International Journal of Business and Technology Management
e-ISSN: 2682-7646 | Vol. 5, No. S4, 137-145, 2023
http://myjms.mohe.gov.my/index.php/ijbtm
SPECIAL ISSUE: 12th International Conference of Engineering Business Management 2023 (ICEBM2023)

# Safeguarding Boiler Operations Tools in Malaysia with Hazard Identification, Risk Assessment, and Risk Control

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Received: 30 July 2023 | Accepted: 1 September 2023 | Published: 1 December 2023

DOI: https://doi.org/10.55057/ijbtm.2023.5.S4.14

**Abstract:** *The functioning of the risk management and hazard detection processes always includes the steam boiler system. The source of harm to people, processes, properties, and the environment is a hazard. The risk explains the likelihood of an advantage or disadvantage, such as financial loss, physical harm, or an accident because of an activity. Risk in this context refers to the possibility and apparent repercussions. This study aims to identify potential hazards in boiler operations and propose risk management and control of potential hazards and analyze the risk factors and hazards for boiler operations based on the nature of work at the boilers in Malaysia using Hazard Identification, Risk Assessment, Risk Control (HIRARC) method. Data collection on the identification and assessment of risks analyzed by HIRARC, evaluated and finding the better solution to determine and control hazards in the workplace so that the workplace is safely. According to the findings, the boiler division's risk rate is comprised of four levels: Extreme Risk (8%), High Risk (14%), Moderate Risk (35%), and Low Risk (43%). The threat of mechanical hazards is rated at 25%, electrical hazards are rated at 10%, chemical hazards are rated at 6%, and physical risks are rated at 59% in the risk assessment for the boiler division. According to the risk assessment, these techniques could prevent future catastrophic events in the boiler operating business.*

**Keywords**: Risk Assessment, Hazard Identification, Risk Assessment, Risk Control (HIRARC), Boiler Safety

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## 1. Introduction

Every industry uses steam, and it is widely accepted that power and processing industries require steam generators and heat recovery boilers [1]. One of the most critical parts of a power plant is the boiler, which converts biofuel into energy. This includes shipping, the largest industry in the world [2]. A few problematic conditions in which the boiler is meant to function include high temperatures, high pressures, and potentially dangerous environments. Conversely, a boiler will malfunction and weaken if subjected to specific circumstances for an extended period. The problems forced the shutdown of power plants. Therefore, we need a solid safety policy and system to reduce the likelihood of failure, particularly for components like the boiler that are more prone to failure [1][2]. Boiler operation creates hazardous workplaces; thus, businesses must guarantee safe working conditions through systematic, routine hazard identification and risk assessment. Both management and employees must abide by safety standards and procedures. Numerous commercial organizations have demonstrated that effective safety management boosts production and benefits power plants [3].

The boiler converts the chemical energy in the fuel into thermal energy in the steam. When no fire is involved, it also transforms the heat energy of hot gases into the heat energy of steam. Boilers are used everywhere, including in office buildings, shopping centers, manufacturing facilities, and residential homes. It either produces steam or hot water. Steam is used to generate electricity for processes or heating, whereas hot water is utilized for processes, portable water supplies, or building heating [4]. Heat transport, thermodynamics, combustion technology, and mechanical engineering principles all play a part in the boiler technology process. Boilers run under pressure, so the risk of an explosion must be considered.

The generated steam is distributed through pipes to feed different producing machinery. A boiler is described as "a closed vessel in which water or another liquid is heated, steam or vapor is generated, steam is superheated, or any combination thereof, under pressure or vacuum, for use external to itself, by the direct application of energy from the combustion of fuels, from electricity, or from nuclear energy [5]. However, a boiler, such as a thermal oil or hot water boiler, does not produce steam. The boiler is one of the equipment components of a plant that uses a lot of energy. As furnace fuel heaters, they are widely used in the production process.

Water in the boiler receives heat from combustion and is eventually converted to heated steam or water. Heating furnace fuel is the process of transferring heat using hot steam or water under pressure. The feedwater system, steam system, and fuel system make up the steam boiler system [6].

