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PILOT STUDY FOR QUANTIFICATION OF EMISSIONS OF GREEN HOUSE GAS FOR DECISION SUPPORT TOWARDS INTERNATIONAL MARITIME ORGANIZATION IMO RULE MAKING

Strictly as per the compliance and regulations of :

Pilot Study for Quantification of Emissions of Green House Gas for Decision Support towards International Maritime Organization (IMO) Rule Making

O. O. Sulaiman[α], N. I. Akmar[σ], B. Michel[ρ], N. Stark[Ѡ], H. Azman[¥] & A.S.A.Kader[§]

Abstract - The shipping industry is responsible for the carriage of 90% of world trade. Thus, it remains the most energy efficient mode of transport. Shipping is expected to have greater impact on global warming considering size of vessel plying the world ocean. The Green House Gas (GHG) emissions are the main air pollutants in maritime transportation. In 2007, CO_2 emission from the shipping amounted to 847 million tones or about 2.7% of global CO_2 emission and it is expected to reach 18% in 2050. In July 2009, Marine Environment Protection Committee (MEPC) approved to circulate interim guidelines on the method of calculation of Energy Efficiency Design Index (EEDI) to create stronger incentives for further improvements in ship's fuel consumption, resulting CO_2 emissions on a capacity basis. This paper present outcome of GHG emission data collection and quantification from ship, the study hope to contribute to regulation for reduction of GHG emission in shipping industry and subsequent mitigation of climate change. Equipment used to measure the concentration of gas and total suspended particulate in the atmosphere are Mini Vol Portable Air Sampler, Graywolf Direct Sense Monitoring Kit, TSI IAQ-Calc and Gas Detector IQ-1000. The equipment's are used to determine the gas concentration, nitrogen dioxide (NO_2), sulphur dioxide (SO_2) and carbon dioxide (CO_2) concentration respectively. Carbon dioxide (CO_2) is the most important anthropogenic GHG. The experimental data analysis is used to validate recommended EEDI calculation.

Keywords : emissions, international maritime organization (IMO), green house gas (GHG), vessel, bidong island, GHG, emission, ship, IMO, EEDI, climate change.

I. Introduction

Air pollution is the on demand case as it has been debated all over the world. The sources of air pollution vary, starting from the individual pollutants to the huge industry activities. Maritime industry is responsible for part of Green House Gas Emision pollution, since there are many types of maritime transports sailing and maneuvering at the sea. The Green House Gas (GHG) emissions from maritime transport must be reduced because it is expected to increase if no mitigations are taken. This paper discusses the result of exhaust emission quantification for University Malaysia of Terengganu (UMT) vessel (Discovery II). The experiment analysis two types of gas, Carbon Dioxide (CO_2) and Nitrogen Dioxide (NO_2).The is a pilot study in preparation for data collection on larger ships. The pilot study involves sailing from Pengkalan Arang Jetty to Bidong Island and it is divided into two modes, maneuvering mode and hoteling mode.

The international shipping is considered the most carbon efficient mode of commercial transport and generally considered as an environmentally friendly means of transportation. This help shipping economy of large scale, as a result of this, maritime and shipping industry experience rapid development and the number of vessels sailing in the ocean continues to increase. However, the significant improvements that have taken place in these industries lead to the increasing of Green House Gas (GHG) considering the large involve of vessel that sail the world ocean. The use of hydrocarbons and their derivatives as fuel contributes to air pollution. The amount of emissions depends on the design, operating conditions and the characteristics of the fuel. Complete combustion of fuel leads to the exhaust that contains only Carbon Dioxide (CO_2) and water vapor. Carbon Dioxide (CO_2) emission depends on fuel consumption and carbon content in the fuel.

Some factors that influencing emission are cold starts, speed, maintenance, engine design and fuel used [1]. The most troublesome GHG emission from diesel engine is NOx and soot (particulates). The black smoke observed from certain ships or boats are due to high carbon particles content and it is obvious during rapid load increase and when older engine at high load. As a response towards the GHG emissions problem, another dimension has been added to the ship's design and operational practices. The improvement in design includes the propeller, hull, superstructure and use of retrofitting system for machineries (exhaust gas after

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filter, humidification, exhaust gas recirculation, electronics injection and lubrication. For the operational practices, the maintenance of the ships are to ensure that ship follow the schedule and guidelines and also by slowing the speed of the ship during at sea as well as cold ironing. Other option being adopted is alternative energy and hybrid concept.

This study focuses on the emissions concentration of Carbon Dioxide (CO_2) and Nitrogen Dioxide (NO_2) that are released from the exhaust of Discovery II. The emissions concentrations are measured by using the Gas Detector IQ-1000. The RV Discover II started sailing to Bidong Island at initial speed 6 knots and continue at speed 12 knots during at sea. The distance of Bidong Island from Kuala Terengganu is 40km. Table 1 show the principal particulars of the Discovery II that has been operated in 12 years.

