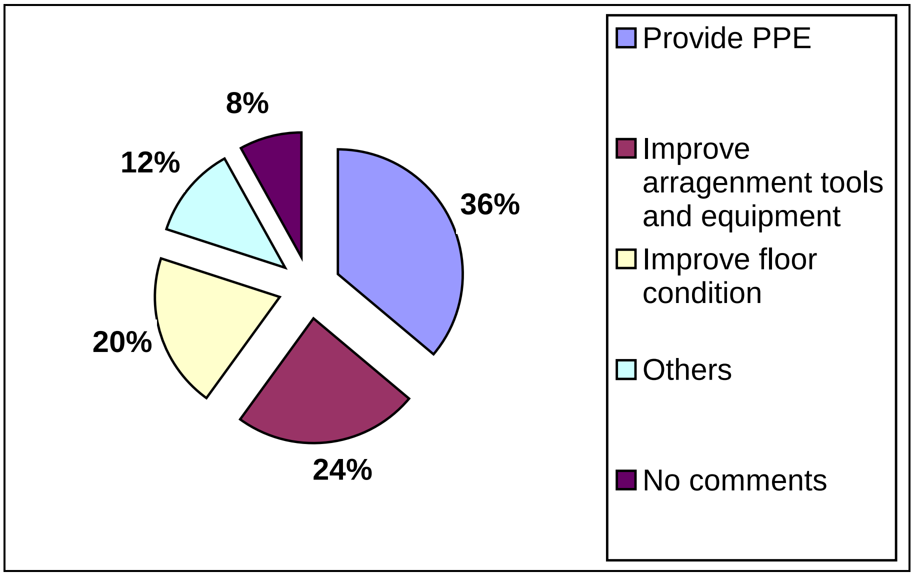

Figure 4.11: Pie Chart 11

The pie chart shows 36% of the respondents suggest the FKM laboratory management should provide the personal protective e quipment (PPE) to the user. Another 24% suggest to improve arrangement of the tools and equipment at FKM 3A, 20 % suggest to improve floor condition and others suggestions are 12%. Majority of the respondents suggest the PPE should be provided are safety g lasses. The respondents who are suggest improving the arrangement of the tools and equipment complain that their difficult to find the needed tools to operates the machine. Proper arrangement of this tools and equipment also will make the laboratory neat and tidy and hazard occurs could be avoided. The respondent complain that the floor at FKM 3A are very slippery because of lubricant and coolant. The floor condition also should be improved regarding the standard of OSHA to avoid the hazard and injury to th e user. Other suggestion are the laboratory instructor or JP (Jurutera Pengajar) must always supervised the user when their conducting the machine. If the JP always in the laboratory, it is easy to the user to get help when they needed. The respondents als o suggest that the JP should be more friendly and kind to make the user comfortable during the job. Below are the examples of others suggestion.

1. *Improve the facilities at the FKM 3A*
2. *Put lab instructor.*
3. *Provide the machine that did not give any bad effect to the user.*
4. *JP should give more guidance and supervise students.*
5. *JP needs to be more kind and help student.*
6. *JP should supervise student and be friendly.*
7. *JP should help and be friendly to students.*
8. *Put more awareness on student.*
9. *The arrangement of the mac hine is to narrow.*
10. *Keep more practice to operate the machine to avoid the injury.*

4.3 OBSERVATION

The observation has been done to this workplace area (General Machine lab, FKM 3A). The task is to observe the user's safety precautions and hazard could obtain while conducting the conventional lathe machine and milling machines. The job observation has been repeated as often as necessary until all hazard can be identify. To determine the hazards that exist or that might occur, this kind of question has been ask as guide to observe the user conducting the machines in workplace area (General Machine lab, FKM 3A) [10].

1. Is the worker wearing personal pr otective clothing and equipment that are appropriate for the job?

2. Is the worker wearing clothing or jewel ry that could get caught in the machinery or otherwise cause a hazard?

3. Are there fixed objects that may cause injury, such as sharp machine edges?

4. Can the worker get caught in or between machine parts?

5. Can the worker be injured by reaching over moving machine ry parts or materials?

6. Is the worker positioned to the machine in a way that is potentially dangerous?

7. Is the worker required to make movements that could lead to or cause hand or foot injuries, or strain from lifting – the hazards of repetitive motions?

8. Can the worker be injured from lifting or pulling objects, or from carrying heavy objects?

4.3.1 Conventional lathe machine

Figure 4.12: Conventional lathe machine (former)

Figure 4.13: Conventional lathe machine (new)

4.3.1.1 Potential Energy

Potential energy occur at this machine are slippery floor and object at high. From this potential energy that has been observed, hazardous energy occurs during conducting this machine. First potential energy obtains from observation is slippery floor and the hazard occurs is the students slippery and falling down. The slippery floor cause by coolant or lubricant from the lathe machine flooded on the floor. This is because the flow rate of the coolant or lubricant that being use to cold the moving parts (workpiece and cutting tool) during running machine is incompatible. Second potential energy obtain is object at high. The hazard occurs from this potential energy is the object will fall or collapse. Majority of the users put the tools, personal things, or workpiece on the top of the head stock. Consequence from this action, the object may fall or collapse to the operators feet. Another consequence is the object that fall on the floor may damage.

4.3.1.2 Kinetic Energy

Kinetic energy occur at this machine are moving machine part and flying object. From the observation, the kinetic energy occurs during operating this machine cause hazard to the operator or the user. Firstly, the kinetic energy which lead to hazard obtains from the observation is moving machine part. The moving m achine parts regarding to lathe machine are the cutting tool and the work piece. The contact with the moving cutting tool while operating the lathe machine cause hazardous energy. The tool such as key leave in the chuck or unsecured work piece can also strike nearby operators. The other kinetic energy obtain from the observation is flying object. The flying chips and coolant also present hazard to the operator.

4.3.1.3 Rotational Movement

The rotational movement energy obtains from the observation to this lathe machine at FKM 3A laboratory is rotating spindle. The operator can be pulled into lathe from working too close to the machine. The observation also found that the students who wear loose wear and accessory such as bracelet incur hazard.

4.3.1.4 Heat and Cold

Temperature is also one of the energy that will cause hazard during conducting the lathe machine. Regarding to the observation in FKM 3A lab, the temperature of the cutting tool and work piece can be identify as energy. The hazard incur is when the student or the operator of the machine need to change cutting tool and work piece for the next process of their job immediately right after finish the current process. The injury occur especially on their hand.

