# DEVELOPMENT OF A RISK BASED INSPECTION (RBI) SOFTWARE FOR AN INTEGRATED EXPLOSION-INSPECTION COMPLIANCE SERVICES (INDUSTRY DEMAND PROJECT)

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**in fulfilment of the requirements for the degree of**

**Bachelor of Mechanical Engineering**

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**2020**

## DECLARATION

I declare that this project report entitled "development of a Risk-Based Inspection (RBO) software for an integrated explosion-inspection compliance services (Industry Demand Project)" is the result of my own work except as cited in the references

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Date : 19 JULY 2020

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I declare that this project report entitled "development of a Risk-Based Inspection (RBO) software for an integrated explosion-inspection compliance services (Industry Demand Project)" is the result of my own work except as cited in the references

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**APPROVAL**

I hereby declare that I have read this project report and in my opinion this report is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering.

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Date : 20 JULY 2020

# DEDICATION

I dedicate this project to my first love where my heaven will forever lies beneath her blessing, my lovely and dearest mother, Meriam binti Ismail.

## ABSTRACTS

This project discussed the periodic inspection stated in IEC 60079-17 where every Ex electrical equipment need to be inspected in three years interval. Such practices are questioned as the interval is baseless and the practice treats every equipment at same level of risk regardless of any external factors. This paper analysed the factors that contributes to assessing the ignition risk of each component. Analytical Hierarchy Process (AHP) method was used to determine the weightage of each factor or criteria and expert judgment were developed to rate the sub-criteria based on the possibility of them to become a source of ignition. Risk interval was developed to determine the level of ignition risk and tolerable interval of periodic inspection is established. 40 samples were taken to be analysed and the result shows that 37.5% of the samples have low ignition risk, 50% have medium ignition risk and 12.5% have high ignition risk. These variations of ignition risk show that every equipment has their own risk and to treat them at the same level of attention is incorrect. New interval for periodic inspection was developed based on the ignition risk of Ex electrical equipment and the interval works where equipment with low ignition risk will have longer interval and equipment with high ignition risk will have shorter interval. This increase the effectiveness of the inspection schedule by prioritization is given to equipment with high risk. In the future, this research about periodic inspection can be merge with sampling strategy to improve the efficiency of the inspection program.

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# CHAPTER 1

# INTRODUCTION

## 1.1 Background Study

International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The objective of IEC is to consolidate international practice on all issues concerning standardization in the electrical and electronic fields. Hazardous area such as oil rig, refinery and oil drilling platform need to use classified electrical equipment that is safe in such areas, rated as Ex electrical equipment. Ex electrical equipment is special electrical appliances or devices that have particular protection to ensure their capability and safety to be applied at hazardous area. Inspection of Ex electrical equipment is critical to assuring the continuing integrity of the types of protection, however the inspection requirements of IEC 60079-17 respect to close inspection in three years interval do not provide adequate inspection especially regarding frequency of inspection. This is because all equipment is treated at same level of inspection in terms of frequency and grade of inspection regardless the different ignition risk that might presence (Energy Institute n.d.; IEC 2013).

A research regarding fire and explosion accidents of oil depots in China shows that from 1951 to 2013, 435 cases were reported which almost 54.71% of the accident happened because of the failure of the management to carry out daily routine operation, maintenance, and repair works. Other than that, the fire and explosion accident likely to occurs due to the long service time (30 or 40 years) for numbers of equipment. This kind of equipment need enhanced inspection and safety maintenance program to ensure the equipment is safe to operate at hazardous area. Furthermore, 20% of the accidents reported due to ignition source come from electric spark, and 12.18% causes by heat source. Ex electrical equipment is design to be placed at certain hazardous area based on the equipment characteristic such as the type of protection, temperature class and gas group. However, the malfunction of this equipment or its protection can result in becoming the source of ignition and lead to fire or explosion accident. Thus, a functional and effective inspection and maintenance is a necessary to avoid any harmful event from going to happen (Bartec 2012; Zhou et al. 2016).

