BACHELOR THESIS & COLLOQUIUM – ME141502

FIRE CAUSE ANALYSIS ON WOODEN SHIP KM. IZHAR

Regian Ganang Alfarizi

NRP. 04211541000011

SUPERVISOR :

Dr. Eng. Trika Pitana, S.T., M.Sc.

Aleik Nurwahyudy

DOUBLE DEGREE PROGRAM

DEPARTMENT OF MARINE ENGINEERING

FACULTY OF MARINE TECHNOLOGY

INSTITUT TEKNOLOGI SEPULUH NOPEMBER

SURABAYA

2020

"This Page Intentionally Left Blank"

BACHELOR THESIS & COLLOQUIUM – ME 184841

FIRE CAUSE ANALYSIS ON WOODEN SHIP KM. IZHAR

Regian Ganang Alfarizi
NRP 04211541000011

Supervisor:
Dr. Eng. Trika Pitana S.T., M.Sc.
Aleik Nurwahyudy

DOUBLE DEGREE PROGRAM OF
DEPARTEMENT OF MARINE ENGINEERING
FACULTY OF MARINE TECHNOLOGY
INSTITUT TEKNOLOGI SEPULUH NOPEMBER
SURABAYA
2020

"This Page Intentionally Left Blank"

SKRIPSI – ME 184841

ANALISA PENYEBAB KEBAKARAN PADA KAPAL KAYU KM. IZHAR

Regian Ganang Alfarizi
NRP 04211541000011

Dosen Pembimbing:
Dr. Eng. Trika Pitana S.T., M.Sc.
Aleik Nurwahyudy

PROGRAM DOUBLE DEGREE
DEPARTEMEN TEKNIK SISTEM PERKAPALAN
FAKULTAS TEKNOLOGI KELAUTAN
INSTITUT TEKNOLOGI SEPULUH NOPEMBER
SURABAYA
2020

"This Page Intentionally Left Blank"

APPROVAL FORM

FIRE CAUSE ANALYSIS ON WOODEN SHIP KM. IZHAR

BACHELOR THESIS

Submitted to comply the requirements to obtain a Bachelor Engineering Degree

On

Marine Operational and Maintenance (MOM)

Bachelor Program Department of Marine Engineering

Faculty of Marine Technology

Institut Teknologi Sepuluh Nopember

Prepared by:

REGIAN GANANG ALFARIZI

NRP. 04211541000011

Approved by supervisors:

Dr. Eng. Trika Pitana, S.T., M.Sc. ( )

NIP. 197601292001121001

Aleik Nurwahyudy ( )

"This Page Intentionally Left Blank"

APPROVAL FORM

FIRE CAUSE ANALYSIS ON WOODEN SHIP KM. IZHAR

BACHELOR THESIS

Submitted to comply the requirements to obtain a Bachelor Engineering Degree

On

Marine Operational and Maintenance (MOM)

Bachelor Program Department of Marine Engineering

Faculty of Marine Technology

Institut Teknologi Sepuluh Nopember

Prepared by:

REGIAN GANANG ALFARIZI

NRP. 04211541000011

Approved by:

Head of Department of Marine Engineering

Beny Cahyono, S.T., M.T., Ph. D.

NIP. 197903192008011008

"This Page Intentionally Left Blank"

APPROVAL FORM

FIRE CAUSE ANALYSIS ON WOODEN SHIP KM. IZHAR

BACHELOR THESIS

Submitted to comply the requirements to obtain a Bachelor Engineering Degree

On

Marine Operational and Maintenance (MOM)

Bachelor Program Department of Marine Engineering

Faculty of Marine Technology

Institut Teknologi Sepuluh Nopember

Prepared by:

REGIAN GANANG ALFARIZI

NRP. 04211541000011

Approved by:

Representative of Hochschule Wismar in Indonesia

Dr.-Ing. Wolfgang Busse

"This Page Intentionally Left Blank"

DECLARATION OF HONOR

I hereby who signed below declare that:

This bachelor thesis has written and developed independently without any plagiarism act, and confirm consciously that all data, concepts, design, references, and material in this report own by Marine Operation and Maintenance (MOM) in Department of Marine Engineering ITS which are the product of research study and reserve the right to use for further research study and its development.

Name	: Regian Ganang Alfarizi
NRP	: 04211541000011
Bachelor Thesis Title	: Fire Cause Analysis on Wooden Ship KM. Izhar
Department	: Marine Engineering

If there is plagiarism act in the future, I will fully responsible and receive the penalty given by ITS according to the regulation applied.

Surabaya, January 2020

Regian Ganang Alfarizi

"This Page Intentionally Left Blank"

FIRE CAUSE ANALYSIS ON WOODEN SHIP KM. IZHAR

Name : Regian Ganang Alfarizi
NRP : 04211541000011
Department : Marine Engineering
Supervisor I : Dr. Eng. Trika Pitana, S.T., M.Sc.
Supervisor II : Aleik Nurwahyudy

ABSTRACT

PELRA is a traditional sea transportation service that uses sailing vessels, motorized sailing vessels and simple motor vessel. This sea transportation service is suitable for places with little demand by connecting islands with a small population or being inland transportation, especially in watersheds in Kalimantan, Sulawesi, and Sumatera. PELRA ship, is mainly made traditionally by using wood. Then the possibilities that the ship is sinking or getting caught on fire is higher. According to KNKT accident reports, PELRA ship accident still occur in every years and the most frequent cause of the accident is fire. Then, the aim of this thesis is to find out the root cause of the fire and find out what can be improved to avoid such an incident on PELRA ship. The study case that being used in this bachelor thesis is fire accident in KM. Izhar case. The method that being used for the research is collecting KM. Izhar data and accident chronology. After the data is collected then the data will be analyzed using five whys method to find out the accident root cause. Then, if the root cause has been found out, the recommendation to prevent such an accident happen again in the future can be made.

Keywords: Root Cause Analysis, Wooden Ship, PELRA

"This Page Intentionally Left Blank"

ANALISA PENYEBAB KEBAKARAN PADA KAPAL KAYU KM. IZHAR

Nama Mahasiswa : Regian Ganang Alfarizi
NRP : 04211541000011
Jurusan : Teknik Sistem Perkapalan
Dosen Pembimbing I : Dr. Eng. Trika Pitana, S.T., M.Sc.
Dosen Pembimbing II : Aleik Nurwahyudy

ABSTRAK

PELRA merupakan layanan transportasi laut tradisional yang menggunakan kapal layar, kapal layar motor, dan kapal motor sederhana. Layanan transportasi ini cocok untuk tempat-tempat terpencil dengan menghubungkan pulau-pulau berpopulasi kecil atau transportasi sungai yang dapat ditemukan di Kalimantan, Sulawesi, dan Sumatera. Kapal PELRA pada umumnya dibuat secara tradisional menggunakan kayu. Tinggi kemungkinan kapal tersebut mengalami kecelakaan dan kebakaran. Berdasarkan laporan kecelakaan KNKT, kecelakaan kaapal PELRA masih terjadi setiap tahunnya dan penyebab yang paling sering terjadi adalah karena kebakaran. Oleh karena itu tujuan penulisan skripsi ini adalah untuk mencari apa yang dapat ditingkatan pada kapal PELRA untuk menghindari kejadian serupa terjadi. Studi kasus yang digunakan pada penulisan skripsi ini adalah kasus kebakaran yang terjadi pada KM. Izhar. Metode yang digunakan dalam penulisan skripsi ini adalah mengumpulkan data KM. Izhar dan kronologi kecelakaan. setelah data dikumpulkan kemudian data di anlisa menggunakan metode five whys untuk menentukan penyebab kecelakaan. Kemudian setelah akar penyebab ditemukan, rekomendasi untuk mencegah kecelakaan terjadi kembali dapat disusun.

Kata Kunci: *Root Cause Analysis*, Kapal Kayu, PELRA

"This Page Intentionally Left Blank"

PREFACE

All praise the authors say into the presence of God Almighty, who has provided his grace so that the author can complete this thesis titled "Fire Cause Analysis on Wooden Ship KM. Izhar". This thesis is supposed to fulfill the Bachelor Thesis course at authors study and also be hoped that authors gain more information regarding this thesis in the future.

The authors would like to say thanks for those who helped the author in the making of the thesis.

1. Allah SWT that has given His grace and guidance so that the author can complete the bachelor thesis reports.
2. Author's beloved parents, Drs. Narwan Trihana, Yuliati Suviani, S.H., Kanthi Wulandari S.Pd, Suprapto and Sih Mandaningrum, S.Pd.
3. Beny Cahyono, S.T., M.T., Ph. D., as a Chairman of the Department of Marine Engineering Department, Faculty of Marine Technology ITS.
4. Dr. Eng. Trika Pitana, ST., M.Sc as a Supervisor I in the process of making this bachelor thesis.
5. Aleik Nurwahyudy as a supervisor II in the process of making this bachelor thesis.
6. Dr. I. Made Ariana, S.T., M.T. as a lecture advisor since first semester until last semester who giving a lot of advice.
7. KNKT for giving any data for the process of writing this bachelor thesis.
8. Panca Muhammad Rizha Purnama who was along together in bitter and sweet moments during this thesis writing.
9. All of MOM Lab members who always there in bitter and sweet conditions.
10. Fellow friends of Double Degree in Marine Engineering batch 2015 who were struggling together for more three and a half years.

The author concerns in the imperfections of this thesis. Therefore, any criticisms and suggestions that are built from the reader will be expected. The author hopes this thesis provides benefits primarily for readers and additional for the author in the process of teaching and learning.

Surabaya, January 2020

Author

"This Page Intentionally Left Blank"

TABLE OF CONTENTS

"This Page Intentionally Left Blank"

LIST OF FIGURES

"This Page Intentionally Left Blank"

LIST OF TABLES

“This Page Intentionally Left Blank”

I. INTRODUCTION

1.1. Background

As an archipelago country, Indonesia has 17,504 islands and has a coastline of 99,093 kilometers. Indonesia's territorial waters reach 6.32 million km2, or around 70% of the total area of Indonesia (BPS, 2016). The awareness that Indonesia is an archipelago country led to a policy reorientation that was more directed towards developing the potential of national maritime resources. In an archipelago country such as Indonesia, ship is one of public transportation that is often used to go from one island to another. Indonesia's geography shows the need for transportation and transportation facilities, to establish communication in order to establish and develop community interaction in various fields. To establish such networks and links, the role of sea transportation becomes important.

As explained in UU no. 17 of 2008, shipping is a unified system consisting of transportation in waters, port, safety and security, and protection of the maritime environment. Therefore, water transportation includes the activities of transporting passengers and / or goods using ships. Types of transportation in waters include sea, river, and lake transportation. As for sea transportation, it is broken down into domestic, foreign, special, and public-transportation services. In Indonesia itself, sea public transportation that connects Indonesia's islands can be divided into two categories, which "*Pelayaran Rakyat*" (PELRA) and is "*Pelayaran Nasional*" (PELNAS).

PELRA is a traditional sea transportation service that uses sailing vessels, motorized sailing vessels and simple motor vessel. This sea transportation service is suitable for places with little demand by connecting islands with a small population or being inland transportation, especially in watersheds in Kalimantan, Sulawesi, and Sumatera. This is because not all small islands can be visited by large ships while on one side the population on the island needs sea transportation services. PELNAS or better known as domestic shipping is a type of sea transportation service that is often used by consumers using services. This is because the fleet is more modern so that transportation services can run efficiently.

Accident Type	Year					total
	2013	2014	2015	2016	2017	
Grounding	0	0	1	3	6	10
Fire	2	3	4	4	14	27
Collision	2	2	3	3	6	16
Sink	2	2	3	6	6	19
Others	0	0	0	2	2	4
Total accident	6	7	11	18	34	76

Table 1.1. Ship Accident Statistics According to KNKT Report

(Source: KNKT Report)

However, ship accidents in Indonesia still occur. PELRA ship, is mainly made traditionally by using wood. Then the possibilities that the ship is sinking or getting caught on fire is higher. This also applies in Indonesia. According to KNKT accident reports, PELRA ship accident still occur in every years and according to table 1.1, the most frequent cause of the accident is fire. However, PELRA has a significant role in strengthening the maritime axis. PELRA can be used to strengthen the identity of the Indonesian nation as a maritime nation, which is indicated by the presence of maritime cultural symbols inside people's shipping activities, both manifested in the physical forms of boats used in shipping and in the shipping organization system, which each has a distinctive pattern representing maritime cultural traditions in each region. Therefore, sea transportation services especially PELRA ship should be improved. Many factors cause accidents, including natural factors such as bad weather and human error factors. This factor causes emergencies on board the ship. Then, the aim of this thesis is to find out the root cause of the fire and find out what can be improved to avoid such an incident on PELRA ship.

