A SYSTEM APPROACH TO OCCUPATIONAL HEALTH AND SAFETY MANAGEMENT

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ABSTRACT

A SYSTEM APPROACH TO OCCUPATIONAL HEALTH AND SAFETY MANAGEMENT

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In this thesis, methods used at present in occupational health and safety management are analyzed and a model safety management system is developed. History, development and recent occupational safety regulations in the United States of America and European Union are introduced to give a sight on this subject in developed countries.

The suggested model is evaluated with work accident data taken from a company and hazard and risk analysis methods are used to investigate these accidents. Preventive measures to eliminate and reduce the consequences of these accidents are recommended. Finally a model safety management system which can be used in all types of industry is developed.

Keywords: Occupational Safety, Hazard Analysis, Safety Management

ÖZ

İŞ SAĞLIĞI VE GÜVENLİĞİNE SİSTEMATİK YAKLAŞIM

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Bu tezde, iş sağlığı ve güvenliği yönetimi konusunda kullanılan methodların analizi yapılmış ve örnek bir güvenlik yönetim sistemi geliştirilmiştir. Bu konu ile ilgili bir fikir verebilmek amacıyla Amerika Birleşik Devletlerindeki ve Avrupa Topluluğunda ki iş güvenliği yasalarının tarihi, gelişimi ve şuanki durumu sunulmuştur.

Örnek, bir şirketten alınmış olan veriler ile değerlendirilmiş ve bu kazaları incelemek için tehlike ve risk analiz methodları kullanılmıştır. Kazaları önleyici ve kazanın sonuçlarını azaltıcı tavsiyelerde bulunulmuştur. Son olarak bütün sanayi tiplerinde kullanılabilecek örnek bir güvenlik yönetimi sistemi geliştirilmiştir.

Anahtar Kelimeler: İş Güvenliği, Tehlike Analizi, Güvenli Yönetimi

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ABBREVIATIONS

CFR: Code of Federal Regulations

EEC: European Economic Commission

EU: European Union

FMEA: Failure Modes and Effects Analysis

FMECA: Failure Mode Effects and Criticality Analysis

FTA: Fault Tree Analysis

HAZOP: Hazard and Operability Analysis

ISO: International Organization for Standardization

RPN: Risk Priority Number

SMS: Safety Management System

SSK: Sosyal Sigortalar Kurumu

OSHA: Occupational Safety and Health Administration

TSE: Türk Standartları Ensitüsü

CHAPTER 1

INTRODUCTION

All sectors of industry are subjected to the pressures accompanying competitive tendering. The profit margins are cut to a minimum in order to win contracts; which causes poorly detailed design, poor quality materials, employment of unqualified and most important, uninsured workers, inadequate safety precautions and procedures and work-related injuries and diseases.

According to the latest statistics, 72367 work accidents occurred in Turkey.[1] On the other hand, an average day in United States of America, 17 workers are killed and 16000 are injured in work-related accidents resulting in a cost to industry more than US$ 110 billion annually.[2]

Work accidents result in loss of work power, loss of production time, changing or repairing the damaged components, compensations and lawsuits. On the other hand, modern manufacturing philosophy is based on Just-in-Time production (JIT) to minimize inventories and investment funds in order to reduce the cost of the products. This work related accidents result in delays in delivery time of the product; causes loss of customer, money, trust and reputation which has greater repercussion at present.

Traditional safety efforts have focused on the engineering aspects of safety; however relatively few accidents (%10) [3] are a consequence of unsafe mechanical or physical conditions. While most on the job accidents and injuries appear to result from employees' unsafe acts, incidents typically are not caused by single operator errors, but are end-events in a chain of interfacing factors on several systems level.

Increasingly complex work processes and changes in working conditions together with the resulting new or changing types of hazard; employers need a new and systematic approach to safety and health at work. Solutions are required which allow the employers to take account of safety and health principles at all levels and activities, and to convert them into appropriate measures on a routine basis.

Turkey is a candidate country to Europian Union (EU). As in many aspects Turkey must adapt to the new Occupational Health and Safety system of the Europian Union.This study is a guide to facilitate the understanding and implementation of new requirements.

In this thesis study, the work accidents and safety problem in a company are investigated and safety problems identified. Risk assessment of the safety problems are carried out and an action plan for the solution is recommended for the most critical activities of the case study company.

The thesis is arranged in the following manner; in the second chapter, the history and existing situation of the safety laws and regulations in Turkey are studied. Additionally, safety laws and organizations, established in United States of America (U.S.A) and European Union (E.U) is examined. In the third chapter methods of hazards analysis techniques are explained and some examples are provided for illustrative purposes. The risk analysis techniques and the technique used in this study are discussed in Chapter 4. In the fifth chapter, some information about the company that is used in the case study is supplied. Then risk analysis of the data is performed and most critical activities are identified. In Chapter 6, a model safety management system is developed and most critical activity in the company is analyzed with the proposed model. In the seventh chapter, conclusion of the thesis is performed and some recommendations given for a better safety management system. In addition to these, some further studies are discussed and suggested.

CHAPTER 2

SAFETY REGULATIONS IN TURKEY, UNITED STATES AND EUROPEAN UNION

2.1 Safety Regulations in Turkey

The first statutory law about safety and health at work was ‘Dilaver Paşa Nizamnamesi’ in 1865. This regulation consisted of 100 articles. [4] Its aim was to increase the productivity of mines rather than to regulate the working conditions. The basic issues were the working hours of employees in the mining industry, their wages, and medical treatment of injured employees. Also according to this regulation, the employer was responsible for the accommodation and nourishment of his workers. [5]

In 1869, ‘Maadin Nizamnamesi’ was established and some improvement took place between 1887 and 1906. This regulation was a more up to date than the ‘Dilaver Paşa Nizamnamesi’. ‘Maadin Nizamnamesi’ was about the precautions to prevent work related accidents, compensation to be paid to workers in case of a work accident. It also made compulsory to provide first-aid kit in mines. In 1921, ’Ereğli Havza-i Fahmiyesi Maden Amelesinin Hukukuna Müteallik Kanun’ was enacted.[5] In the opinion of some experts, this law is the advent of the modern Work and Safety Law since it regulated the workers’s rights. For instance; in the Article 8 of this law, the working hours was determined as 8 hours per day.

Because during the Ottoman period the industry was not developed; therefore extend of the laws was very specific and most of the laws were aimed at the mining industry. With the Republic of Turkey, an industrial revolution started and programmed till present. With these developments, it became a necessity to enact and prepare various laws about workers health, safety and social security against work related accidents and diseases.

The laws in force about workers' safety, health and social security in Republic of Turkey are shortly presented below.

- T.C Constitution: The articles 43, 44, and 48 are related with the subject. According to article 43, nobody should be employed to do a work, which is not compatible with his or her age, power or sex. In article 44, everyone has the right of rest and rest periods are arranged by law. In article 48, everyone is entitled to social security.
- 'Borçlar Kanunu' (Law of Obligations): It was enacted in 1926 and numbered 818. The article 332 of this law made employer responsible to take precautions for the safety and health of his employees.
- 'Umumi Hifzıssıhha Kanunu' (Public Health Law): It was enacted in 1930. Many of the articles are related to safety and health at work. The article 180 makes it compulsory to employ a doctor (part-time or full time) if the number of employees exceeds 50.
- 'Sosyal Sigortalar Kanunu' (Social Security Law, 1964\506): There are articles which the rights of the worker as regard. The definitions of work accidents and occupational diseases are given. Moreover the responsibilities of employer, employee and government are defined.
- 'İş Kanunu' (Labor Law, 1971\1475): In Part 5 of this law, there are 10 articles on the subject. In article 73, employers are required to take all necessary precautions for safety and the employees are obliged to abide these precautions.
- Article 74 of this law, Ministry of Labor and Social Security have the right to publish regulations to protect workers from the work related accidents

and occupational diseases and supply a safe working environment. Most of the regulations about safety at work were published in accordance with the article 74 of this law.

Although most of the regulations are translated from ILO regulations, some of the ILO regulations are not fully applicable for Turkey because some practices are different from these regulations. Besides, these regulations can not easily and fully be comprehended by the workers and a great circle of employers; which is also valid for other countries as well. This is a common problem not only in Turkey but all over the world. Thus these regulations must be interpreted capably in order to be understood by the workers and employers.

At present; ‘Sosyal Sigortalar Kurumu’ (Social Security Authority) regulates the occupational health and safety regulations in Turkey. It is the first modern social security organization in the Republic of Turkey and was established in 1945 in accordance with article 3008 of ‘İş Kanunu’ (Work Law). In 2000, the Institution has been re-organized and divided into two as General Directorate of Insurance Affairs and General Directorate of Health Affairs.

Besides ‘Sosyal Sigortalar Kurumu’, Chamber of Mechanical Engineers works on safety and health at work. Chamber defines the roles of the engineers that are responsible from the occupational health and safety in their workplace. According to the Chamber of Mechanical Engineers, engineers should take the measures necessary for the safety and health protection of workers, including prevention of occupational risks and provision of information and training considering;

- The design of work place and production technique used.
- Tools, equipment, and raw material used in the production technique.
- Properties and rated capacities of the tools and equipment used in the production.

- Experience, knowledge, skills, and abilities of the worker assigned to the production technique.

In addition, Chamber of Mechanical Engineers prepare reports to inform the Ministry of Labor and Social Security about the necessary changes that should be done on the standards and regulations about the safety at work and recent improvements in technology and production techniques.

Chamber prepares a certification program and train engineers on the pinpoints of the safety and health at work topic. Furthermore they organize national congress to inform engineers, employees and workers on occupational health and safety at work topic. Researcher from different universities gives seminars and out comings of this seminars are published. [6] In 2001, Chamber identify possible hazard for the critical activities such as: manual work and working with power tools, electrical work, pressure vessels, welding, construction, material handling, and mining, are identified and necessary protection recommendations are made.[7]

In a near future, Republic of Turkey is going to be a member to European Union and as in many aspects; Turkey should adapt its occupational health and safety management system to European Union. During the literature survey conducted, it is observed that there are little efforts to achieve this adaptation. This study is prepared to shed light to this adaptation period and develop a system approach to promote and sustain occupational health and safety concept in Turkish industry.

2.2 Safety Regulations in the United States

Some of the details of the safety regulations vary state to state, however there is increasing trend toward greater uniformity in the provisions of regulations through adoption of the standards of nationally recognized regulations developed by federal institutes such as American National Standards Institute. Although some states have established comprehensive safety standards applicable to all employments, there is a tendency to develop special regulations for particular industries, operations or hazards. Boilers, construction, elevators, mechanical power transmission, cranes, fire protection, floors and stairways, illumination, ventilation, electrical hazards, explosives, ladders spray painting, welding are some of areas that needs special regulations. State safety regulations make the employer and its supervisory personnel responsible for compliance with the regulation and for suitable instruction to the worker. The employee is required to make use of safeguards provided for his protection and conduct to his work in conformance with the established safety rules.

In 1970, the Congress established the Occupational Safety and Health Administration (OSHA). OSHA is headed by an Assistant Secretary of Labor for Occupational Safety and Health. As defined in its enabling legislation, P.L. 91-596, the Occupational Safety and Health Act of 1970, OSHA's mission is to "Assure so far as possible every working man and woman in United States safe and healthful working conditions." This mandate involves the application of a set of tools by OSHA (e.g., standards development, enforcement, compliance assistance) which enable employers to maintain safe and healthful workplaces. [8]

OSHA established the first nationwide program for job safety and health by directing the Secretary of Labor to set safety and health standards for whole industry. Every employer in interstate commerce has a twofold obligation to provide employment and a workplace where health and safety hazards are minimized.

OSHA's vision is to eliminate workplace injuries, illnesses, and deaths so that all of America's workers can return home safely every day. To realize this vision, workplace environments must be characterized by a genuine commitment to workplace safety and health shared by both employers and workers, and the necessary training, resources, and support systems must be in place to make this happen. To achieve this vision, OSHA will be a results-oriented Agency, using data proactively to identify workplace safety and health problems and apply a comprehensive strategy that combines common sense regulation; a firm, fair, and consistent enforcement policy; and wide-ranging approaches to compliance assistance that meet the needs of workers and employers and effectively use the resources.

Since OSHA's inception, it has made substantial progress in occupational safety and health; for example, since 1970, the work-related fatality rate has been cut in half and overall injury and illness rates have declined in industries where OSHA has concentrated its attention. In some areas the progress has been notable: brown lung disease has been virtually eliminated in the textile industry, and trenching and excavation fatalities have been reduced by 35% since 1970. [9]

Major organizational elements are of the OSHA are;

- **Office of the Assistant Secretary:** Advises and assists the Secretary of Labor on all matters related to the policies and programs that are to assure safe and healthful working conditions for the working men and women, and provides executive direction to the occupational safety and health program.
- **Directorate of Health Standards Programs:** Develops and promulgates workplace standards and regulations to ensure healthful working conditions for the workforce.
- **Directorate of Safety Standards Programs:** Provides workplace standards and regulations to ensure safe working conditions for the workers.
- **Directorate of Federal/State Operations:** Provides for the development, evaluation, and performance analysis of State occupational safety and health programs; educates and trains employers and employees in the recognition, avoidance and prevention of unsafe and unhealthful working conditions; provides for a program of consultation and advice to employers and employees and their representative organizations as to

effective means of preventing occupational injuries and illnesses; and develops, implements and evaluates voluntary programs in cooperation with industry, labor and their representatives.

- **Directorate of Construction:** Serves as OSHA's principal source for standards, regulations, policy, programs, and assistance to OSHA Offices, other Federal agencies, the construction industry, and the general public with respect to construction safety and health.
- **Regional Administrators:** Plan, direct, and administer comprehensive occupational safety and health programs throughout OSHA's regions. OSHA standards are part of the Code of Federal Regulations (C.F.R) published by the Office of the Federal Register. The regulations of all federal-government agencies are published in the C.F.R. Title 29 contain all of these standards assigned to OSHA. Title 29 is divided into several parts, each carrying a four number designator such as Part 1901, 1910. These parts are divided into sections, each carrying a numerical designator. For example, '29 C.F.R. 1910.1' means Title 29, Part 1910, Section1, Code1 of Federal Regulations. Some of the OSHA standards related with the Manufacturing industry are contained in Part 1926 of the C.F.R. Subparts C-Z. These subparts are represented in Appendix A.

2.3 Safety Regulations in the European Union

All the countries that are a member of the European Union have their own safety and health regulations, the details of which vary from country to country. However there is tendency towards the uniformity among the European Union. The common point in these regulations is that the individual member states have a responsibility to encourage improvements in the safety and health of workers in their territory; and taking measures to protect the health and safety of workers at work.

European Union publishes directives to encourage improvements in safety and health policy of the union and to harmonize conditions to avoid competition at the expense of safety and health due to the different levels of safety and health protection in member states' legislative systems. However; these directives do not justify any reduction in levels of protection already achieved in some of the individual Member States.

Council Directive 89/391/EEC is the most important directive on occupational health and safety published on 12, June, 1989. It is composed of 19 articles and determines the main frame of the occupational health and safety policy of the union. The object of this directive is to introduce measures to encourage improvements in the safety and health of workers at work and it contains general principles concerning the prevention of occupational risks, the protection of safety and health, the elimination of risk and accident factors, the informing, consultation, balanced participation in accordance with national laws and/or practices and training of workers.

This directive has very important bearing on the health and safety related activities of the member countries and is going to be the basis of the new regulations in Turkey. Discussing this directive in length well shed additional light on the scope of this thesis.

2.3.1 Council Directive 89/391/EEC

This directive gives some responsibilities to both employers and workers to ensure the safety and health of workers in every aspect related to the work. According to this directive responsibilities of employers are;

- The employer shall take the measures necessary for the safety and health protection of workers, including prevention of occupational risks and provision of information and training, as well as provision of the necessary organization and means.
- The employer shall be alert to the need to adjust these measures to take account of changing circumstances and aim to improve existing situations.

- The employers shall cooperate in implementing the safety, health and occupational hygiene provisions and, taking into account the nature of the activities, coordinating their actions in matters of the protection and prevention of occupational risks, and informing one another and their respective workers and/or workers' representatives of these risks.

It is well worth pointing out that these articles are overlapping with articles 2-4 of the 'İşçi Sağlığı ve İş Güvenliği Tüzüğü' (Worker's Health and Occupational Safety Code).