4.3.1.5 Miscellaneous

The others energy that would lead the operator to the hazard while conducting the lathe machine in FKM 3A laboratory. There are human movement and sharp edge. Basically from the observation, the number of student conducting one lathe machine is two to three persons. So the tendency of the stud ents to collide each other is high. Then the student exposed to collapse or fall on the floor or sharp edge of the lathe machine.

4.3.2 Milling machine

Figure 4.14: Milling machine (former)

Figure 4.15: Milling machine (new)

4.3.2.1 Potential Energy

The observation that has been done at FKM 3A laboratory found the potential energy that occur is when handling and lifting the work piece during operating the milling machine. The hazard occur when the student moving to change and clamping the heavy work piece. Handling and lifting the work piece weight more than 5 kg will cause hazard such as the work piece fall down or collapse to operator's feet or floor. The work piece also could damage. The work piece could slip off from the operator's grip because of the oily condition consequence from the coolant and lubricant used during machining process. The clamp on the milling machine itself is heavy to move and setting up before the machining start. Besides that, the slippery floor could be the potential energy to this milling machine. During the observation, the floor flooded cause by the coolant or lubricant splashing out while machining process that has been done by the students. The slippery floor could lead the students slip and fall down in the FKM 3A laboratory.

4.3.2.2 Kinetic Energy

From the observation that has been done at FKM 3A laboratory, the kinetic energy occurs at milling machine are moving machine part and flying object. One of the flying objects occur is the lubricant or cutting oil. T he splashing of the cutting oil will cause hazardous energy to operator's eye and face. Another flying object is flying chips. It is also incur hazardous energy to operator's eye and face. In the other hand, the moving machine part that will lead to hazard ous energy is the milling machine table. This is because the table will move during the process of machining. Other student who standing near the machine and not alert with the movement of the milling that conducted by the operator could collide by the tab le and cause injury.

4.3.2.3 Rotational Movement

The rotational movement energy that would lead this milling machine causing hazard is the spinning of the cutting tools. The hazard occur when the student contact with the revolving cutter. The work piece also mig ht spin and strike the student if the work piece is not clamp properly. The spinning cutting tool could incur hazard when the students not tightening the cutting tool to the machine properly. Consequence from this hazard, the students might injured on thei r skin and body if the accident happen.

4.3.2.4 Heat and Cold

During the observation, the heat energy occurs on the work piece and cutting tool right after the machining process stopped. The students or operator lead hazard when touching the machining part on the work piece or to remove the work piece and cutting tool. It might cause injury to the operator's hand.

4.3.2.5 Miscellaneous

The miscellaneous injury that occurs during observation is human movement energy. Majority of the students that has been observe conduct the milling machine in a group consist of three to four persons for each milling machine. This situation will affect the area of the machine. The area for each machine becomes narrow. The hazard occurs such as operator might be pulling into milling machin e by collide with other operator in their group.

4.3.3 Observation picture

Figure 4.16 **Figure 4.17**

Figure 4.18

Figure 4.19

Figure 4.20

Figure 4.21

Figure 4.22

Figure 4.23

Figure 4.24 **Figure 4. 25**

Figure 4.26 **Figure 4.27**

Figure 4.28 **Figure 4.29**

4.4 INTERVIEW

The interview has been conducted in the workplace during the user conducting the machine. The randomly interview has been conducted to elicit information from the student and laboratory instructor or JP (Jurutera Pengajar) about their awareness on safety precaution while conducting the conventional lathe machine and milling machines in this General Machine Laboratory, FKM 3A. Some of the questions are taken from reference Occupational Safety and Health Association (OSHA) standards 1910.211-2.19 as guidelines to interview the respondents [appendix A1].

Below are the of the interview questions.

1. Does FKM laboratory management have recorded any accident or injury happened during machining or others operations?

   The JP say there is no recorded data or documented report of any accident or injury.

2. The observation and survey found that the floor in FKM 3A laboratory are very slippery during the coolant and cutting oil splashing to the floor. Why this happened? It is there any solution that FKM laboratory management done to solve problem?

   The respondent says that the floor in the laboratory FKM 3A is actually only coating with the epoxy which is painted by green color. This floor is only for lighting purpose. The floor coating was not made to avoid slippery. The cost to coat the floor with suitable coating is expensive.

3. Why the user do not wear the safety glass during operating the machine whereas they have the safety glass.

Majority of the respondent says that they feel uncomfortable if wearing the safety glass. They also said that they cannot see clearly when wear the safety glass. It is because the sweating make them cannot see clearly the machining process. Other reason why they unlik e to wear the safety glass is no strict enforcement from the JP require them to wear all the time during machining process. They only wear the safety glass when the JP coming to them. Otherwise they prefer to not wear the safety glass. Some of the students say they feel embracing to wear the safety class.

4. Why the students do not report the injury to the JP or lecturer when the accident happen even though minor injury. (this documented data is very important for the future to analysis data and to make im provement on control and reduce the hazard or injury)

   The respondent says that no need to report because only small matter and they can overcome this problem by self. They also said that they scared to make report because the JP will mad and blame them i f the accident occurs cause by the students themselves. Some of them feel guilty when the accident causes damage to the machine or the work piece. Other reasons is the students worry to paid replacement to damage that they have done.

4.5 PROPOSE SAFETY EVALUA TION

4.5.1 Volume of conventional lathe machine

Table 4.1: Evaluation and proposed measure for conventional lathe machine

Energy	Hazard / Comments	Evalu ation	Proposed measures
Potential energy 1. Slippery floor cause by	➢ Students slip/ fall during operating	3	-Eliminate energy by coating floor with suitable standard floor

coolant & lubricant flood) 2. Object at high (tools and things on the top head stock)	the machine. ➢ The object fall on feet ➢ Object fall and damage	1	-use PPE (safety shoe) -Eliminate energy by put all the things on the table beside the machines
Kinetic energy 1. Moving part – contact with cutting tool & work piece 2. Flying object - flying chips and coolant	➢ Injury to operator's body ➢ May cause injured to eye and face.	2 2	-Prevent the bulid- up extreme magnitude energy by not touch the workpiece & cutting tool while its moving. -Restric and control the magnitude of energy by reduce speed -PPE safety glass & shoe
Rotational movement 1. Spindle	➢ Pulled into lathe machine – wear loose clothe or accessory such bracelet.	2	-Restrict the magnitude of energy by reduce speed to suitable require speed for the material to machines -Protection of the object by wear PPE
Heat & cold Change cutting tool and work piece for the next process of their job immediately right after finish the current process	➢ Operator's hand may injured. (the tools and work piece still hot)	1	-Separate the object from energy flow by time. -Wait until the object cold to touch.