1.2. Problem Statement

Based on the background above, the problems are:

a. What is the root cause of fire on board PELRA ship?
b. What can be improved to avoid fire incident on PELRA ship?

1.3. Scope of Problem

a. The object that being analyzed in this thesis is limited only for KM. Izhar case.
b. The analysis is focused in fire cause analysis

1.4. Objectives

a. To find out the root cause of fire on board PELRA ship, especially in KM. Izhar case.
b. To find improvement to improve PELRA ship safety.

1.5. Benefits

a. To help PELRA ship become safer so the ship credibility and passenger trust increases

"This Page Intentionally Left Blank"

II. LITERATURE REVIEW

2.1 Overview

PELRA is a traditional sea transportation service that uses sailing vessels, motorized sailing vessels and simple motor vessel. This sea transportation service is suitable for places with little demand by connecting islands with a small population or being inland transportation, especially in watersheds in Kalimantan, Sulawesi, and Sumatera. This is because not all small islands can be visited by large ships while on one side the population on the island needs sea transportation services.

E.	JENIS KAPAL													
1	KAPAL MOTOR (KM)	11	10	1	5	7	8	6	7	5	8	9	1	**78**
2	KAPAL TRADISIONAL (KLM)	0	2	0	1	4	3	4	1	0	1	2	0	**18**
3	KAPAL TUG BOAT (TB)	4	1	1	2	3	2	4	0	1	3	2	1	**24**
4	KAPAL TONGKANG (BARGE)	2	0	0	0	1	0	0	0	1	0	0	0	**4**

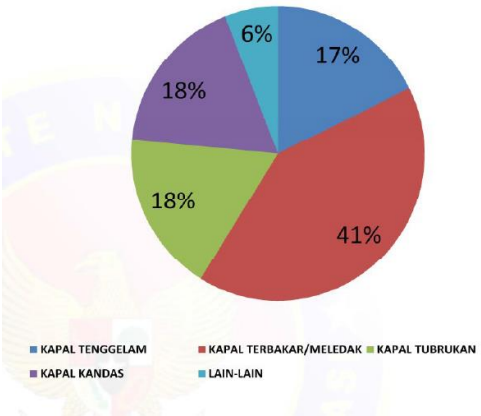


Table 2.1. KNKT Accident Report

Source: KNKT report

However, ship accidents in Indonesia still occur even the government has state their regulation such as Non-Convention Vessel Standards (NCVS) for Indonesian flagged non convention vessels. PELRA ship, is mainly made traditionally by using wood. Then the possibilities that the ship is sinking or getting caught on fire is higher. This also applies in Indonesia. According to KNKT accident reports as shown in table 2.1, PELRA ship accident still occur in every years and fire is the most frequent cause in a ship accident in Indonesia. Hence the cause of the accident need to be analyzed so the recommendation or improvement can be done to avoid such an accident happen in the future. This thesis objective is to analyze the cause of fire in KM. Izhar accident and check its appropriateness according Indonesian flag NCVS.

2.2 PELRA

PELRA is a traditional sea transportation service that uses sailing vessels, motorized sailing vessels and simple motor vessel. This sea transportation service is suitable for places with little demand by connecting islands with a small population or being inland transportation, especially in watersheds in Kalimantan, Sulawesi, and Sumatera. This is because not all small islands can be visited by large ships while on one side the population on the island needs sea transportation services. PELRA is generally identic with wooden ships using sails that are operated with simple management. An example of PELRA ship can be seen at figure 2.1.

Since long time ago, PELRA's business has been well known as a means of transporting agricultural, plantation, production and livestock products. PELRA can also transport passengers from remote or inland areas whose volume is relatively limited (Karana, 2003). There are many types of PELRA fleet such as lete, lambo, nade, and pinisi. At the moment, almost all PELRA fleets are using Motorized Sailboats.

Figure 2.1. PELRA Ship

(Source: hubla.dephub.go.id)

Until now, PELRA still has an important role in maintaining connection of supply of staples to remote areas which cannot be reached by other shipping lines. Geographically, Indonesia is an archipelago country. Many small islands and rivers which certainly cannot be reached by large ships. There it is the function of the PELRA ship was to distribute the distribution of commodities, both basic food and other needs. The fleet that is local wisdom, in its operations, does not depend much on port infrastructure such as loading and unloading equipment, fresh water, and docking. PELRA ship itself is enough to only rely on human labor, it is also still capable of loading and unloading, so the majority of the pier activities are adjusted to their interests and needs (Wijaya, 2016). The draft of the PELRA ship is not very high, that is, it is only around 2 meters, and it is different from iron vessels that can

reach up to 4 meters. So that the PELRA fleet has access to enter areas of shallow waters. Another advantage that is owned by PELRA ships is free and non-permanent shipping routes. Based on Article 16 paragraph 3 of UU no. 17 Year 2008, the shipping fleet of PELRA can be operated domestically and across borders, both on fixed and regular routes as well as on non-permanent and irregular routes. The flexibility in this route provides benefits for PELRA in its business activities.

PELRA has a significant role in strengthening the maritime axis. PELRA can be used to strengthen the identity of the Indonesian nation as a maritime nation, which is indicated by the presence of maritime cultural symbols inside people's shipping activities, both manifested in the physical forms of boats used in shipping and in the shipping organization system, which each has a distinctive pattern representing maritime cultural traditions in each region.

The average lifespan of the PELRA fleet is 15 to 20 years, it is rather difficult for them to replace or add to their fleets because government regulations related to logging which is the main materials for boat building are now limited (Jinca, 2016). This will affect the ship safety. According to KNKT accident reports, PELRA ship accident still occur in every years. Therefore, sea transportation services especially PELRA ship should be improved.

2.3 Fire

Fire can be defined as a thermochemical phenomenon which requires the availability of three chemical physical elements simultaneously. Those elements are respectively fuel or flammable substance, oxygen, and ignition source energy as shown in figure 2.2. (Benintendi, 2018). Those element now can be called as fire triangle.

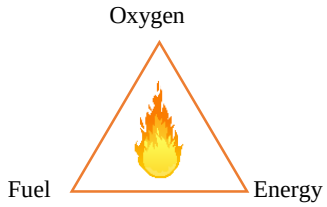


Figure 2.2. Fire Triangle

(Source: private document)

Fire or explosion can be resulted from a mixture of air or oxygen and a flammable substance, if properly energized by the ignition source will undergo a combustion reaction. The difference between these two phenomena is essentially related to the energy release rate which is related, in turn, to a significant pressure rise, depending on some factors, such as congestion and turbulence. In process safety calculations, fire is generally associated to thermal effects only, whereas explosion is also accompanied by significant mechanical effects (Benintendi, 2018). Ignition sources provide the necessary energy amount to trigger and sustain combustion. Reaction rate

of combustion is also affected by ignition process, possibly promoting fire to deflagration and to detonation, depending on the circumstances.

Systematic ignition source list can be found in the BS EN 1127-1. Those are:

- Hot Surfaces
- Flames and hot gases
- Mechanically generated sparks
- Electricity apparatus stray electric currents, cathodic corrosion protection
- Static electricity
- Lightning
- Radio frequency electromagnetic waves
- Ionising radiations
- Ultrasonics
- Adiabatic compression and shock waves
- Exothermic reactions, including self-ignition of dusts

When fuel is present in suitable proportions, and combination with oxygen, the attainment of the minimum ignition energy threshold is the only conditional factor. Consequently, control of ignition sources, identification of their probability, and quantification of their occurrence are fundamental aspects in consequence and risk assessment.

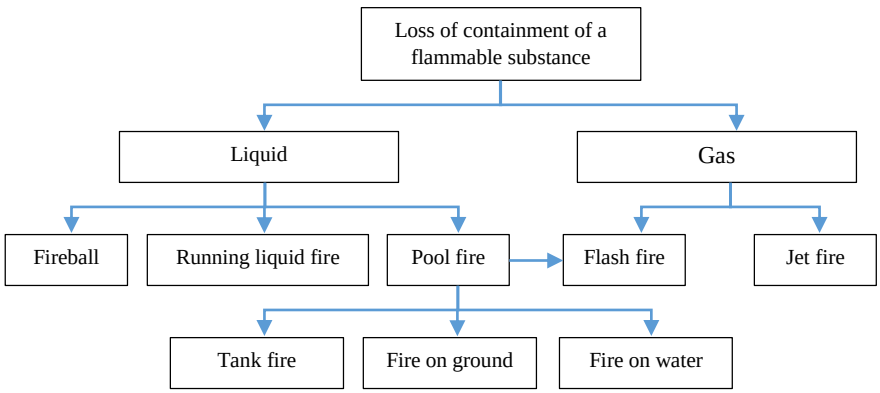


Figure 2.3. Type of Fire That May Occur

(Source: private document)

In industrial installation or hazardous substance transport, fire can be classified according to the conditions which the combustion take place and the state of flammable medium involved (Casal, 2018). Although the combustion of solid materials may also cause large fires, the most common fuels in industrial accidents are usually liquids and gases. Therefore, the accident starts with the loss of containment of a flammable fluid.

If it is a liquid, the release can create a pool on the ground—covering a limited area if a dike is present—or on water; the outcome is similar in the case of a tank that has lost its roof due to an explosion. In all of these cases, the ignition will start a pool fire (a tank fire may be considered to be a particular case of a pool fire). If the liquid is flowing, which is not common, the ensuing running liquid fire will have different features and can sometimes be very difficult to extinguish. If the liquid undergoes flash vaporization due to a sudden depressurization, a fireball will probably be created. When the material released is a gas or a vapor, if ignition takes place immediately there will be a jet fire. If ignition is not immediate, a cloud containing a flammable mixture may build up under certain meteorological conditions; the ignition of this cloud will cause a flash fire. A flash fire can also occur if a pool is not ignited, due to the vaporization of the fuel. Pool and tank fires are the most frequent types of fire, followed by jet fires, flash fires and fireballs.

2.4 Fire Suppression

The purpose of the firefighting system is to save assets, control the fire to prevent the spread of fire, provide cooling, and provide firefighting. Various firefighting methods are available to protect assets. Portable outages and fixed outages can be used to put out fires. The effectiveness of all extinguishing measures can be determined by the flow rate of the extinguishing media and the method or delivery arrangement. The type of fire exposure must be confirmed and analyzed before the extinguishing is applied. By determining the type of fire that occurs, fire protection measures are in accordance with the protection philosophy applied to the assets that can be assessed. The easiest method for determining protection needs is to use materials and pressures involved in the process.

Type of fire suppression can be classified as follows (Nolan, 2011):

2.4.1 Portable Fire Extinguisher

A portable fire extinguisher is a device used to put out fires of limited size. Portable extinguishers are classified by expected application on a specific type of fire (i.e., A, B, C, or D) and the expected area of suppression. The four types of fires are grouped according to the type of material that is burning.

Class A fires are those in which ordinary combustibles such as wood, cloth, and paper are burning. Class A fire extinguishers are usually water based. Water provides a heat absorbing (cooling) effect on the burning material to extinguish the fire. Pressurized water extinguishers use air under pressure to expel the water which is directed with a short hose.

Class B fires are those in which flammable liquids, oils, and grease are burning. Class B fires are put out by excluding air, by slowing down the release of flammable vapors or by interrupting the chain reaction of the combustion. Three

types of extinguishing agents are typically used: carbon dioxide, dry chemical, and foam water for fires involving flammable liquids, greases, and oils.

Class C fires are those involving live electrical equipment. The extinguishing agent in a Class C fire extinguisher must be electrically non-conductive. Both carbon dioxide and dry chemicals can be used for electrical fires. An advantage of carbon dioxide is that it leaves no residue after the fire is extinguished. When electrical equipment is not energized, extinguishers for Class A or B fires may be used.

Class D fires involve combustible metals such as magnesium, potassium, and sodium. A heat-absorbing extinguishing medium is needed for fires in combustible metals. Also the extinguishing medium must not react with the burning metal. The extinguishing agents, known as dry powders, cover the burning metal and provide a smothering blanket.