Energy Institute in their paper titled *Guidelines for managing inspection of Ex electrical equipment ignition risk in support of IEC 60079-17* emphasizes how the Ex electrical equipment inspection should be adjusted according to their ignition risks. Several factors such as the age of equipment, the environmental conditions and type of equipment define the ignition risk of an equipment. Ex electrical equipment might have different ignition risk and the inspection should prioritize high risk equipment in their inspection by increasing the frequency of inspection and enhance the level of inspection. This should improve the quality of inspection of Ex electrical equipment and reduce the chances of ignition. Risk based inspection concept is very suitable and have various advantages to be applicable in this effort (Energy Institute n.d.).

Risk based inspection is a component in the development of inspection and maintenance programme. It is used to assess the assets based on the risk, where risk is defined as the combination of probability of failure and consequence of failure. The risk analysis can be carried out quantitatively and qualitatively. It been practise in several field such as offshore industry, refinery plant and asset management (Singh 2015). RBI prioritizes inspection based on risk, express the expected values, and integrating the likelihood and consequence of failure. Application of RBI can ensure many benefits such as more precise assessment, tolerable inspection interval, decrease the number of failure occurrences and the ability to prevent unnecessary outrages and downtime (Mohamed, Hassan, and Hamid 2018). This will not only maintain the integrity of the equipment, but also decrease the expenditure for the inspection program.

EXS Synergy is a company specializing in integrated Explosion-Protection (Ex) compliance services, particularly for the oil, gas, petrochemical and energy industry globally. They provide comprehensive, cost-effective solutions in Hazardous Area-related services, with a primary focus on the inspection and maintenance of Ex installations for the energy industry, particularly the Oil, Gas, and Petrochemical sector. The company hopes to create an Explosive-Protection program using a Risk-Based Inspection in support with IEC 60079-17 concept to evaluate and supervise electrical appliances and equipment safety. The programme will identify the possible type of damage, the possible location, the rate that the damage might evolve as well as which failure will contribute to casualties. With this RBI program, a suitable inspection scheme can be deployed that provides adequate confidence about the condition of the equipment and the effectiveness of the inspection. It will also reduce the cost for inspection activity for their client and attract more companies to participate in this inspection program.

## 1.2 Problem Statement

It is a fault to treat every Ex electrical equipment at the same risk. However, IEC 60069-17 in its guidelines for periodic inspection state that all equipment needs to be inspected within 3 years interval. Thus, many inspections of Ex electrical equipment are done at the equal level of frequency and grade of inspection without considering the different ignition risk that might apply. Yet the Ex electrical equipment is located at different hazardous area and various type of protection concept present different ignition risks. Nevertheless, the equipment may have different ages or be located at different environmental condition. Thus, to treat all Ex electrical equipment at the same level of risk is not an adequate and efficient practise as it might lead to waste of inspection funds and endanger all the personnel and equipment at the hazardous area.

## 1.3 Objective

1. To determine and evaluate the criteria that contribute towards the risk of explosion.
2. To determine the new interval for periodic inspection based on the risk of the Ex electrical equipment.

## 1.4 Scope

The focus of this project is to develop a new interval for periodic inspection based on IEC 60079-17 using RBI methodology. The risk of the equipment will be assessed based on the characteristic of the equipment; installation zone, equipment faulty, type of equipment, type of protection, level of protection, age of equipment, and environmental condition, etc. The program will develop new interval for periodic inspection complied with IEC 60079-17.

# CHAPTER 2

# LITERATURE REVIEW

## 2.1 Electricity and Explosive atmosphere

Explosive atmosphere is a common environment at certain places such as petrol station, oil refinery and wood factory. The hazardous area in these places are divided according to presence of flammable material. Other than mechanical, electrical equipment also have the tendency to be the source of ignition. Thus, certain electrical equipment has special protection according to the requirements. All this electrical equipment is also grouped matching to their applications.

### 2.1.1 Explosive Atmosphere

As shown in Figure 2.1, there are three essential materials for an explosion to occur which are flammable substances, oxygen presence and source of ignition. All these factors need to be presence at the same time or else, no explosion will occur. Flammable material can be in terms of vapour and dust and it is categorized by its ease of ignition (Bal 2018). Ignition can come from various sources such as hot surfaces, flames and sparks (Bartec 2012). As all these elements need to be present at the same time, we can control the explosive environment by managing one of the elements from exceeding the safe parameters. We can control the amount of oxygen in an area, or the properties of the flammable area to keep the are below hazard.

Another way we can control the environment by using explosive protected instruments to demolish the source of ignition (IEC 2011).