Table 1 : The principal particulars of Discovery II

Length overall	16m
Breadth	4.05m
Depth	2.15m
Fuel	4000L
Fresh water	1000L
Main engine	300HP/1800RPM
Speed (design)	12 knots
Cruise speed	10knots
Gross tonnage	43T
Net tonnage	16.82T

The experiment is divided into two which are maneuvering mode and hoteling mode. The hoteling mode data is recorded near Bidong Island so that the data is not influence by the land activities.

II. Background

The quests for an efficient fuel friendly to the environment have been recognized in maritime industry for a long time. Need for improvements of gasoline and diesel by chemical reformulation that can lead to decrease in GHG release and ozone forming pollutants and carbon monoxide emissions have become issues of the time. Beside this, machineries that cannot use such conditional and additional inconvenience posed by these reformulation chemicals are subject to performance problems like cold start ability, smooth operation and avoidance of vapor lock.

Emission from combustion impacts generation of fossil fuel scarcity, photochemical smog, and oil dependent world. Aggressive quest for alternative energy, international and local regulation build-up as well as reassessment and revolution work on plan to reduce emission of existing and new engine are faced with new challenge of matching energy efficiency at minimum emission. Pollution control of emission is linked to traditional factors of reliability, fuel economy per shaft power, capital cost and maintenance. Maximizing overall energy efficiency that includes performance of temperature, electrical, thermodynamic and mechanical as well insulated boiler system to achieve combustion efficiency close to 100% and thermal efficiency of the order of 90% has a ways been the drive of the time for new low pollution and high efficiency technology. Technology try to recuperate or prevent heat loss by high temperature exhaust gas and in coolant systems reduces the thermal efficiency [6].

For marine electrical energy, technology is after 70 percent of the primary energy that is lost in the power generation & transmission stage, while thermal efficiency improvement sough insulation, recycling of gaseous effluents, rate of heat transfer in combustion chamber and liquid coolants. Designer of combustion chamber aim to achieve high combustion efficiency as unburnt fuel is considered to be pollutants, this create new directions for new engine and retrofit system for existing engines. The issue of emission compliance is a disguise blessing of doubles incentive opportunity for humanity to develop complete combustion efficiency and reduces emission. A good combustion require high temperature, a resident time sufficient long, present of oxidizer heat transfer from flame to solid surface that compose of conduction, convection and radiation luminosity and present of solid particles that can lead to significance change in ratio of radioactive to convective heat transfer.

Problem associated with achieving maximum efficiency are linked to pollution control, complete oxidation and burning of fuel, combustion efficiency and pollution prevention. However, oxide of nitrogen presents major problems due to contradictory requirement of pollutant formation and combustion efficiency, because, formation of oxides of nitrogen has affinity to high temperature. Compare to formation sulfur, control require removal of sulphur before burning or extraction from effluent before send it for combustion task.

III. Global Warming and its Impact

Global warming is the unusually rapid increase in Earth's average surface temperature over the past century primarily, due to the greenhouse gases released of exhaust waste from burning fossil fuels. The current climatic warming is occurring much more rapidly than past warming events. In Earth's history before the Industrial Revolution, Earth's climate changed due to natural cause unrelated to human activity. These natural causes are still in play today, but their influence is too small or they occur too slowly to explain the rapid warming seen in recent decades. Models predict that as the world consumes more fossil fuel, greenhouse gas concentrations will continue to rise and Earth's average surface temperature will rise with them. Based on plausible emission scenarios, average surface temperatures could raise between 2°C and 6°C by the end of the 21st century. Some of this warming will occur even if the future of greenhouse gas emissions are reduced, because the Earth system has not yet fully adjusted to environmental changes that is currently being experienced.

The "greenhouse effect" is the warming that happens when certain gases in Earth's atmosphere trap heat. These gases let in light but keep heat from escaping, like the glass walls of a greenhouse. The sunlight shines onto the Earth's surface, where it is absorbed and then radiates back into the atmosphere as heat. In the atmosphere, "greenhouse" gases trap some of this heat, and the rest escapes into space. The more greenhouse gases are in the atmosphere, the more heat gets trapped. Levels of greenhouse gases (GHGs) have gone up and down over the Earth's history, but they have been fairly constant for the past few thousand years. Global average temperatures have stayed fairly constant over that time as well, until recently. Through the burning of fossil fuels and other GHG emissions, humans are enhancing the greenhouse effect and warming Earth.

Some impacts from increasing temperatures that already happened are ice is melting worldwide, especially at the Earth's poles. Besides, the number of penguins on Antarctica has fallen from 32,000 breeding pairs to 11,000 in 30 years. Sea level also rises faster over the last century. Some butterflies, foxes, and alpine plants have moved farther north or to higher, cooler areas. Precipitation (rain and snowfall) has increased across the globe, on average. Spruce bark beetles have boomed in Alaska thanks to 20 years of warm summers. The insects have chewed up 4 million acres of spruce trees.

The ozone layer is a belt of naturally occurring ozone gas that sits 9.3 to 18.6 miles (15 to 30 kilometers) above Earth and serves as a shield from the harmful ultraviolet radiation emitted by the sun. Ozone is a highly reactive molecule that contains three oxygen atoms. It is constantly being formed and broken down in the high atmosphere, 6.2 to 31 miles (10 to 50 kilometers) above Earth, in the region called the stratosphere [7].