Miscellaneous a. Human movement (too many student opearates the machine in one time)	➢ Student collide and fall to the sharp edge of the machine	2	Separate the object from energy flow by reduce the number of user per machine Safety protection on energy source-machine safe guard

4.5.2 Volume of milling machine

Table 4.2: Evaluation and proposed measure for milling machine

Energy	Hazard / Comments	Evaluation	Proposed measures
Potential energy 1. Handling and lifting (work piece weight more than 5 kg)	➢ Object fall and damage	2	-Restrict the magnitude of the energy by lighter object to be handled -Safer alternative solution by using lift to handle the object
2. Slippery floor	➢ Students slip/ fall during operating the machine.	3	-Eliminate energy by coating floor with suitable standard floor -use PPE (safety shoe)
Kinetic energy 1. Flying object (cutting oil & chips)	➢ May cause injured to eye and face	2	-Restrict the magnitude of energy by reduce speed -Protection of the object using PPE
2. Moving machine part (table)	➢ Injury to operator's body	1	-Prevent build-up magnitude of energy by control the equipment

Rotating movement 1. Spinning cutting tools.	➢ Injury to operator's hand, skin and body	2	-Restrict the magnitude of the energy by reduce to suitable require speed for the material to machines -Protection of the object by wear PPE
Heat and cold energy 1. Temperature of work piece 2. Temperature of cutting tool	➢ Injury to operator's hand	1	-Separate the object from energy flow by time. -Wait until the object cold to touch.
Miscellaneous 1. Human movement energy **(**too many persons using one machine at one time)	➢ Might be pulling into milling machine ➢ Collide between each other (group members) ➢ Fall	2	-Separate the object from energy flow by reduce the number of user per machine -Safety protection on energy source-machine safe guard

From the table, the evaluation of the hazard is following the table of a direct risk acceptance scale applied in energy analysis. Instead, a judgment can be made on whether the system (or present situation) is acceptable as it is, or whether it needs to be improved. In this case study, the judgment has been made by observation. The evaluation code zero can be defined as negligible risk and the energy cannot cause any signifi cant injury. From the observation that has been done to FKM 3A laboratory, there is energy that can be evaluated as zero such as electric energy. The code of one means the risk occurs can be acceptable, but no safety measure required. The energy for code o ne can cause injury but barriers are adequate. For the code two is safety measure are recommended. The comment for this code is the barriers should be improved.

The code number three is safety measure is essential for this energy evaluation. This is because of the serious consequences and inadequate barriers.

Based on evaluation hazard that has been determined, the next stage is made to propose to reducing hazard. The safety measure proposed on the table 4.1 and table 4.2 are based on the energy hazard t hat has been identified during observation, questionnaire and interview. The safety measure proposed has been guided by finding safety measure using energy analysis (table 5.3) by Lars Harms-Ringdahl [2] as shown in appendix A3. There are some suggestion o n safety measure proposed such as wear safety shoes and safety glass that already been practical at FKM 3A laboratory but still not 100% successful. Therefore, the safety measure requires proposing again until it achieves the target.

4.6 PROPOSE IMPROVEMENT ON SAFETY

In order to have safety environment, l aboratory should have future aim & mission to have zero injury/accident. Based on survey, observation and interview that has been done at workplace area at FKM 3A, suggestion on improvement safety and to con trol hazard occur are divided to two responsible sides. First side is employers which mean FKM lab management and the other side is employees which mean the students or the user of the machines. To develop these safety obligations into contract of safety measure, a refinement process was carried out as looking for overall safety measure from this study. This is because the data collection found that to control and reduce hazard on the workplace, all factor must be consider such as ethics or psychology and t he managements besides the hazardous energies occur.

4.6.1 Employer safety obligation (FKM laboratory management)

(i) Provide personal protective equipment
(ii) Have visible safety documentation
(iii) Maintain a safe workplace
(iv) Conduct regular safety training with all student
(v) Supply proper work equipment

(vi) Investigate hazards and risks

(vii) Ensure that safety incident investigations do not focus on blame

(viii) Make sure that work demands do not compromise safety

(ix) Manage injured or ill student with compassion

(x) Discipline student who do not use personal protective equipment

(xi) Keeps work equipment functioning properly such as tools and floor conditions.

(xii) Ensure that safety documentation details safety procedures

(xiii) Conduct safety induction training with all new student

(xiv) Inform student about the injury management process

(xv) Regularly update safety documentation

(xvi) Encourage student to report hazards and risks

(xvii) Be familiar with the hazards and risks in the student's working environment

(xviii) Warning or strict action to student refuse to apply safety precaution such as evaluate their soft skill

(xix) Provide training in the safe use of work equipment

(xx) Erect barriers around hazards

(xxi) Provide safety signage that can be understood by everyone

(xxii) Encourage safety awareness amongst student

4.6.2 Employee safety obligations (Students)

(i) Use the personal protective equipment that is provided

(ii) Be familiar with safety documentation

(iii) Not take shortcuts when carrying out work processes

(iv) Maintain a clean, safe work environment

(v) Willingly participate in safety training

(vi) Use work equipment properly

(vii) Inform work teams of current hazards and risks

(viii) Ensure that work demands do not compromise safety

(ix) Report work equipment faults

(x) Follow safety rules

(xi) Make sure that work behavior does not compromise safety

(xii) Take responsibility for safety

(xiii) Report hazards, risks, incidents or near misses

(xiv) Co-operate with the injury management process

(xv) Become informed about new safety rules

(xvi) Care about the safety of co-workers

(xvii) Attend safety meetings

(xviii) Comply with procedures regarding hazards and risks

(xix) Co-operate with safety investigation teams

(xx) Not pressure co-workers to break safety rules

(xxi) Know how to respond in an emergency situation

(xxii) Encourage co-workers to work safely

CHAPTER 5

CONCLUSION AND RECOMMENDATIONS

5.1 CONCLUSION

This study is based on only one case study at workplace FKM's Laboratory (General Machine lab) Universiti Malaysia Pahang. It appeared that the safety analysis by using energy analysis method be useful in practical applications at workplace FKM's Laboratory (General Machine lab). This energy analysis method is a simple method and can be applied to the workplace. The method with a step-by-step procedure has been practically tested.