Directive determines the methodology of prevention from the occupational risks. The steps of this methodology is as follows;

- Eliminating or reducing risks;
- Evaluating the risks which cannot be eliminated or reduced;
- Combating the risks at source;
- Adapting the work to the individual, especially as regards the design of work places, the choice of work equipment and the choice of working and production methods, with a view, in particular, to alleviating monotonous work and work at a predetermined work-rate and to reducing their effect on health.
- Adapting to technical progress;
- Replacing the dangerous by the non-dangerous or the less dangerous;
- Developing a coherent overall prevention policy which covers technology, organization of work, working conditions, social relationships and the influence of factors related to the working environment;
- Giving collective protective measures priority over individual protective measures;
- Giving appropriate instructions to the workers.

According to this directive responsibilities of workers can be listed as follows;

- Make correct use of machinery, apparatus, tools, dangerous substances, transport equipment and other means of production
- Make correct use of the personal protective equipment supplied to them and, after use, return it to its proper place
- Refrain from disconnecting, changing or removing arbitrarily safety devices fitted
- Inform the employer and/or the workers with specific responsibility for the safety and health of workers of any work situation they have reasonable grounds for considering represents a serious and immediate danger to safety and health and of any shortcomings in the protection arrangements
- Cooperate with the employer and/or workers with specific responsibility for the safety and health of workers, for as long as may be necessary to enable any tasks or requirements imposed by the competent authority to protect the safety and health of workers at work to be carried out;
- Cooperate with the employer and/or workers with specific responsibility for the safety and health of workers, for as long as may be necessary to enable the employer to ensure that the working environment and working conditions are safe and pose no risk to safety and health within their field of activity.

This directive emphases two cardinal points in occupational health and safety concept. These are;

- The workers' obligations in the field of safety and health at work shall not affect the principle of the responsibility of the employer
- The employers' are responsible from hazards where occurrences are due to unusual and unforeseeable circumstances, beyond the employers' control, or to exceptional events.

Clearly the employer of the workplace must eliminate the both the existing and potential (unforeseeable, unusual) hazards.

2.4 Discussion on Safety Regulations and Applications

Safe and healthy working conditions do not happen by chance. Employers need to have a written safety policy for their enterprise setting out the safety and health standards which is their objective to achieve therefore all countries develop their safety and health regulations.

These regulations reflect formal response to safety and health at work and include the provision and use of specific safety equipment, methods of carrying out specific tasks safely, and the inspection and appropriate use of tools. However regulations only identify some common type of hazards while there are many different kind of hazards which can't be specified in these regulations one by one. Furthermore, regulations only specify hazards and do not investigate the hazards technically; whether they are avoidable or not. On the other hand, regulations recommend some general preventive measures which do not consider type of industry and activity. So, the levels of preventive measures specified in this regulation are the minimum requirements to be considered. The level of preventive measures can only be determined by a systematic safety and health management system for each company.

Rapid changes in work processes, working conditions introduce new hazards to safety and health at work on the other hand recent improvements in technology might eliminate some of the hazards specified in these regulations. Since safety policies can't be revised frequently; there might some missing or misleading points in safety regulations. In addition to these, safety regulations are prepared considering the general circumstances. However, type and risk of the hazard might depend on many parameters such as; work environment, working time (night or day shift), season (winter or summer), age and sex of the worker and etc. For instance working at the night shift might introduce new hazards in contrast to working at the day shift due to insufficient illumination of the workplace, or younger workers are always exposed to more risk in comparison to older workers due to their in experience. Therefore in modern safety and health regulations such as in European Union, there are sections to encourage recent developments and more favorable provisions for the safety and health of the workers at work.

No matter how developed the health and safety regulations are, there always be some shortcomings to the wrong interpretation or some precautions may become useless by changes and improvements in technology. It is therefore vital to develop a safety and health management system which is simple and applicable to all types of industry. In addition to this, at present a new trend has emerged around the world with total quality management systems (ISO 9000). In a near future environmental management systems (ISO 14000) and occupational health and safety management systems will become an integrated part of total quality management systems. As in many developing countries such as Turkey occupational health and safety management systems are relatively a new issue however the establishments in these countries need to adapt their management strategies to this international system in the shortest course of time. In this thesis, a systematic approach is developed for occupational health and safety management and by employing this approach existing or potential hazards can be identified in any type of industry and some appropriate preventive measures can be taken.

Hazard identification and hazard analysis are the two essential components of an occupational health and safety management system and must be conducted systematically in order to get compatible out comings. Therefore, in chapter 3, hazard identification and hazard analysis methods are explained and some examples are provided.

CHAPTER 3

HAZARD ANALYSIS

3.1 Importance of Hazard Analysis:

A hazard is the potential for harm that might cause physical injury and/or damage to health or property. A hazard often is associated with a condition or activity that, if left uncontrolled, can result in an injury or illness. Identifying hazards and eliminating or controlling them as early as possible will help prevent injuries, illnesses and potential losses. In occupational health and safety studies, a variation of hazard analysis technique called as job hazard analysis technique is commonly used. Job hazard analysis is a technique that focuses on job tasks as a way to identify hazards before they occur. It focuses on the relationship between the worker, the task, the tools, and the work environment

Many workers are injured and killed at the workplace every day due to work related accidents. Besides, a work related accident results in damage to property, medical expenses and delays in delivery time. Managers and supervisors can use the findings of hazard analysis to eliminate and prevent hazards in their workplaces. As a result of this, fewer worker injuries and illnesses; safer, more effective work methods; reduced workers' compensation costs; and increased worker productivity is achieved.

Hazard analysis is one of the crucial components of a safety and health management system and a systematic approach is needed in order to obtain compatible results. To analyze hazards, firstly both potential and existing hazards must be identified. In this part of the thesis, three methods that are commonly used in hazard identification are explained. (3.2.1-3.2.3)

3.2 Hazard Identification:

In order to conduct a hazard analysis in a systematic way, all the hazards that may lead to unwanted consequences have to be identified in a systematic manner. This systematic approach is called as hazard identification. There are 3 principle methods used for hazard identification.

3.2.1 Employee concerns and observations

It is very important to involve the employees in the hazard identification process. Employees have a unique understanding of the job, and this knowledge is invaluable for identifying hazards in a work place Employees in the workplace may notice hazards or have concerns about potential hazards at any time. They may have pain or discomfort, notice unusual odors, overstraining etc. These concerns should be reported to a supervisor or manager immediately. Supervisor or manager should encourage reporting of suspected hazards by all employees. A form such as in Figure 3.1 can be used to determine workers concerns, recommendations, etc. Besides, worker can report potential and existing hazards that he has detected personally.

In fact, if workers know there is a hazard, they are obligated by law to report it to the supervisor/manager. This obligation also exists in the 'İşçi Saglığı ve İş Güvenliği Tüzüğü' (Worker's Health and Occupational Safety Code) and emphasized more strongly in Council Directive 89/391/EEC. It states that 'Employees must inform the employer and/or the workers with specific responsibility for the safety and health of workers of any work situation they have reasonable grounds for considering what represents a serious and immediate danger to safety and health and of any shortcomings in the protection arrangements' On the other hand supervisors are required to be competent and to take every reasonable precaution to protect the worker. This obligation is addressed in the Council Directive 89/391/EEC as ‘The employer shall take the measures necessary for the safety and health protection of workers, including prevention of occupational risks and provision of information and training, as well as provision of the necessary organization and means.’ Therefore, supervisors should check out worker concerns to determine if there is a hazard or if controls should be improved.

Job Title:	
Job Location:	
Description of the Job:	
Divide your Job into steps	**Description of each step and associated hazard**
Step 1	
Step 2	
Step 3	
Step 4	
Step 5	
List Environmental Factors: (Illumination, condition of air, noise, vibration, temperature, etc)	
List machinery and tools employed:	
Recommendations and concerns :	

Figure-3.1: A sample form to determine workers concerns, recommendations

3.2.2 Investigations of Accidents

Accident investigations are conducted to identify hazards that were either missed during earlier inspections or are present because of inadequate controls. Another objective is to identify the casual factors associated with the accident, so that both the hazards and the casual factors can be controlled and future occurrences prevented. The process concludes with preparation of a final report with recommendations for corrective action and follow-up to ensure closure.

The accident investigation should fully cover and explain the technical elements of the causal sequences and should also describe the management system that should have, or could have, prevented the occurrence. Supervisors and others who investigate accidents should be responsible for clearly documenting the causes uncovered during the investigation. Supervisors should be careful to avoid the tendency to lay sole blame on an the employee. Though in most cases human error is involved, there is often a managerial deficiency involving procedures, training, or staffing levels. Even if the injured worker openly blames him- or herself, the accident investigator must not be satisfied that all contributing causes have been identified.

3.2.3 Workplace Inspection

The workplace inspection is a regular and common method of identifying hazards. Workplace inspections identify hazards that could endanger the health or safety of workers in the workplace. The inspection is conducted with a team and team members usually include operating and maintenance personnel, design and/or operating engineers, specific skills as probability and statistics, engineering (electrical, mechanical, chemical, or nuclear), systems analysis, health sciences, social sciences, and physical, chemical, or biological sciences. In general, inspections of the workplace are intended to:

- Identify and record potential and actual hazards
- Identify any hazards that require immediate attention
- Ensure that existing health and safety standards and procedures are met
- Ensure that existing controls are working

Types of inspection are listed below.

- **Regular Planned Inspection:** Done on a regular basis by the health and safety representative. The manager should also do his or her own regular inspections of the workplace
- **Spot Inspection:** Usually conducted by managers or supervisors as part of their safety responsibilities. This inspection is not periodic.
- **Maintenance Inspection:** Usually the responsibility of supervisors as part of their regular duties and daily operations
- **Pre-operation checks of equipment:** Completed before starting a work activity that uses potentially hazardous equipment.

3.3 Fault Tree Analysis

Fault tree analysis (FTA) is widely performed in the industry to evaluate engineering systems during their design and development, in particularly in nuclear power generation. A fault tree may simply be described as a logical representation of the relationship of primary events that lead to a specified undesirable event called the "top event" and is depicted using a tree structure with OR, AND, etc. logic gates. In this study top event will be an accident or an activity that might cause hazard.

The fault tree method was developed in the early 1960s by H.A. Watson of Bell Telephone Laboratories to perform analysis of the Minuteman Launch Control System. A study team at the Bell Telephone Laboratories further refined it and research center of the Boeing Company played a pivotal role in its subsequent development. [10]

In 1965 several papers related to the technique were presented at the System Safety Symposium held at the University of Washington, Seattle. In 1974, a conference on "Reliability and Fault Tree Analysis" was held at the University of California, Berkeley. A paper appeared in 1978 providing a comprehensive list of publications on Fault Trees. The three books that described FTA in considerable depth appeared in 1981. [11]

There are many objectives in performing FTA, which can be summarized as identifying critical areas and cost-effective improvements, understanding the functional relationship of system failures, meeting jurisdictional requirements, providing input to test, maintenance, and operational policies and procedures, understanding the level of protection that the design concept provides against failures, evaluating performance of systems, providing an integrated picture of some aspects of system operation, confirming the ability of the system to meet its imposed safety requirements.

3.3.1 Analytical Developments of Basic Gates in FTA

A fault tree is developed using logic gates such as OR and AND that relate logically various basic fault events to the undesirable or the top event (hazardous activity). Boolean algebra is an invaluable tool to represent a fault tree diagram in a mathematical form. Boolean expressions for OR and AND gates are presented below.

3.3.1.1 OR Gate

An m input fault events A_1, A_2, A_3, …, A_m OR gate along with its output fault event A_0 in a Boolean expression is shown in Figure-3.2. Thus, mathematically, the output fault event A_0 of the m input fault event OR gate is expressed by

$$A_0=A_1+A_2+A_3+....+A_m \qquad 3.1$$

Where A_i is the i^{th} input fault event for i = 1,2,3…m.

OR Gate implies that one the input events (A_1, A_2, A_3, …, A_k) occurs at a time in order to undesirable top event happen. It is obvious that the probability of the undesirable top event (P_{x0}) is greater than the probability of the input events (P_1, P_2, P_3….) due to the nature of summation.

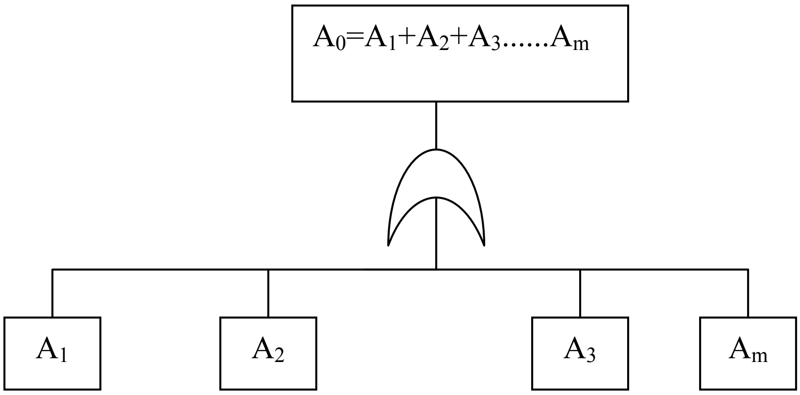

Figure-3.2: OR Gate with its inputs and outputs

3.3.1.2 AND Gate

A_k input fault event A_1, A_2, A_3, …, A_k AND gate along with its output fault event X_0 in a Boolean expression is shown Figure-3.3. Thus, mathematically, the output fault event X_0 of the k input fault event AND gate is expressed by:

$$A_0=A_1.A_2.A_3.....A_k \quad 3.2$$

Where X_i is the i^{th} input fault event for i = 1,2,3…k.

AND Gate implies that all the input events (A_1, A_2, A_3, …, A_k) occurs at the same time in order to undesirable top event happen. It is obvious that the probability of the undesirable top event (P_{x0}) is smaller than the probability of the input events (P_1, P_2, P_3….) due to the nature of multiplication.

3.3.2 Steps for Performing FTA

The development or construction of a fault tree is top-down, in that the undesirable or top event namely, accident or hazardous activity, is the tree root and the logical combination of sub-events are employed to map out the tree until reaching the basic initiating fault events. Nonetheless, steps such as those listed below are involved in performing FTA.

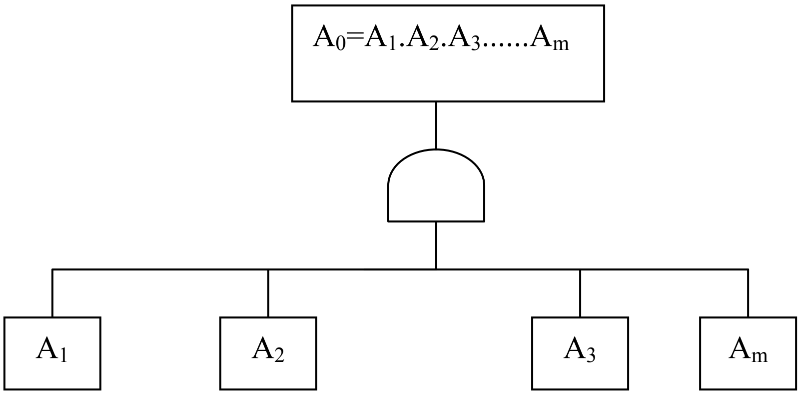

Figure-3.3: AND Gate with its inputs and outputs

- Define process, analysis associated assumptions, what constitutes accident, etc.
- If the simplification of the scope of the analysis is necessary, develop a simple system block diagram showing relevant inputs, outputs, and interfaces.
- Identify undesirable or top fault events (Accident or hazardous activity) to be analyzed and if necessary develop fault trees for all top-level events.
- Identify all the causes that can make the top event (hazardous activity) occur using fault tree symbols and the logic tree format. More specifically, using deductive reasoning, highlight event that can lead to the occurrence of the top event.
- Assuming the causes of the previous step as intermediate effects, continue developing the logic tree by identifying the causes of these intermediate events.
- Develop the fault tree to the lowest level of detail as required.
- Perform analysis of the completed fault tree with respect to understanding the logic and the interrelationships among various fault paths, gaining insight into the unique modes of product faults, etc.
- Determine appropriate corrective measures.
- Prepare documentation of the analysis process and follow up on identified corrective measures.

In order to illustrate the construction of a Fault Tree, a grinding process will be investigated. In the specified example, process under consideration is a worker grinding an iron part weighing about 50 Newton on a horizontal grinding machine in the machine-shop of the company. The worker grinds 20-25 castings per hour.