The carbon trading came about in response to the Kyoto Protocol. Signed in Kyoto, Japan, by some 180 countries in December 1997, the Kyoto Protocol calls for 38 industrialized countries to reduce their greenhouse gas emissions between the years 2008 to 2012 to levels that are 5.2% lower than those of 1990. A carbon trading system allows the development of a market through which carbon (carbon dioxide) or carbon equivalents can be traded between participants, whether countries or companies. Each carbon credit is equal to one hundred metric tons of carbon dioxide, which can be traded or exchanged in market. There are two kinds of carbon trading which are emission trading and trading in Project-based credits. The two categories are put together as hybrid trading system. Carbon trading is also called pollution trading [8].

The exhaust fumes contain a large number of different chemicals or emissions. Once released into the air, exhaust Emissions are breathed in and transported in the bloodstream to all the body's major organs. Diesel seems potentially to be more of a problem than petrol. Potentially dangerous vehicle emissions include carbon monoxide, nitrogen dioxide, sulphur dioxide and particulate matter. Although research has clearly linked exhaust emissions to a range of health problems in the population, the exact risk to any individual is difficult to define. The most obvious health impact is on the respiratory system. It's estimated that air pollution of which emissions are the major contributor is responsible for 24,000 premature deaths in the UK every year. A Dutch study confirm that, of 632 children aged seven to 11 years found that respiratory disorders worsened as air pollution increased and a longer term study of older Dutch residents, published in 2009 found that illness due to lung disorders increased in areas of high nitrogen dioxide and particulate matter associated with exhaust emissions. Some of the impacts to health due to the emissions are cancer, central nervous system may grow older and blood implication.

a) Green House Gas (GHG) emission from shipping

If global shipping were a country, it would be the sixth largest producer of greenhouse gas emissions. Only the United States, China, Russia, India and Japan emit more carbon dioxide than the world's shipping fleet. Nevertheless, carbon dioxide emissions from ocean-going vessels are currently unregulated. These measures can have an almost immediate effect on emission reductions, and a reduction of 33 percent below the business-as-usual baseline could be attained at no cost. Previous attempts by the industry to calculate levels of carbon emissions were largely based on the quantity of low grade fuel bought by shipowners. The latest UN figures are considered more accurate because they are based on the known engine size of the world's ships, as well as the time they spend at sea and the amount of low grade fuel sold to shipowners. The UN report also reveals that other pollutants from shipping are rising even faster than CO_2 emissions. A spokesman for the Department for Environment, Food and Rural Affairs said the government would support the development of a global emissions trading scheme through the IMO, and was also "investigating the feasibility of including maritime emissions" in the EU's trading scheme. He said the shipping industry must take its "share of responsibility" for tackling climate change.

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b) Imo and GHG Emission

According to the Second IMO GHG Study 2009, the level of GHG emitted by international shipping was estimated to have 870 million tones or about 2.7% of the global man made emission of COx in 2007. Exhaust gases are the main source of GHG emissions from ships and COx is the most important GHG that contribute to global warming. The COx emission is expected to increase to 6% in 2020. If no mitigation measures are taken, it can increase to 250% in 2050. Figure 1 showed the exhaust emissions from shipping industry between 1997 and 2007.

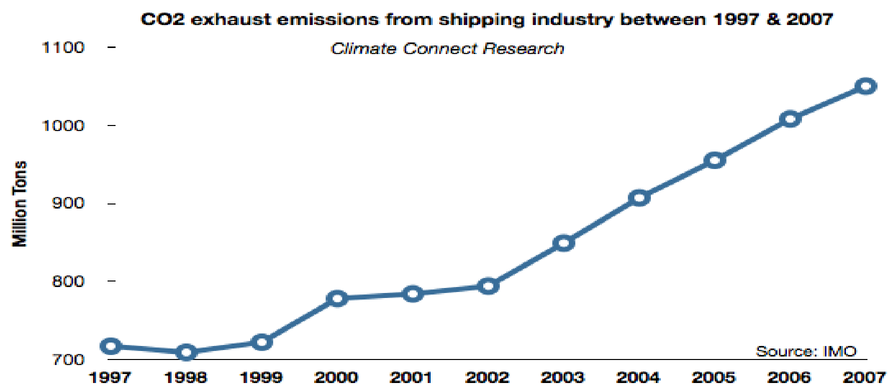

Figure 2 : CO2 exhaust emissions from shipping industry between 1997 and 2007

Figure 2 revealed one of the reason, regulatory institution for stepping up the On July 2011, International Maritime Organization (IMO) adopted a new chapter to MARPOL annex VI which is to reduce GHG emission from international shipping by improving the energy efficiency for ships. The hull design, propulsion techniques and operational practices are expected technology that can be improved in order to increase the energy efficiency for ships. The Marine Environment Protection Committee (MEPC) approved the interim guidelines on the method of calculation of Energy Efficiency Design Index (EEDI) towards determining minimum energy efficiency level for new ships. It is apply to all merchant ships of 400 gross tonnages and above regardless of the national flag the fly or the nationality of the owner [5].