One reason for this is that it by using this energy method, all hazardous energy occurs during data collection can be identified. Therefore, the safety measure can be proposed to control and reduce hazard. One further argument is that all people involved in the case study easily understood the basic idea. The application of safety analysis has added to the quality of overall safety analysis of the system.

In the other hand, there is another factor which can incur hazard that has been identified along this study besides the energy factor which is the ethics or attitude. This problem can be overcome by psychological management that has been proposed. As overall, the safety conscious among students and lecturers while working can be increase and the situation which may cause harm can be avoided if all people are working together and co-operate to follow the rules and suggestion that was proposed.

5.2 RECOMMENDATION

Safety analysis by using energy analysis method is a simple and systematic method and suitable for obtaining a quick overview of existing hazards. From the study that has been done at workplace FKM's Laboratory (General Machine lab) clearly this method give the result and suggested improvements based on energy factor itself. Besides energy method, there are many more methods that can be use to analysis safety such as job safety analysis, deviation analysis, and etc. The different methods use to analyze safety will give different results and suggested improvements. For further recommendation, other method should be use to see whether it is suitable or not to analyze safety at the FKM laboratory as sc ope. This is because a single method should not be expected to handle all type hazards or safety problems occur at the workplace.

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APPENDIX A

Checklist of questions to survey for machine guarding problems from Referen ce OSHA Standards 1910.211-2.19

The following checklist is intended to assist supervisors and/or workers to de termine if machinery and machine guarding are required, if such protection readily available and is it properly used. Any no answers should cause the supervisor/worker to initiate corrective action. Reference OSHA Standards 1910.211-2.19.

A checklist of questions to survey for machine guarding problems should be tailored to each shop operation. Some of the items may include:

General Requirements	Yes	No
Electrical Power/Controls		
Is each machine equipped with a master switch which can be locked and tagged during repair or maintenance operations?	☐	☐
Are power controls and operating controls located within easy reach of the operator at his/her regular work station?	☐	☐
Are controls brightly marked and easily identified allowing the operator to cut off power at the point of operation?	☐	☐
Is each machine provided with an appropriate electrical ground?	☐	☐
Is a trip device provided on machinery on which injury might result if motors were to inadver tently restart after power failures?	☐	☐
Are main "kill" switches centrally located, easily identified, and accessible to shop supervisors or co-workers for use in interrupting power in emergency situations?	☐	☐
Guarding		
Are appropriate guards provided to protect the operator and other employees from hazards such as exposed belts, pulleys, sheaves, drive shafts, drive couplings, chains, rotating parts, flying chips and sparks?	☐	☐
Are employees appropriately reprimanded if they are observed removing protective devices, or if they are observed operating any equipment with protective devices not in place?	☐	☐
Are combs, featherboards or suitable jigs provided for the use of operators performing work for which standards guards cannot be installed? (Examples: dadoing, grooving, jointing, moulding, and rabbeting.)	☐	☐
Personal Protective Equipment		
Is appropriate eye protection provided to, and its use required by, operators and helpers where the operation of the machine may produce flying objects or dust?	☐	☐
Is appropriate hearing protection provided to, and its use required by, operators and helpers, who must work around equipment which may emit noise levels described in OP-G-1.1.2.3?	☐	☐
Is the wearing of loose fitting clothing or neckties prohibited for employees who operate shop equipment?	☐	☐
Is the wearing of gloves, rings, neck chains and other hazardous jewelry prohibited of employees who operate or work on machines with working parts?	☐	☐
Are employees with long hair required to keep the hair restrained while working around machinery with moving parts?	☐	☐

If employees must work around operating machinery with a potential to produce kickbacks, are they provided with and required to wear heavy aprons?	☐	☐
Housekeeping		
Are appropriate brushes provided employees working at machines which produce slivers, sawdust, and other debris?	☐	☐
Are employees instructed to never clean their machines or the surrounding area with bare hands?	☐	☐
Are employees instructed to never clean their machines while they are operating?	☐	☐
Is compressed air allowed for cleaning ONLY where it can be reduced to 30 P.S.I.? Is such reduction enforced by the supervisor?	☐	☐
Is eye protection provided and its use required where compressed air is used for cleaning operations?	☐	☐
Are oily rags, waste, and other materials saturated with combustible substances disposed of in approved metal containers with self-closing lids?	☐	☐
Are such containers clearly marked for disposal of combustible materials and emptied on a daily basis?	☐	☐
Are local exhausts installed on machines which produce large amounts of dust, sawdust, or other fine debris?	☐	☐
Is a safety zone established and well marked around each machine?	☐	☐
Are machines spaced so as to allow adequate safety zones?	☐	☐
Lockout and Tagging		
Is each machine completely shut down and the control switch locked and tagged by the person performing maintenance, prior to any maintenance attempt?	☐	☐
Training		
Are only personnel thoroughly trained in the operation of a machine allowed to operate machinery?	☐	☐
Does the supervisor ensure that an employee is thoroughly trained in the safe operation of a machine prior to that employee's being allowed to operate it?	☐	☐
Are all manufacturer's operations manuals and diagrams on file in the shop and made available to employees responsible for operating any machines?	☐	☐
If manufacturer's literature is not available, has the supervisor written to the manufacturer to request such material?	☐	☐
Does the supervisor constantly observe shop practices to ensure that all safety regulations are being observed?	☐	☐
When unsafe acts are noted, does the supervisor ensure they are corrected and that they do not recur?	☐	☐
Has a safety procedure been written for each machine, kept by the shop supervisor and been made available to all operators?	☐	☐
Does the procedure include:		
• Clearing the operating area of obstructions?	☐	☐
• Designating the dimensions of a "safety" zone for	☐	☐

each machine in the shop?		
• Specifying the personal protection devices required during the operation of the machine or when assisting?	☐	☐
• Prohibition of the wearing of loose fitting clothing , long free-flowing hair, jewelry, neckties or other apparel which may increase the risk of accidents?	☐	☐
• Inspection of the machine prior to each start, such inspection to inclu de:		
• check of operating controls?	☐	☐
• check of safety devices?	☐	☐
• check of power drives, sharpness of cutting edges and other parts to be used?	☐	☐
• Are any deficiencies noted corrected prior to operating the equipment?	☐	☐
Machines used for both Wood -Working and Metal-Working		
Buffing and Wire Brushing Wheels		
Are operators provided with and required to use eye protection, in accordance with OP -G-1.1.2.3, during buffing operations?	☐	☐
Are goggles or face shields and leather gloves provided and their use required by employees operating wire brushing wheels?	☐	☐
Drill Presses		
Are all employees who may work with drill presses alert to the potential for injury by:		
• coming in contact with the drill bit?	☐	☐
• being struck by insecurely clamped materials being worked on?	☐	☐
• being struck by flying metal chips or wood shavings?	☐	☐
• leaving the key in the chuck?	☐	☐
• brushing shavings away with bare hands?	☐	☐
Is it required that all stock be properly secured to the press to prevent accidental movement during drilling?	☐	☐
Are operators prohibited from making measurements near the tool, reaching across th e table or adjusting the machine or stock while the machine is in motion?	☐	☐
Are operators and assistants provided and required to wear eye protection in accordance with OP -G-1.1.2.3 when operating, working or standing in close proximity of the	☐	☐