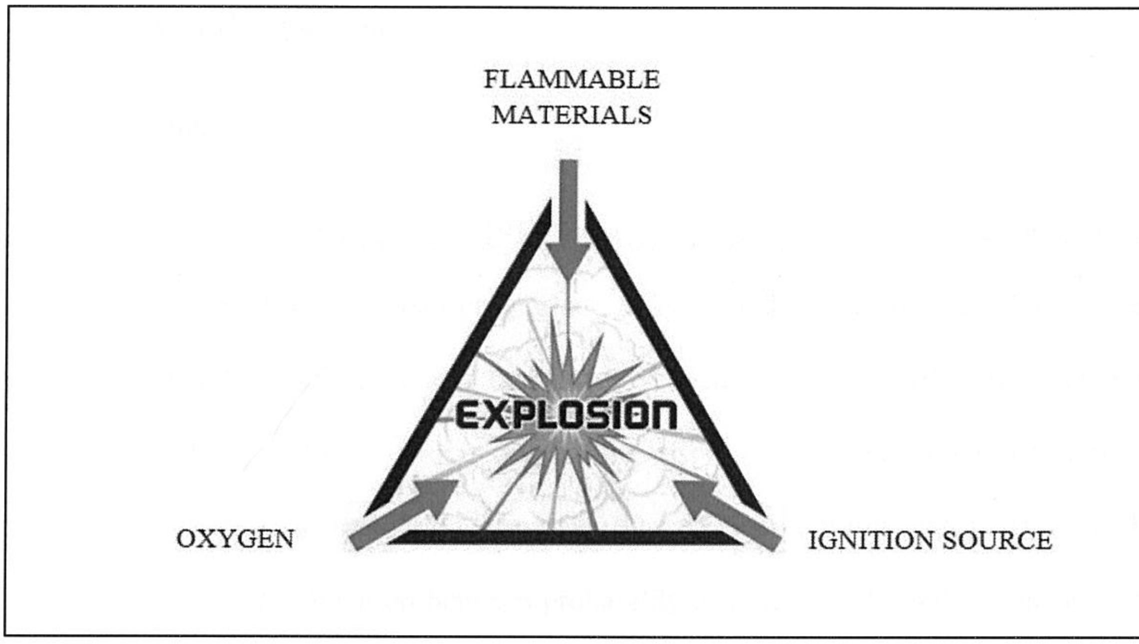


Figure 2.1 : Elements of Explosion

### 2.1.2 Electricity as source of ignition

Electrical spark is the most common ignition sources compare to mechanical generated sparks and hot surface (Bartec 2012). According to a study, 49% of gas explosion accidents caused by electrical spark (Li, Wang, and Shan 2019). The electrical sparks may be caused by the failure of certain electrical equipment. One of the factors contributes to electrical failure is human errors. An important conclusion was drawn where an analysis shows the majority hazardous events were caused by maintenance personal that fail to sustain the integrity of the equipment, causing equipment failure. On the other hand, the absence of proper inspection and maintenance program to detect and prevent any possible breakdown also contribute to the electrical equipment failure (Heo and Park 2010). It is understandable that a good and holistic inspection and maintenance program help in avoiding any explosion caused by electrical sparks from happening.

## 2.2 Risk Based Inspection

### 2.2.1 Definition

Risk-Based Inspection (RBI) is a component or method in developing an inspection and management programme. It is carried out in complex environment where numbers of inter-related factors were considered (Singh 2015). It uses risk as a basis for prioritising and managing the effort of an inspection programme to rationally allocate inspection resources (Drożyner and Veith 2002). Risk can be define as the combination between probability of failure (PoF) and consequence of failure (CoF) (Singh and Markeset 2009). RBI helps in helping management to prioritise high risk components in their inspection, determine inspections interval, expecting damage mechanism and selecting the best inspection method (Bhatia et al. 2019; DNV 2009).

### 2.2.2 Probability of Failure (PoF)

Probability of failure (PoF) is a multiplication of management factor, generic failure frequency (GFF) and likelihood factor. It is assessed from the certain influencing factors, such as number of equipment in an area, potential damaged mechanisms, effectiveness of inspection, present equipment conditions, and the nature of the process and equipment design (Drożyner and Veith 2002). Damaged mechanisms consist of general corrosion, fatigue cracking, low temperature exposure, high temperature degradation and others (Chang et al. 2005). Failure probability analysis is the key role of risk analysis (W. Wang et al. 2017). Bayesian network, Monte Carlo simulation, First Order Reliability Method (FORM) and fuzzy logic are example of theory that suitable to be used to assess the data and determine the probability of failure quantitatively (DNV 2009; Mohamed, Hassan, and Hamid 2018; W. Wang et al. 2017).