Emission is inherent consequence of powered shipping, fuel oil burning as main source of continuous combustion machineries like boilers, gas turbines and incinerators. GHG emission is closely linked to machineries combustion. For a long time environmental issues in shipping has focused more on release to water, only lately release to air and soil has become serious issue of concern because of pressure from climate change impacts. Shipping is still considered far less emission pollutant compare to other mode transportation, but a thorough analysis on the volume ship and risk impose to the ocean media that support all activities on earth pose a big question on the actual quantity of emission. However, since environment differs, so are the impact and the presence of pollutants, thus they are dependent on the volume of shipping traffic. Yet the science of transportation of atmospheric gas dictates more about need for the whole world to work together. Recent IMO resolution on these mandated nations to collect data on emission so that reliable compliance measures can be incorporated into annex of MARPOL in order to meet the requirement for Energy Efficiency Design Index (EEDI), Ship Energy Efficient Management Plan (SEEMP) and Ship Energy Efficiency Operational indicator (SEEOI). Study of emission from ship has not been fully initiated or studied in Malaysia.

The purpose of this multidiscipline research project is therefore to record and analyse the different Green House Gas Emison from boat, ships, near or within the vicinity of port, inlandwater port areas, shipping lanes in order to determine the characteristics and source of emison at different locations for require rule making and decisuon support for choice of environmental prevention and contriol technology. Table 2 shows Inland waterways environmental performance in European waters concluded the following.

Table 2 : Emission reduction potential

	NOx	PM	FC	Cox	Sox
	%	%	%	%	%
After treatment					
SCR (Selected catalytic reduction)	-81	-35	-7.5	-7.5	-7.5
PMF (Particulate matter filter)	None	-85	2	2	2
Drive management systems					
ATM (Advising temporal)	-10	-10	-10	-10	-10
Diesel fuel quality / substitutes					
(BD) Bio – Diesel	-10	-30	15	65	~-100
BDB (Biodiesel blend , 20%BD)	2	-6	3	-13	~-20
LSF (Low sulfur fuel)	None	-1.7	none	None	~-100
New engine technology					
NGE (Natural Gas Engine)	-98.5	-97.5	4.5	-10	-100

IV. Methodology

a) Study Location

Thus, there are recent GHG gas emission quantification in other part of the world, but the data are hard to to be applied to pother region, because, reliability of environmental research require localization. RV Discovery II is sailed from Pengkalan Arang Jetty to Bidong Island. The data is collected during its saling, maneuvering and hoteling mode, the data is recorded near to the Bidong Island that is far from the land. Therefore, the concentration of gases recorded by the equipment is mainly coming from the vessel engine. Data information related the following are used:

- Emission factors for each components air emission factors for air is established by regulatory bodies
- Fleet information on board data based ship performance information
- Ship operational data (power consumption, speed time at sea)
- Shipping movement information from different source within fleet that call Malaysia and European ports
- Analysis will be made for contribution by vessel and operations

b) Equipment

The equipment used for collecting the concentration of gases is the Gas Detector IQ-1000. It can detect over 100 toxic and combustible gases using a single sensor. The calibration is automated with no manual adjustments necessary. The power is provided by 6 'D' size alkaline or nickel cadmium batteries. The data that is successfully recorded is displayed on the unit and stored in data acquisition system and then transferred to through the RS 232 computer port or send to printer for further analysis.

This equipment is placed on the safe and balance area near the exhaust of Discovery II. The sensor is then pointed 20 cm away from the exhaust hole. The setting of the equipment is changed by selecting three types of gases, Carbon Dioxide (CO_2), Nitrogen Dioxide (NO_2) and Sulphur Dioxide (SO_2) as parameters that are going to be measured. The procedure of using the Gas Detector IQ-1000 is as followed:

i. AC power supply is connected to the unit.
ii. Sensor is connected to the unit.
iii. Gas detector IST IQ-1000 is turned on by pressing the POWER button and waits until the reading appeared at every sensor.
iv. The pump is turned on by pressing the PUMP button.
v. The LOG DATA button is pressed to record the data.
vi. The LOG DATA and PUMP are turned off after the sampling is finished.

Figure 3 shows the experimental setup of the pilot study conducted on Discovery II.

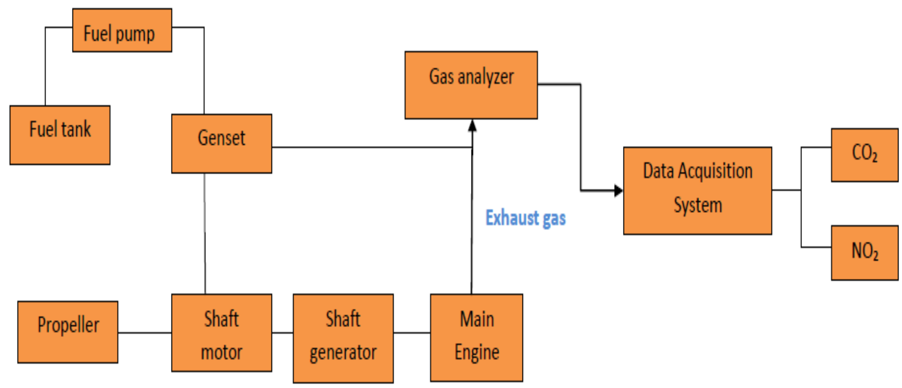

Figure 3 : Experimental Setup

EEOI represent performance index that provides the CO2 level per unit of cargo/passenger moved by unit of distance.