A worker injuring his hand while grinding the burrs is chosen as the undesirable top event. In order for the to top event to be happen, all 3 events namely;

- hand coming into contact with the grinding wheel (Event 1)
- no guarding (Event 2)
- grinding wheel turning (Event 3)

must occur at the same time. Therefore an AND Gate is used to connect this input events with the undesirable top event. To illustrate the probabilistic relation between the input events and undesirable top event let us consider the probability of each event. Assuming that probability of the worker's hand contact with the grinding wheel is (P_1) is 0.30. If worker is an experienced, this probability might be less than that or it might be higher if the worker is younger. The probability of working without a guarding (P_2) can be assumed as 0.75. This probability changes depending on the time spent without machine guarding. If time elapsed without machine guarding increases P_2 increases. The probability of grinding machine to be working during the shift (P_3) can be assumed as 0.80. This value can be lower if the machine used less frequently or higher if the machine used more than that. Then the probability of the undesirable top event (P_0) to happen can be found as;

$$P_0 = P_1 * P_2 * P_3 = 0.30 * 0.75 * 0.80 = 0.18 \quad (3.3)$$

It can be observed that the probability of worker injures his hand is smaller than the 3 input events due to the nature of AND Gate.

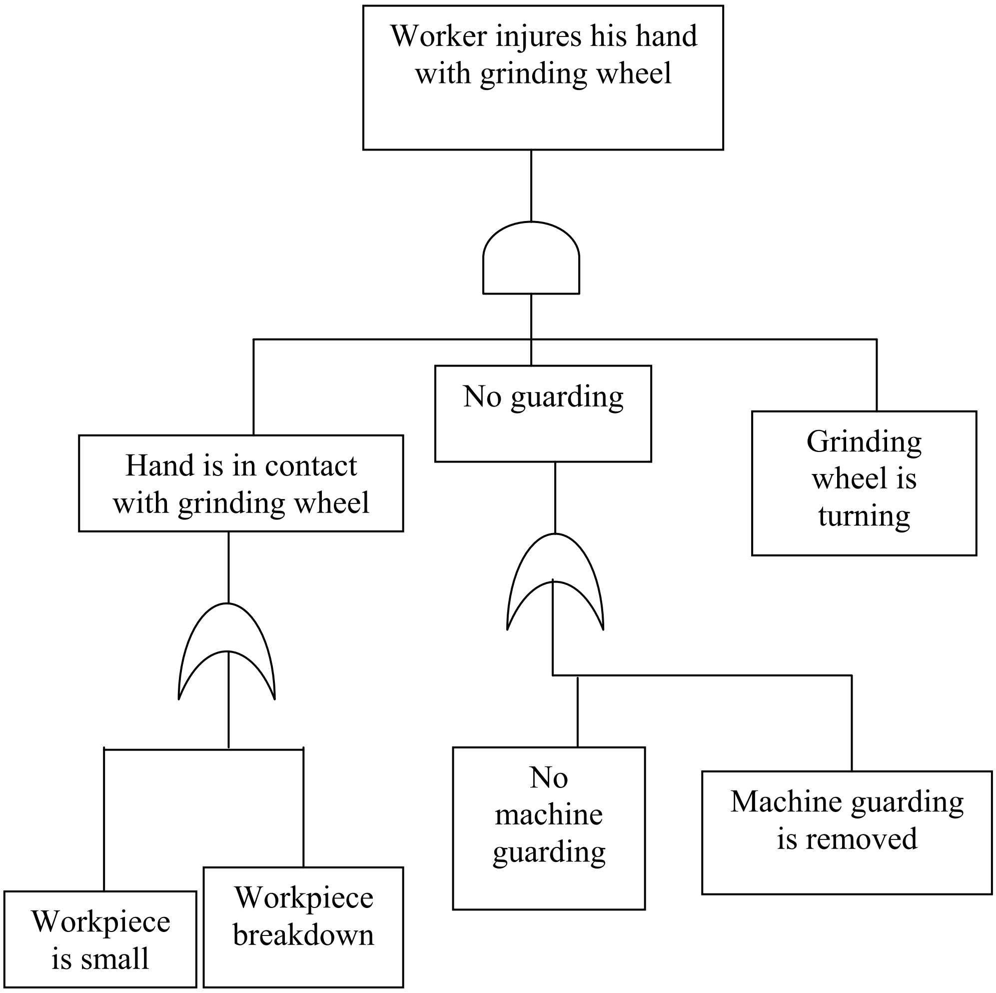

Figure-3.4: A sample Fault Tree for a grinding process

To investigate an OR gate let us use the top event hand is in contact with grinding wheel. In order to top event to happen either work piece must be small or work piece to break down. If one of these events come to be true, than top event happens. Therefore an OR Gate is used. To illustrate the probabilistic relation between the top event and input events assume that the probability of work piece to be small (P_4) is 0.25 and the probability of work piece to break down (P_5) is 0.05. Since this 2 event is independent from each other, P_1 can be expressed as;

$$P_1 = P_4+P_5-P_4*P_5 = 0.25+0.05-0.25*0.05=0.29 \quad 3.4$$

It can be observed that the probability of the Event 1 is greater than the 2 input events due to nature of the OR Gate.

3.3.3 Advantages and Drawbacks of FTA

Once a fault tree is developed, it is possible to obtain its dual without much additional effort. The dual of a "fault tree" is the "success tree". Thus, in order to obtain a "success tree" from a "fault tree", replace all OR gates with AND gates in the original fault tree and vice versa, as well as replace all fault events with success events. Just like any other reliability analysis method, the FTA approach also has its benefits and drawbacks. Some of the benefits of the FTA approach are as follows:

- It identifies failures (hazardous activity) deductively.
- It serves as a graphic aid for process management and hazard analysis
- It provides insight into the process behavior.
- It can handle complex systems more easily.
- It allows concentration on one particular hazardous event at a time and requires the analyst to understand thoroughly the process under consideration prior to the starting of FTA.
- It provides options for management and others to conduct either qualitative or quantitative reliability analysis.

On the other hand, some of the drawbacks of the FTA approach include being time consuming, costly, end results difficult to check, and it doesn't consider relationships between each sub-event.

3.4 Failure Modes and Effects Analysis

FMEA is a structural method to study an activity or process that seeks to anticipate and minimize accidents or hazards. The main objective is to improve first-pass success through the early identification of issues that might create hazards. FMEA asks the question, “What can go wrong?” even if there is no existing hazard. FMEA methodology provides a structural method with resulting documentation to aid in meeting specified objectives. When FMEA is extended to classify each potential hazard effect according to its severity, the method is known as failure mode effects and criticality analysis (FMECA). [10]

The history of FMEA goes back to the early 1950s with the development of flight control systems when the U.S. Navy’s Bureau of Aeronautics, in order to establish a mechanism for reliability control over the detail design effort, developed a requirement called “Failure Analysis”. Subsequently, the Bureau of Naval Weapons introduced it into its new specification on flight controls. [12]

In the 1970s, the U.S. Department of Defense directed its effort to develop a military standard entitled “Procedures for Performing a Failure Mode, Effects, and Criticality Analysis”. Today FMEA/FMECA methods are widely used in the industry to conduct analysis of systems, particularly for use in aerospace, defense, and nuclear power generation, and are well-known tools of quality systems.

The name FMEA can be broken down in related terms. Failure Mode is the manner in which an activity could potentially create a hazard or an accident. Effects, is the potential nonconformance or hazard stated in terms of the person doing that activity or on working environment and equipment. Cause is the potential reason(s) of the specified hazard or accident. By performing an FMEA, failure modes will be anticipated, and then risks can be determined and assessed for the specific activity.

3.4.1 Terms and Definitions

There are many terms used in performing FMEA/FMECA and some of them are to be explained in this part.

- **Failure Cause:** The factors such as design defects, quality defects, physical or chemical processes, or part misapplications that results in an accident or hazard.
- **Failure Mode:** A state or manner through which an accident or hazard is perceived.
- **Failure Effect:** The consequence of an accident or hazard on a person, environment, and equipment
- **Criticality:** A relative measure of a failure mode's consequences and its occurrence frequency.
- **Severity:** A failure mode's consequences, taking into consideration the worst case scenario of an accident, determined by factors such as damage to machinery, the degree of injury, or ultimate system damage.
- **Corrective Action:** A change such as design, process, procedure, or materials implemented and validated to rectify accident or hazard cause.
- **Criticality Analysis:** An approach through each possible accident or hazard is ranked with respect to the combined influence of occurrence, probability and severity.
- **Undetectable Failure:** A postulated accident or hazard in the FMEA for which no hazard detection approach is available through which the concerned operator can be alerted of the failure.

3.4.2 Steps for Performing FMEA

FMEA can be performed in six steps. These steps are as follows:

- Define system and its associated requirements,
- Establish ground rules,
- Describe the system and its associated functional blocks,
- Identify failure modes and their associated effects,
- Prepare critical items list,
- Document the analysis.

For illustrative purposes the previous example will be used.

3.4.2.1 Define system and its associated requirements

This is concerned with defining the process or operation under consideration and the definition, normally incorporates a breakdown of the process into blocks, block functions, and the interface between them. Usually a systematic definition of the process does not exist and the analyst must develop his/her own definition using documents.

In the specified example, process under consideration was a worker grinding an iron part weighting about 50 Newton on a horizontal grinding machine in the machine-shop of the company. Worker grinds 20-25 casting in an hour.

3.4.2.2 Establish ground rules

Usually, developing the ground rules is a quite straightforward process when the system definition and mission requirements are reasonably complete. Nonetheless, examples of the ground rules might include primary and secondary mission objectives statement, limits of environmental and operational stresses, statement of analysis level, delineation of mission phases, and definition of what constitutes accident or hazard.

In the specified grinding example, ground rule should be established by the manager of the company. However no such rule is established in the company. For illustrative purposes one can assume that there won't be more than 3 accidents in 1000 working hours.

3.4.2.3 Describe the system and its associated functional blocks

This step is concerned with the preparation of the description of the system under consideration. System block diagrams are widely used to determine the accident or hazard relationships among the overall process; thus, it graphically shows all steps of the process In addition this, the block diagram shows the entire process's inputs and outputs.

In the specified grinding example using narrative functional statement, overall process can be divided into 3 subgroups. These are;

- Reach into metal box to right of machine, grasp casting, and bring it to the wheel.
- Push casting against wheel to grind off burr.
- Place finished casting in box to left of machine.

3.4.2.4 Identify failure modes, their associated effects and criticality

This is step concerned with performing analysis of the accident and their effects. A form such as shown in Figure-3.5 is used as a worksheet to assure systematic and thorough coverage of all accident. Specified grinding process is inspected and table is filled up by using this results.

3.4.2.5 Prepare critical items list and Documenting

The critical items list is prepared to facilitate communication with the workers and top managers. For the specified grinding process critical items that workers must obey are:

- Wear steel-toe shoes
- Use protective gloves that allow better gripping
- Place the castings to the specified place.

Documenting is the final step of the FMEA performing process and is concerned with the documentation of analysis. This step is at least as important as the other previous five steps because poor documentation can lead to ineffectiveness of the FMEA.

Process	**Accident or Hazard (Failure Mode)**	**Potential Effects of Accident or Hazard**	**Potential Cause of Accident**	**Recommended Action**
Grinding	Worker could drop the casting onto his feet	A broken toe.	Slipping of casting part while picking up from metal box	Use protective gloves that allow better gripping Wear steel toe-shoe
Grinding	A muscle strain to the lower back.	Slows the process	Reaching, lifting 50 N. casting from the metal box.	Place castings closer to work zone Train worker for the correct lifting procedure.

Figure-3.5: A sample FMEA form prepared for a grinding process

The criticality of each hazard and accident can be determined by using the one of the methods mentioned in the Risk and Risk Management chapter.

3.5 What-If Analysis

What –If Analysis is a structured brainstorming method of determining what things can go wrong and judging the likelihood and consequences of those hazardous situations occurring.[13] The answers to these questions form the basis for making judgments, regarding the acceptability of those risks and determining a recommended course of action for those risks judged to be unacceptable. An experienced analysis team can effectively and productively discern major hazards in a process or system. Lead by experienced team leader, each member of the analysis team participates in assessing what can go wrong based on their past experiences and knowledge of similar situations.

Team members usually include operating and maintenance personnel, design and/or operating engineers, specific skills as probability and statistics, engineering (electrical, mechanical, chemical, or nuclear), systems analysis, health sciences, social sciences, and physical, chemical, or biological sciences. At each step in the procedure or process, What-If questions are asked and answers generated. To minimize the chances that potential hazards are not overlooked, moving to recommendations is held until all of the potential hazards are identified.

3.5.1 Steps for Performing What if Analysis

What if Analysis can be performed in four steps. These steps are as follows:

- Defining the boundaries of the analysis
- Gathering information
- Conducting analysis
- Reporting

3.5.1.1 Defining the Boundaries of the Analysis

The first steps in performing an effective analysis include defining the boundaries of the analysis, involving the right individuals and to have the right information. The boundaries of the analysis may be a single hazardous event, a collection of related equipment or an entire hazardous process. A narrow focus results in an analysis that is more detailed and explicit in defining the hazards and specific recommended controls. As the analysis boundaries expand to include the equipment involved in a large complex process or even an entire facility the findings and recommendations become more overview in nature. The boundaries can include, the steps involved in the operation of the equipment or facility or sudden equipment failures.

Assembling an experienced, knowledgeable team is probably the single most important element in conducting a successful What-If analysis. Individuals experienced in the design, operation, and servicing of similar equipment or facilities is essential. Their knowledge of design standards, regulatory codes, past and potential operational hazards, brings a practical reality to the review.

3.5.1.2 Gathering Information

The next most important step is gathering the needed information. One important way to gather information on an existing process or piece of equipment is for each review team member to visit and walk through the operation. Tapes of the operation, still photographs are important and often under utilized excellent sources of information. Additionally, design documents, operational procedures, or maintenance procedures are essential source of information for the analysis team.

3.5.1.3 Conducting Analysis

In this step firstly; What-If" questions must be formulated around human errors, process hazards, and equipment failures by using the documents available and knowledge of the analysis team. These hazards and failures can be considered during normal production operations, during construction; during maintenance activities. The questions could address any of the following situations:

- Hazards due to follow procedures or procedures followed incorrectly
- Procedures incorrect or latest procedures not used
- Operator inattentive or operator not trained

- Procedures modified due to hazards
- Process conditions creates hazards
- Equipment failure
- Hazards due to utility failures such as power, steam, gas
- External influences such as weather, vandalism, fire

Experienced personnel are knowledgeable of past hazards and likely sources of potential hazards. That experience should be used to generate "What-If" questions; the same example will be used. Some typical questions that could be generated are shown in Figure-3.6 for illustration purposes.

As the "What-If" questions are being generated, the analyzer should ensure that all input potential errors or hazards are considered. Determining the answer to each question as it is generated creates the danger of closing too soon on all possible hazards.

After revealing the most credible "What-If" scenarios, then the analyzer answers the question, what would be the result of that situation occurring? For example, consider the following answers illustrated in Figure-3.6 to the "What-If" questions in specified grinding process example.

The next step is to make judgments regarding the likelihood and severity of that situation. In other words risk is assessed in this part. The analyzer needs to make judgments regarding the level of risk and its acceptability. As an example, consider Figure-3.7 for the risk criticality assessment and recommendations to the answers in the example specified.

3.5.1.4 Reporting

Reporting is the final step of the What-If Analysis performing process and is concerned with the documentation of analysis. This step is at least as important as the other previous five steps because poor documentation can lead to ineffectiveness of the analysis. A sample form for reporting is shown in Figure-3.7.

What If?	Answer	Likelihood	Consequences	Recommendations
1. Picking up the iron casting worker drop it on his feet 2. Picking up the iron casting sharp burrs and edges cut workers hand 3. Worker's hand contacts with grinding wheel 4. Flying chips reaches worker's eye.	1. Leg, foot injury 2. Deep cuts on hand. Lower production rate. 3. Injures fingers. 4. Loss of eye-sight			

Figure-3.6: A sample What-If analysis answers for a grinding process

3.5.2 Advantages and Drawbacks of What-If Analysis

What-If Analysis technique is simple to use and has been effectively applied to occupational health and safety systems. No specialized tools or techniques are needed. Individuals with little hazard analysis experience can participate in a full and meaningful way. The results of the analysis are immediately available and usually can be applied quickly.

On the other hand, the technique does rely heavily on the experience and intuition of the analyzer. It is somewhat more subjective than other methods, such as Hazard and Operability Analysis (HAZOP), which require a more formal and systematized approach. If all of the appropriate What-If questions are not asked, this technique can be incomplete and miss some hazard potentials. It may be appropriate to assign those more dangerous portions of the system to a more rigorous review such as HAZOP.