The extinguisher label provides operating instructions and identifies the class or classes of the fire on which extinguisher may be used safely. Approved extinguishers also carry the labels of the laboratories where they were tested.

Portable fire extinguishers should be positioned in all process facility areas so that the travel distance to any extinguisher is a maximum of 15 meters (50 ft). They are generally sited on the main walkways or exits from an area, near the high hazard itself and near other emergency devices. They are mounted so individuals can easily retrieve them, typically approximately 1 meter (3.5 ft) from the walking surface with a red highlighting at the mounting location.

2.4.2 Water Suppression Systems

Water is the most useful and vital fire suppression medium, whether used for fixed systems or manual firefighting efforts for process facilities. It is relatively inexpensive and normally plentiful. It has enormous heat absorption properties. Approximately 3.8 liters (1 gallon) of water absorbs about 1512 kcal (6000 Btu), when vaporized to steam. Steam created by water evaporation expands to about 17 000 times its volume in open atmospheres, thereby limiting combustion processes by displacing oxygen in the area.

The objective of water suppression systems is to provide exposure cooling, fire control suppression of fire incidents and assist in the dispersion of combustible or toxic vapors. When water suppression systems are provided, due concern should be made for the disposal of the released water. Of primary importance is the capability and location of surface drainage systems. Firewater usage usually places greater demands on the facility gravity sewer system than rainfall or incidental process fluid spillages. There are several types of suppression system that using water as the media. Those are fire pumps, water sprinkles, water nozzle, etc.

2.4.3 Foam Suppression Systems

Foam systems are provided wherever there are large quantities of liquid hydrocarbons that pose a high fire risk. Foam is an aggregate of water, chemical compounds, and air-filled bubbles that float on the surface of combustible liquids to prevent vapor formation. They are used primarily to provide a cohesive floating blanket on the liquid surface of the liquid material it is protecting. It extinguishes a fire by smothering and cooling the fuel, i.e., covering the liquid surface and stops re-ignition by preventing the formation of combustible mixtures of vapor and air over the liquid surface. Foam will also cool the fuel and surrounding equipment involved in the fire. Foams are supplied in concentrates that are appropriately proportioned into water supply systems. They are then aspirated with air to produce the foam bubbles.

Foam is a homogenous blanket of a mixture of liquid chemical and air or a nonflammable gas. Foam fire suppression systems are classified as high or low expansion. High expansion foam is an aggregate of bubbles resulting from the mechanical expansion of foam solution by air or other nonflammable gas. Low expansion foams are typically applied to the surface of exposed flammable liquids, especially in outdoor areas. High expansion foams are commonly applied to large enclosed areas where high winds would not affect the foam usefulness and where interior locations are hard to reach.

2.4.4 Gaseous Systems

For gaseous systems, gas type that usually used is Carbon dioxide (CO_2). CO_2 is a non-combustible gas that can penetrate and spread to all parts of a fire, diluting the available oxygen to a concentration that will not support combustion. Carbon dioxide systems will extinguish fires in practically all combustibles except those which have their own oxygen supply and certain metals that cause decomposition of the carbon dioxide. CO_2 does not conduct electricity and can be used on energized electrical equipment. It will not freeze or deteriorate with age. Carbon dioxide is a dangerous gas to human life because it displaces oxygen. Concentrations above 9 percent are considered hazardous, while 30 percent or more are needed for fire extinguishing systems. Carbon dioxide systems are generally ineffective in outdoor applications, as wind effects will dissipate the gas rapidly. For fire extinguishing and inerting purposes, CO_2 is stored in liquid form that provides for its own pressurized discharge.

2.5 Accident Type

Any vessel that does the activities can probably have one or some problem caused by several factors such as sailing route condition, climate, human error, vessel, and unpredictable things, which is finally can slightly damage the vessel or fatally damage the vessel. Those factor can create sailing disturbance.

Sailing disturbance can be classified according to the event based on situation, such as:

- Collision

  Emergency caused by ships crash, or with port or some material, will possible to damage in ship, casualties, oil spill in the sea, pollution and fire.

- Pollution

  Ocean pollution can happen by trash disposal or oil spilling in bunkering, waste disposal of tank ship cargo, leak tank waste caused by crash.

- Leakage

  Leakage in ship can caused by shatter, but can also cause by crushed or fire and ship outer plate damage by corrosion. The water come in quickly, while the ability to handle the leakage is limited, even the ship can be leaned, cause the situation hard to handle.

- Fire / Explosion

  Fire in ship can happen in some vulnerable location such as engine room, cargo room, ship equipment storage, electrical installation and captain and crew accommodation room.

- Man over Board

  People fell to the sea is one accident that become emergency in term of rescue. Help given is not easily done, because very depend to the climate, ability of the helper and availability of facilities.

- Shattered

  Ship shattered initially signed by heavy rotation in propeller, sudden blackened smoke in funnel, ship body vibrate, speed change and suddenly stop. In shatter, the ship motionless, and ship position will very depend to water level, and inside situation very depend on the ship condition.

Emergency can incur loss to the ship on board, passenger, goods, and the ship crews itself. To handle the emergency condition, the first thing to do is to find out the whole situation so the condition sign can be identified and the emergency condition can be handled by the ship's crews.

2.6 Regulation for Wooden Ships

To ensure ship safety, a ship is usually registered in a class. By getting certified by the class, it can be said that the ship is safe to sail. It can also built trust to get ship insurance and gaining customer loyalty. Since wooden ships have different material

compared to convention/modern ship, then wooden ship has its own regulation. In Indonesia, there are regulations regarding wooden ships issued by BKI since 1996. The regulation consist of several chapters (BKI, 1996), those are:

- Chapter I - General
- Chapter II - Materials
- Chapter III - Main Size and Construction Size
- Chapter IV - Constructions
- Chapter V - Engine Room
- Chapter VI - Bolts and Nails Installation
- Chapter VII - Sizing
- Chapter VIII - Outer Skin Coating
- Chapter IX - Tanks
- Chapter X - Steering Wheel
- Chapter XI - Equipment

Recently, to support activities of shipping operators in Indonesia, Non Convention Vessel Standards (NCVS) for Indonesian-flagged non convention vessels are applied by Ministry of Transportation. The standard of the regulation is adapted with Indonesian geographical condition to avoid burdensome in established requirements. This regulation is applied for (Indonesian Ministry of Transportation, 2009):

- All merchant vessel on domestic voyages;
- Merchant vessels less than 500 gross tonnage on international voyages;
- Vessels with non-mechanical propulsion (barge, pontoon and sailing vessel);
- Wooden vessels with sail and auxiliary propulsion engine (KLM) and wooden vessels with propulsion engine;
- Fishing vessels;
- Pleasure craft
- Vessels with NOVEL design;
- State vessels which are used for commercial purpose;
- All existing vessels which have been modified for other purpose

The expectation by implementing NCVS is to make Indonesian vessel national standard so there is no standard difference for the same vessel in two different places. This regulation of Indonesian-flagged non convention vessels is in the Appendix of Minister for Transportation Regulation Number: KM No. 65 Year 2009. It regulates quality standard of things related to vessels and its crew.

2.7 Root Cause Analysis

The value of root cause analysis is that conclusions are reached that may address a much broader range of issues than those immediately to do with the event being

investigated. Many of the techniques that are available, however, can be classified into one of the following groups (Sutton, 2010):

- Argument by analogy: story telling

Many people use stories to develop root causes by analogy. They examine incidents that have occurred elsewhere and develop lessons that can be used in the current situation. Indeed, many companies encourage the dissemination of incident stories in order to create a lessons learned culture, and some professional organizations publish information to do with incidents that can be used by other companies.

- Barrier Analysis

Barrier analysis is a rapid assessment tool used in behavior change projects. The purpose of barrier analysis is to identify behavioral determinants, so that more effective behavior change, communication messages, strategies, and supporting activities can be developed. Barrier analysis is a relatively easy approach that can be conducted in a short period of time, allowing implementers to quickly make decisions based on the findings.

- Categorization

One of the fundamental discussions to do with incident analysis concerns the use of predefined categories for root causes, or whether a more open-ended, less structured approach is more appropriate.

- System synthesis

Two methods that can be described to illustrate system synthesis approach is Why Tree Analysis and Fault Tree Analysis. Because both methods rely on the cause and effect principle it is useful to ensure that the links between causes and effects are properly understood. This can be done by asking the following questions when creating a cause/effect relationship. These questions are:

1. What concrete, measurable proof is there that the cause exists?

2. Is there proof that the postulated cause could lead to the effect?

3. What proof exists that the cause actually did lead to the effect?

4. What other causes are needed, along with the postulated cause, for the effect to occur?

5. Could a completely different set of causes lead to the effect?

2.7.1 Five Whys Analysis

5 whys method is a method of helping to determine a causal relationship in a problem or event of failure. This method can be used in almost every problem

occurs in a system (Serrat, 2009). This method is one of the simplest investigative methods that can be easily solved without statistical analysis. Also known as Why tree, which is a simple form of root cause analysis, by repeatedly asking the question, "Why?" until the root cause is founded.

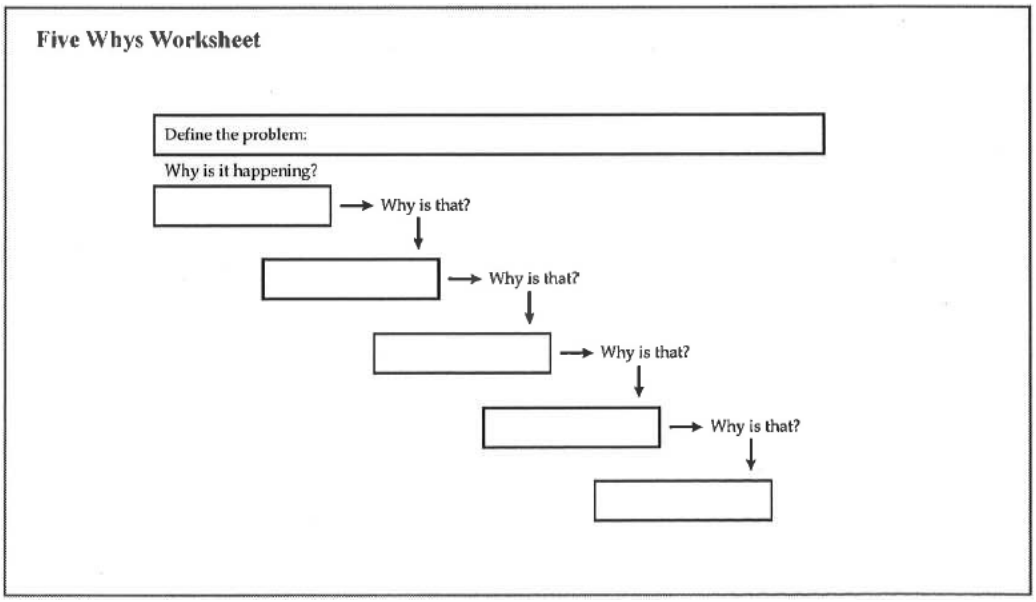


Figure 2.4. Five Whys Worksheet

(Source: The Five Whys Technique by Olivier Serrat)

Figure 2.4 shows how 5 whys method worksheet. The first step of this method starts with a statement that is why this happened. The next step is to change the answer of the first question into the why question for the second question. The next answer becomes the question why at the third level and so on. By increasing the question of why, it will increase the likelihood to finding the root causes that underlie the problem or failure.

In 5 whys analysis also implied a method to use why tree, this method called Fault Tree Analysis. This method is one of the best ways to start 5 whys so that causes can be seen. Why trees that were originally just simple problems can grow complex with a variety of cause and effect branches.

2.7.2 Pareto Analysis

Pareto analysis technique is an easy to use technique that helps to choose the most effective change to make. Pareto analysis is a formal technique for finding the changes that will give the biggest benefits (Vorley, 2008). It is useful where many possible courses of action are competing for an attention.

Pareto analysis is usually used when (Tague, 2005):

- When analyzing data about the frequency of problems or causes in a process

- When there are many problems or causes and you want to focus on the most significant

- When analyzing broad causes by looking at their specific components

- When communicating with others about your data

2.7.3 Event Tree Analysis

Event tree analysis is an analytical technique to identify and evaluate the sequence of events in a potential accident scenario. ETA uses a logic visual tree structure known as an event tree (ET). The purpose of ETA is to determine whether an event will develop into a serious accident or if the event can be controlled by the safety system and procedures applied in the system design. ETA can produce various possible outputs from an initial event, and can predict the likelihood of accidents occurring for each outcome.