drill press while it is being operated?		
Are all power transmission parts effectively guarded?	☐	☐
Is a spring-safety guard provided to guard the drill bit and to catch metal slivers and wood chips?	☐	☐
Lathes		
Are operators and assistants provided with and required to wear eye protection in accordance with OP-G-1.1.2.3 when operating the lathe or when they are within close proximity of the lathe during operation?	☐	☐
Have operators been instructed to allow lathes to stop of their own accord? Are they aware of the dangers of using hand pressure to stop spinning chucks after power has been turned off?	☐	☐
Is each exposed power transmission part effectively guarded for complete operator protection?	☐	☐
Note: If a supervisor or operator has reason to believe that a machine may not be effectively guarded, Environmental Health and Safety should be consulted.		
Are operators instructed to avoid taking deep cuts when working with wood to avoid the cutting tool's being forcibly ejected?	☐	☐
Are operators prohibited from wearing loose clothing, long loose hair, or jewelry which may become tangled in the revolving parts of the machinery?	☐	☐
Are operators prohibited from measuring or calibrating while the lathe is in motion?	☐	☐
Are all cutting heads covered as completely as possible by metal hoods or shields?	☐	☐
Are guards designed in such a manner as to allow easy access to make adjustment to the stock or cutting head?	☐	☐
Where an exhaust system is used, does the metal guard form part or all of the exhaust hood?	☐	☐
Metal-Working Machines		
Milling Machines		
Are all operators thoroughly familiar with the leading cause of accidents with milling machines, and are they warned to avoid these situations, i.e.:		
• Failure to draw the job back to a safe distance when loading and unloading?	☐	☐
• Leaving the cutter to remove chips while the machine is in motion?	☐	☐
• Using incorrectly dressed cutters?	☐	☐
Is appropriate eye protection provided to operators, and is its use enforced, as provided in OP-G-1.1.2.3?	☐	☐
Are shims, blocks and clamps provided to hold stock in place?	☐	☐
Are operators instructed to make certain that such clamping devices are mounted low enough to clear the arbor and cutter?	☐	☐
Are operators instructed to lower the table prior to backing work under a revolving cutter?	☐	☐

Are adjustments to the speed of the machine, the rate of feed or coolant flow, or other function prohibited while the machine is in operation?	☐	☐
Are machine equipped with hand-adjusting wheels, mounted on the shaft by clutches or ratchet devices, so that the wheels do not revolve when the automatic feed is in use?	☐	☐
Do horizontal machines have a splash guard and pans for catching thrown cutting lubricant and lubricant running from the tools?	☐	☐
Is the placing of hand tools on the worktable prohibited at all times?	☐	☐
Are operators prohibited from reaching around cutters to remove metal chips or debris?	☐	☐
Are brushes provided and their use required for cleaning the machines?	☐	☐
Metal Shapers		
Are all operators familiar with the primary causes of injury in shaping operations, i.e.:		
• Placing the hand or fingers between the tool and the work?	☐	☐
• Running the bare hand over sharp metal edges?	☐	☐
• Measuring the job while the machine is running?	☐	☐
• Failing to clamp the work or tools prior to starting the cut?	☐	☐
Is eye protection provided and its use required, as provided in OP-G-1.1.2.3?	☐	☐
Do all mechanical presses containing full revolution clutches incorporate a single stroke device and an anti-repeat mechanism into the press system?	☐	☐
Is it required that pressure on hydraulic presses be bled off and switches locked out prior to maintenance being performed?	☐	☐
Do all point of operation guards protect the operator by one of the following methods (the answer to at least one of the four following must be "yes "):		
• Does the guard prevent or stop normal stroking of the press, if the operator's hands are inadvertently placed in the point of operation?	☐	☐
• Does the guard prevent the operator from inadvertently reaching into the point of operation?	☐	☐
• Are the controls designed so that the operator must use both hands to operate the press, and are the controls located at a safe distance from the point of operation?	☐	☐
• Must the point of operation be enclosed before a press stroke can be initiated?	☐	☐
Are hand tools provided and required to be used to free or	☐	☐

scrap pieces from the die? Are employees aware that this operation should never be done with bare hands?		
Has a regular inspection program been established and maintained to ensure that all parts, auxiliary equipment and safeguards are in good repair and properly adjusted?	☐	☐

The following Checklist is intended to assist the reader in determining the degree of compliance, within his/her operation, with the requirements of this procedure. Any "no" answer should be cause for concern and corrective action.

	Yes	No
Is electrical equipment free from recognized hazards which are likely to cause death or serious physical harm to employees?	☐	☐
Are any electrical circuits overloaded by the use of either an expansion device or extension cords?	☐	☐
Is each electrical circuit breaker or fuse clearly marked with the name(s) of the electrical appliance served by that breaker or fuse?	☐	☐
Are all extension cords used for portable equipment the three-wire type with three prong plugs?	☐	☐
Are the wire sizes of any extension cords capable of handling the load without heating?	☐	☐
Are all appliance cords and extension cords free of exposed wiring and splices?	☐	☐
Are any extension cords being used in lieu of a permanent installation?	☐	☐
Do any appliance or extension cords present a tripping hazard?	☐	☐
Are all appliances appropriately grounded?	☐	☐
Does all electrical equipment bear a UL or FM or other appropriate label?	☐	☐
Are all equipment cords free of signs of wear or splices?	☐	☐
Are all insulating covers free of cracks, holes or other signs of damage?	☐	☐
Is all electrical equipment sound, without visible damage, excessive heating, a "burning" smell?	☐	☐
Are all electrical wall outlets sound and free of cracks, breaks or other signs of damage?	☐	☐
Does any electrical equipment cause any degree of shock when touched?	☐	☐
Are any electrical cords bent, stretched or kinked?	☐	☐
Are only certified electricians allowed to repair electrical equipment?	☐	☐
Is all equipment which may arc, spark or flame kept separated and isolated from combustible material?	☐	☐
Is there sufficient clearance around electrical equipment for workers to move about freely?	☐	☐

APPENDIX B

QUESTIONNAIRE

1. Have you ever had an injury during conducting milling or lathe machine?

   Yes   No   If yes, please state kind of injury ____________

2. Are there any false floors or platforms used to provide dry standing & walking surfaces at FKM 3A (lab milling & lathe machine)?