What If?	Answer	Likelihood	Consequences	Recommendations
1. Picking up the iron casting worker drop it on his feet	1. Leg, foot injury	Possible	Serious	Wear steel toe-shoe
2. Picking up the iron casting sharp burrs and edges cut workers hand	2. Deep cuts on hand. Lower production rate.	Possible	Minor	Remove large burrs before grinding process.
3. Worker's hand contacts with grinding wheel	3. Injures fingers.	Quite possible	Serious	Use gloves to protect hands
4. Flying chips reaches worker's eye.	4. Loss of eye-sight	Possible	Minor	Use protective eye glasses.

Figure-3.7: A sample What-If analysis form for a grinding process

CHAPTER 4

RISK AND RISK ASSESSMENT

4.1 Definition of Risk and Risk Assessment

A risk is the chance or likelihood that someone will be harmed by a hazard or an accident. Thus in simple terms risk assessments determine the hazards, the probability of harm occurring and the possible consequences. This allows controls to be identified, and they can then be introduced to reduce risk, or its effects, and provide the information for the production of safe systems of work.

Risk assessment is the systematical method to determine the possible hazards, the probability of harm occurring, and the possible consequences of that harm and its severity.

Risk assessment may simply be divided into 2 processes. [14] These are risk analysis and risk evaluation. In turn, risk analysis is concerned with the utilization of available data for determining the risk to human, environment, or property/equipment from hazards and usually is made up of steps such as scope definition, hazard identification, and risk determination. The stage at which values and judgments make entry to the decision process is known as risk evaluation.

The complete process of risk assessment and risk control is called risk management. The term "risk control" is simply the decision making process concerned with managing risk as well as the implementations, enforcement, and re-evaluation of its effectiveness periodically, using risk assessment end results as one of the input factors

4.2 Risk Analysis Process

Risk can only be managed effectively after its comprehensive analysis. Risk analysis serves as a useful tool in identifying health and safety problems and approaches to uncover their solutions, satisfying regulatory requirements, and facilitating objective decisions on the risk acceptability.

A multi-disciplinary approach is often required to conduct risk analysis and it may require adequately sufficient knowledge in areas such as probability and statistics, engineering (electrical, mechanical, chemical, or nuclear), systems analysis, health sciences, social sciences, and physical, chemical, or biological sciences.

The risk analysis process is composed of six steps as shown in Figure-4.1.

4.2.1 Establishing scope definition

In the first step of the risk analysis process and the scope is defined and documented. However, it is imperative that the process under consideration must initially be thoroughly understood. Nonetheless, the following five basic steps are involved in defining the risk analysis scope:

1. Describe the problems leading to risk analysis and then formulate risk analysis objectives on the basis of major highlighted concerns.
2. Define the system under consideration by including factors such as general process description, environment definition, and physical and functional boundaries definition.
3. Describe the risk analysis associated assumptions and constraints.
4. Highlight the decisions to be made.
5. Document the total plan.

4.2.2 Identifying hazards

This is the second step of the risk analysis process is basically concerned with the identification of hazards that will lead to a risk in the process. This step also calls for the preliminary evaluation of the significance of the identified hazardous activities.

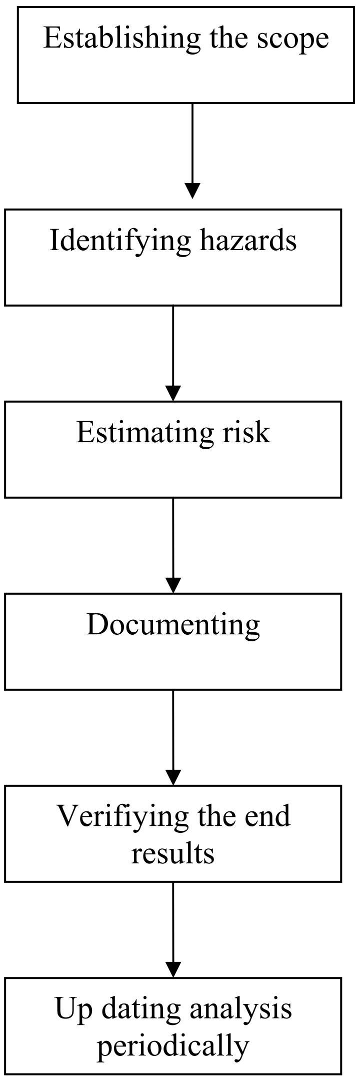

Figure-4.1: Flow chart for risk analysis process

The main purpose of this evaluation is to determine the appropriate course of action. In this step hazardous activity is divided into steps and hazards associated with each steps are identified. It should be noted that while dividing the activity into steps care must be taken not to make the steps too general, thereby missing specific steps and their associated hazards. On the other hand, if they are too detailed, there will be too many steps. A rule of thumb is that most of the activities can be described in less than ten steps.

An important point to remember is to keep the steps in their correct sequence. A step which is out of order may cause some potential hazards to be overlooked or consider hazards which do not actually exist.

Some of the methods that can be used to identify hazards were dealt in greater detail in Chapter 3 of this study.

4.2.3 Estimating Risk and Its Criticality

This is the third step of the risk analysis process. Risk is estimated and then level of its criticality is determined. As it is mentioned above, risk is the chance or likelihood that someone will be harmed by a hazard. Therefore it is an expression of combined severity and probability of loss. After this definition risk can be expressed as;

$$\text{Risk} = \text{Probability} * \text{Severity} \qquad 4.1$$

In this expression severity is the answer to the question ‘How serious is the consequence of this loss?’ and probability is to ‘How often this loss event takes place?’ It is obvious that answers of these questions variable. Thus; scale for the severity and probability change according to process, management strategy and sensitivity to that specific kind of risk. However there are standards prepared to scale severity and probability.

In the above equation probability includes the exposure time to that specific type of risk. If worker exposed to that risk longer the probability of that risk is higher. In order to illustrate this effect more clearly exposure time is dealt separately from the probability after this point.

The criticality assessment is used to prioritize risks namely, the accident or hazards, discovered during the system analysis on the basis of their effects and occurrence likelihood. There are 2 methods used commonly these are Risk Priority Number (RPN) Technique and Criticality Matrix Method.

4.2.3.1 RPN Technique

This method calculates the risk priority number for an accident or hazard. According to the formula developed by Alp Esin [16] RPN number is calculated by using three factors: severity, occurrence probability, and exposure time. In this approach, exposure time is introduced as a separate factor for the ease of use.

More specifically, the risk priority number is computed by multiplying the rankings (i.e., 1–10) assigned to each of these three factors. Thus, mathematically the risk priority number is expressed by;

$$RPN = Severity \cdot Occurrence \cdot Exposure \quad (4.2)$$

Severity is a rating (1–10) of the seriousness of the hazard or accident on the worker or working environment. A rating scale for the severity is shown in Table 4.1 [16]. Some of the guidelines are left free so that user can iterate between ratings.

Occurrence is a rating (1–10) of the probability of the accident or hazard to occur during the total process time. A rating scale for the probability is shown in Table 4.2. [14]. Exposure is a rating (1–10) of the time exposed to the potential hazard. A rating scale for the exposure is shown in Table 4.3. [16].

Table 4.1: Scale for the level of severity

Rating	Guideline	Rank
Very High	Indicates a potential accident or hazard that cause death (9 with warning 10 without warning)	10
		9
High	Permanent disability	8
High to Moderate		7
Moderate	Serious injury.	6
Moderate to Low		5
Low	Three day injury	4
Low to Minor		3
Minor	Minor injury	2
Very Minor		1

Table 4.2: Scale for the level of probability

Accident	Likelihood of Accident or Hazard	Ranking
Very High	Almost in inevitable	10
		9
High	Repeated	8
		7
Moderate	Occasional	6
		5
		4
Low	Relatively few	3
		2
Remote	Unlikely	1

Table 4.3: Scale for the level of exposure

Rating	Guideline	Rank
Very High	Always exposed to risk	10
		9
High	Exposed to risk within hours	8
		7
Moderate	Exposed to risk within minutes	6
		5
Low	Exposed to risk within second	4
		3
Remote	Exposed to risk instantaneously	2
		1

Accidents and hazards with a high RPN are considered to be more critical; thus, they are given a higher priority in comparison to the ones with lower RPN. Nonetheless, rankings and their interpretation may vary from one organization to another. Tables presented in this part for exposure, occurrence probability, and severity used in one organization. They are used here for illustrative purposes.

In this study a different scale for severity, probability, and exposure is prepared according to the occupational accident data that is compiled. This scale is simpler and compatible with the standard. It is modified from the Health and Safety Advisory Group in United Kingdom. [17] Scales are shown in Table 4.5-Table 4.7.

Table 4.4: Scale for the level of severity used in this study

Level	Hazard Effect
5	Death or permanent disability
4	Over 30-day injury: long-term disability
3	Over 3-day injury: temporary disability
2	Under-3 day injury
1	Minor injury

Using the hazard effect table, probability level table, and exposure level table associated risk level can be calculated. A rating scale for the RPN is also prepared. Rating scale for the RPN is shown in Table 4.7.

Table 4.5: Scale for the level of probability used in this study

Level	Probability
5	Will invariably happen: almost certain
4	Highly probable
3	Possible: Feasible
2	Possible: Might happen
1	Remote possibility/negligible

Table 4.6: Scale for the level of exposure used in this study

Level	Exposure
5	Always exposed to risk
4	Exposed to risk within hours
3	Exposed to risk within minutes
2	Exposed to risk within second
1	Exposed to risk instantaneously

Table 4.7: Scale for the level of RPN

RPN	Action
64-125	Unacceptable Risk: Requiring immediate action
30-64	Risk Reduction: High Priority
18-30	Medium Risk: Action as soon as possible
8-18	Low Priority: Further Reduction may not be feasible
1-8	Low Risk: No further action required

4.2.3.2 Criticality Matrix Method

For the purpose of comparing each risk to all other risk types with respect to severity, a critical matrix can be developed. A sample matrix is shown Figure-4.2.

← Probability →

Severity of Consequences	Improbable	Remote	Occasional	Probable	Frequent
Catastrophic					
Critical					
Marginal					
Negligible					

Figure-4.2: A sample critical matrix

The criticality matrix is developed by inserting process or activity identification number values in matrix locations denoting the severity category classification and either the criticality number (Ki) for hazard type or the occurrence level probability. The distribution of criticality of hazard is depicted by the resulting matrix.

This matrix serves as a useful tool for assigning corrective measure priorities. The direction of the arrow, originating from the origin, shown in the critical matrix, indicates the increasing criticality of the hazard and the darkened region in the figure shows the approximate desirable region as shown in Figure-4.3.

For severity classifications A and B, the desirable region has low occurrence probability or criticality number. On the other hand, for severity classifications C and D failures, higher probabilities of occurrence can be tolerated. Nonetheless, hazards belonging to classifications A and B should be eliminated altogether or at least their probabilities of occurrence be reduced to an acceptable level through changes.

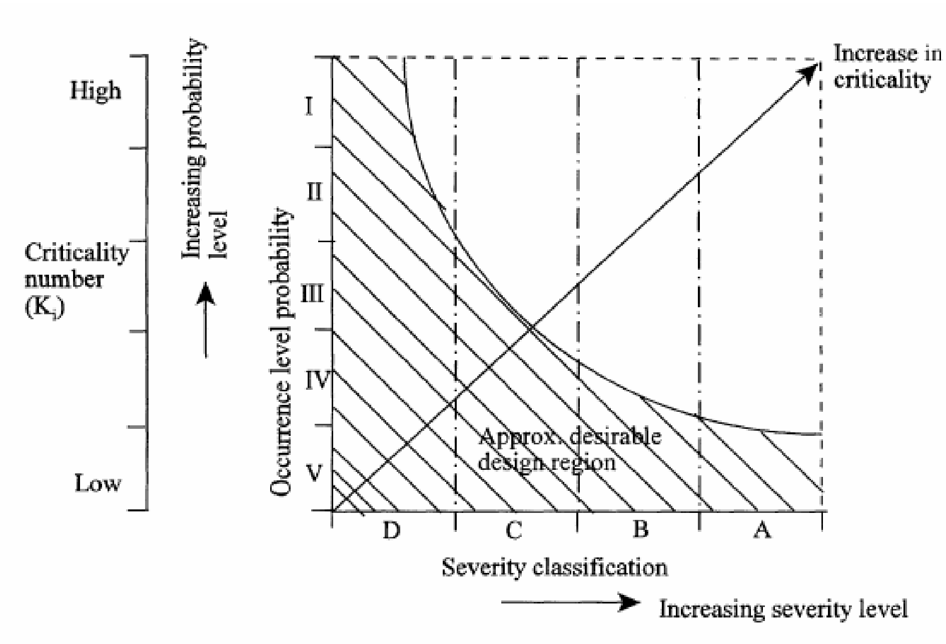

Figure-4.3: Explanation of a critical matrix

4.2.4 Documenting

Documenting is the fourth step of the risk analysis process and is basically concerned with effectively documenting the risk analysis plan, the preliminary evaluation, and the risk estimation. The documentation report should contain sections, such as title, abstract, conclusions, table of contents, objectives/scope assumptions/limitations, system description, analysis methodology description, results of hazard identification, model description and associated assumptions, quantitative data and associated assumptions, results of risk estimation, references, appendices, discussion of results, and sensitivity analysis.

4.2.5 Verifying and Updating

The fifth step of the risk analysis process is basically concerned with verifying the end results. More specifically, it may be stated that verification is a review process used to determine the integrity and accuracy of the risk analysis process. Verification is conducted at appropriate times by person(s) other than the involved analyst(s).

The final step of risk analysis is concerned with periodically updating the analysis as more up-to-date information becomes available.

CHAPTER 5

THE CASE STUDY

5.1 Description of the Company

The company manufactures high volume of small and medium size castings in gray, nodular and vermicular cast iron for JIT delivery to international customers. The production plant is located near Bilecik and the headquarter office of the company is in İstanbul. The company employs 65 white-collar (engineer) and 375 blue collar (direct worker) personnel in the plant in Bilecik. Due to the privation of the company; name of the company will not used in this study.

Company manufactures mainly products for automotive industry such as exhaust manifolds in nodular and vermicular iron, engine brackets, levers and various casting in nodular iron for car engines**,** brake cylinders, brake bodies, brake calipers in nodular iron. In addition to these, various casting for washing machine and durable white goods are manufactured. The production capacity of the plant is about 70.000 tons and company sells about %85 of its products to export markets mainly in Europe.

Quality policy of the company is to create customer satisfaction; trough producing the highest quality products at the lowest possible cost, and through delivering the specified quantity, at the specified time, at the specified location. The quality policy of the company is accredited by QS 9000 Certification and ISO 9002 Certification.

The company does not have a special occupational health and safety department with trained personnel. A foreman on duty is to deal with the occupational health and safety problems. There is no intermediate link between the foreman and the management of the company. Thus health and safety problems are left in the hands of foreman, reinforced only by the casual visits of the higher managers of the firm.

The occupational accidents that occurred in 2002 and reported to S.S.K are going be analyzed in this study. The complete list of these accidents is presented in Appendix B. List includes the date, type, and the consequences of the accidents in terms of lost work day.

5.2 Types of Accidents Observed in Company

Accidents that occur in the specified company can be classified according to their causes. A brief explanation of each type is provided in this section.

Flying Chip or Crop: This type of hazard results from any type of chip or crop that becomes airborne, because of moving parts and shearing action. The airborne chip is generally hot due to the friction forces that occur while moving or shearing. This hot chip moving with the high velocity might create hazards when contacts to skin and eye. Grinding process is an example that creates this kind of hazard.

Hit by an Object: This type of hazard is somewhat similar to flying chip or crop case however usually the object has greater mass. Therefore the hazard associated with this event is more serious than the first case.

Object Falling from Height: This type of hazard results from an object falling from an elevated position. The severity of the hazard depends on the height and the mass of the object. The use of mobile cranes particularly within the premises of the working environment in order to install or remove equipment, increase the risk of this kind of hazard. In addition to these; demolitions and dismantling work might create this kind of hazards.

Strain from lifting, pulling, and pushing: Lifting, pulling, and pushing results in strain to lower back, shoulders, and arms. This strain causes spine and muscles to be deteriorated. Many of the workers faced with this kind of hazard since installing or removing of an equipment or work-piece is a daily activity.

Stuck between objects: This type of hazard results from, squeezing a part of the body between 2 objects. In this type of hazard at least one of the objects must be moving. Mass and velocity of the object determines the severity of the hazard on human body. As an example to this kind of hazard worker can be stuck between the transport vehicle and the wall or a rigid body.

Slip, trips or fall on the same level: Slips occur when there is too little friction between a person's feet and the walking surface. Many factors can cause a slip. Ice, oil, water, cleaning fluids, and other slippery substances are probably the most obvious causes of slips in work places.