2.7.4 Fault Tree Analysis

Fault tree analysis is a techniques that provide a systematic explanation of the combination of possible events in the system that cause damage. Basically, a fault tree is a logic diagram where logic gates are used to determine the relationship between events entered and events expended.

2.7.5 Failure Mode & Effect Analysis

Failure Mode and Effect Analysis (FMEA) is a systematic approach that applies a labeling method to help the engineers identify potential failure modes and their effects. FMEA is a technique of evaluating the reliability of a system to determine the effects of the failure of the system. Failures are classified according to the impact they have on the success of a system's mission.

2.7.6 Fishbone Diagram

The Fishbone Diagram (sometimes called the Ishikawa diagram) is used to identify all the factors that have an impact on such a problem. A fishbone diagram is a visual way to look at cause and effect. The process is called Fishbone Diagram because of the way in which the information gathered is arranged visually like the skeleton of a fish. Fishbone diagrams will identify various potential causes of an effect or problem, and analyze the problem through a brainstorming session. Problems will be separated into several related categories (QAPI, 2016), such as people, materials, machines, procedures, policies, and so on. Each category has causes that need to be elaborated through brainstorming sessions.

Below is a comparison table based on various analysis technique to perform root cause analysis:

Section (See "Quality Management - Tools & Techniques") 	**1. Define the Problem** *(Identify Improvement Area)*	**2. Understand the Problem** *(Evaluate Improvement Area)*	**2. Understand the Problem** *(Collect Data)*	**2. Understand the Problem** *(Data Analysis)*	**3. Immediate Action** *(Develop Action Plan)*	**4. Corrective Action** *(Implement Action Plan)*	**5. Confirm the Solution** *(Monitor Action Plan)*
Activity Sampling		•	•	•			
Brain Storming (NGT)	•	•			•		
Cause and Effect Dgrms		•			•	•	
Check Sheets			•			•	
Gemba Gembutsu - 5whys		•	•				
Histograms				•			
Pareto Analysis	•			•			•
Performance Measurem't	•	•				•	•
Process Mapping	•	•	•				
Quality Planning					•		•
Risk Assessment (FMEA)	•	•			•		
Root Cause Analysis	•	•	•	•	•	•	•

Table 2.2. Various Analysis Technique Comparison

(Source: Mini Guide to Root Cause Analysis by Geoff Vorley)

By the table 2.2, it can be concluded that root cause analysis can be done by combining some techniques. Nowadays many root cause analysis software offers powerful products and simple workflow to perform root cause analysis using various techniques. Then in this thesis a software will be used if it is necessarily required.

"This Page Intentionally Left Blank"

III. METHODOLOGY

3.1 Flow Chart

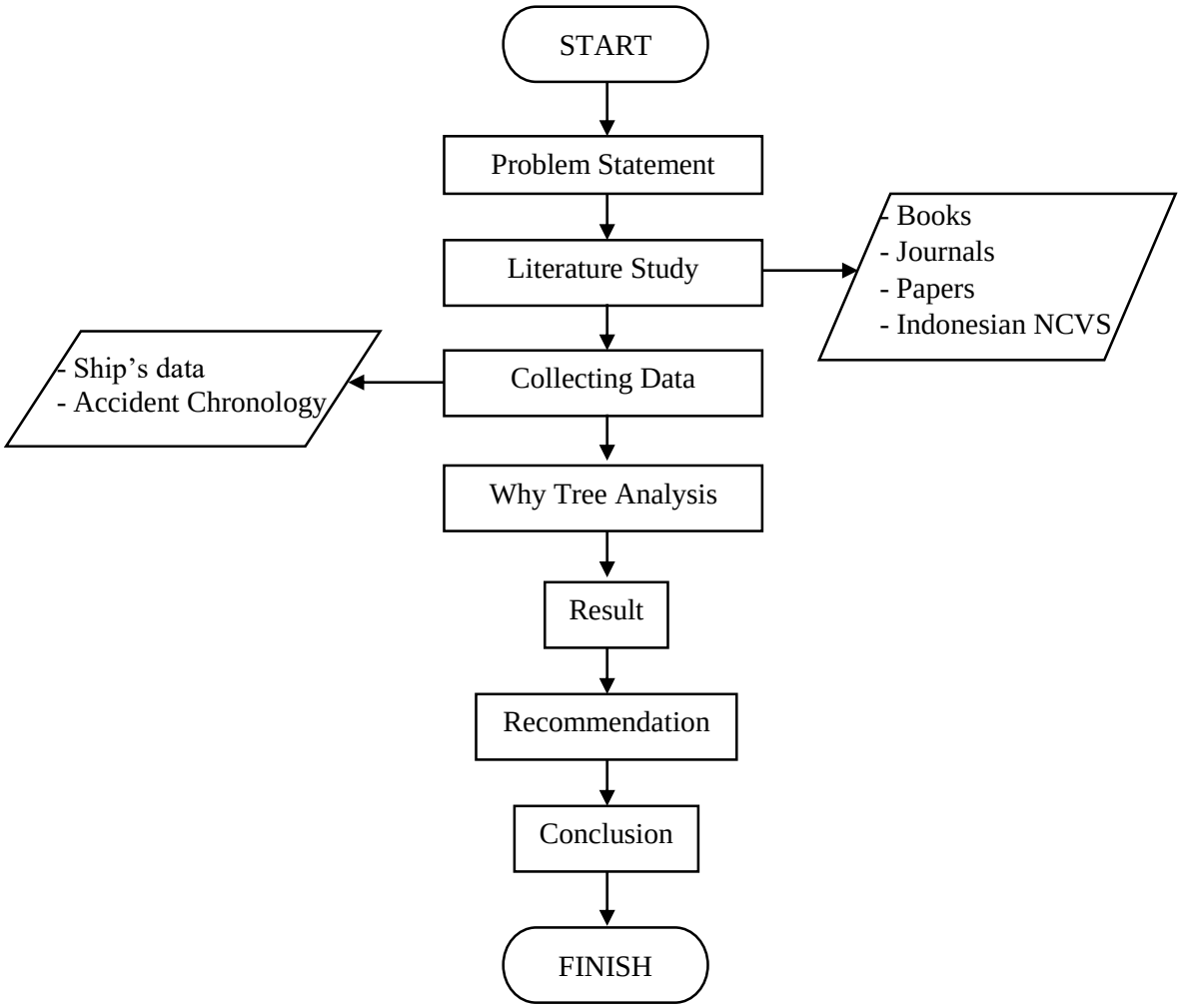


Figure 3.1. Flow Chart of Methodology

(Source: Private Documents)

3.1.1 Identification and State of Problem

Identification and state of problem are conducted to obtain the research question. The problem comes from the company's problem. At this stage, question and

problem are being prepared to determine specific objective of this thesis. By stating the problem, then the purpose of this thesis can be understood in this stage.

3.1.2 Study Literature

Literature review is done to obtain valid information as a standard and scientific base for this thesis.

3.1.3 Collecting Data

Collecting data is conducted after studying the literature. The data are being gathered from ship data accident chronology.

3.1.4 Processing Data

Data from the data collection then processed. The data will be analyzed by using 5 ways analysis to find out the root cause of the accident.

3.1.5 Result and Recommendation

When the data has been processed then it comes the result of the analysis. By the result, a recommendation can be provided to improve the system.

3.1.6 Conclusion

Writing conclusion and suggestion from the result of the thesis is carried out since the aim of this thesis is to get the root cause of the accident.

"This Page Intentionally Left Blank"

IV. DATA ANALYSIS

4.1. Data Identification

To conduct data analysis, the first step to do is identifying KM. Izhar ship's data and accident chronology to find out the evidence of the ship accident.

4.1.1 Ship Data

Figure 4.1. KM. Izhar

(Source: KNKT Documentation)

KM. Izhar as shown on figure 4.1 is a passenger and cargo ship. The ship was built in 2016 which its construction was made using wood. This ship was built in one of local shipyard in Kaleorang, Pulau, Salabangka, Central Sulawesi. The ship's registered in Kendari port authority as GT 89.NO.1419/LLO. The ship dimension as follow:

L	: 22.95 m
B	: 5.44 m
H	: 1.72 m
GT/NT	: 89/27

The ship is loaded by one main engine and two secondary engine. The main engine is a four-strokes Mitsubishi engine which has 8 cylinders with V configuration and 480 PK amount of power. Meanwhile, the secondary engine is a four-strokes Mitsubishi 4 cylinders inline engine. Every engine is connected with shaft and a gearbox and a propeller.

To maneuvering, the ship uses single rudder which is installed behind the main engine. Then the rudder is connected to steering wheel using rope.

KM. Izhar is equipped with navigation equipment such as GPS and compass. To communicate, the ship is equipped with VHF radio. Besides radio, the captain also uses phone cellular to communicate with the ship owner.

The ship is consist of three deck, those are lower deck, main deck, and upper deck. In lower deck, the deck is consist of three rooms. Those are cargo hold, engine room, and storage room. In the main deck, the rooms is consist of several rooms. Those rooms are navigation room, two crew cabins, passenger accommodation that can accommodate 76 passengers, praying room, toilet and kitchen. In the upper room, the space can be used as additional cargo holds and to put the life raft.

For safety equipment the ship is equipped with 68 life jackets that has been placed in passenger accommodation room and 2 life jackets in crew's cabin. For the life raft, the ship is equipped with 4 life rafts placed in the upper deck. For firefighting equipment, KM. Izhar is equipped with 5 units of chemical portable. Water from barrel in the toilet can also be used as another potential firefighting source.

4.1.2 Chronology

16 August 2019, Ship's agent proposed ship departing document to KSOP Kendari. On the document, the ship was scheduled to depart in 17 August 2019 at 04.00 WITA. In 21.00 WITA, the passenger started to come to KM. Izhar.

Cargo loading had been done at 21.30 WITA. The oilman started the main engine and one of secondary engine since another secondary engine has trouble with its gearbox. The oilman also started the generator set to produce electricity.

At 22.00 WITA, captain received the sailing approval by KSOP Kendari.

The ship then leaving the port at 22.30 WITA to sail to Salabangka. In navigation room there was the captain, 2 crews in upper deck, 1 crew in ship's bow, and an oilman and 1 crew in ship's stern. Oilman checked the engine room several times before the oilman go to ship's stern.

Around 23.00 WITA, one of the passenger found out that there was smoke came out from the engine room's door. Oilman who heard the passenger then immediately went to engine room and the smoke already gotten dark. From the oilman view, the fire source was in the secondary engine. The oilman with crew then pick up the water from the barrel which locate in the ship's stern then flush the water into engine room. The smoke that got thicker prevents the oilman and crew to enter the engine room. Passenger in accommodation room immediately run to ship's bow to avoid fire. The captain then turn off the engine and searching any safe place to ground the ship. But since the rudder became uncontrollable, the ship just float off. The fire got bigger, passenger started to jump to the sea. Life

raft was throw away from the ship to the sea to help the passenger. The captain directing the passengers to leave the ship since the fire cannot be extinguished. From total 7 crews and 80 passengers, 1 crew got heavy injuries, 1 passenger got minor injuries, and 13 passengers passed away.

4.2. Root Cause Analysis

After identifying the data, the next step is processing the data. The data will be analyzed to find out why the ship is caught on fire. The step to do in this analysis is as follows:

a. Define the Problem

b. Create Why Tree

c. Identify the Solution

4.2.1 Define the Problem

At this step, the problem is defined, creating team member, reference, and rules check. To define the problem, it is necessary to know what the problem is, when the problem occur, and where is the problem occur. For more detailed, significant can be filled and input the environment condition, revenue, cost, and the frequency. Defined problem for this research is shown in table 4.1.

What	KM. Izhar's Engine Room Fire Accident
When	23.30 WITA, 16 August 2019
Where	Konawe, South East Sulawesi
Significant	Fire Safety Issues

Table 4.1. Define the Problem

(Source: Private Document)

4.2.2 Create Why Tree

Create why tree is the second step after defining the problem. The tree making is consist of action and condition causes. Each causes should be provided with evidence. Cause effect chart is created by analyzing the data and do a brainstorming to add any cause possibility. The first step is creating causes based on fire triangle. Overheat in engine room as the potential heat, fuel spill in engine room as the potential energy, and oxygen presence in engine room since the ship was made by wood. After that, another factor also included to support another causes. In this case, the factor is how the crew handled the problem for the first time. The why tree can be seen at figure 4.2. Detailed tree can be seen at **Attachment 1** and **Attachment II**.