EEOI estimation takes into consideration:

cargo mass term (mcargo) which is expressed as tonnes, TEU, passengers, etc.

- actual fuel consumption (FC).
- carbon factor (CF) selected based on fuel type
- actual distance (D) over ground.
- acceptable damping factor voyage fluctuations and rolling

$$\text{EEOI} = \frac{\sum_j FC_j \times C_{Fj}}{m_{cargo} \times D}$$

EEDI represent combined impact of commercial, operation and technical aspects. Its estimation face challenges related voyage definition, data collection, data quality, bunker consumption uncertainty, sea state conditions, weather, etc. Figure 4 shows the flow chart EEDI calculation for new ships. EEDI values that can be used to calculate overall EEDI for anticipated operations like loaded voyage at a range of operating speeds, ballast voyage at a range of operating speeds, loading alongside and discharge alongside. At design stage EEDI could be used to support decisions for suitability of ships for different trades.

Comparison of EEOI and EEDI define improvement in auxiliary power to more closely represent actual operation. Calm water EEOI values could be compared with EEDI values to assess degradation in performance. Such comparison could also be used to compare different transport modes.

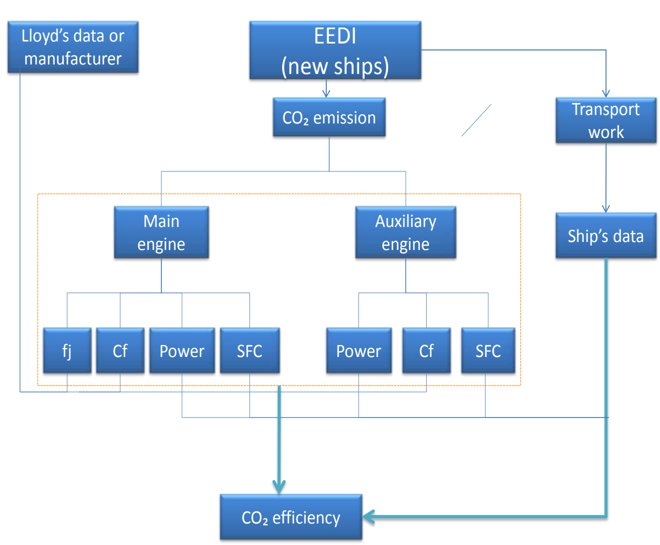

Figure 4 : Research methodology flowchart

EEDI is the abbreviation of Energy Efficiency Design Index. Marine Environment Protection Committee (MEPC) has developed the EEDI formula for new ships in order to require the minimum energy efficiency level for new ships and to stimulate continued technical development of all the components influencing the fuel efficiency of a ship. It also separate the technical and design based measures from the operational and commercial measures as well as enable the comparison of the energy efficiency of individual ships to similar ships of the same size which could have undertaken the same transport work. The EEDI formula provides a specific figure for an individual ship design, expressed in grams of CO per ship's capacity mile (a smaller EEDI value means a more energy efficient ship design) and calculated by a given formula based on the technical design parameters of a given design:

$$\frac{\left(\prod_{j=1}^{M} f_j\right)\left(\sum_{i=1}^{nME} P_{ME(i)} \cdot C_{FME(i)} \cdot SFC_{ME(i)}\right) + \left(P_{AE} \cdot C_{FAE} \cdot SFC_{AE}*\right) + \left(\left(\prod_{j=1}^{M} f_j \cdot \sum_{i=1}^{nPTI} P_{PTI(i)} - \sum_{i=1}^{neff} f_{eff(i)} \cdot P_{AEeff(i)}\right) C_{FAE} \cdot SFC_{AE}\right) - \left(\sum_{i=1}^{neff} f_{eff(i)} \cdot P_{eff(i)} \cdot C_{FME} \cdot SFC_{ME}\right)}{f_i \cdot Capacity \cdot V_{ref} \cdot f_w}$$

Where: ME and AE represent main engine(s) and auxiliary engine(s); P, the power of engine (kW); CF a conversion factor between fuel consumption and CO2 based on carbon content; SFC, the certified specific fuel consumption on the engines (g/kWh); Capacity, the deadweight (tonnes); Vref is the ship speed (knot); and fj is a correction factor to account for ship specific design elements fw is a non-dimensional coefficient indicating the decrease of speed in representative sea conditions of wave height, wave frequency and wind speed. fi is the capacity factor for any technical/regulatory limitation on capacity, and can be assumed one (1.0) if no necessity of the factor is granted. The EEDI formula can be simplified to:

EEDI = CO_2 emission / transport work

The CO_2 emission represents total CO_2 emission from combustion of fuel at design stage, including propulsion and auxiliary engines, taking into account the carbon content of the fuels in question. If shaft generators or innovative mechanical or electrical energy efficient technologies are incorporated on board a ship, these effects are deducted from the total CO_2 emission. If wind or solar energy is used to board a ship, the energy save by such measures will also be deducted from the total CO_2 emissions, based on actual efficiency of the system. The transport work is calculated by multiplying the ship's capacity as designed (deadweight for cargo ships and gross tonnage for passenger ships) with the ship's design speed measured at the maximum design load condition and at 75% of the rated installed shaft power. Speed is the most essential factor in the formula and may be reduced to achieve the required index. Table 3 shows necessary input data and assumption.

The nitrogen emission per year can be estimated from;

5.34lb/Hr).(8760hr/year).(ton/200lb)

Where 5.34lb is assumed emission factor

Table 3 : Input Data

Activities	Category	Source
Ship Movements	Data Records for each vessel: vessel type, Previous and current ports, date of movement, etc	Navigation data
Main engine power	Correlations for vessel type and DWT	Navigation data, Marine Department, or Environmental department's
Aux engine power Estimate	using aux/main engine power ratio	From Within Malaysia and European ports
Load factors	by mode Factors	Malaysian ports environmental department best practices methods. Emission factors Entec, 2002, Swedish Methodology for Environmental Data, 2004, Starcrest, 2004, MAN B&W, 2004. Vessel speed Navigation data or default values.
Time underway	Port-to-port distances were estimated individually for 80% of movements. Simplified distance estimates for balance.	Equal to distance/vessel underway speed.

Time manoeuvring	For each vessel type. Includes intraport distances in large ports	Equal to manoeuvring distance/vessel speed
Time hoteling	By vessel type, based on vessel arrival & departure., fuel statistics and emission factors OR trading pattern vessels	Navigation data

IMO SEEMP guidelines are a mechanism for a shipping company to improve energy efficiency of a ship's operation. SEEMP provides guidance for the development of model plan for characteristics and needs of individual companies and ships.

V. Result and Discussion

From three types of gases that have been selected, only two types are successfully detected by the Gas Detector IQ-1000 which is Carbon Dioxide (CO_2) and Nitrogen Dioxide (NO_2). The data of exhaust emissions are analyzed by using Microsoft Excel and Minitab 15. Table 4 shows the summary of the test when Discovery II starts maneuvering at 6 knots.

Table 4 : The concentration of Carbon Dioxide (CO_2) and Nitrogen Dioxide (NO_2)

Time (am)	Carbon Dioxide (ppm)	Nitrogen Dioxide (ppm)
9:21:59	0	0
9:22:07	0	0.7
9:22:08	70	4.2
9:22:09	290	8.7
9:22:10	820	13.4
9:22:11	1650	17.5
9:22:12	2000	20
9:22:59	2000	20

Based on the data collected, the graph time versus amount of gas concentration (ppm) is plotted. Figure 5 and Figure 6 shows the graph of the concentration of the Carbon Dioxide (CO_2) and Nitrogen Dioxide (NO_2) respectively.

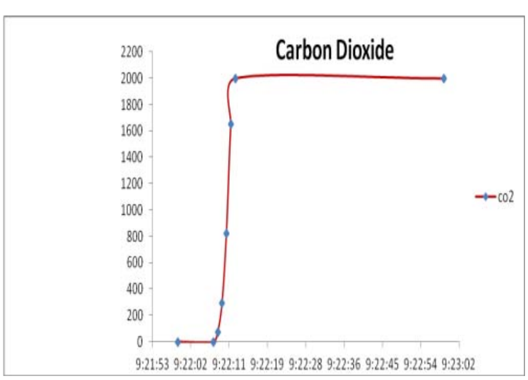

Figure 5 : The concentration of Carbon Dioxide (CO_2) versus time

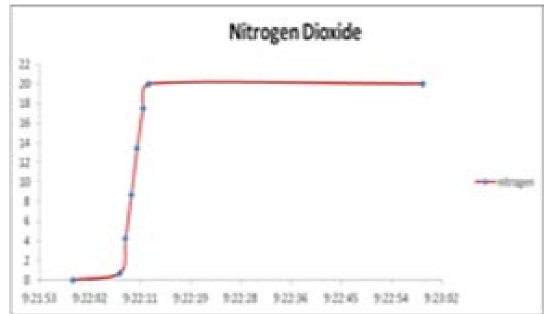

Figure 6 : The concentration of Nitrogen Dioxide (NO_2) versus time

According to the graph for both gases concentration, the reading recorded increasing drastically until they reached the maximum value. This is because; the engine of the boat needs high energy to maneuver at the initial. The maximum reading for Carbon Dioxide (CO_2) is 2000 ppm while for the Nitrogen Dioxide (NO_2) the maximum reading is 20ppm. The Figure 7 and Figure 8 below show the data analyzed by using Minitab 15. The histogram shows acute skew to the left and agreement to the rise in the release of the gas during the experiment.