Trips occur when one's foot contacts an object and one is thrown off balance. The main cause of tripping is the objects that are left on a walkway. Poor lighting and uneven walking surfaces also results in tripping

Falls on the same level can be caused by a number of things. Slips and trips frequently result in a fall.

Exposure to extreme heat: This hazard arises, from the contact with the hot body or work-piece that is present at the workplace. This type of hazard results in severe burns injuries and long time disability. The severity of the hazard depends on level and duration of exposure to hot body or work-piece.

Contact with moving machine part: Machines, under some circumstances, can be hazardous to the health and safety of worker. Contact with moving parts can result in lost or severe cuts on fingers, hands and arms. Source of this kind of hazard can be investigated in 3 parts. These are

- The point of operation
- Power transmission apparatus
- Other moving parts

The point of operation means that point where work is performed on the material, such as cutting, shaping, boring, or forming of stock.

Power transmission apparatus can be defined as all components of the mechanical system which transmit energy to the part of the machine performing the work. These components include flywheels, pulleys, belts, connecting rods, couplings, cams, spindles, chains, cranks, and gears.

Other moving parts can be defined as all parts of the machine which moves while the machine is working. These can include reciprocating, rotating, and transverse moving parts, as well as feed mechanisms and auxiliary parts of the machine.

Exposure to chemical substances: This hazard arises, from the effects of chemical agents that are present at the workplace or as a result of any work activity involving chemical agents. The severity of the hazard depends on their hazardous properties of the chemical hazard, the level, type and duration of exposure.

5.3 Accident Data Compilation

For this thesis study, 180 work accident reports for the year 2002 were analyzed. The list of the work accidents in this study are listed in Appendix B. Table-5.1 represents the number of work accidents and their percentage's in descending order, in order to make a comparison between the types of the work accidents in that company.

Amongst 180 work accidents in the company, the most frequent cause of the work accident is the flying chip or crop which has the highest percentage of 42. There is no significant difference between the frequencies of other types of accident accept from exposure to chemical substances. This type of work accident has the lowest percentage of 1% and occurred only 3 times in 2002. The distribution of all work accidents in this study according to their type is presented in Table-5.1 and the Pareto analysis in Figure 5.1.

Table 5.1: Number and Percentage of the Work Accidents in the Company

TYPE OF THE ACCIDENT	NUMBER OF ACCIDENT	PERCENTAGE OF ACCIDENT
Flying chip or crop	77	42,78
Object falling from height	21	11,67
Contact with moving machine part	19	10,56
Hit by an object	17	9,44
Strain from lifting, pulling, pushing	12	6,67
Stuck between objects	11	6,11
Slip, trips or fall on the same level	10	5,56
Exposure to extreme heat	10	5,56
Exposure to chemical substances	3	1,67

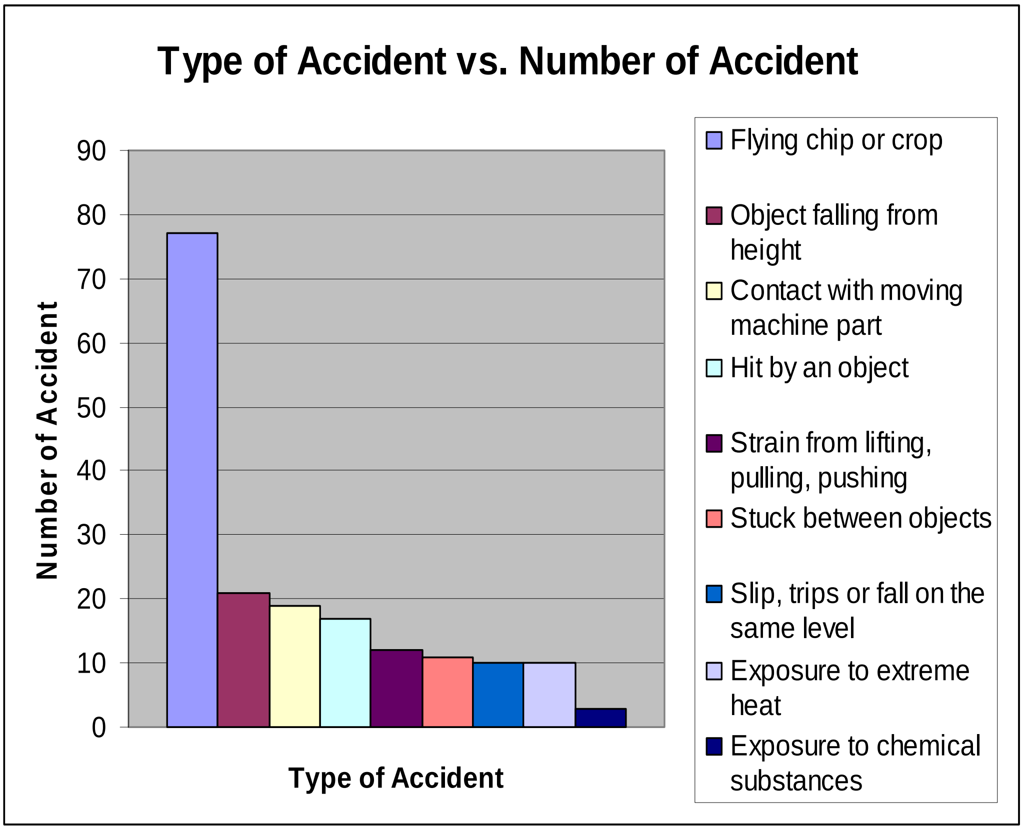

Figure-5.1: The distribution of all work accidents according to their type

In order to investigate the consequences of these types of accident on the workers, numbers of lost work days are considered. Table-5.2 represents the number of lost work days and their percentages in descending order, to make a comparison between the types of the work accidents and their consequences on workers.

Table 5.2: Number and Percentage of the Lost Work Days in the Company

TYPE OF THE ACCIDENT	NUMBER OF LOST WORK DAY	PERCENTAGE OF LOST WORK DAY
Flying chip or crop	199	21,17
Object falling from height	194	20,64
Exposure to extreme heat	155	16,49
Strain from lifting, pulling, pushing	109	11,60
Stuck between objects	98	10,43
Contact with moving machine part	90	9,57
Slip, trips or fall on the same level	50	5,32
Hit by an object	40	4,26
Exposure to chemical substances	5	0,53

Of the 180 work accidents in the company, flying chip or crop type of work accident results in the highest percentage of lost working day with 21%, considering total number of work accidents. Object falling from the height has the second highest percentage of 20% which is very close to the flying chip or crop type of work accident. The distribution of lost working day according to type of accidents is presented in Figure-5.2.

It is worth pointing out that, the total number of lost working day is about 940 days. Assuming that there is no work accident and a worker works about 260 days a year, the company could save up about 940 work days which is equal to the 4 worker's working full time in a year.

Classification of lost work days in the company with respect to the types of the accidents are given in Table-5.3.

The accidents were analyzed according to the lost working day. For this purpose, they were grouped into three as under-3 Day, Over-3 Day and Over-45

Day. In 180 work accidents in the company, flying chip or crop type of work accident resulted in the highest loss with 54% for ‘Under 3-Day’. There was no significant difference between the other types of accident. The distribution of under 3-day lost working day according to type of accidents is presented in Figure-5.3. Table-5.4 represents the number of under 3-day lost work days and their percentages in descending order, to make a comparison.

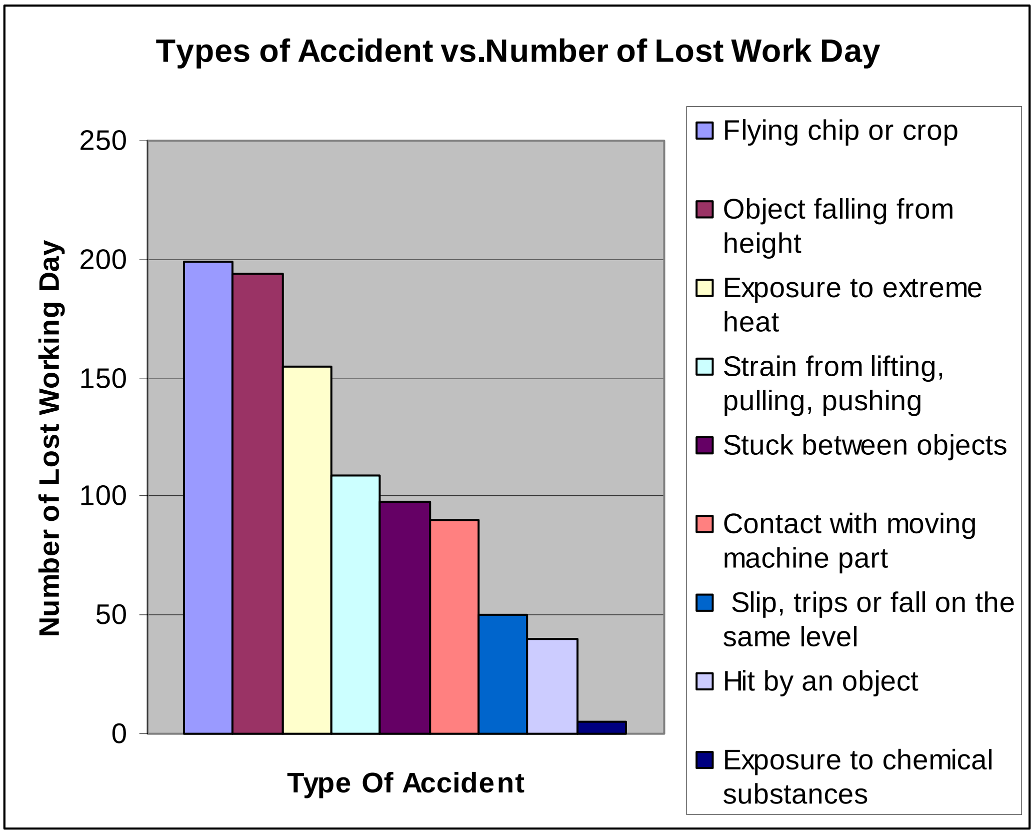

Figure-5.2: The distribution of all work accidents according to lost work day

When the over 3-day lost work day case is considered, contact with a moving machine part has the highest percentage of 22. Flying chip or crop, object falling from height, strain from lifting, pulling, and pushing has the second highest percentage of 15%. The distribution of over 3-day lost working day according to type of accidents is presented in Figure-5.4. Table-5.5 represents the number of under 3-day lost work days and their percentages, in descending order to make a comparison.

Table 5.3: Classification of Lost Work Days in the Company

TYPE OF THE ACCIDENT	UNDER 3-DAY	OVER 3-DAY	OVER 30 -DAY
Flying chip or crop	68	8	1
Object falling from height	13	5	3
Hit by an object	13	4	0
Contact with moving machine part	8	11	0
Stuck between objects	8	2	1
Slip, trips or fall on the same level	6	4	0
Strain from lifting, pulling, pushing	4	7	1
Exposure to extreme heat	3	6	1
Exposure to chemical substances	3	0	0

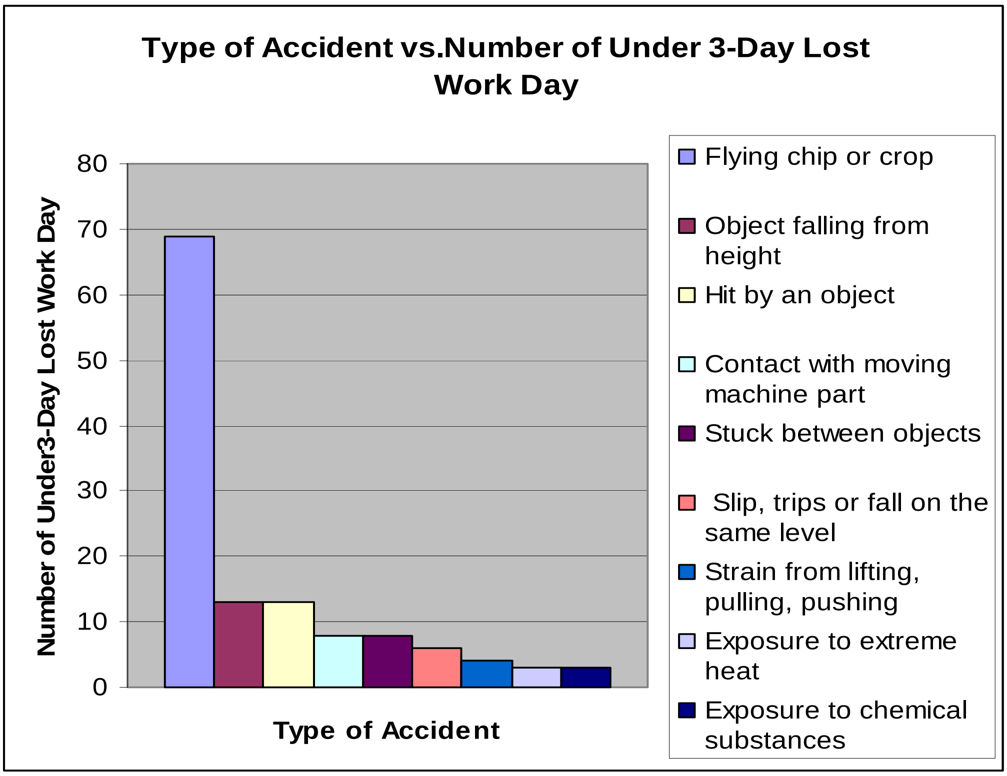

Figure-5.3: The distribution of work accidents according to Under 3-Day lost work day

Table 5.4: Number and Percentage of the Under 3-Day Lost Work Days in the Company

TYPE OF THE ACCIDENT	UNDER 3-DAY	PERCENTAGE OF UNDER 3-DAY
Flying chip or crop	69	54,33
Object falling from height	13	10,24
Hit by an object	13	10,24
Contact with moving machine part	8	6,30
Stuck between objects	8	6,30
Slip, trips or fall on the same level	6	4,72
Strain from lifting, pulling, pushing	4	3,15
Exposure to extreme heat	3	2,36
Exposure to chemical substances	3	2,36

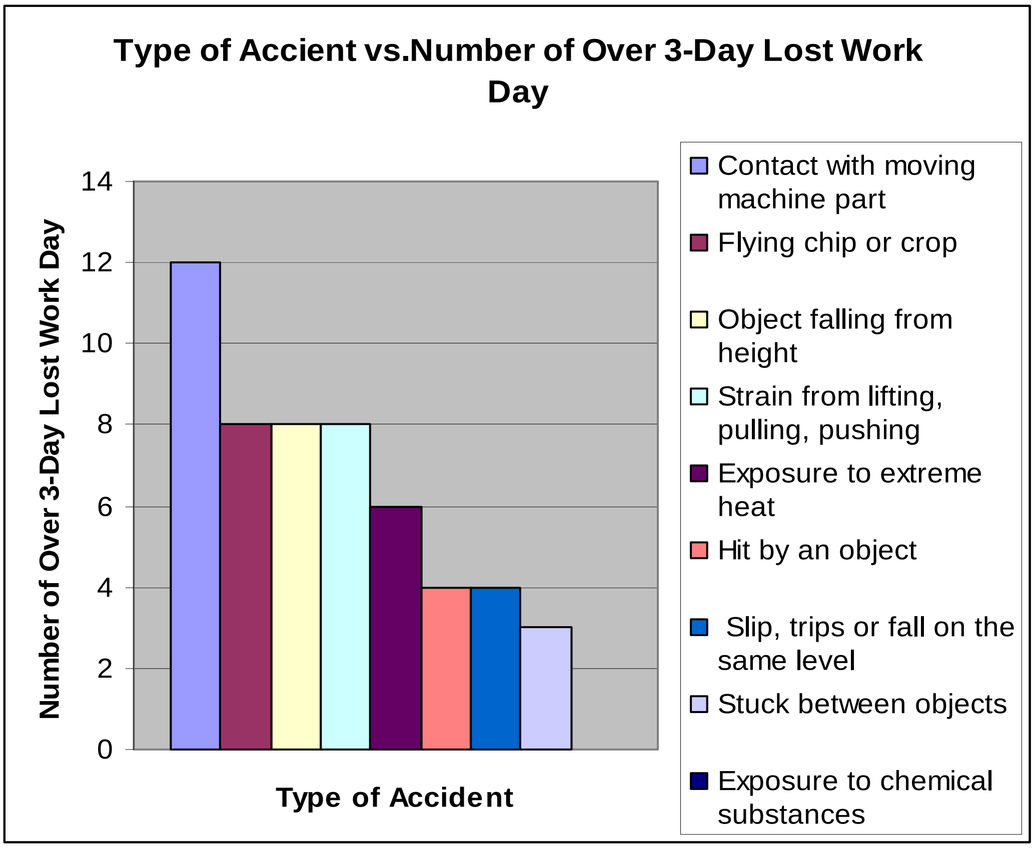

Figure-5.4: The distribution of all work accidents according to Over 3-Day lost work day

Table 5.5: Number and Percentage of the Over 3-Day Lost Work Days in the Company

TYPE OF THE ACCIDENT	OVER 3-DAY	PERCENTAGE OF OVER 3-DAY
Contact with moving machine part	12	22,64
Flying chip or crop	8	15,09
Object falling from height	8	15,09
Strain from lifting, pulling, pushing	8	15,09
Exposure to extreme heat	6	11,32
Hit by an object	4	7,55
Slip, trips or fall on the same level	4	7,55
Stuck between objects	3	5,66
Exposure to chemical substances	0	0

5.4 Risk Analysis of Data

As it is mentioned in the risk anaylsis section of this study a qualitive risk analysis technique is used. In this approach the individual occurrence probabilities of the accidents and hazardous activities are grouped into distinct logically defined levels, which establish the qualitative occurrence probabilities. Same steps are applied for the severity and exposure time to that specific hazard. For the purpose of comparing each accident type to all other accidents and hazardous activities RPN (Risk Priority Number) is used to scale the data. RPN method is used commonly in occupational health and safety studies since a relative scaling is needed rather than exact significant figures.