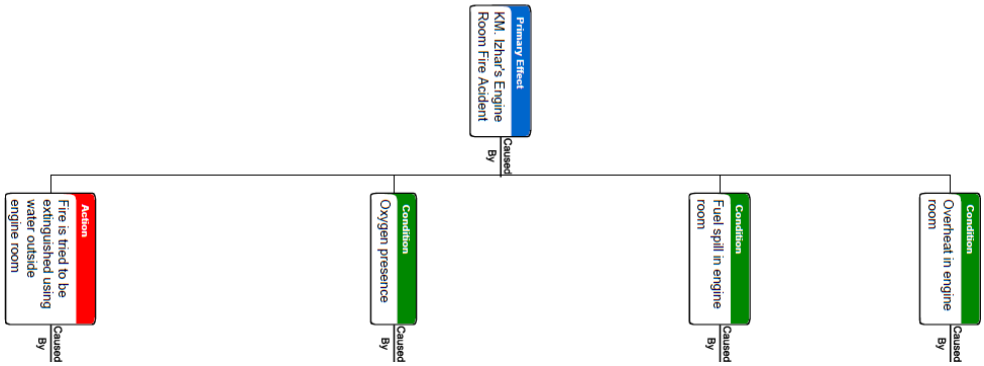


Figure 4.2. Create Why Tree

(Source: Private Document)

4.2.3 Identify Effective Solution

After analyzing the data, brainstorming and creating the data, next step is to identify the possible effective solution of each cause. To simplify the work, why tree will be translated into table form as shown in table 4.2.

No.	Effects	Causes	Evidences	Solutions
1	KM. Izhar's Engine Room Accident (1)	Overheat in engine room (1.1)	Fire start from engine room	-
		Fuel spill in engine room (1.2)	Fire start from engine room	-
		Oxygen presence (1.3)	Ship construction made from wood	-
		Crew late response (1.4)	Crew witnesses based on accident report	-
2.	Overheat in engine room (1.1)	Only secondary engine no. 2 is working to support main engine (1.1.1)	Crew witnesses based on accident report	Schedule routine check and maintenance task
		Inadequate ventilation (1.1.2)	Ship photo documentation	Provide better ventilation system to release heat
	Fuel spill in engine room (1.2)	Oilman wash the engine using fuel (1.2.1)	Crew witnesses based on accident report	Provide training to the crew
		Improper modification of marinized diesel engine (1.2.2)	Ship photo documentation	Use standard material for marine used

	Crew late response (1.4)	Oilman absences in engine room (1.4.1)	Crew witnesses based on accident report	Provide training to the crew
		Fire alarm absence in the ship (1.4.2)	Accident investigation report	Provide fire alarm as required in Indonesian NCVS
3.	Only secondary engine no. 2 is working to support main engine (1.1.1)	Secondary engine no. 1 gearbox trouble (1.1.1.1)	Crew witnesses based on accident report	Schedule routine check and maintenance task
		Inadequate preventive assessment of maintenance needs (1.1.1.2)	Accident investigation report	Schedule routine check and maintenance task
	Oilman wash the engine using fuel (1.2.1)	Unintended action (1.2.1.1)	Crew witnesses based on accident report	Provide training to the crew
		Inadequate work Planning (1.2.1.2)	Crew witnesses based on accident report	Provide training to the crew
	Improper modification of marinized diesel engine (1.2.2)	Risk assessment process is inadequate (1.2.2.1)	There is no supporting document	Provide research due to material used in the ship
		Inadequate material used (1.2.2.2)	Ship photo documentation	Use standard material for marine used
	Oilman absences in engine room (1.4.1)	Oilman had a conversation with another crew in ship stern (1.4.1.1)	Crew witnesses based on accident report	Provide training to the crew
		Oilman can't enter engine room to extinguished the fire source (1.4.1.2)	Crew witnesses based on accident report	-
		Lack of self-discipline (1.4.1.3)	Accident investigation report	Provide training to the crew
4.	Oilman had a conversation with another crew in ship stern (1.4.1.1)	Poor decision making (1.4.1.1.1)	Accident investigation report	Provide training to the crew
		Inadequate team culture (1.4.1.1.2)	Accident investigation report	Provide training to the crew
	Oilman can't enter engine room to extinguished the fire source (1.4.1.2)	Oilman can't reach the fire source using portable extinguisher (1.4.1.2.1)	Crew witnesses based on accident report	-

		There is only one door to access engine room (1.4.1.2.2)	Crew witnesses based on accident report	-
		Ship construction makes the fire quickly spread (1.4.1.2.3)	Ship construction made from wood	-
	Lack of self-discipline (1.4.1.3)	Human Behavior (1.4.1.3.1)	Crew witnesses based on accident report	Provide training to the crew
		Over-reliance on equipment (1.4.1.3.2)	Crew witnesses based on accident report	Provide training to the crew
5.	Poor decision making (1.4.1.1.1)	Inadequate initial training (1.4.1.1.1.1)	Accident investigation report	Provide training to the crew
		Inadequate update training (1.4.1.1.1.2)	Accident investigation report	Provide training to the crew
		Lack of perception of risk (1.4.1.1.1.3)	Accident investigation report	Provide training to the crew
	Oilman can't reach the fire source using portable extinguisher (1.4.1.2.1)	There is no firefighting outfit (1.4.1.2.1.1)	Accident investigation report	Provide firefighting outfit as required in Indonesian NCVS
		Absence of firefighting pump (1.4.1.2.1.2)	Accident investigation report	Provide firefighting pump as required in Indonesian NCVS
		Oilman doesn't wearing mask (1.4.1.2.1.3)	Crew witnesses based on accident report	Provide mask as required in Indonesian NCVS

Table 4.2. Cause Effect and Its Solution

(Source: Private Document)

4.3. Recommendation

According to Indonesian Non-Convention Vessel Standards (NCVS) Chapter III section 7 for firefighting equipment, KM. Izhar which has 89 GT and length of 22.95 meters should have (Indonesian Ministry of Transportation, 2009):

- Equipped with minimum 1 unit of fire pump and 1 unit emergency fire pump including fire hose and nozzle
- Portable fire extinguisher with minimum size of:

Extinguisher Characteristic	Water	Foam	Dry Powder	Wet Chemical
Min. Size/Rating	9 L / 3A	9 L / 3A	4.5 kg / 3A	7 L / 3A
	4.5 L / 2A	4.5 L / 2A	2 kg / 2A	7 L /2A

Table 4.3. Minimum Size of Portable Extinguisher

- Fire alarm in Crew's accommodation, passenger's accommodation, engine room, and cargo hold
- Escape Route
- Fire control Plan
- Firefighting Bucket with minimum capacity of 4 L
- Crew firefighting equipment which including:
    - Water resistance protective suits from non-conducting material to protect the crew from heat
    - A rigid helmet to protect against impact and an axe
    - Emergency flashlight/torch with minimum illumination of 3 hours
    - Breathing apparatus which is a smoke helmet/mask which should be provided with suitable air pump and a sufficient length of air hose to reach from the open deck or a self-contained compressed air operated breathing apparatus at least 1200 liters of volume or other self-contained breathing apparatus which should be capable of functioning at least 30 minutes.

In reality, KM izhar equipped with 5 portable fire extinguishers and a firefighting bucket. Each portable fire extinguisher has 4 kg of dry powder. 2 units are placed in engine room and the rest is placed in the ship's bridge. There's no information about fire control plan and escape route. The pump in engine room is used for water cooling systems and there's no emergency fire pump. The absence of fire detector and fire alarm also reduce the emergency response effectiveness. The captain was late to make decision and many passengers didn't wear life jacket.

From the investigation, can be found also the fact that KM Izhar were using marinized diesel engine. From KM. Izhar engine room photo documentation as show in figure 4.3., there are some parts that was modified such as piping and fuel tank. For piping, KM Izhar use PVC pipe and flexible rubber tube/hose. For its fuel tank, KM Izhar use plastic reservoir that usually used in households.

Figure 4.3. KM Izhar Engine Room

Based on NCVS Chapter II section 23.1 for non-portable fuel tanks, the construction is should be made of carbon steel, stainless steel, copper, marine-grade aluminum alloy or FRP. In 1990 American Boat and Yacht Council make standard for fuel tank corrosion resistance requirements as can be seen on table 4.4.

Material	Specification	Minimum Nominal Sheet Thickness	Gauge	Welding Processes
Nickel-Copper	ASTM-B127 Class A	.031 in. (.79 mm)	22 U.S. std.	Resistance Seam, Inert Gas Shielded Are, Oxy-acetylene
Copper-Nickel	ASTM-B122	.045 in. (1.14 mm)	17 AW.G.	Inert Gas Shielded Arc Oxy-acetylene Resistance
Copper	ASTM-B152 Type E.T.P.	.057 in. (1.45 mm)	15 AW.G.	Inert Gas Shielded Arc Carbon Arc Oxy-acetylene
Copper-Silicon	ASTM-B97 Types A,B, & G	.050 in. (1.27 mm)	16 AW.G.	Inert Gas Shielded Arc Carbon Arc Oxy-acetylene Metal-Arc
Steel Sheet	ASTM-A93	.0747 in. (1.90 mm)	14 Mfrs.	Metal-Arc Oxy-acetylene Aluminized ASTMA-463 .0478 in. (1.21 mm) Steel (5) 18 Mfrs. Inert Gas Shielded Arc Resistance

Aluminized Steel	ASTM A-463	.0478 in. (1.21 mm)	18 Mfrs.	Metal-Arc Oxy-acetylene Inert Gas Shielded Arc Resistance
Aluminum	Alloy 5052 or 5083 or 5086	.090 in. (2.29 mm)	----	Inert Gas Shielded Arc Resistance
Stainless Steel	316L	.031 in. (.79 mm)	22 U.S. std.	Metal-Arc Oxy-acetylene Inert Gas Shielded Arc Resistance

Table 4.4. Fuel Tank Corrosion Resistance Requirements

(American Boat and Yacht Council, 1990)

In section 35.23 of NCVS Chapter II, for fuel pipes system, the material that being used is made of black steel pipes or other equivalent material which is in accordance to recognized standards. PVC or plastic pipes are restricted to systems conveying water. Meanwhile for flexible hoses, only type-approved fire resistant hoses are permissible for fuel and oil transfer.

In further investigation, the fact that cooling system of the ship was also modified. Because the engine is marinized diesel, the origin of the cooling system was using fresh water. Then it is modified by adding seawater cooling system. The most highlighted problem is the fitting of the pipe. The pipe of seawater cooling is only fitted by using rubber from used inner tube/tire that wrapped around at the end of the pipe. This method of fitting can causing leak of seawater in the pipe connection. If seawater is leaking, then it can affecting another component such as corrosion. This cooling system modification also need to be assessed before it is used. Risk assessment should be perform to qualify the modified system. If the modified cooling system can't perform to cool the engine in any condition, then it can increase the possibility of engine overheating.

From 7 crews of KM Izhar, only ship captain that has a certificate of proficiency 60 mils. The rest of it doesn't have any certificate. This condition that causing the late response and late ship evacuation.

The fact that the rules has been issued but disobeyed, government with its related institutions should make decisive action to avoid such an incident repeated again. Government could give penalty to ship owner/company for not fulfilling Indonesian NCVS so a ship with no sea worthiness stop operating for a while till

the requirement is fulfilled or give subvention to ship owner/company to fulfill the regulations. Government also should give penalty to local authority since the local authority can exempt a ship from the application NCVS. To avoid this accident happened in the future hence the solutions that being proposed are:

- Provide training to the crew
- Provide better ventilation system to release heat
- Schedule routine check and maintenance task
- Use standard material for marine used
- Provide equipment as required in Indonesian NCVS
- Local Authority need to be assertive to give exempt of Indonesian NCVS

"This Page Intentionally Left Blank"

V. CONCLUSION

Conclusion

There are several conclusion according to analyzed data which is causing the fire accident on KM. Izhar based on KNKT accident report such as marinized diesel engine that doesn't have any historical maintenance, inadequate material used in engine room, uncertified crew, and disobey Indonesian NCVS rules especially on firefighting equipment. Those main factors contribute in causing another causes happened that made the scenario worse, which are:

- Ship Construction which mainly made from wood and the engine room that not watertight, made the fire quickly spread.
- Crew late response was caused by the absence of fire alarm in the ship. Besides that, uncertified crew make the evacuation not properly done.
- Oilman which responsible with the engine room disobey his job because he had a conversation with another crew in ship stern.
- Portable extinguisher and water bucket was the only available firefighting equipment onboard the ship. The absence of firefighting outfit, firefighting pump, and mask make the crew cannot reach the fire source using portable extinguisher.
- Only one out of two secondary engine was working to support main engine because of gearbox trouble. This condition made the engine to work extra. This condition made the temperature in the engine room hotter. Inadequate ventilation and unsupported material for marine used in the engine room also made the scenario worse. Then the fire started first at the secondary engine.