The size, capacity, and technology of boilers vary. The risk associated with most miniature boilers is minimal, whereas the risk associated with large boilers increases if not appropriately handled [7]. Therefore, smaller boilers industries will require primary and straightforward safety measures. Large boiler plants in companies, however, will necessitate stringent safety measures. Boilers must be properly operated and maintained following the code of conduct. Boilers are subject to unique controls under local legislation in most nations, and enterprises may be required to get a license under local laws before installing large-capacity boilers [8].

Two central boilers are used in power generation: fire-tube and water-tube boilers. Most of the time, small-scale applications use fire tube boilers [9]. The benefit of these boilers over other varieties is that they are small and take up little room. In fire-tube boilers, combustion gases can move through tubes that are submerged in water. Additionally, the advantages are easier to fabricate and use. Fire-tube boilers' drawbacks include a lengthy steam generation process and a quick response to load changes.[6] Fire or hot fuel gases from the burner are channeled via tubes that are part of a fire-tube boiler. The major components of the boiler's trunk are fluid and pressure vessels. Water is mainly used as a circulating fluid for heating or to create steam for burning [8].

The water-tube boiler has combustion-inscribed tubes as well as tubes that are filled with water. The benefits of a water-tube boiler are described as the steam produced with a lower unit weight per pound, an increase in steam pressure in a shorter amount of time, more flexibility, and an increased capacity for operating at higher steam generation rates. This kind has two primary drums: the upper drum is called the steam drum, and the lower drum is called the mud drum. Both are related to the pictured riser tubes and descender tubes [10].

Applications involving heating frequently use boilers. The Fire-tube boiler's construction is simple. A fire tube boiler burns the fuel inside a furnace [4]. The hot gases from the furnace

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then move through the fire tubes. The fire tubes are immersed in water inside the main vessel of the boiler [5]. As the hot gases are transported through these tubes, heat energy from the gases is transferred to the water around them. As a result, steam is generated in the water, which rises to the surface naturally and is then held on top of the water in a vessel that is like the fire tube boiler. The steam is then removed from the outlet and sent to the designated usage. The feed water inlet supplies the boiler with water [7]. Since the steam and water are stored in the same vessel, producing steam at extremely high pressures is difficult. A fire tube boiler's main boiler vessel is under pressure. Thus, if it ruptures, there is a possibility that an explosion may result in a severe accident [6].

Boilers have many potential hazards that safety devices and safe work practices must control. Before identifying the hazards, one must understand the meaning of hazards. In this context, the hazard is defined as "a source or situation with a potential for harm in terms of injury or ill health, damage to property, or a combination of these." To begin identifying hazards, the management must know what activities are involved. Activities can be divided into two categories which are routine and non-routine. Routine activities include daily operation, chemical preparation, fuel storage, and handling, while non-routine activities include boiler overhaul, boiler operation, and emergency response. The first stage in hazard identification is a selection of jobs to be analyzed [5].

Recently, several studies suggests that there are needs for risk management frameworks in boiler operation activities [5][6][7][8][9][10]. In Malaysia, no specific risk assessment frameworks have been developed for the boiler operations. Unlike other developed countries and other high-risk industries that have established specific risk assessment frameworks and techniques, Malaysia practices a general risk management framework, which refers to hazard identification, risk assessment and risk control (HIRARC) guidelines, 2008 and standards such as OHSAS 18001-Occupational Health and Safety Management standards, Factory and Machinery Act 1967. These poses challenges to the boiler operator in Malaysia.

In the past years, there has been increasing interests in safety and accident study in boiler operations research. Previous studies focused more on safety risk issues in boiler operation activity such as Hazard Identification Risk Assessment and Risk Control (HIRARC) [5]. However, there has been limited research on boiler operations risk management. It was suggested that risk assessment need to be explored in boiler operation activities as it is still lacking [9][11][12][13]. It implies that implementation of risk assessment is limited and needs to be explored more.

## 2. Methodology

### Hazard Identification, Risk Assessment, and Risk Control (HIRARC)

With a qualitative methodology, this study review aims to learn more about the dangers and worker safety related to boiler operation.[10][11][12]. The degree of risk to workplace safety can then be calculated using Hazard Identification, Risk Assessment, and Risk Control (HIRARC), which starts with identifying hazards and how to assess the risk and ends with risk control. Through data processing and analysis, the boiler division will assess worker risk safety utilizing the HIRARC technique. The best course of action is identifying the most important accident-causing factors in the boiler division through data analysis and processing. Data analysis is first used to calculate the risk value resulting from consequence rating findings, exposure, and likelihood to determine risk values that can be expressed as scores during the risk level assessment step. The value is then evaluated considering the study's findings to see whether it can still be approved and whether the employees' top limit for additional risk-reduction measures has been achieved. When processing data for this study, the Hazard Identification, Risk Assessment, and Risk Control (HIRARC) approach was used to create the assessment table below.[15][16][17][18].