This type of risk analysis method has some advantages since it is easy to apply and can be used by personnel that do not have an engineering background. In addition to these in this method no accident or failure rate data is needed and all effects of the evaluated activity can be measured.

In order to determine the probability value for the RPN value, one must consider total number of that specific accident data. Considering Table 5.1, flying chip or crop type accident has the highest percentage and occurred 77 types in that year so the probability level for this accident can be taken as 'highly probable' which is equal 4 from Table 5.6. For the other cases, except for the exposure to chemical substances, probability level can be chosen as 'Possible: Might happen' case which is equal to 2. Probability level for the exposure to chemical substances cases can be chosen as 'Remote possibility/negligible' since it is occurred 3 times in that year. This level of probability is equal to 1 as shown in the probability level table.

Secondly, to calculate RPN value, severity values for that specific type of accidents must be considered. Table 5.7 used to estimate the severity level. Since number of lost working day is classified in 3 distinct categories, severity value for the accident is calculated in following manner by using Table 5.7.

Severity = (# of Under-3 Day*2 + # of Over-3 Day*3+ # of Over-30 Day*4)/Total # of Acc. 5.1

Table 5.6: Scale for the level of probability

Level	Probability
5	Will invariably happen: almost certain
4	Highly probable
3	Possible: Feasible
2	Possible: Might happen
1	Remote possibility/negligible

To illustrate the use of this equation flying chip or crop type of accident can be used. In this type of accident, number of Under-3 Day accident is 68, number of Over-3 Day accident is 8, number of Over-30 Day accident is 1 and total number of accident is 77. By using the equation above; severity can be found as;

Severity = (68*2+8*3+1*4)/77 = 2.12

Same procedure is applied for the other type of accident and results are shown below.

Table 5.7: Scale for the level of severity

Level	Hazard Effect
5	Death or permanent disability
4	Over 30-day injury: long-term disability
3	Over 3-day injury: temporary disability
2	Under-3 day injury
1	Minor injury

Finally to calculate RPN value, exposure time to that specific type of hazard must be estimated. Table 5.8 is used to estimate the exposure level. For the flying chip or crop, hit by an object, stuck between objects, strain from lifting, pulling, pushing and contact with moving machine part exposure level is taken as 4 since workers are exposed to this risks within working hours every day. In object falling from height and slip, trips or fall on the same level cases, exposure level is taken as 5 since workers are under that risk both in working hours and in leisure time during the work day. For exposure to extreme heat and exposure to chemical substances cases exposure level is taken as 3 since exposure to chemical substance and heat is possible in cleaning and maintenance period. This period is relatively short and can be expressed as 'exposed to risk within minutes' case.

Table 5.8: Scale for the level of exposure

Level	Exposure
5	Always exposed to risk
4	Exposed to risk within hours
3	Exposed to risk within minutes
2	Exposed to risk within second
1	Exposed to risk instantaneously

The RPN value for the all types of accidents and hazards are tabulated in descending order, to make a comparison between the types of the work accidents and RPN values. This table is shown in Table 5.9.

Table 5.9: RPN values for different types of accidents

Type of Accident	Probability Level	Severity	Exposure Level	RPN
Flying chip or crop	4	2,13	4	34,08
Slip, trips or fall on the same level	2	2,75	5	27,5
Object falling from height	2	2,52	5	25,2
Hit by an object	2	2,58	4	20,64
Stuck between objects	2	2,4	4	19,2
Strain from lifting, pulling, pushing	2	2,36	4	18,88
Contact with moving machine part	2	2,24	4	17,92
Exposure to extreme heat	2	2,8	3	16,8
Exposure to chemical substances	1	2	3	6

The distribution of RPN values with respect to types of accidents is presented in Figure-5.5. As it is mentioned in Chapter 4, risk is the combination of the probability, severity, and exposure time to that hazardous activity. When the Table 5.9 is investigated, although the severity and exposure time of the slip, trips or fall on the same level type of accident has higher level in severity and exposure time, since flying chip or crop type of accident occurs more frequently than the slip, trips or fall on the same level case RPN value associated with that case is higher. Therefore flying chip or crop type of accident is considered to be more critical; thus, given a higher priority in comparison to the ones with lower RPN value.

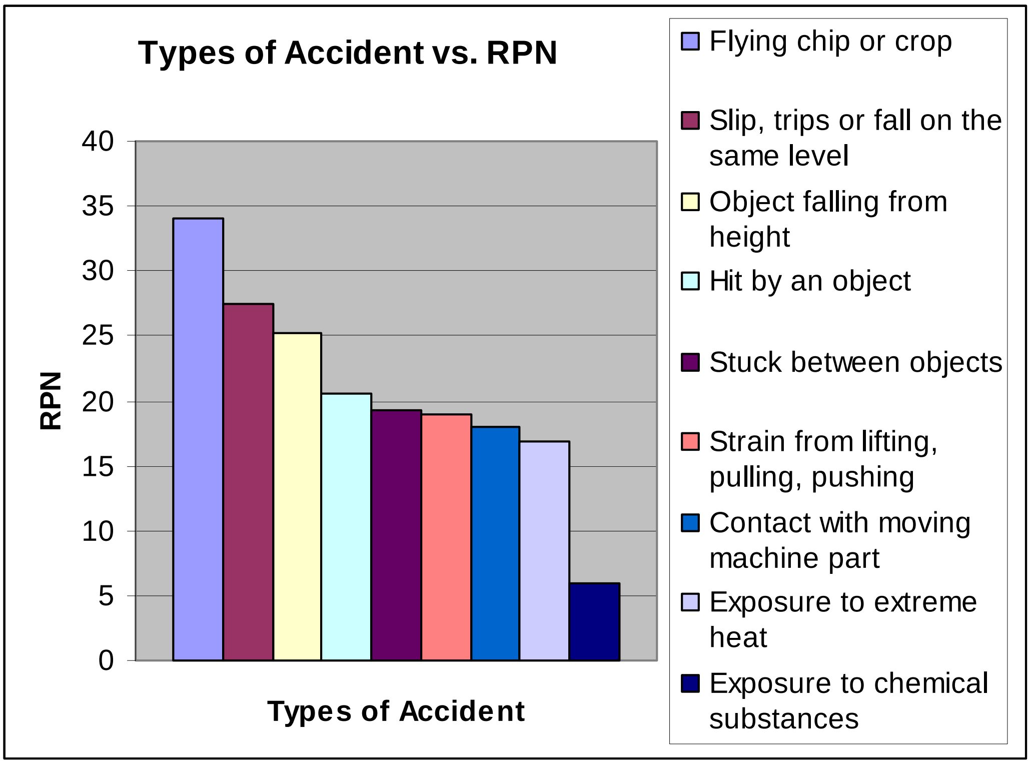

Figure-5.5: The distribution of RPN values with respect to types of accidents

CHAPTER 6

CASE STUDY OF THE MOST RISKY ACCIDENT

Flying chip or crop type of accident was shown to be the most risky accident type and its RPN was calculated in Section 5.4 and shown in Table 5.9 of this study. RPN for this type of accident was 34. In addition, according to the table prepared for the level of RPN (Table 4.7), this level of RPN has high priority for reduction and was therefore given the first priority in this study.

In this part of the thesis, the most risky accident type is going to be treated in the light of the system concept. A management system is developed to conduct a job in a safe manner. Using the safety system some preventive measures to reduce the level of risk can be identified and implemented during the course of activity or process. This approach is applicable to all types of industry and work practices in a systematic way and it integrates occupational health and safety with all other activities in a company

6.1 Current Situation in the Company

According to the accident data, the main source of flying chip or crop type of accident is the grinding process. During the walkthrough conducted in the company, it was observed that there were two lines of grinding machines. The operation was as follows;

- Workers sat on the stools and handled the part from a box placed on their right.

- Ground the part on the manual pedestal type grinding machine without using coolant.
- Put the finished part into a box placed on their left.

It was also observed that workers did not use face shield or goggle. During the interview with the engineer responsible for the machine-shop, the engineer emphasized that the employer supplied every worker a safety goggle; however the workers did not use the goggles supplied. When the grinding machines used in the processes were examined, it was seen that there were guards for the wheels however there were no other types of shields or protection used on the machinery to protect workers from flying chips.

In the following section, a system is proposed to eliminate the flying chip or crop type accident and some recommendations are made.

6.2 Developing Safety Management System

In this part of the study a safety management system is developed and flying chip or crop type of accident is analyzed step by step according to the system approach.

Occupational health and safety management is a systematic method to integrate safety into management and work practices at all levels so that work is accomplished while protecting the worker, and the environment. This aim can only be accomplished through effective integration of safety management into all facets of work planning and execution. In other words, the overall management of safety functions and activities should become an integral part of work accomplishment.

Figure 6.1 illustrates the conceptual relationship among the guiding principles. These functions are interdependent collection of functions that often occur at the same time.

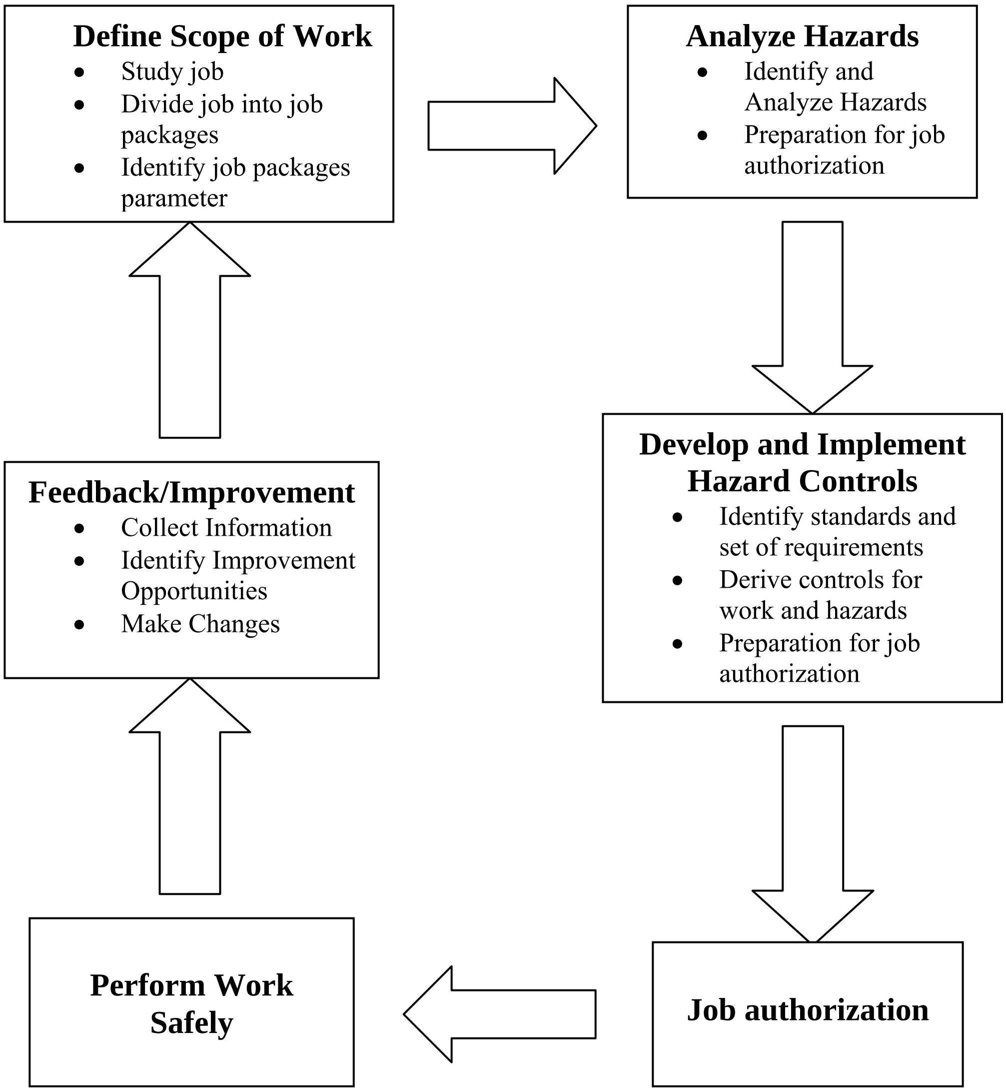

Figure-6.1: The conceptual relationship among the guiding principles in a SMS model

The output of each function can affect the results of each of the other functions and the whole system. For instance assessment and feedback conducted at any time during the performance of one function can affect future work planning. The steps as regards the system approach are outlined below.

6.2.1 Define Scope of Work

The fundamental objective of defining the scope of work is to identify the scope, schedule, and costs of activities necessary to achieve work and expectations in a safe manner. A well-defined scope of work is critical to the success of a safety management system because it sets the stage for the scope and depth of hazards identification and analysis.

When the flying chip or crop type of accident is considered; since the job, which is to remove fins, burrs, and rough spots, is rather simple then there is no need to divide this job into job packages. The scope and procedure of the job should be as follows:

- Part should be studied by a competent personnel and a decision should be made whether or not that part can be ground on the available machinery.
- The cast parts should be checked. If the sizes of fins are too large to remove by grinding, they should be removed by chiseling before grinding on the machinery.
- The cutting speed and feed should be decided considering the material of the part and the power of the machinery.
- Cutting speed, feed rate, type of machinery, and material of the work piece under consideration, an appropriate wheel should be selected by the competent personnel.
- Maintenance of the wheels should be planned. (When and how to dress and true the wheel, when to change wheel)

This step is finalized by job authorization. Job authorization is a form that is used to inform workers about the out comes of each step. For instance at the end of this step cutting speed, feed, type of abrasive wheel, machining time per part, total machining time is written on the job authorization form as shown in Table-6.1.

6.2.2 Analyze Hazards

The objective of hazards analysis is to develop an understanding of the potential hazard that would affect the health and safety of the worker, and the environment. Hazard controls are then established based on this understanding and other factors related to the job package. The analysis includes two steps; these are identifying and categorizing the hazard and analyzing accident scenarios related to hazardous job packages.

Potential and existing hazards are as follows for the flying chip or crop type accident in a grinding operation.

- There were no shields or any other protection on the machinery to protect workers from the flying chips. In addition; workers did not use goggle or face shield. Flying chips can reach to workers eye and damage the workers eye due to high temperature and velocity.
- Grinding machinery used in process had two speed settings. Improper settings such as excessive cutting speed increase the risk of flying chip or crop type of accident and can cause the wheel to burst
- Work piece was fed to machinery by hand. Excessive feed increase the risk of flying chip or crop type of accident and can cause the wheel to burst
- As the diameter of the wheel is reduced due to wear, cutting speed drops and the operator has to increase the pressure applied to the wheel to remove the same amount of material. This increases the temperature of the part and wheel. Increased temperature of wheel creates stress which causes wheel to burst.
- Selection of wrong type of wheel can cause the wheel to burst.
- Cracks on the wheel can cause the wheel to burst.
- An unbalanced wheel mounted on the machinery creates vibration which can cause the wheel to burst.

- Dull and loaded wheel generates heat which increases the temperature of the part and wheel. Increased temperature of wheel creates thermal stress on the wheel. This can cause the wheel to burst.