Suggestion

Based on the research, there are several suggestion that can be improved in PELRA ship performance to prevent such an accident happened again, those are:

- Provide training to the crew so the crew has good work attitude, good self-discipline, know their job, and can make quite quick good decision.
- Provide better ventilation systems so it can maintain heat in the engine room, especially for the sister ship.
- Provide schedule routine check and maintenance task to prevent equipment failure when it is on duty.
- Provide research due to material used on the ship so it can fulfill the material standard for marine used.
- Provide equipment as required in Indonesian NCVS.
- For the local authority, they need to decide assertive decision to give their exempt for the application of Indonesian NCVS.

“This Page Intentionally Blank”

REFERENCES

American Boat and Yacht Council. (1990). ABYC H-33: Diesel Fuel Systems. Washington, D.C.: American Boat and Yacht Council Inc.

Benintendi, R. (2018). *Process Safety Calculations.* Elsevier Ltd.

BKI. (1996). *Buku Peraturan Klasifikasi dan Konstruksi Kapal Laut, Peraturan Kapal Kayu.* Jakarta: BKI.

BPS. (2016). *Luas Daerah dan Jumlah Pulau Menurut Provinsi.* BPS.

Casal, J. (2018). *Evaluation of the Effects and Consequences of Major Accidents in Industrial Plants.* Elsevier B. V.

Indonesian Ministry of Transportation. (2009). NCVS Indonesian Flagged. Jakarta: Indonesian Ministry of Transportation.

Jinca, M. Y. (2016). Pelra, Anak Tiri Angkutan Pelayaran Indonesia. *Indikator*.

Karana, S. (2003). Armada Pelayaran Rakyat Sebagai Sarana. *e-Journal BPPT.*

Nolan, D. (2011). *Handbook of Fire and Explosion Protection Engineering Principles.* Oxford: Gulf Professional Publishing.

QAPI. (2016). *How to Use the Fishbone Tool for Root Cause Analysis.* CMS.

Serrat, O. (2009). *The Five Whys Technique.* Manila: Knowledge Solution.

Sutton, I. (2010). *Process Risk and Reliability Management. Operational Integrity Management.* Oxford: Elsevier Ltd.

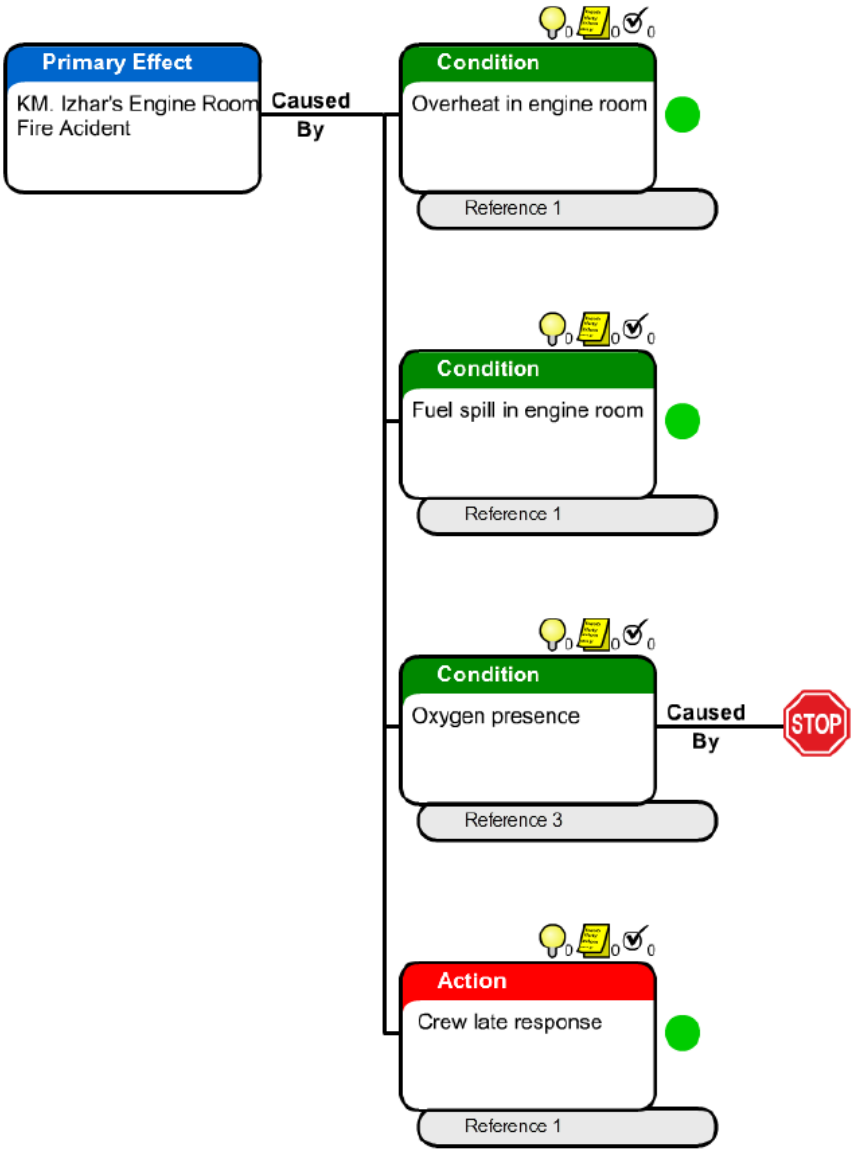
Tague, N. R. (2005). *The Quality Toolbox.* ASQ Quality Press.

Vorley, G. (2008). *Mini Guide to Root Cause Analysis.* Quality Management & Training Ltd.

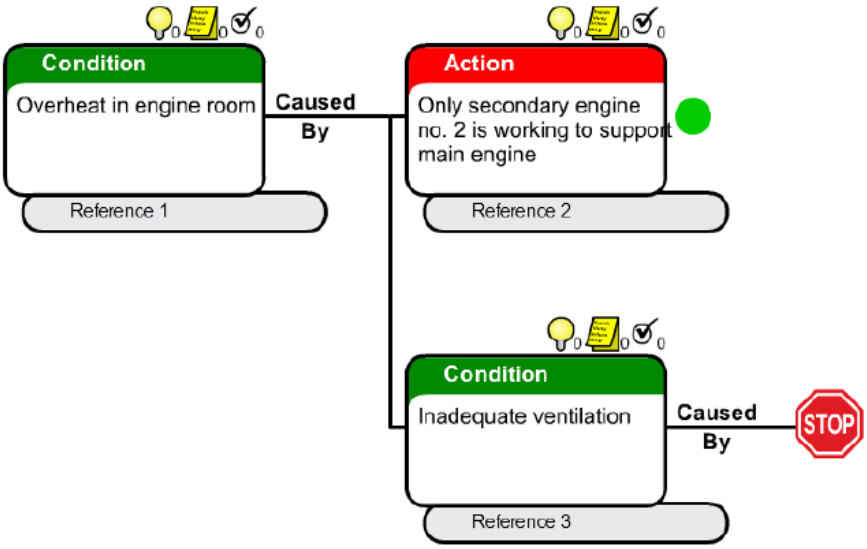
Wijaya, K. (2016). Pelra, Anak Tiri Angkutan Pelayaran Indonesia. *Indikator*.

“This Page Intentionally Blank”