   Yes   No

3. Did you wear any personal protective equipment (PPE) while conducting the milling & lathe machine? If yes please thick the equipment?

   Yes   No   ☐ Safety shoes   ☐ Safety Helmet

   ☐ Safety glasses   ☐ Other __________

4. Do you enforce the use of this protective equipment?

Safety shoes	Yes	No
Safety glasses (goggle)	Yes	No
Safety Helmet	Yes	No

5. Are safety glasses provided by FKM?

   Yes   No   Not sure

6. Does your own personal protective equipment (PPE) meet or exceed ANSI standards?

   Yes   No   Not sure

7. Do you have your own awareness on safety precaution when conducting the milling/lathe machine?

   Yes   No   Sometimes   Not sure

8. How you use or operate the machine? (you may thick more than one answer)

☐ by myself ☐ partner ☐ group which consist _____ persons

9. Do you practice consistent good housekeeping after use the milling/lathe machine?

| Yes | No | Sometimes |

10. Are the lecturer or JP (Jurutera Pengajar) supervised on the job?

| Always | Never | Sometimes |

11. Any suggestion/recommendation to improve safety at FKM 3A (lab milling & lathe machine)?

APPENDIX C

Safety measure	Examples
The energy	
1. Eliminate the energy	Work on the ground, instead of the height. Lower the conveyor belt to ground level. Remove hazardous chemicals.
2. Restrict the magnitude of the energy	Lighter the objects to be handled. Smaller containers for substances. Reduce speed.
3. Safer alternative solution	Less dangerous chemicals. Handling equipment for lifting. Equipment requiring less maintenance.
4. Prevent the build-up of a extreme magnitude of energy	Control equipment. Facilities for monitoring limit positions. Pressure relief valve.
5. Prevent the release of energy	Container of sufficient strength. Safety railings on elevated platforms.
6. Controlled reduction of energy	Safety valve. Bleed-off. Brake on rotating cylinders.
Separation	
7. Separate the object from the energy flow:	
a) in space	One-way traffic. Partition off dangerous areas.
b) in time	Schedule hazardous activities outside regular working hours.
8. Safety protection on the energy source	Machine safeguards. Electrical insulation. Heat insulation.
Protection of the object	
9. Personal protective equipment	Protective shoes, helmets.
10. Limit the consequences when accident occurs	Facilities for stopping the energy flow. Emergency stop. Emergency shower facilities. Specialized equipment for freeing a person (if stuck).

Table 5.3: Finding safety measure using Energy Analysis by Lars Harms-Ringdahl [2].

APPENDIX D

GANTT CHART FOR FINAL YEAR PROJECT 1

Subject \ Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Title confirmation															
Set Objective and scope															
Problem Statement															
Literature Review															
Research Methodology															
PSM 1 Report															
PSM 1 Presentation															

APPENDIX E

GANTT CHART FOR FINAL YEAR PROJECT 2

Subject \ Week	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Preparation															
Literature Review															
Survey															
Analysis data survey															
Observation															
Interview															
Analysis Data															
Propose improvement of safety															
PSM 2 Presentation															
PSM 2 Report															

APPENDICES F

Example of Questionnaire Answer from Respondent

APPENDICES G
Standard from OSHA

Personal Protective Equipment (PPE)

OSHA Standards

Personal protective equipment (PPE) is addressed in specific standards for the general industry, shipyard employment, marine terminals, and lonshoring. This page highlights OSHA standards, the Regulatory Agenda (a list of actions being taken with regard to OSHA standards), preambles to final rules (background to final rules), Federal Registers (rules, proposed rules, and notices), directives (instructions for compliance officers), and standard interpretations (official letters of interpretation of the standa rds) related to PPE. Information related to the construction industry is covered by a separate topic p age.
Section 5(a)(1) of the OSH Act, often referred to as the General Duty Clause, requires employers to "furnish to each of his employees employment and a place of employment which are free from recognized hazards that are causing or are likely to cause death or serious physical harm to his employees". Section 5(a)(2) requires employers to "comply with occupational safety and health standards promulgated under this Act".

> **Note:** Twenty-four states, Puerto Rico and the Virgin Islands have OSHA-approved State Plans and have adopted their own standards and enforcement policies. For the most part, these States adopt standards that are identical to Federal OSHA. However, some States have adopted diff erent standards applicable to this topic or may have different enforcement policies.

Highlighted Standards
General Industry (29 CFR 1910)

- 1910 Subpart G, Occupational health and environment control
  - 1910.94, Ventilation [related topic page]
  - 1910.95, Occupational noise exposure [related topic page]
- 1910 Subpart H, Hazardous materials
  - 1910.120, Hazardous waste operations and emergency response [related topic page]
- 1910 Subpart I, Personal protective equipment
  - 1910.132, General requirements
  - 1910.133, Eye and face protection [related topic page]
  - 1910.134, Respiratory protection [related topic page]
  - 1910.135, Head protection
  - 1910.136, Occupational foot protection
  - 1910.137, Electrical protective devices
  - 1910.138, Hand protection
  - Appendix A, References for further information (Non -mandatory)
  - Appendix B, Non-mandatory compliance guidelines for hazard assessment and personal protective equipment selection
- 1910 Subpart J, General environmental controls
  - 1910.146, Permit-required confined spaces [related topic page]
- 1910 Subpart Q, Welding, cutting, and brazing
  - 1910.252, General requirements [related topic page]

- 1910 Subpart Z, Toxic and hazardous substances [related topic page]

Shipyard Employment (29 CFR 1915)

- 1915 Subpart I, Personal protective equipment
  - 1915.151, Scope, application and definitions
  - 1915.152, General requirements
  - 1915.153, Eye and face protection
  - 1915.154, Respiratory protection
  - 1915.155, Head protection
  - 1915.156, Foot protection
  - 1915.157, Hand and body protection
  - 1915.158, Lifesaving equipment
  - 1915.159, Personal fall arrest systems (PFAS)
  - 1915.160, Positioning device systems
  - Appendix A, Non-mandatory guidelines for hazard assessment, personal protective equipment (PPE) selection, and PPE training program
  - Appendix B, General testing conditions and additional guidelines for personal fall protection systems (Non-mandatory)

Marine Terminals (29 CFR 1917)

- 1917 Subpart E, Personal protection
  - 1917.91, Eye and face protection
  - 1917.92, Respiratory protection
  - 1917.93, Head protection
  - 1917.94, Foot protection
  - 1917.95, Other protective measures

Longshoring (29 CFR 1918)

- 1918 Subpart J, Personal protective equipment
  - 1918.101, Eye and face protection
  - 1918.102, Respiratory protection
  - 1918.103, Head protection
  - 1918.104, Foot protection
  - 1918.105, Other protective measures
  - Appendix I, Cargo gear register and certificates (Non-mandatory)

Regulatory Agenda

- The OSHA Regulatory Agenda contains an entry related to personal protective equipment (PPE).