After identifying hazards associated with flying chip or crop type accident, some hazard controls to eliminate this hazards is proposed in the next step below. Before finalizing this step, hazard associated with the process should be written to the job authorization form. Hazards associated with the example are shown in the 'Potential Hazards' part of the job authorization form shown in Table-6.1.

6.2.3 Develop and Implement Hazard Controls

The objective of developing and implementing hazard controls is to identify applicable standards and sets of requirements, identify controls to prevent/mitigate hazards. In order to identify related standards and sets of requirements a literature survey can be conducted and related laws and regulations can be investigated.

After the controls for the hazards and job packages are derived these controls should be implemented to the work packages. In order to achieve this, recommendations, DO-DO NOT lists and check lists can be prepared and attached to the job authorization and supplied to responsible line supervisors.

For the hazards identified in the case study, hazard controls is developed in the same sequence in this part under the light of regulations and standards.

- Since there was no proper shield on the machinery, a shield should be designed. Requirements for shield are specified in section 147 of 'İşçi Sağlığı ve İş Güvenliği Tüzüğü' (Worker's Health and Occupational Safety Code) and in part 1.1.2 of 'Makinalarda İş Kazalarına Karşı Genel Güvenlik Kuralları' (General Safety Rules Against Occupational Accidents in Machinery) standard of TSE.

- The shields should be transparent so that worker can control the contact point of wheel with the work piece. It should also be adjustable according to the position of the worker and the shape of the work piece; otherwise shield can slow down the process or it can create new hazards.
- Shield must not have sharp corners or burrs to injure the worker. The shield should be impact resistant so that when chip or crop hits to the shield it does not break or shatter. A sample shield is shown in Figure-6.2.

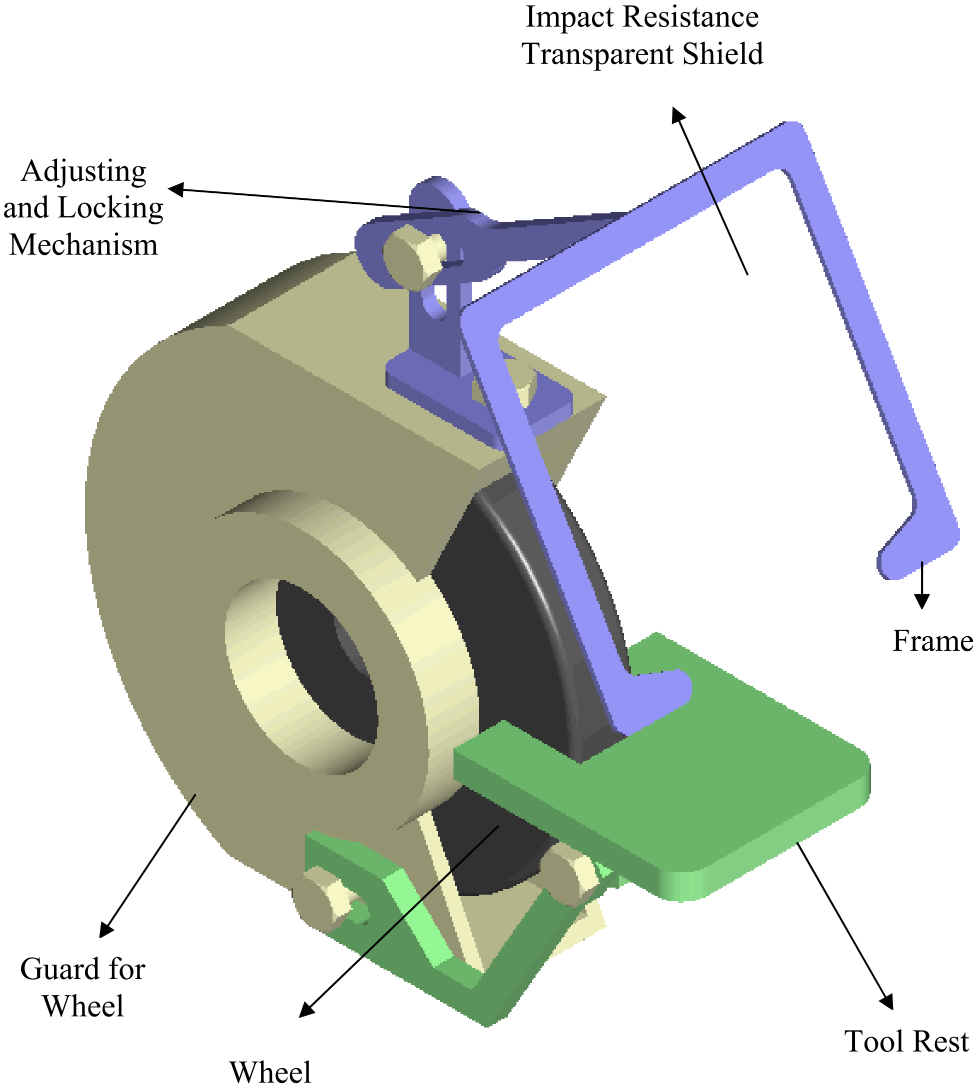

Figure-6.2: Sample shield for the grinding process

- There is always probability of the chip flying over the shields therefore workers should always use face shield to eliminate this risk. Face shields should be visible and impact resistance. This is also a requirement according to the 'İşçi Sağlığı ve İş Güvenliği Tüzüğü' (Worker's Health and Occupational Safety Code) and it is specified in section 524.
- Speed level of the machinery should be adjusted and locked so that the worker can not switch to other speed accidentally or intentionally.
- Requirements for manual feed in grinding process are specified in section 175 of 'İşçi Sağlığı ve İş Güvenliği Tüzüğü' (Worker's Health and Occupational Safety Code). The part that is to be ground should be placed on a rigid body or a table and then fed to the machinery from there. Applied pressure to the wheel should not slow the motor noticeably.
- Diameter of the wheel can be reduced during the operation; this reduces the cutting speed of the wheel. To balance resultant effect of the reduced diameter wheel, it should be operated at a higher rotational speed. When to switch the higher speed setting should be decided by competent personnel. If higher speed setting can not be used due to process specifications, reduced diameter wheel should be replaced by a new wheel. When to replace the wheel should be decided by competent personnel.
- Wheel that is going to used in the process should be selected; considering the cutting speed, feed rate, type and power of machinery and material of the work piece Appropriate wheel should be selected by the supervisors. These requirements are also specified in section 172 and section 174 of 'İşçi Sağlığı ve İş Güvenliği Tüzüğü' (Worker's Health and Occupational Safety Code).
- The surface of the wheel that is going to be used in the process should be identified from the manufacturer's catalog and other surfaces should be closed with the guard of the machinery. This requirement is specified in section 174 of 'İşçi Sağlığı ve İş Güvenliği Tüzüğü' (Worker's Health and Occupational Safety Code).
- Cracks on the wheel can initiate during storage. Wheels should be stored according to conditions specified in manufactures catalog. Ideal conditions

to store wheels are 16 to 24 °C and relative humidity between 35 to 50 percent. If a wheel is damaged during storage or mounting, it should not be used.

- Wheel should be tested by the ringing method for cracks before mounting. Wheel should be held in the bore delicately and tapped gently with a light nonmetallic implement, such as the handle of a screw driver for light wheels, or a wooden mallet. A clear ringing sound indicates that the wheel has no cracks. The wheel should be rung four times at 90 degree angles to assure that there is no crack. If the test indicates cracks on the wheel, it should not be used in the process.
- Cracks on the wheel can initiate during grinding therefore each wheel should be visually inspected by the supervisor before each work shift. This requirement is specified in section 174 of 'İşçi Sağlığı ve İş Güvenliği Tüzüğü' (Worker's Health and Occupational Safety Code).
- Wheels should be balanced before mounting by competent personnel. This requirement is specified in section 174 of 'İşçi Sağlığı ve İş Güvenliği Tüzüğü' (Worker's Health and Occupational Safety Code).
- Wheels should be trued and dressed by competent personnel before starting process. These two operations can be achieved by an off hand dresser recommended by the manufacturer of the wheel.

6.2.4 Job Authorization

Job authorization is a form which specifies the name of worker, work do to, all related parameters related with that work, and sequence of work is prepared. This job authorization clearly defines roles and responsibilities by specifying how job packages are to be carried out and identifying who has the responsibility and authority to carry out these job packages. This work permit should be send to line supervisors, line engineers and workers.

In order to prepare a job authorization, responsible supervisor should ensure that the worker assigned for the job possesses the necessary experience, knowledge, skills, and abilities. Thus to assign a worker to a job, the responsible manager should compare the qualifications of the worker and the qualifications need to conduct to that job and then prepare the job authorization. If the knowledge and experience of the worker is inadequate for that process, training program needed should be also added to the job authorization.

For this case study; a sample job authorization form is prepared and shown in Table-6.1. This form specifies the name of worker, name or code of part to be grind, cutting parameters such as cutting speed, feed rate, type of abrasive wheel, and hazards with each step, implementations to control and eliminate hazards. In addition, a check list is prepared and shown in Table-6.2. In the company same workers are working in the grinding process therefore engineers do not have to assign workers for grinding process. However, a job authorization form should be supplied to them since cutting parameters, hazards, and hazards controls can vary for different work piece.

6.2.5 Performing Work

Work is performed in accordance with that information specified on the work permit. Any deviation from the work permit during the work package should be immediately informed to line managers and supervisors.

6.2.6 Feedback/Improvement

Feedback and improvement complete the safety management system loop by connecting practical experiences of work conducted to planning for future work.

Mechanisms that support these goals include worker and management observations, pre- and post-work review meetings, quality and safety issue resolution processes, issue tracking systems, performance indicators, and lessons.

Table-6.1: A Job Authorization Form for the Company

Process	Grinding
Name of Part	
Name of the Worker	
Process Specifications	Cutting Speed : Feed Rate: Type of Abrasive Wheel: Machining time (min/part): Total number of part to be machined: Total machining time: Time for maintenance: Time for wheel change: Time for wheel dressing:
Potential Hazards	Removed shield Wrongly adjusted shield Excessive cutting speed Excessive feed Wrong abrasive wheel Cracks on abrasive wheel Large burrs on the part
Training	• One worker grinds the work piece under the supervision of the line engineer and other workers observes the preparation for process. • Physical indications of crack on the abrasive wheel should be illustrated to workers preferably using visual techniques.
Authorization	Name of Engineer to check the wheel for cracks: Name of Personnel to balance the wheel: Name of Personnel to dress the wheel:

Table-6.1: A Job Authorization Form for the Company (Cont.)

Hazard Controls	• Do not remove the shield on the machinery. Adjust the guarding and check it with the work piece whether or not you can work comfortably. • Use locking mechanisms to lock the other speed level. • Before starting job inspect the abrasive wheel visually. If you observe cracks inform your supervisor. Do not start grinding. • Check the burrs on the part. If they are large remove those by hand tools before you start process. • Use your face shield and then start process. • During the process if you observe one of the physical indications of crack, immediately stop process and inform your supervisor.

The feedback and improvement function can be accomplished with the following procedures:

- Inspections, workers concerns about the job, accident reports are the common methods of gathering data. Regular inspections with responsible engineers should be planned and results of this inspection should be sent to the planners of the process. Besides regular inspections, casual visits to machine shop should be planned and safety precautions and procedures should be checked.
- During the inspection if it is observed that the workers do not obey the rules and regulations, they should be reported to managers. A reward system should be organized for the workers that obey safety precautions and procedures.

Table-6.2: A Check List Form for Workers

CHECKLIST	**Y**	**N**	**N/A**
Do you read the Job authorization and understand the potential hazards?			
Before new wheels are mounted, do you visually inspected and tested?			
Have you checked the type of the abrasive wheel?			
Have you inspected wheel for cracks?			
Do you know the physical indications of crack on the abrasive wheel?			
Have you removed large burrs on the work piece?			
Do you adjust the shield of the machinery and check if you can comfortably work?			
Have you locked the locking mechanism for the speed?			
Have you adjusted the feed table for stable feed?			

- Workers concerns are the invaluable sources of data therefore supervisor or manager should encourage workers to report their concerns about the job. A form such as shown in Figure 3.1 can be used to determine workers concerns, recommendations, etc.
- Accident reporting is a crucial method of data collecting. These reports should be filled by a supervisor just after the accident. Interviews should be conducted with the witnesses of the accident and possible causes of the accident should be written on this form. Besides this, preventive measures and management strategies to avoid accident should be specified in the accident form. Accident reporting form used in the company is shown in Table-6.3. This form does not recommend preventive measures for the accident. A form such as shown in Table- 6.4 can be used to report accidents in the company.

Table-6.3: Accident Report used in the Company

Date of Accident	06.03.2003
Place that the accident occurred	Temizleme II
Time to start work that day?	08.00 a.m
Name of the worker	Avni Gürkan
Social security number of the worker	1101199803318
Age of the worker	22
Date of starting job in the company	05.02.2003
What is the job of the worker?	Grinding
What was he doing when accident happened?	Grinding
Result of accident (Death, permanent disability, injury, minor injury, etc.)	Minor injury
What is the number of lost working day?	Not specified
Name and signature of the witnesses	Kamil Can
Cause of the accident and how did it happened?	While grinding, a chip reaches to workers eye. He was using goggle.

Table-6.4: A Sample Accident Report for the Company

Name of the worker	Avni Gürkan
Social Security Number	1101199803318
Age and Gender	22, Male
Job Title	Grinding technician
When did he start this job?	05.02.2003
Time employee began work at that day	08.00 a.m
Date and time of accident	06.03.2003, not specified
Names of Witnesses	Kamil Can
What was he/she doing when accident occurred? (Describe the activity as well as the tools, equipment, or material the employee was using.)	Grinding the work piece with a safety goggle on the pedestal type grinding machine without using a coolant.
Divide the activity into steps and describe each step (Describe the activity as well as the tools, equipment, or material the employee was using.)	1. Workers sat on the stools and handled the part from a box placed on their right. Worker uses gloves to protect his hands. 2. Ground the part on the manual pedestal type grinding machine without using coolant. Worker uses goggle. 3. Put the finished part into a box placed on their left.
What happened? (Describe how the injury occurred)	In the second step of the activity, a chip become projectile and flies through the safety goggle and reached to workers eye.

Table-6.4: A Sample Accident Report for the Company (Cont.)

Are there any other factors that attributed to the accident? If yes specify these factors. (Inadequate illumination, condition of air, noise, vibration, high/low temperature, other personnel, etc)	No.
What is the injury or harm? (Describe the part of the body that was affected and how it was affected.)	Eye, temporarily lost eye sight
What is the type of injury? (Death, permanent disability, injury, minor injury, non injury.)	Minor injury.
What object or substance directly harmed the worker?	Hot chip.
What is the number of lost work day?	Not specified.
How could this accident have been prevented? (Describe the tools, machinery, material and safety equipment to prevent the accident. Does worker conduct the job according to the rules specified in the job authorization form? If no what is/are the misbehavior(s) of the worker?)	• By using an adjustable impact resistant shield on the machinery. • By adjusting the shields according to the position of worker and shape and size of work piece. • By using face shields instead of safety goggles. • By using the cutting parameters specified by the responsible engineers in the job authorization form. Worker uses higher cutting speed than the speed specified in the job authorization.

Table-6.4: A Sample Accident Report for the Company (Cont.)

What are the workers concern and recommendations to avoid the accident? (This part should be filled by worker that had involved in the accident. Worker should clearly specify that are there any missing information or ambiguity with the job authorization form and safety measures? Did he/she have necessary tool, machinery and safety equipment to conduct the job? Does he/she have necessary information and training to conduct the job assigned? What are the recommendations to avoid this accident?)	
Actions that could be taken by supervisor or managers	• Appropriate shields for machinery and face shields for the workers should be supplied. • Regular inspections with responsible engineers should be planned and results of this inspection should be sent to the planners of the process. • A reward system should be organized for the workers that obey safety precautions and procedures.

- Necessary educational and training programs should be organized in order to train workers about the changes in the job and procedures.
- Data gathered should be used to review job and job packages by analysis. Analysis involves the application of hazard analysis methods, based on the data generated to prevent work accidents and injuries. Example analysis outputs include suggested corrective and preventive actions, or improvement recommendations.
- All workers affected by the changes in the new methods, procedures, or protective measures adopted should be informed. Therefore, if there are changes on the job procedures, new job authorization form should be prepared and this form should be sent to workers immediately.

CHAPTER 7

DISCUSSION AND RECOMMENDATIONS

Safety in the context of work life is the discipline of preserving the health of those who manufacture, construct, operate, maintain and demolish engineering works. Accidents that occur during work activities result in injury and death of worker. These accidents affect not only the worker but also whole family of the worker and the company that the worker employed. Therefore more serious attention to matters of health and safety at work should be given to eliminate accidents or to reduce the consequences of the accidents.