### 2.2.3 Consequence of Failure (CoF)

Another element in determining the risk of an event is consequence of failure (CoF). It is the combination of losses that could be encountered as a result of failure. The CoF is the summation of three main parts which is personal injury or losses, environmental losses and business losses (El-Reedy 2012). The consequence of failure could lead to injury or death of worker, leakage of poisonous gas/liquid and shutdown of a plant/refinery (API 2016; Tan et al. 2011).

### 2.2.4 Risk Based Inspection Method

#### a) Qualitative Approach

Qualitative approach is basically based on expert judgement. The factors will be ranked and evaluate using simple calculation. Weight of every parameters will be combined to produce final likelihood or consequences definition. There are several parameters that need to be consider in the calculation which is equipment, damage, process, mechanical, inspection and condition. All these parameters will summarise the likelihood factor. For the consequence factors, the parameter that need to be considered is the damage magnitude of the event based on five sub-factors: chemical, state, pressure, credit and degree of exposure. Another parameter that need to be analysed is the health factor which define from four sub-factors: toxic quantity, dispersibility, credit and population factors. All this likelihood and consequences can be presented in the matrix with likelihood will be on the vertical axis while consequence will be on the horizontal axis. However, using completely this approach in risk assessment is not recommended as it is hard to get precise assumption in terms of the impact of an inspection strategy (Drożyner and Veith 2002).

**b) Quantitative Approach**

Quantitative approach analyse risk based on various components. The probability of failure and consequence of failure calculated using the data obtained from inspections and modelling results. The risk is analysed depends on five aspect which is system definition, hazard identification, consequence assessment, probability assessment and risk result. The risk analysis will evaluate both likelihood and the consequence of the events from thousands of scenarios and data. However, this method is as the calculation can be so complicated and daunting (Drożyner and Veith 2002; Singh 2015).

**c) Semi Qualitative/Semi Quantitative Approach**

As both quantitative and qualitative approach have their own weaknesses, thus an approach was developed by combining both approach as a good balance of precision and practicality. This approach called semi qualitative or semi quantitative (Singh 2015). This approach were applied in subsea pipeline, oil refinery plant, driller pressure management, sewerage network and offshore platform (Bhatia et al. 2019).

## 2.3 IEC, Energy Institute and RBI

International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. IEC 60079-17 is a standard that provide the details about initial inspection and on-going inspection to ensure the safety and integrity of electrical equipment in hazardous areas.

According to IEC 60079-17, there is 4 types of inspection practised in the standard, which is initial inspection, periodic inspection, sample inspection and continuous supervision. For periodic inspection, the interval of the inspection is set to three years. It means all the equipment need to be inspected within three years interval at the same level of inspection in terms of frequency, grade of inspection etc. However, the inventory of Ex electrical equipment is typically located in different hazardous areas (where the probability of a flammable atmosphere being present differs) and the various Ex electrical equipment type of protection concepts present different ignition risks. In addition, the equipment may have different ages or be located where the environmental conditions differ (Energy Institute n.d.; IEC 2013).

Risk-Based Inspection (RBI) is a targeted, effective, and balanced approach to inspection. When applied correctly, it should result in high risk equipment located in high risk areas being inspected more frequently than other equipment located in other areas. The RBI principles can be promoted to the inspection of Ex electrical equipment to meddle with the interval between periodic inspection and resulting to more efficient use and targeting of inspection resources. It allows the high-risk Ex electrical equipment being inspected to a more rigorous level of inspection than lower risk items (Energy Institute n.d.).

## 2.4 Criteria that contribute to the risk of explosion

RBI develops the inspection and maintenance program based on the risk. There are few parameters that contribute towards the risk of explosion such as the probability of source of ignition and the probability of flammable atmosphere being present (Energy Institute n.d.). The probability of source of ignition is contributed by certain criteria such as the temperature class and gas group of installed area, the type of Ex equipment, the type of Ex protection, the level of protection, the age of the equipment, the environmental condition