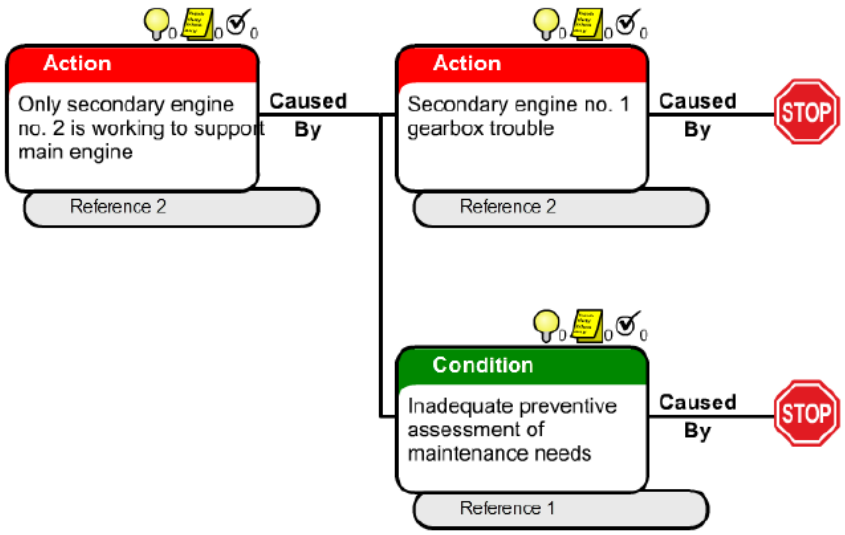
ATTACHMENTS I



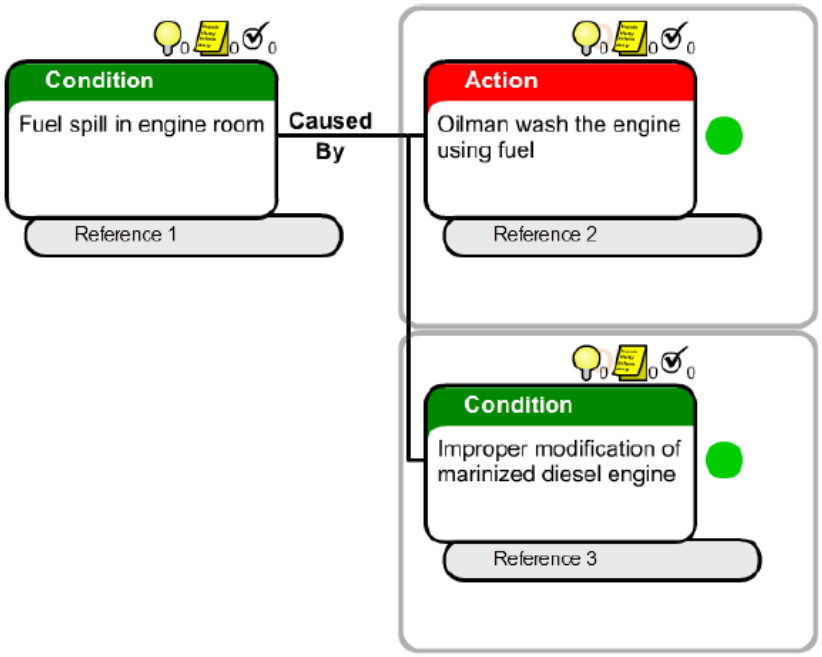
1. First Stage Why-Tree



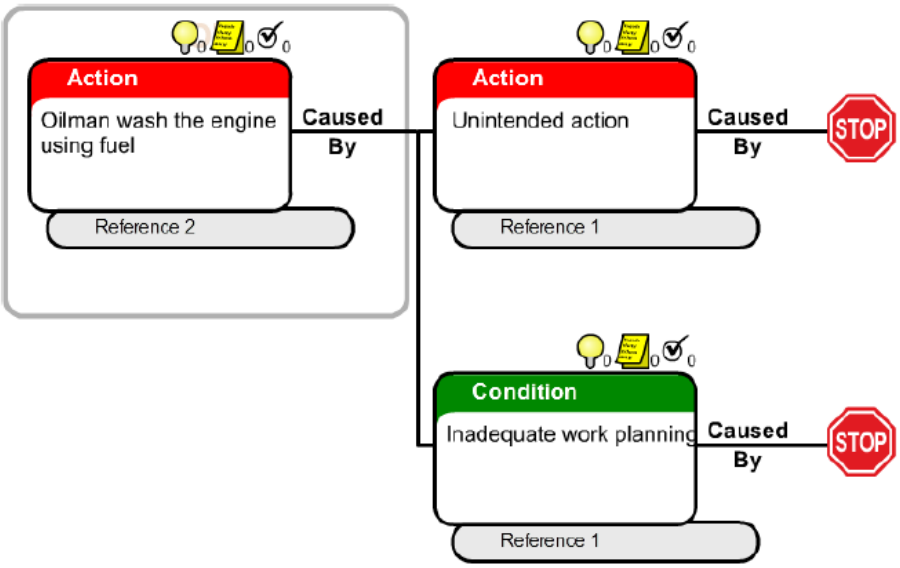
1.1 Second Stage Why-Tree



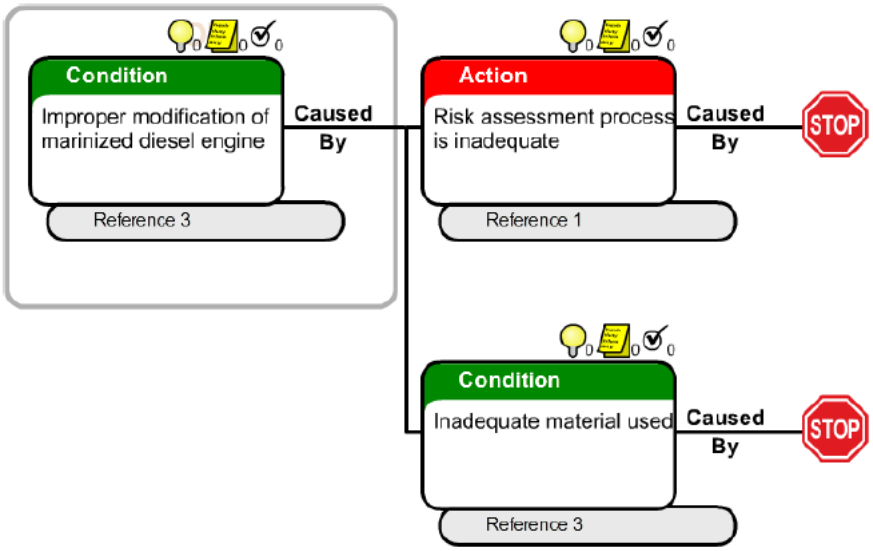
1.1.1 Third Stage Why-Tree



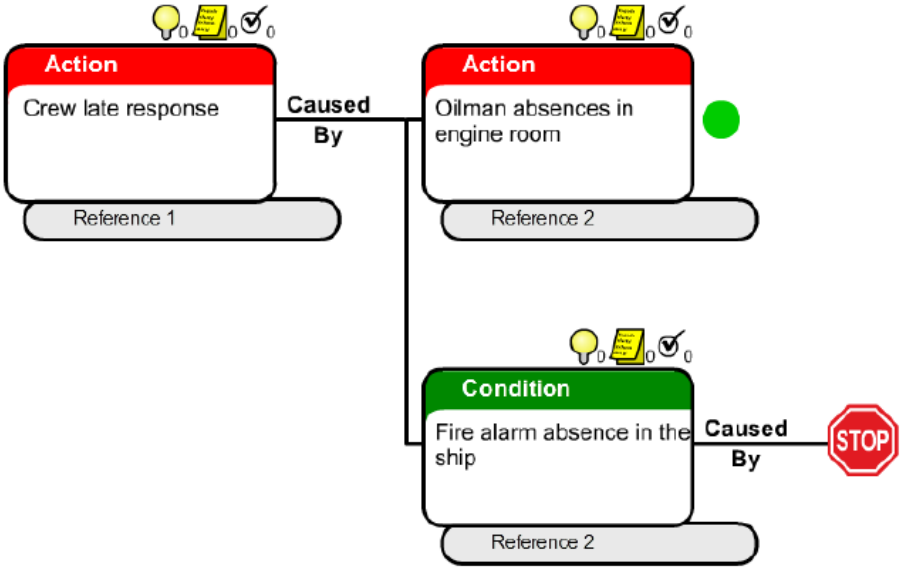
1.2 Second Stage Why-Tree



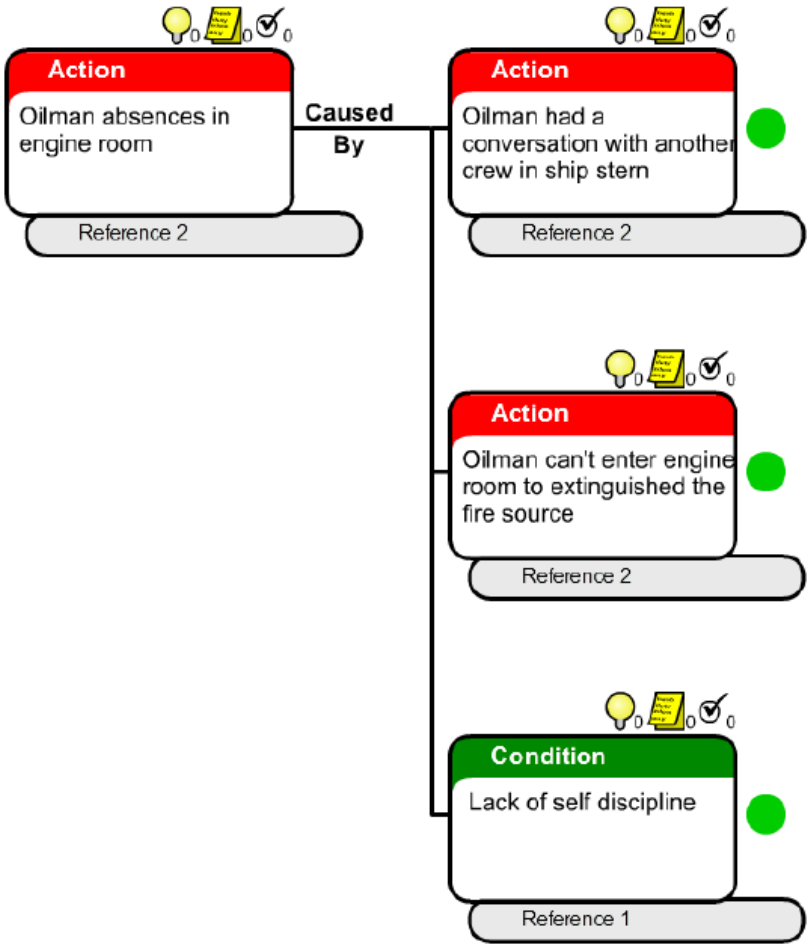
1.2.1 Third Stage Why-Tree



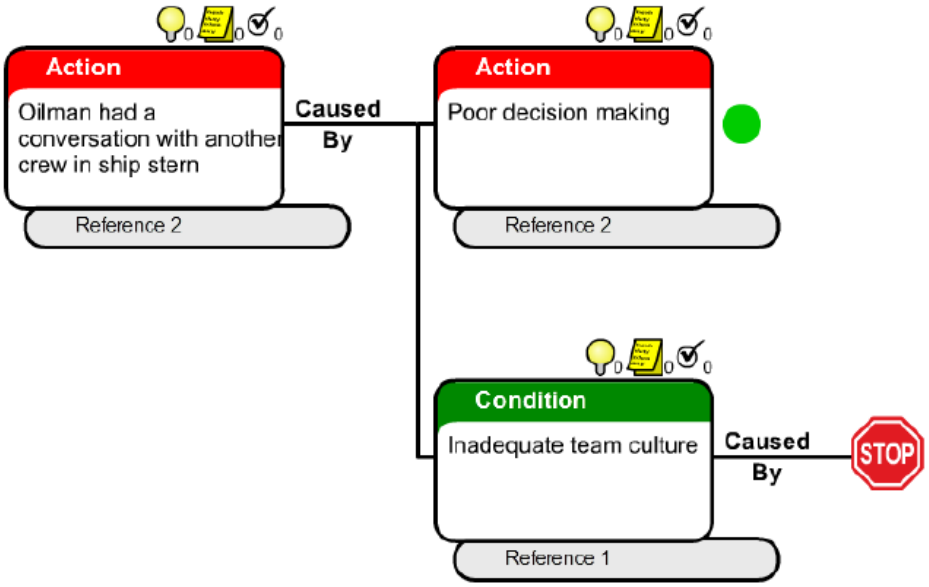
1.2.2 Third Stage Why-Tree



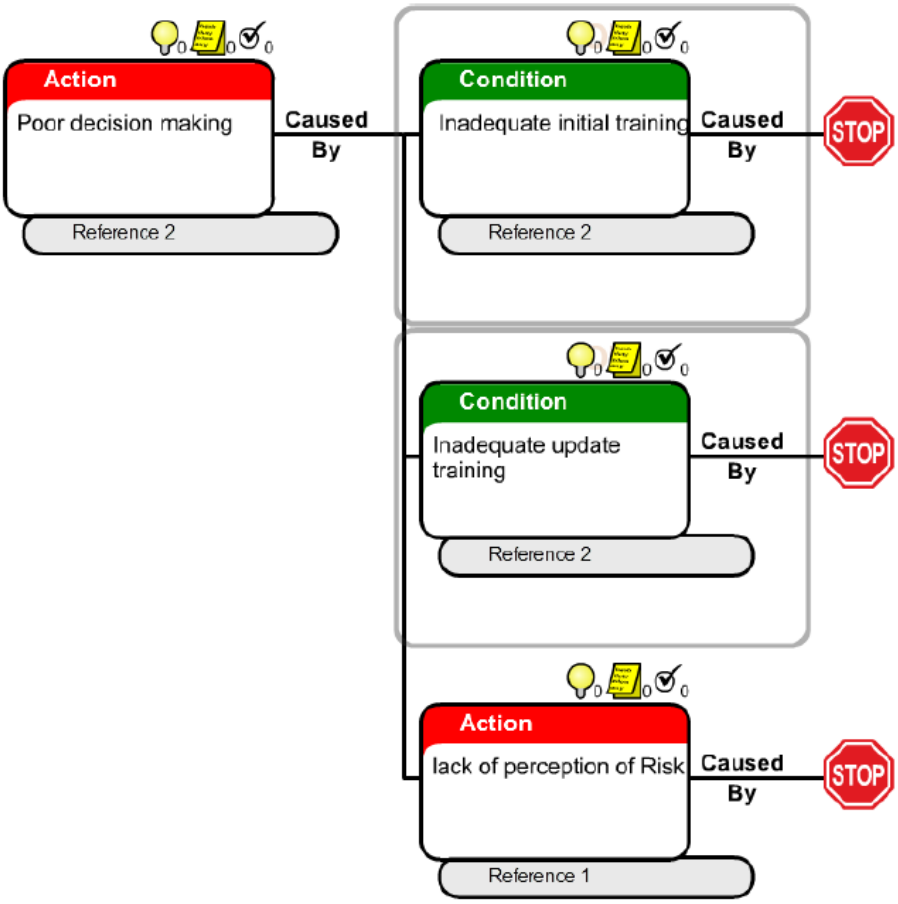
1.4 Second Stage Why-Tree



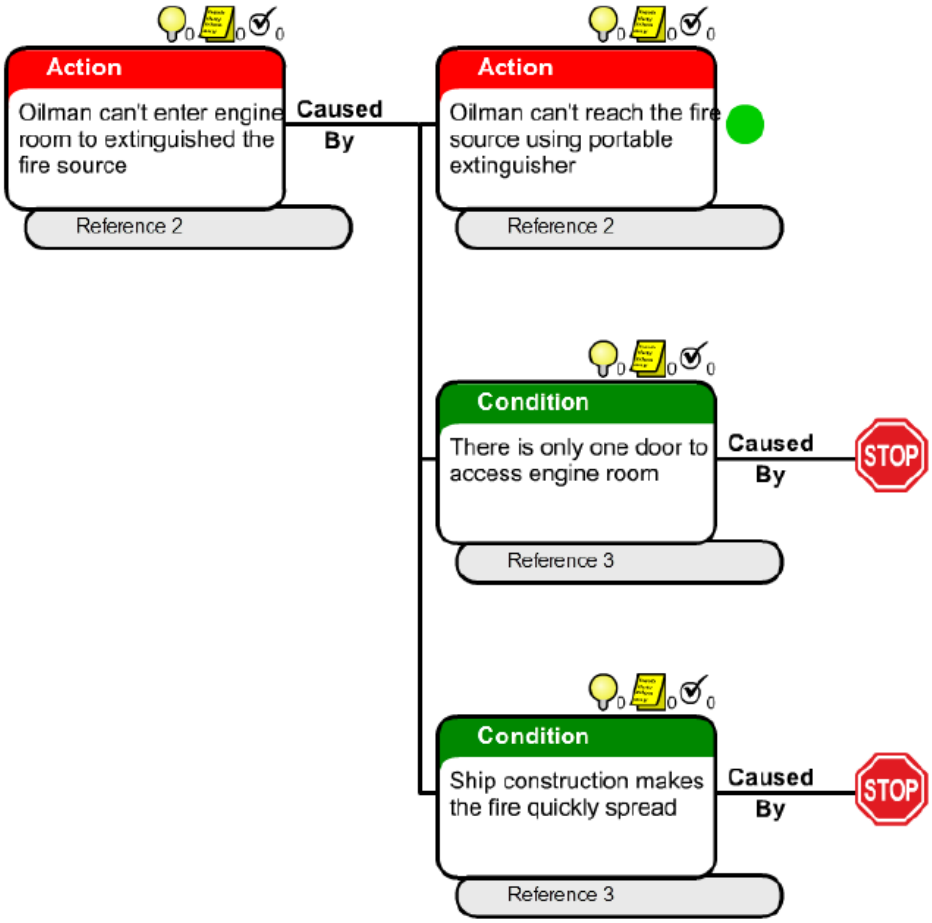
1.4.1 Third Stage Why-Tree



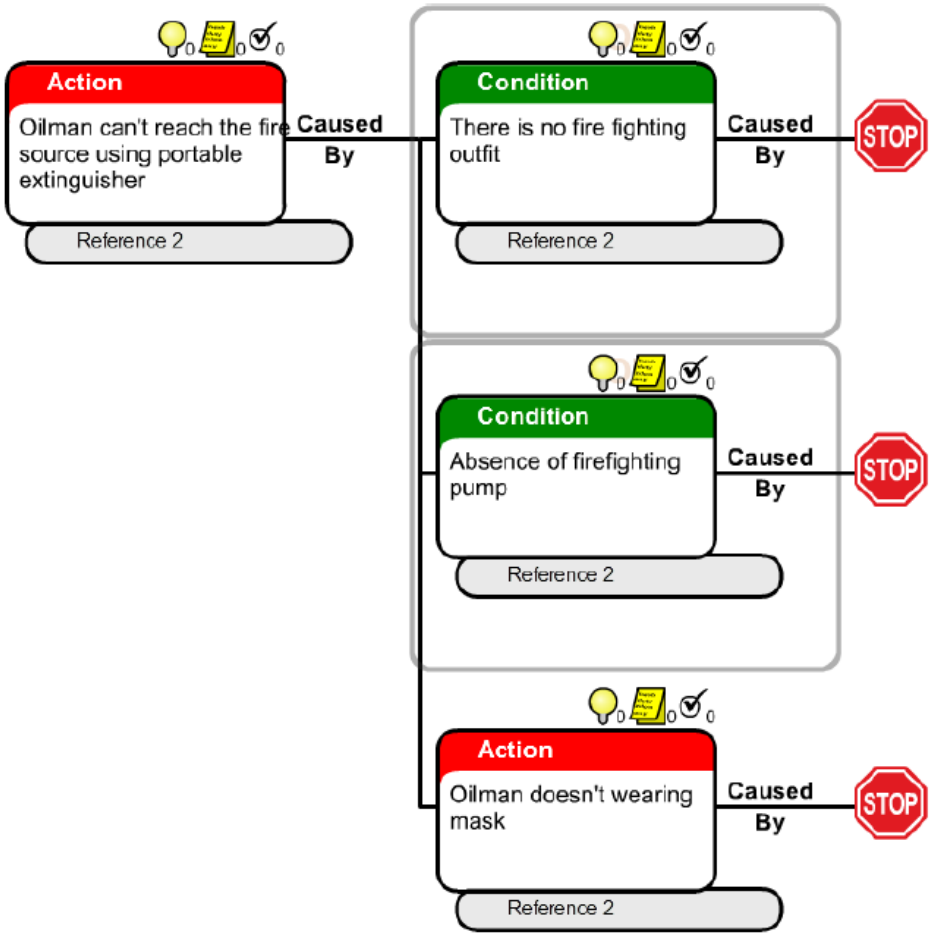
1.4.1.1 Fourth Stage Why-Tree



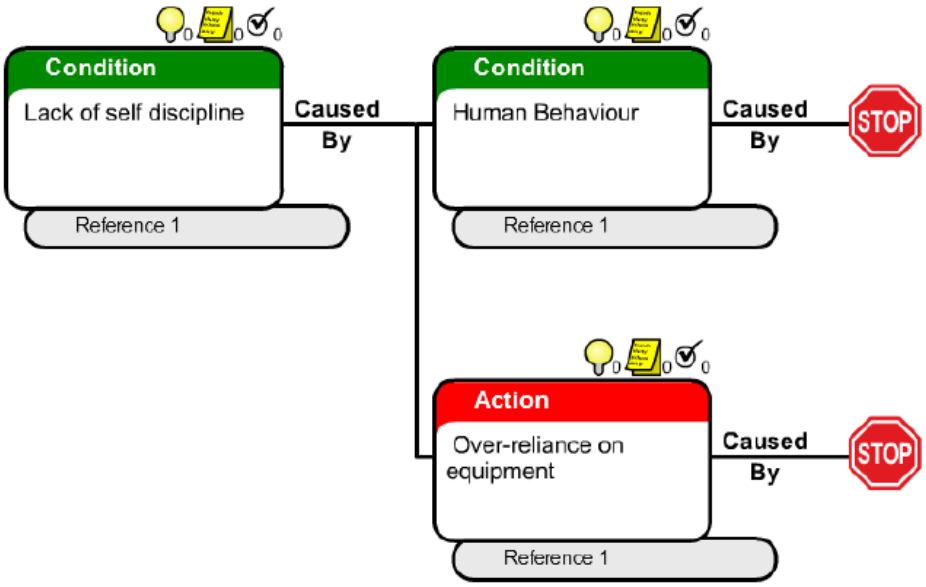
1.4.1.1.1 Fifth Stage Why-Tree



1.4.1.2 Fourth Stage Why-Tree



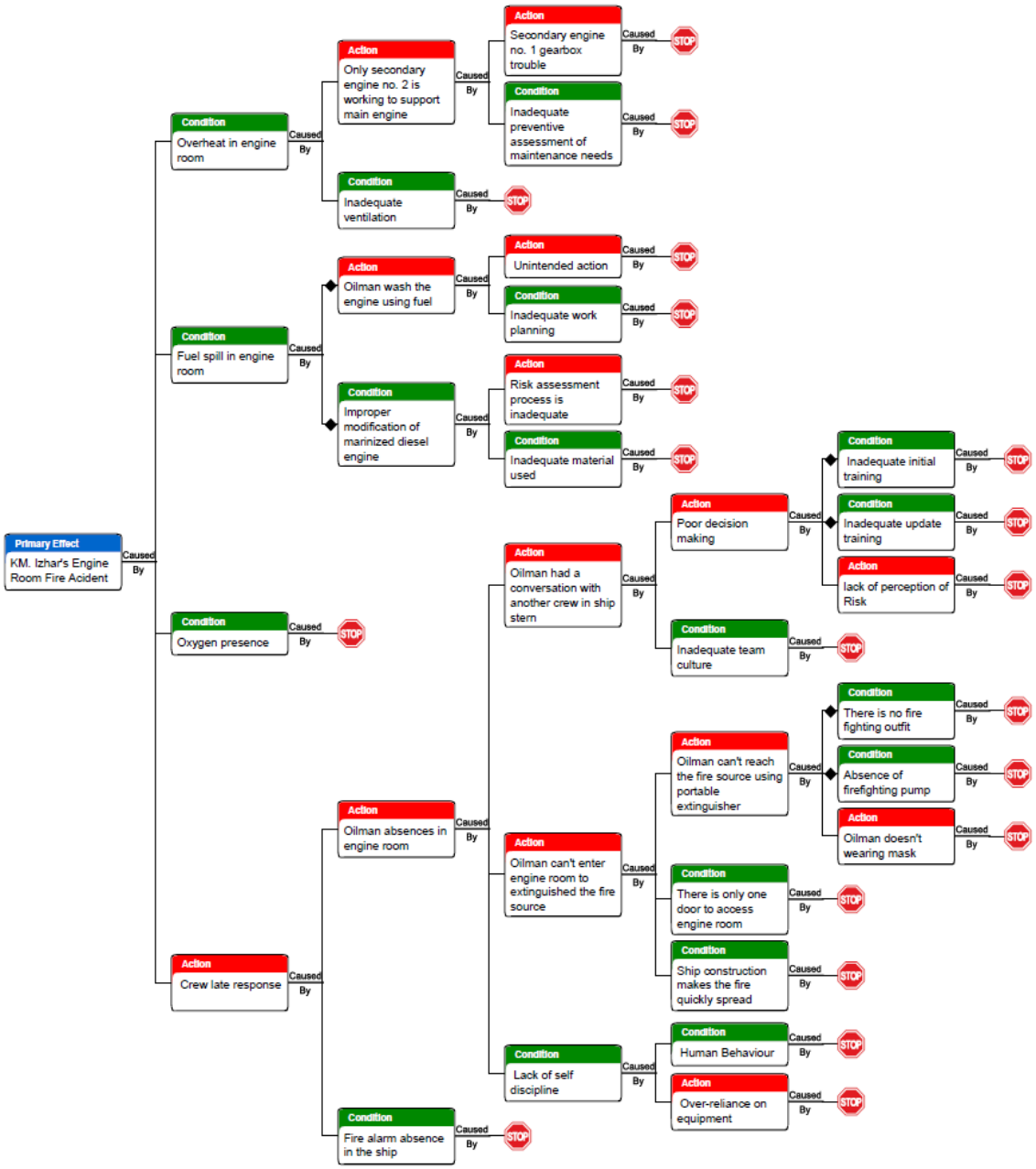
1.4.1.2.1 Fifth Stage Why-Tree



1.4.1.3 Fourth Stage Why-Tree

“This Page Intentionally Blank”

ATTACHMENTS II


Primary Effect
KM. Izhar's Engine Room Fire Acident
Caused By
Condition
Overheat in engine room
Action
Only secondary engine no. 2 is working to support main engine
Action
Secondary engine no. 1 gearbox trouble
Condition
Inadequate preventive assessment of maintenance needs
Condition
Inadequate ventilation
Condition
Fuel spill in engine room
Action
Oilman wash the engine using fuel
Action
Unintended action
Condition
Inadequate work planning
Condition
Improper modification of marinized diesel engine
Action
Risk assessment process is inadequate
Condition
Inadequate material used
Condition
Oxygen presence
Action
Crew late response
Action
Oilman absences in engine room