According to a recent analysis, two semi-quantitative risk assessment methodologies for occupational risk assessment are recognized in the literature. Based on two-dimensional risk matrices that consider incidents' frequency and impact [9]. The method used to estimate industry risk that is most frequently used is semi-quantitative analysis. The semi-quantitative risk assessment matrix and the risk calculator are thus the two methods of risk analysis that are most frequently used. The risk equation described below is used in the semi-quantitative risk assessment method.

Equation 1.0 Risk (RV) = Severity (S) x Likelihood (L)

Severity is assessed based on harm to human health, property loss, and environmental harm. Table 1 displays the level and severity values used in the risk assessment. In addition, the likelihood is determined by the observation made to learn more about each unique hazard that manifests. Table 2[11][14] displays the levels and values of the likelihood utilized in the risk assessment.

**Table 1: Level of severity, consequences, and severity value**

| Level of Severity | Consequences | Severity Value |
|---|---|---|
| Disaster | Many deaths, property damage, and production cannot be recovered | 5 |
| Fatality | Approximately one death, damage to property if the hazard occurs | 4 |
| Severe Injuries | Non-fatal injury, permanent disability | 3 |
| Minor Injuries | Cause disability but not permanent injury | 2 |
| Negligible injuries | Minimal bruises and wounds. The injury needs first-aid treatment | 1 |

**Table 2: Levels of likelihood, frequency, and likelihood value**

| Level of Likelihood | Frequency | Likelihood Value |
|---|---|---|
| Most likely | Most likely to occur | 5 |
| Likely | May occur and is not unusual | 4 |
| Expected | May occur in the future | 3 |
| Rarely | Unknown to occur after several years | 2 |
| Unexpected | Practically impossible and never happened | 1 |

The semi-quantitative risk assessment matrix table determines if the risk value is low, medium, or high. A low level of risk is represented by the green box (RV = 1- 4) in Table 3, a medium level of risk by the yellow box (RV = 6-10), and a high level of risk by the red box (RV = 11-25) [11][12][13]. Table 3 shows the semi-quantitative risk assessment matrix table.

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**Table 3: The semi-quantitative risk assessment matrix**

| | | | LIKELIHOOD (L) | | | | |
|---|---|---|---|---|---|---|---|
| | | | 1 Unexpected | 2 Rarely | 3 Expected | 4 Likely | 5 Most Likely |
| SEVERITY(S) | Negligible injuries | 1 | 1 | 2 | 3 | 4 | 5 |
| | Minor Injuries | 2 | 2 | 4 | 6 | 8 | 10 |
| | Severe Injuries | 3 | 3 | 6 | 9 | 12 | 15 |
| | Fatality | 4 | 4 | 8 | 12 | 16 | 20 |
| | Disaster | 5 | 5 | 10 | 15 | 20 | 25 |

## 3. Results and Discussion

### Hazard Identification, Risk Assessment, and Risk Control (HIRARC)

This section discusses the results of the Hazard Identification, Risk Assessment, and Risk Control (HIRARC) initiative [15]. The findings showed that embers, high electric pressure, explosions, fire, hot material, chemical exposure, chemical inhalation, steam leaks in drums, hot water, excess gas pressure, falls, crushed, and charcoal dust are the main hazards. The table of observations for the activities taken to identify dangers during boiler operation is displayed below.