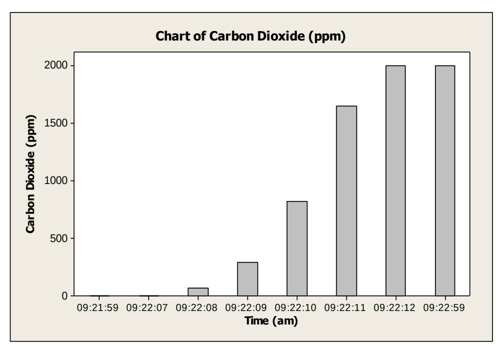

Figure 7 : The concentration of Carbon Dioxide

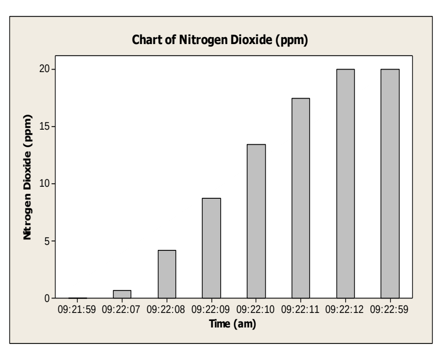

Figure 8 : The concentration of Nitrogen Dioxide

Table 5 shows the summary of the test during Discovery II maneuvering at sea.

Table 5 : The concentration of Carbon Dioxide (CO_2) and Nitrogen Dioxide (NO_2)

Time (am)	Carbon Dioxide (ppm)	Nitrogen (ppm)
9:57:47	2000	0.9
9:57:50	2000	0.9
9:57:51	2000	1.6
9:57:54	2000	2.1
9:57:55	2000	3.6
9:57:56	2000	6.2
9:57:57	2000	8.8
9:57:58	2000	11.1
9:57:59	2000	13.1
9:58:00	2000	14.9
9:58:01	2000	16.4
9:58:02	2000	17.7
9:58:03	2000	18.7
9:58:04	2000	19.5
9:58:17	2000	20

Based on the data collected, the graph time versus amount of gas concentration (ppm) is plotted.

Figure 9 and Figure 10 show the graph of the concentration of the Carbon Dioxide (CO_2) and Nitrogen Dioxide (NO_2) respectively.

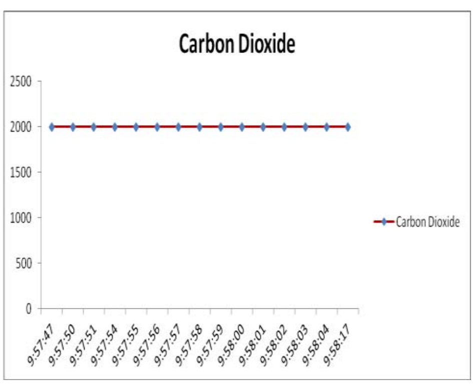

Figure 9 : The concentration of Carbon Dioxide (CO_2) versus time

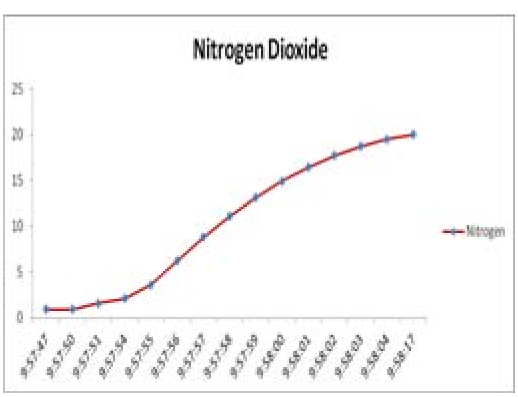

Figure 10 : The concentration of Nitrogen Dioxide (NO_2) versus time

According to the graph, The concentration of Carbon Dioxide become constant at maximum value of 2000 ppm. For the concentration of Nitrogen Dioxide, the graph plotted is smoother than the previous graph, because the vessel starts to sail then. It is increasing slowly at the beginning and continue without drastic until it reach the maximum value. The Figure 11 below shows the data analyzed by using Minitab 15 for Nitrogen Dioxide only. The histogram shows similar trend with previous Nitrogen reading.

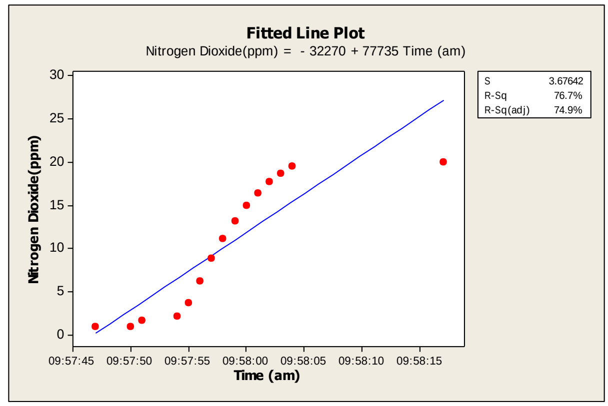

Figure 11 : The concentration of Nitrogen Dioxide

Table 3 shows the summary of the test during Discovery II is in hoteling mode.