Preambles to Final Rules

- Personal Protective Equipment (PPE) for Shipyard Employment (1996)
  - I. Background
  - II. Workplace Hazards
  - III. Summary and Explanation of Final Rule
  - IV. Summary of Final Economic Analysis, Regulatory Flexibility Analysis, and Environmental Impact Assessment Summary
  - VI. Statutory Considerations
- Personal Protective Equipment (PPE) for General Industry (1994)
- Search all available preambles to final rules.

Federal Registers

- Employer Payment for Personal Protective Equipment; Final Rule. Final Rules 72:64341-64430, (2007, November 15).
- Personal Protective Equipment (PPE) Standards for Shipyard Employment; Extension of the Office of Management and Budget's (OMB) Approval of Information Collection (Paperwork) Requirements. Notice 71:29987-29989, (2006, May 24).
- Nationwide Site-Specific Targeting (SST) Inspection Program. Notice 69:41851-41852, (2004, July 12).
- Employer Payment for Personal Protective Equipment. Notice 69:41221-41225, (2004, July 8). Discusses the evidence currently in the record and presents a series of questions to assist the public in providing further information that would be helpful to OSHA.
- Employer Payment For Personal Protective Equipment. Proposed Rules 64:15401-15441, (1999, March 31). Suggests the employer's responsibility for payment of personal protective equipment costs.
- Personal Protective Equipment for Shipyard Employment (PPE). Final Rules 61:29957-29958, (1996, June 13). Makes corrections to the final rule on personal protective equipment for shipyard employment, which was published in the federal register on May 24, 1996 at 61 FR 26322.
- Personal Protective Equipment for Shipyard Employment (PPE). Final Rules 61:26321-26360, (1996, May 24). Discusses revisions of PPE standards for shipyard employment.
- Personal Protective Equipment for General Industry. Final Rules 61:19547-19548, (1996, May 2).
- Personal Protective Equipment for Shipyard Employment. Proposed Rules 59:34586-34589, (1994, July 6).
- Personal Protective Equipment for General Industry. Final Rules 59:33910-33911, (1994, July 1). Corrects the final rule on personal protective equipment for general industry.
- Personal Protective Equipment for General Industry. Final Rules 59:16334-16364, (1994, April 6). Discusses revisions of personal protective equipment standards.
- Search all available Federal Registers.

Directives

- National Emphasis Program – Crystalline Silica. OSHA Directive CPL 03-00-007, (2008, January 24). Includes an updated list of industries commonly known to have overexposures to silica; detailed information on potential hazards linked to silica and about current research regarding silica exposure hazards; guidance on calculating the Permissible Exposure Limits (PELs) for dust containing respirable crystalline silica in the construction and maritime industries; and guidance on conducting silica-related inspections.
- Inspection Procedures for 29 CFR 1910.120 and 1926.65, Paragraph (q): Emergency Response to Hazardous Substance Releases. CPL 02-02-073, (2007, August 27). Also available as a 444 KB PDF, 119 pages. Updates enforcement procedures for compliance officers who need to conduct inspections of emergency response operations. It defines additional terms and expands on training requirements for emergency responders and other groups such as skilled support personnel. This OSHA instruction revises CPL 02-02-059, issued April 24, 1998.
- Enforcement Procedures for the Occupational Exposure to Bloodborne Pathogens. CPL 02-02-069 [CPL 2-2.69], (2001, November 27).
- Respiratory Protection Program Guidelines. CPL 02-02-054 [CPL 2-2.54A], (2000, July, 14).
- Inspection procedures for the Respiratory Protection Standard. CPL 02-00-120 [CPL 2-0.120], (1998, September 25).
- Logging Operations, Inspection Procedures and Interpretive Guidance Including

Twelve Previously Stayed Provisions. CPL 02-01-022 [CPL 2-1.22], (1996, September 27).

- 29 CFR Part 1915, Subpart I, Personal Protective Equipment (PPE) for Shipyard Employment -- Inspection Procedures and Interpretive Guidelines. STD 02-04-002 [STD 2-4.2], (1996, September 27).
- Inspection Guidelines for 29 CFR 1910. Subpart I, the revised Personal Protective Equipment Standards for General Industry. STD 01-06-006 [STD 1-6.6], (1995, June 16).
- Logging Operations, Inspection Procedures and Interpretive Guidance. CPL 02-01-019 [CPL 2-1.19], (1995, March 17).
- Exemption for Religious Reason from Wearing Hard Hats. STD 01-06-005 [STD 1-6.5], (1994, June 20).
- Guidelines for Laser Safety and Hazard Assessment. STD 01-05-001 [PUB 8-1.7], (1991, August 5).
- 29 CFR 1910.134(e)(5)-- Respirator Fit-Testing. CPL 02-02-029 [CPL 2-2.29], (1980, October 27).
- Inorganic Mercury and its Compounds. CPL 02-02-006 [CPL 2-2.6], (1978, October 30). Procedures regarding exposure to mercury in the workplace, including the use of personal protective equipment.
- Search all available directives.

Standard Interpretations

- General Duty Clause (5(a)(1)) citations on multi-employer worksites;NFPA 70E electrical safety requirements and personal protective equipment. (2003, July 25). Discusses the relevance of NFPA 70E industry consensus standard to OSHA requirements.
- Interpretation of OSHA requirements for personal protective equipment to be used during marine oil spill emergency response operations. (1995, September 11). Discusses OSHA requirements for personal protective equipment to be used during marine oil spill emergency response operations.
- The application of the Personal Protective Equipment standard to PPE hazard assessment and training for laboratory and clinical health care workers. (1995, January 23). Discusses the application of 29 CFR 1910.132 to PPE hazard assessment and training for laboratory and clinical health care workers.
- Clarification of 1926.28(a) as to whether an orange vest constitutes personal protective equipment. (1984, July 23). Reconsiders whether orange vests are personal protective equipment within the meaning of 29 CFR 1926.28(a).
- OSHA regulations governing the use of personal protective equipment. (1976, December 2). Addresses OSHA regulations governing the use of personal protective equipment.
- Search all available standard interpretations.