**Table 4: Impact Matrix for Boiler Operation**

| No | Location | Activities | Potential Hazards | Risk Level |
|---|---|---|---|---|
| 1 | Warehouse | Initial unloading of coal transported using container trucks and coal stored for the combustion process | 1. Coal Dust | Medium |
| | | | 2. Sparks | Medium |
| | | | 3. Heat Radiation | Medium |
| 2 | Hopper | The process of protruding coal in the area will have flowed to each conveyor if there is a blockage in the area | 1. Heat Radiation | Low |
| | | | 2. Fall | Low |
| 3 | Conveyor | Distributing coal that is ready for use for the following combustion process. | 1. Stuck | Low |
| | | | 2. Heat Radiation | Medium |
| 4 | Crusher | Cracking coal according to a predetermined size so that the combustion process can run smoothly if the fuel follows what is needed | 1. Coal Dust | Medium |
| | | | 2. Coal Splash | Low |
| | | | 3. Noise | Medium |
| 5 | Triway | Separating coal that is following its size in boilers 1 and 2 for the combustion process | 1. Stuck | Low |
| | | | 2. High-Pressure Electricity | Medium |
| 6 | Bunker | Collects coal to be burned in the furnace after being carried by the conveyor before the coal is fed through the coal feeder | 1. Heat Radiation | Medium |
| | | | 2. Fall | Low |
| 7 | Coal Feeder | Receive coal from the coal bunker and control the amount of coal put into the pulverizer. | 1. Coal Dust | Medium |
| | | | 2. Noise | Medium |
| 8 | Furnace | The overall process in the combustion process boilers that have met the previous requirements must attach importance to safety for this combustion process | 1. Explosion | High |
| | | | 2. Burn | High |
| | | | 3. Hot material | Medium |
| | | | 4. Coal Dust | Medium |
| | | | 5. Heat Radiation | Medium |
| | | | 6. Noise | Medium |
| | | | 7. High-Pressure Electricity | Medium |

| No | Location | Activities | Potential Hazards | Risk Level |
|---|---|---|---|---|
| 9 | Chemical Maintenance Boiler | Controlling pH and corrosion control in metal boiler water and steam pipes. Since the feed water content of boilers often contains impurities that damage boiler operation and efficiency, it is this substance that will fix the problem | 1. Exposed to chemicals | Low |
| | | | 2. Inhaled | Low |
| 10 | Line Steam | Regulate the course of steam in the combustion process so that the steam is stable in the steam drum | 1. Noise | Low |
| | | | 2. Heat Radiation | Low |
| 11 | Reheater | Reheat (raise) the vapor temperature on the superheater to get the heat back in this process | 1. High-Pressure Electricity | Medium |
| 12 | Steam Drum | Collects water from the economizer to be heated by the standard water cycle method, where water with a lower temperature will drop and water whose temperature will enter the drum while releasing the steam to be separated between the steam and the water | 1. Hot Steam | High |
| | | | 2. Heat Radiation | Medium |
| | | | 3. Leakage in the drum | Low |
| 13 | Cyclone | Collecting coal that does not burn in the furnace process to be pushed back using a compressor so that it re-enters the furnace process | 1. Coal Dust | Medium |
| | | | 2. Sparks | Low |
| 14 | Super Heater | Further heating saturated steam (saturated steam until it produces completely dry steam) | 1. Hot Steam | High |
| | | | 2. Hot Water | Low |
| 15 | Economizer | Heating water after passing through the high-pressure heater, the heating is carried out by utilizing the heat from the flue gas, which is the residue of combustion in the furnace | 1. Hot Steam | Low |
| | | | 2. High-Pressure Electricity | Low |
| | | | 3. Excess Gas Pressure | Low |
| 16 | Chimney | Provides ventilation for hot exhaust gases or smoke from the boiler furnace to be discharged into the outside atmosphere | 1. Coal Dust | Low |
| | | | 2. Heat Radiation | Low |
| 17 | Downcomer | Flow the hot grains of water to be heated through the pipes arranged in the furnace wall. | 1. Hot Water | Low |
| 18 | Scoot blower | Cleaning deposits, ash, and slags by using steam so that the flow of gas can carry away dust, ash, or soot | 1. Coal Dust | Medium |
| | | | 2. Heat Radiation | Low |
| 19 | Safety Valve | Protects against the danger of overpressure in boiler steam, as well as protects piping and other process tools | 1. Excess Gas Pressure | Low |
| | | | 2. Coal Dust | Medium |
| 20 | Burner | Burning coal and silica sand and using High-Speed Diesel to make coal more flammable | 1. Burn | Medium |
| | | | 2. Embers | Medium |
| 21 | Id Fan | Vacuum the boiler so that the gas flow rate becomes smooth and sucks the combustion gas starting from the furnace, passing through the air heater to the stack (chimney) | 1. Coal Dust | Medium |
| | | | 2. High-Pressure Electricity | Medium |