Table 6 : The concentration of Carbon Dioxide (CO_2) and Nitrogen Dioxide (NO_2)

Time (pm)	Carbon Dioxide (ppm)	Nitrogen (ppm)
12:21:52	2000	0.4
12:21:52	2000	0.4
12:21:55	2000	0.9
12:21:56	2000	1.8
12:21:57	2000	2
12:21:59	2000	3.8
12:22:00	2000	6.8
12:22:01	2000	10.1
12:22:02	2000	12.9
12:22:03	2000	15.2
12:22:04	2000	17.1
12:22:05	2000	18.7
12:22:06	2000	20
12:23:10	2000	20

Based on the data collected, the graph time versus amount of gas concentration (ppm) is plotted.

Figure 12 and Figure 13 show the graph of the concentration of the Carbon Dioxide (CO_2) and Nitrogen Dioxide (NO_2) respectively.

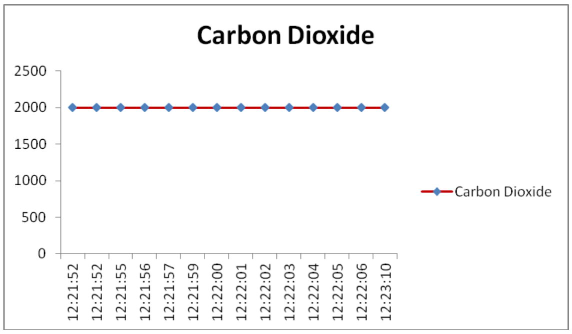

Figure 12 : The concentration of Carbon Dioxide (CO_2) versus time

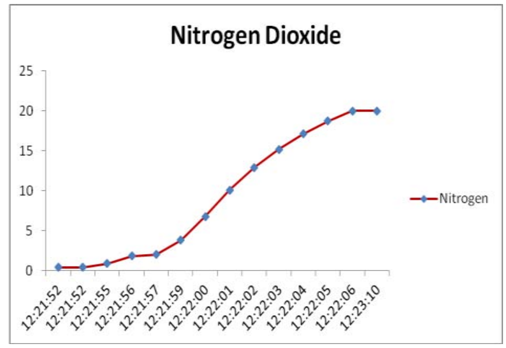

Figure 13 : The concentration of Nitrogen Dioxide (NO_2) versus time

According to the graph, the concentration of Carbon Dioxide (CO_2) still not change and keep consatnt. For the concentration of Nitrogen Dioxide, it is increasing slowly and sometimes constant at the beginning then it continue to increase until it reach maximum value. The Figure 14 below shows the data analyzed by using Minitab 15 for Nitrogen Dioxide only. Similar histogram trend is obtained.

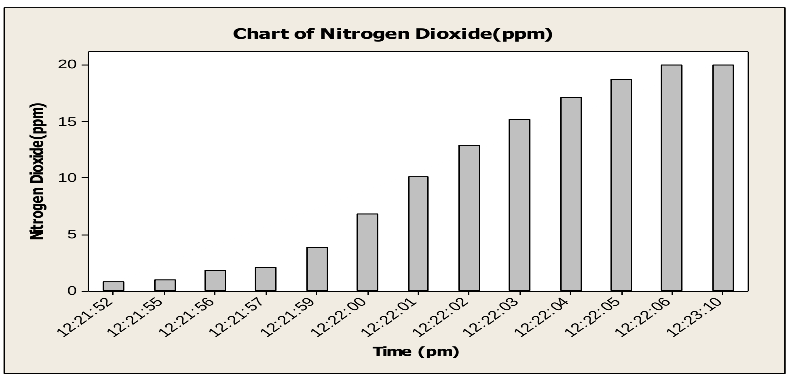

Figure 14 : The concentration of Nitrogen Dioxide

VI. Conclusion

The maximum reading of Carbon dioxide and Nitrogen Dioxide that can be detected by the Gas Detector IST IQ-1000 are 2000ppm and 20ppm respectively. At the initial stage of the experiment, the amount of Carbon Dioxide increased dramatically and it remains constant until the experiment is finished. For the Nitrogen Dioxide, it also increased dramatically at the initial of the experiment and its amount keeps changing and not constant until the experiment is finished. The overall data showed that the Nitrogen Dioxide measured keep changing and not uniform. For the first reading, the data collected finished in 5 seconds while the second reading, third reading and fourth reading finished in 33 seconds, 18 seconds and 8 seconds respectively. For the hoteling mode which is fifth reading and sixth reading, the data collected finished in 25 seconds and 14 seconds respectively. The amount of Nitrogen Dioxide in each data collected is increasing, decreasing and sometimes constant. The data collected in this pilot study is based on the unsophisticated device. The experimental set up is the first experiment we have done in measuring the gas emission. The pilot study is preparation for similar experiment on ocean going vessel, and inadequacy experience in the pilot study will be mitigated for better accuracy.

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