In Turkish Constitution, article 60, everyone has the right of social security and the government is obliged to organize and take precautions to provide and maintain social security. In S.S.K Law, the responsibility of workers is given to the employer and if the employer does not comply with these responsibilities, they will be penalized. In spite of these regulations, both workers and employers do not obey the safety requirements and do not take care of safety precautions. So in Turkey and all around the world, unfortunately every year many work accident happen.

In this study, occupational health and safety problem in Turkish industry was investigated under the legislative provisions of the European Union. For this purpose, a case study was conducted at a manufacturing company and the accident reports of this company were used for the hazard identification and analysis. By using Prato analysis, the most risky accident type was determined as the removal of the chips of castings by manual grinding. Then, a model safety management system was developed and the most risky type of accident was investigated by using this system.

In the course of this study, a scale to determine the priorities was developed. This scale is preferable over the others in the sense that it is simpler and can be used easily by personnel who do not have engineering background. On the other hand, this method heavily depends on personal judgment of the user. For this reason, conceptual training on occupational health and safety and on risk analysis method should be given to personnel. These training programs should be prepared by ‘Çalışma ve Sosyal Güvenlik Bakanlığı’ (Ministry of Labor and Social Security). Since the number of experts to prepare training program might be limited in the ‘Çalışma ve Sosyal Güvenlik Bakanlığı’ (Ministry of Labor and Social Security), experts in the universities should be resorted to.

Number of experts on occupational health and safety in Turkish industry is inadequate and engineers working in the manufacturing industry have limited information on this subject. On account of this, relevant courses on occupational health and safety should be opened at the university during the fourth year of undergraduate program. All engineering students should take lectures on health and safety legislation and safe system of work. This training should cover an outline of safety legislation and duties of employers and employees. It should also cover methods of hazard analysis, and techniques to eliminate this hazard to work safely. In addition to these, occupational health and safety management system should be introduced and case studies can be assigned to the students to give industrial experience on this subject.

A reform is recently done in government’s policy on safety and health at work within the adaptation period to European Union. ‘Çalışma ve Sosyal Güvenlik Bakanlığı’ (Ministry of Labor and Social Security) is the responsible organization for the safety and health at work.. However, during the interviews done in this organization, it was observed that some of these responsibilities cannot be fulfilled effectively. S.S.K is the other governmental organization responsible for the safety and health at work, and providing statistical data. The database kept in this institution should be more effectively used for the prevention of occupational risks, protection of safety and health, elimination of risk and accident factors. In addition, necessary improvements in regulations and codes should be prepared by using these statistics.

Besides, standardization in record keeping and record-keeping system is needed in Turkey. During the data search for the case study conducted in Chapter 5, six companies are visited and asked for the accident records. However, only one company could supply a data, which contains date, place, cause, and effect of accident. İn accordance with the harmonization efforts, all European countries are required to keep statistics in accordance with the principles of ESAW (European Statistics on Accidents at Work). Therefore national organizations should prepare standard record keeping system since these records should serve to pinpoint the locations and underlying causes of work accidents; information that is vital to identify, eliminate hazards and to plan more effective accident prevention programs. They also provide feedback opportunity to asses the efficacy of overall safety management system.

Many manufacturing companies in Turkey employ uninsured workers. It is legal to try the worker 30 days from the date of employment while the worker is uninsured. The employer abuses this flexibility in law and workers are forced to work without insurance from then on. Moreover, as there was an economic recession in Turkey, workers had difficulties in finding job. Employers abused the economic recession and removed safety and insurance issues from the contract with the employee. As a result, workers face more risks in work and cannot file a complaint. It falls to the Unions to remedy this practice, which makes them prone to more health and security risks.

With the new 'İş Kanunu' (Labor Law), companies that employs less than 50 worker are not obliged to apply this law in their companies. This results in lack of legislative provision in these small enterprises. Since over %70 percent of work accidents occurred in these small enterprises in Turkey, occupational health and safety concept in these companies becomes a vital problem. As a future study, employer-employee relations in these companies should be investigated and an appropriate approach that can fit effectively to promote and sustain health and safety organization in small companies should be developed.

It is hoped that the occupational health and safety system proposed in this study will help to reduce the number of accidents and will contribute to develop safety culture in Turkish industry. However, the achievements would be limited in short term due to some shortcomings such as; wrong interpretation due to the lack of training, inspection and legal provisions. Therefore, this system should be closely followed up by inspectors of 'Çalışma ve Sosyal Güvenlik Bakanlığı' (Ministry of Labor and Social Security) and general hazards identified by the inspectors and accident reports should be used to prepare necessary improvements in regulations and codes.

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As a suggestion for future study on this subject, a user friendly interactive computer programs that can conduct hazard and risk analysis can be programmed. In the hazard analysis program, the events that result in that specific hazard, their relation (AND\OR Gates) and probabilities can be given as input data by the user and program can calculate the occurrence probability of that hazard. In the risk analysis program, probability, severity and exposure levels for specific type of hazard can be given as input to the program and program can evaluate the risk level of that hazard. At the start up of the program, user can select desired scale from different chooses or can modify one of the given chooses depending on the management strategy.

Since 1990, European countries are trying to harmonize the statistical activities (ESAW, European Statistics on Accidents at Work), which will provide a sounder basis to make comparisons. The suggested program could encompass such statistical analyses, which will help the large companies to gauge themselves.

Another useful outcome of such a computerized system could be immediate accident reporting. Not only the red tape but also the time spent to prepare 'S.S.K İstatistik Yıllığı' (SSK Statistics Year Book) would be considerably reduced. By using such a system, accident reports for every company can be stored in the database and statistical information about the most frequent accident type with the prevention methods for that specific type of accident can be send to that company as feedback by the regional S.S.K department. This computerized system would also shorten the time spend to inspect that company and increase the effectiveness of the inspection since inspectors can get information about that company before inspection visit.

In a near future, Republic of Turkey is going to be a member to European Union and as in many aspects Turkey should adapt its occupational health and safety management system to European Union. During the literature survey conducted, it was observed that there were little efforts to achieve this adaptation. This study is prepared to shed light to this adaptation period and develop a system approach to promote and sustain occupational health and safety concept in Turkish industry. It is believed that this study will contribute to develop occupational health and safety culture in Turkish industry in long term and reduce the number of work accidents in Turkey.

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APPENDIX A

OSHA STANDARDS RELATED WITH MANUFACTURING

- Subpart C- General safety and health provisions
- Subpart D- Occupational health and environmental controls
- Subpart E- Personal protective and life saving equipment
- Subpart F- Fire protection and prevention
- Subpart G- Signs, signals and barricades
- Subpart H- Materials handling, storage, use and disposal
- Subpart I- Tools-hand and power
- Subpart J- Welding and cutting
- Subpart K- Electrical
- Subpart L- Scaffolding
- Subpart M- Floor and wall openings
- Subpart N- Cranes, derrick, hoists, elevators, and conveyors
- Subpart O- Motor vehicles, mechanized equipment and marine operations
- Subpart P- Excavations
- Subpart Q- Concrete and masonry construction
- Subpart R- Signs, signals and barricades
- Subpart S- Steel erection
- Subpart T- Underground construction, caissons and cofferdams
- Subpart U- Demolition
- Subpart V- Blasting and use of explosives
- Subpart W- Power transition and distribution
- Subpart X- Rollover protective structures, overhead protection
- Subpart Y- Commercial diving operations
- Subpart Z- Toxic and hazardous substances

APPENDIX B

ACCIDENT RECORD

Number	Date	Cause of Accident	Number of Lost Work Day
1	02.01.2002	Contact with moving machine part	2
2	02.01.2002	Contact with moving machine part	3
3	04.01.2002	Object Falling from height	0
4	04.01.2002	Strain from lifting, pulling, pushing	55
5	05.01.2002	Contact with moving machine part	6
6	05.01.2002	Flying chip or crop	3
7	07.01.2002	Flying chip or crop	0
8	09.01.2002	Contact with moving machine part	4
9	09.01.2002	Contact with moving machine part	11
10	09.01.2002	Flying chip or crop	0
11	09.01.2002	Stuck between objects	2
12	10.01.2002	Contact with moving machine part	13
13	10.01.2002	Flying chip or crop	2
14	10.01.2002	Flying chip or crop	3
15	11.01.2002	Strain from lifting, pulling, pushing	5
16	13.01.2002	Flying chip or crop	2
17	13.01.2002	Strain from lifting, pulling, pushing	6
18	15.01.2002	Exposure to extreme heat	0
19	15.01.2002	Flying chip or crop	2
20	21.01.2002	Flying chip or crop	0
21	23.01.2002	Stuck between objects	2
22	24.01.2002	Slip, trips or fall on the same level	5
23	25.01.2002	Flying chip or crop	0
24	26.01.2002	Flying chip or crop	5
25	28.01.2002	Flying chip or crop	0
26	30.01.2002	Object Falling from height	45
27	01.02.2002	Slip, trips or fall on the same level	3
28	02.02.2002	Stuck between objects	2
29	05.02.2002	Hit by an object	3

30	08.02.2002	Exposure to extreme heat	3
31	09.02.2002	Flying chip or crop	0
32	12.02.2002	Flying chip or crop	3
33	12.02.2002	Hit by an object	1
34	12.02.2002	Slip, trips or fall on the same level	3
35	12.02.2002	Strain from lifting, pulling, pushing	5
36	15.02.2002	Flying chip or crop	3
37	15.02.2002	Strain from lifting, pulling, pushing	3
38	20.02.2002	Exposure to extreme heat	4
39	25.02.2002	Flying chip or crop	3
40	26.02.2002	Hit by an object	4
41	05.03.2002	Flying chip or crop	6
42	05.03.2002	Strain from lifting, pulling, pushing	7
43	11.03.2002	Object Falling from height	45
44	11.03.2002	Object Falling from height	4
45	12.03.2002	Contact with moving machine part	5
46	13.03.2002	Exposure to chemical substances	2
47	18.03.2002	Flying chip or crop	0
48	19.03.2002	Hit by an object	0
49	23.03.2002	Contact with moving machine part	3
50	23.03.2002	Object Falling from height	2
51	24.03.2002	Object Falling from height	10
52	25.03.2002	Slip, trips or fall on the same level	3
53	26.03.2002	Strain from lifting, pulling, pushing	0
54	27.03.2002	Flying chip or crop	0
55	27.03.2002	Strain from lifting, pulling, pushing	3
56	02.04.2002	Stuck between objects	0
57	09.04.2002	Flying chip or crop	2
58	10.04.2002	Flying chip or crop	1
59	11.04.2002	Flying chip or crop	3
60	13.04.2002	Flying chip or crop	3
61	13.04.2002	Slip, trips or fall on the same level	6
62	15.04.2002	Flying chip or crop	2
63	16.04.2002	Flying chip or crop	2
64	17.04.2002	Flying chip or crop	0
65	17.04.2002	Slip, trips or fall on the same level	10
66	18.04.2002	Flying chip or crop	0

67	19.04.2002	Flying chip or crop	5
68	19.04.2002	Object Falling from height	3
69	19.04.2002	Object Falling from height	2
70	22.04.2002	Flying chip or crop	3
71	24.04.2002	Flying chip or crop	5
72	25.04.2002	Flying chip or crop	3
73	25.04.2002	Flying chip or crop	1
74	27.04.2002	Flying chip or crop	1
75	29.04.2002	Hit by an object	3
76	03.05.2002	Flying chip or crop	4
77	04.05.2002	Flying chip or crop	7
78	06.05.2002	Contact with moving machine part	7
79	06.05.2002	Flying chip or crop	1
80	06.05.2002	Flying chip or crop	2
81	07.05.2002	Flying chip or crop	2
82	08.05.2002	Object Falling from height	45
83	09.05.2002	Flying chip or crop	0
84	09.05.2002	Flying chip or crop	0
85	10.05.2002	Flying chip or crop	3
86	10.05.2002	Flying chip or crop	0
87	13.05.2002	Object Falling from height	3
88	14.05.2002	Contact with moving machine part	5
89	14.05.2002	Flying chip or crop	3
90	19.05.2002	Flying chip or crop	3
91	23.05.2002	Hit by an object	2
92	24.05.2002	Flying chip or crop	0
93	28.05.2002	Contact with moving machine part	0
94	29.05.2002	Contact with moving machine part	4
95	03.06.2002	Stuck between objects	2
96	07.06.2002	Flying chip or crop	0
97	11.06.2002	Flying chip or crop	4
98	13.06.2002	Flying chip or crop	2
99	14.06.2002	Contact with moving machine part	5
100	14.06.2002	Flying chip or crop	3
101	17.06.2002	Flying chip or crop	3
102	17.06.2002	Slip, trips or fall on the same level	3
103	18.06.2002	Exposure to extreme heat	9

104	20.06.2002	Exposure to chemical substances	0
105	20.06.2002	Flying chip or crop	3
106	23.06.2002	Strain from lifting, pulling, pushing	5
107	26.06.2002	Hit by an object	0
108	27.06.2002	Object Falling from height	3
109	28.06.2002	Flying chip or crop	3
110	29.06.2002	Flying chip or crop	1
111	09.07.2002	Flying chip or crop	0
112	12.07.2002	Flying chip or crop	0
113	13.07.2002	Object Falling from height	0
114	23.07.2002	Slip, trips or fall on the same level	3
115	24.07.2002	Flying chip or crop	1
116	25.07.2002	Hit by an object	2
117	31.07.2002	Hit by an object	2
118	31.07.2002	Strain from lifting, pulling, pushing	0
119	01.08.2002	Flying chip or crop	0
120	04.08.2002	Stuck between objects	3
121	07.08.2002	Flying chip or crop	2
122	07.08.2002	Object Falling from height	10
123	10.08.2002	Object Falling from height	0
124	14.08.2002	Flying chip or crop	60
125	17.08.2002	Object Falling from height	2
126	19.08.2002	Hit by an object	0
127	23.08.2002	Flying chip or crop	0
128	23.08.2002	Object Falling from height	5
129	26.08.2002	Exposure to extreme heat	100
130	26.08.2002	Flying chip or crop	0
131	03.09.2002	Flying chip or crop	2
132	04.09.2002	Stuck between objects	0
133	06.09.2002	Flying chip or crop	0
134	06.09.2002	Flying chip or crop	0
135	10.09.2002	Flying chip or crop	0
136	10.09.2002	Hit by an object	5
137	11.09.2002	Flying chip or crop	3
138	12.09.2002	Hit by an object	4
139	12.09.2002	Strain from lifting, pulling, pushing	10
140	16.09.2002	Stuck between objects	30

141	24.09.2002	Flying chip or crop	0
142	30.09.2002	Contact with moving machine part	3
143	05.10.2002	Exposure to extreme heat	10
144	05.10.2002	Flying chip or crop	3
145	07.10.2002	Flying chip or crop	0
146	08.10.2002	Object Falling from height	5
147	09.10.2002	Object Falling from height	2
148	10.10.2002	Flying chip or crop	3
149	11.10.2002	Object Falling from height	3
150	12.10.2002	Hit by an object	3
151	14.10.2002	Contact with moving machine part	3
152	14.10.2002	Flying chip or crop	0
153	15.10.2002	Contact with moving machine part	1
154	16.10.2002	Hit by an object	3
155	17.10.2002	Exposure to chemical substances	3
156	17.10.2002	Hit by an object	2
157	21.10.2002	Flying chip or crop	2
158	21.10.2002	Flying chip or crop	10
159	24.10.2002	Exposure to extreme heat	20
160	26.10.2002	Object Falling from height	2
161	27.10.2002	Slip, trips or fall on the same level	14
162	30.10.2002	Contact with moving machine part	5
163	30.10.2002	Object Falling from height	3
164	01.11.2002	Stuck between objects	10
165	02.11.2002	Exposure to extreme heat	5
166	12.11.2002	Slip, trips or fall on the same level	0
167	13.11.2002	Strain from lifting, pulling, pushing	10
168	18.11.2002	Flying chip or crop	0
169	19.11.2002	Contact with moving machine part	3
170	19.11.2002	Stuck between objects	45
171	21.11.2002	Hit by an object	4
172	21.11.2002	Stuck between objects	2
173	22.11.2002	Hit by an object	2
174	26.11.2002	Flying chip or crop	0
175	27.11.2002	Contact with moving machine part	7
176	27.11.2002	Flying chip or crop	3
177	29.11.2002	Exposure to extreme heat	4

178	29.11.2002	Exposure to extreme heat	0
179	30.11.2002	Flying chip or crop	3
180	30.11.2002	Flying chip or crop	3