Condition
Fire alarm absence in the ship
Action
Oilman had a conversation with another crew in ship stern
Action
Oilman can't enter engine room to extinguished the fire source
Condition
Lack of self discipline
Action
Poor decision making
Condition
Inadequate team culture
Condition
Inadequate initial training
Condition
Inadequate update training
Action
lack of perception of Risk
Action
Oilman can't reach the fire source using portable extinguisher
Condition
There is only one door to access engine room
Condition
Ship construction makes the fire quickly spread
Condition
Human Behaviour
Action
Over-reliance on equipment
Condition
There is no fire fighting outfit
Condition
Absence of firefighting pump
Action
Oilman doesn't wearing mask
STOP

“This Page Intentionally Blank”

AUTHOR BIOGRAPHY

The Author's name is Regian Ganang Alfarizi, born on 14 February 1997 in Sumbawa Besar, West Nusa Tenggara. However, fortunate to have a formal education at SDN Borobudur 1, author continued his study at SMPN 1 Salaman, and SMAN 1 Magelang. In 2015, author proceed to pursue bachelor degree at Department of Marine Engineering (Double Degree Program with Hochschule Wismar), Faculty of Marine Engineering, Institut Teknologi Sepuluh Nopember Surabaya specializes in Marine Operation and Maintenance. Author accepted as student in Institut Teknologi Sepuluh Nopember through SNMPTN. During the study period, Author did activities in campus organizations such as: PSM ITS (2015), Marine Icon (2016-2018), Students Organization of Marine Engineering as a head of musics and arts division (2018-2019) and MOM Laboratory member (2018-2020).