A hazard identification observation sheet has been created by the authors of this study in the boiler division to collect precise data and assess the degree to which the study's goals were met. Twenty-one (21) different labour tasks were performed by employees in the boiler division,

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according to the findings of interviews and identification tables prepared by the authors in the observation sheet. Thus, it can be said that employees in the boiler division do not fully comprehend the risks associated with their workplace. They did not fully comprehend the causes of danger in the working environment of the boiler division; they only discussed the risks associated with hot materials or fuel, noise, and electricity, all of which can be regarded as High Risks. Then the next step is risk assessment and control so that it becomes a HIRARC registration document which will be compared with secondary data, namely the company's HIRARC [13].

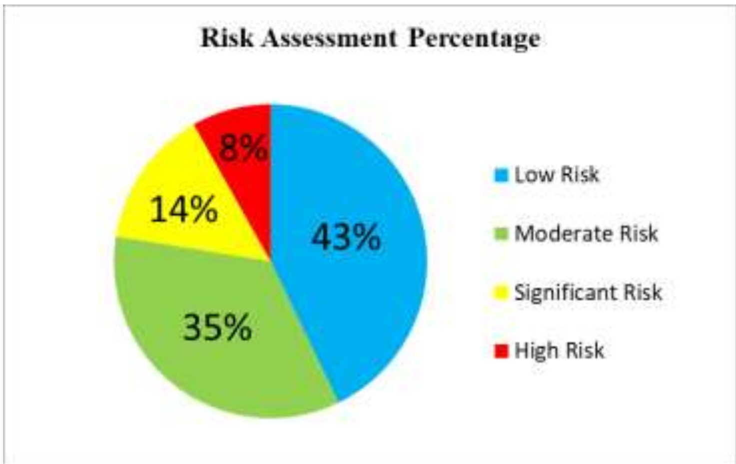


**Figure 1: Risk Assessment Analysis**

According to the findings of the risk assessment analysis, there is a low risk of 21 types of hazards (42.8%), a moderate risk of 17 types of hazards (34.7%), a significant risk of 7 types of hazards (14.3%), and a high risk of 4 types of hazards (8.2%) for all potential hazards. Additionally, there are up to 12 different types of mechanical dangers (24.5%), up to 5 different types of electrical hazards (10.2%), up to 3 different types of chemical hazards (6.1%), and up to 29 different categories of physical hazards (59.2%).

## 4. Conclusion

Based on the results of the data analysis, the following conclusions can be drawn from the results of research observations in the form of documents carried out by researchers as well as the results of interviews with informants. It was found that the sources of danger in the boiler division were coal dust, sparks, heat radiation, falling, being crushed, coal splash, noise, high-pressure electricity, explosion, burning, hot materials, exposure to chemicals, inhaling chemicals, hot steam, leaks in steam drums, hot water, excess gas pressure, and burning coals. Secondly, occupational safety and health risk assessment based on the source of hazard in the boiler division has a risk level ranging from the lowest to the highest score. Thirdly, Occupational health and safety risk assessment based on the type of hazard in the boiler division has a risk level ranging from the lowest to the highest score. That is Mechanical Hazard: 25%, Electric Hazard: 10%, Chemical Hazard: 6%, and Physical Hazard: 59%. In conclusion, these techniques could prevent future catastrophic events in the boiler operating business' especially in Malaysia. It could enhance the existing safe work system practices during boiler operation whereby implementing the effective risk assessment technique could directly check the lack of any ineffective practices such as reviewing procedures. Besides, it could also increase the visible leadership awareness in the organization through a tri-party involvement approach. Therefore, this study's significant contribution is crucial in comprehensive risk identification, including analyzing all risk factors during boiler operation.

**Acknowledgement**
This study was financially supported by the Universiti Teknologi Malaysia (UTM) Fundamental Research Grant (Q.K130000.3856.22H17), the Ministry of Higher Education (MOHE) under the Fundamental Research Grant Scheme (FRGS) (grant number: FRGS/1/2019/TK03/UTM/02/14 (R.K130000.7856.5F205)), Razak Faculty of Technology and Informatics (UTM), Universiti Teknologi Malaysia (UTM); for all the support towards making this study a success.

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