Occupational Safety & Health Administration
200 Constitution Avenue, NW
Washington, DC 20210

Regulations (Standards - 29 CFR)

Eye and face protection. - 1910.133

Regulations (Standards - 29 CFR) - Table of Contents

- **Part Number:** 1910
- **Part Title:** Occupational Safety and Health Standards
- **Subpart:** I
- **Subpart Title:** Personal Protective Equipment
- **Standard Number:** 1910.133
- **Title:** Eye and face protection.

1910.133(a)

General requirements.

1910.133(a)(1)

The employer shall ensure that each affected employee uses appropriate eye or face protection when exposed to eye or face hazards from flying particles, molten metal, liquid chemicals, acids or caustic liquids, chemical gases or vapors, or potentially injurious light radiation.

1910.133(a)(2)

The employer shall ensure that each affected employee uses eye protection that provides side protection when there is a hazard from flying objects. Detachable side protectors (e.g. clip-on or slide-on side shields) meeting the pertinent requirements of this section are acceptable.

1910.133(a)(3)

The employer shall ensure that each affected employee who wears prescription lenses while engaged in operations that involve eye hazards wears eye protection that incorporates the prescription in its design, or wears eye protection that can be worn over the prescription lenses without disturbing the proper position of the prescription lenses or the protective lenses.

1910.133(a)(4)

Eye and face PPE shall be distinctly marked to facilitate identification of the manufacturer.

..1910.133(a)(5)

1910.133(a)(5)

The employer shall ensure that each affected employee uses equipment with filter lense s that have a shade number appropriate for the work being performed for protection from injurious light radiation. The following is a listing of appropriate shade numbers for various operations.

Filter Lenses for Protection Against Radiant Energ y

Operations	Electrode Size 1/32 in.	Arc Current	Minimum(*) Protective Shade
Shielded metal arc welding	Less than 3	Less than 60 ...	7
	3-5	60-160	8
	5-8	160-250	10
	More than 8	250-550	11
Gas metal arc welding and flux cored arc welding		less than 60 ...	7
		60-160	10
		160-250	10
		250-500	10
Gas Tungsten arc welding		less than 50 ...	8
		50-150	8
		150-500	10
Air carbon	(Light)	less than 500 ..	10
Arc cutting	(Heavy)	500-1000	11
Plasma arc welding		less than 20 ...	6
		20-100	8
		100-400	10
		400-800	11
Plasma arc cutting	(light)(**)	less than 300 ..	8
	(medium)(**)	300-400	9
	(heavy)(**)	400-800	10
Torch brazing		....	3
Torch soldering		....	2
Carbon arc welding		....	14

Filter Lenses for Protection Against Radiant Energy

Operations	Plate thickness-inches	Plate thickness-mm	Minimum(*) Protective Shade
Gas Welding:			
Light	Under 1/8	Under 3.2	4
Medium	1/8 to 1/2	3.2 to 12.7	5
Heavy	Over 1/2	Over 12.7	6
Oxygen cutting:			
Light	Under 1	Under 25	3
Medium	1 to 6	25 to 150	4
Heavy	Over 6	Over 150	5

Footnote(*) As a rule of thumb, start with a shade that is too dark to see the weld zone. Then go to a lighter shade which gives sufficient view of the weld zone without going below the minimum. In oxyfuel gas welding or cutting where the torch produces a high yellow light, it is desirable to use a filter lens that absorbs the yellow or sodium line in the visible light of the (spectrum) operation.

Footnote(**) These values apply where the actual arc is clearly seen. Experience has shown that lighter filters may be used when the arc is hidden by the workpiece.

1910.133(b)

Criteria for protective eye and face devices.

1910.133(b)(1)

Protective eye and face devices purchased after July 5, 1994 shall comply with ANSI Z87.1-1989, "American National Standard Practice for Occupational and Educational Eye and Face Protection," which is incorporated by reference as specified in Sec. 1910.6.

1910.133(b)(2)

Eye and face protective devices purchased before July 5, 1994 shall comply with the ANSI "USA standard for Occupational and Educational Eye and Face Protection," Z87.1-1968, which is incorporated by reference as specified in Sec. 1910.6, or shall be demonstrated by the employer to be equally effective.

[59 FR 16360, April 6, 1994; 59 FR 33910, July 1, 1994; 61 FR 9227, March 7, 1996; 61 FR 19547, May 2, 1996]

Next Standard (1910.134)

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Occupational Safety & Health Administration
200 Constitution Avenue, NW
Washington, DC 20210

Regulations (Standards - 29 CFR)

Occupational foot protection. - 1910.136

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- **Part Number:** 1910
- **Part Title:** Occupational Safety and Health Standards
- **Subpart:** I
- **Subpart Title:** Personal Protective Equipment
- **Standard Number:** 1910.136
- **Title:** Occupational foot protection.

1910.136(a)

General requirements. The employer shall ensure that each affected employee uses protective footwear when working in areas where there is a danger of foot injuries due to falling or rolling objects, or objects piercing the sole, and where such employee's feet are exposed to electrical hazards.

1910.136(b)

Criteria for protective footwear.

1910.136(b)(1)

Protective footwear purchased after July 5, 1994 shall comply with ANSI Z41 -1991, "American National Standard for Personal Protection -Protective Footwear," which is incorporated by reference as specified in Sec. 1910.6, or shall be demonstrated by the employer to be equally effective.

1910.136(b)(2)

Protective footwear purchased before July 5, 19 94 shall comply with the ANSI standard "USA Standard for Men's Safety-Toe Footwear," Z41.1-1967, which is incorporated by reference as specified in Sec. 1910.6, or shall be demonstrated by the employer to be equally effective.

[59 FR 16360, April 6, 1994; 59 FR 33910, July 1, 1994; 61 FR 9227, March 7, 1996; 61 FR 19547, May 2, 1996; 61 FR 21228, May 9, 1996]

Next Standard (1910.137)

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200 Constitution Avenue, NW
Washington, DC 20210