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RISK ASSESSMENT FOR ENTERING ENCLOSEDSPACES ON BOARD SHIPS

Mohana Krishnan G.[1] and Manu Menon[2]
[1]Politeknik Ungku Omar, Ipoh, Perak, Malaysia
[2]Scomi Energy Services Bhd., Petaling Jaya, Selangor, Malaysia
E-Mail: gkmohana@msn.com

ABSTRACT

The present work provides a systematic and objective approach to assessing hazards and their associated risks that will provide an objective measure of an identified hazard as well as provide a method to control a risk involving enclosed spaces on board ships. An enclosed space is a space with poor or no natural ventilation which is not designed for continuous occupancy, where access is limited and which may contain a dangerous atmosphere. The atmosphere may be oxygen-deficient or oxygen-enriched and/or contain flammable and/or toxic gases or vapours. Seafarers or other personnel entering enclosed spaces should be made aware about the dangers involved, take the necessary safety precautions and most importantly, ensure that risk assessment on the particular enclosed space has been carried out. Risk assessment is the process of gathering data and synthesizing information to develop an understanding of the risk of a particular work environment. To obtain the risk levels, a risk assessment process is applied whereby it consist of the hazards identification, likelihood of it happening and its severity. This is followed by risk control whereby the hazard is either eliminated or inactivated in a manner such that the hazard does not pose a risk to workers who have to enter into an enclosed area. The qualitative method was to used carry out risk assessment whereby the likelihood of an incident taking place and the level of severity of hazard were considered in calculating the risk arising. Results obtained from the risk matrix can then be used as a guide to reduce or eliminate the hazards within the enclosed space.

Keywords: enclosed/confined space, hazard, risk assessment, risk matrix, risk control.

INTRODUCTION

Working in an enclosed space can expose a person to a very risky situation that cause may diseases, injury or even death if an accident were to occur due to human error. In most cases the cause of death is due to inhalation of toxic gases or working in an oxygen deficient enclosed space. There is a high volume of reported accidents [1, 2, 3] that support the idea of many injuries and fatalities involving seafarers occurred whilst working in an enclosed space. Investigations into the circumstances of casualties that have occurred have shown that accidents on board ships are in most cases caused by insufficient knowledge of, or disregard, for the need to take precautions rather than a lack of guidance.

The International Maritime Organization (IMO) is a specialized agency created by the United Nations responsible for the safety and security of shipping activities and the prevention of marine pollution by ships. In May 2013 the Maritime Safety Committee (MSC) of the International Maritime Organization (IMO) [4,5] adopted amendments in the International Convention for the Safety of Life at Sea (SOLAS) Regulation III/19 which added a new requirement for mandatory enclosed space entry and rescue drills. From the 1st January 2015 all persons involved in enclosed space entries, and / or assigned to enclosed space rescue duties, will be required to take part in enclosed space entry and rescue drills at intervals not exceeding two months. These recommendations are intended to complement national laws or regulations, accepted standards or particular procedures which may exist for specific trades, ships or types of shipping operations.

Risk assessment has long being applied in the marine and offshore oil and gas industries. Marine regulatory bodies and classification societies such as American Bureau of Shipping (ABS) had highlighted the importance of carrying out risk assessment to improve the safety standards involving enclosed spaces. Prior to entering enclosed spaces for maintenance, repair or inspection purposes, hazard identification, risk assessment and risk control (HIRAC) is carried out. Risk assessment is carried out to identify the hazards and later used to analyze or evaluate the risk associated with that hazard. Finally, appropriate ways to eliminate or control the hazard is implemented. Risk assessments are very important as they form an integral part of a good occupational health and safety management plan. The assessment carried out helps to:

- Create awareness of hazards and risks.
- Identify who may be at risk (employees, contractors, etc).
- Determine if existing control measures are adequate or if more should be done.
- Prevent injuries or illnesses when done at the design or planning stage.
- Prioritize hazards and control measures.

In practical terms, a risk assessment is a thorough look at a workplace to identify those things, situations, processes, etc that may cause harm, particularly to people. After identification is made, it is possible to evaluate how likely and severe the risk is, and then decide what measures should be in place to effectively prevent or control the harm from happening.

Enclosed spaces

An enclosed space is defined as a space of enclosed nature which has limited openings for entry and exit, inadequate ventilation and is not designed for continuous worker occupancy [5]. This includes cargo spaces, double bottoms, fuel tanks, ballast tanks, cargo pump-rooms, cofferdams, chain lockers, void spaces, duct keels, inter-barrier spaces, boilers, engine crankcases, engine scavenge air receivers, sewage tanks, and adjacent connected spaces and any other spaces that are normally kept closed. An enclosed space may include a deck area that due to its construction and location has poor or limited access and where a dangerous atmosphere may accumulate. Some enclosed spaces are easy to identify, for example enclosures with limited openings such as ballast tanks. Others may be less obvious, but can be equally dangerous, for instance unventilated or poorly ventilated rooms. The list of spaces as shown in Table-1 can be produced on a ship-by-ship basis to identify enclosed spaces.

Table-1. List of enclosed spaces commonly found on ships.

CO_2 rooms	Pressure Vessels	Lube oil tanks
Fresh water tanks	Sewage tanks Pump-rooms	Compressor rooms
Double Hull Space	Thruster spaces	Duct keels
Cofferdams	Battery lockers	Gas bottle storage lockers

Limited openings for entry and exit

Enclosed space openings are limited primarily by size or location. Openings are often small, perhaps only 450mm (18 inches) in diameter, and are difficult to move through easily. Small openings make it difficult to get equipment in or out of the spaces, especially life-saving equipment when rescue is needed. Conversely, openings which are large, for example open-topped spaces such as ships' holds, or pump room access, create other problems. Access to open-topped spaces may require the use of ladders, hoists, or other devices, and escape from such areas may be very difficult in emergency situations.

Inadequate ventilation

Because air may not move freely in and out of enclosed spaces because of their design, the atmosphere inside can be quite different from the atmosphere outside. Deadly gases may be trapped, particularly if the space is used to store or process chemicals or organic substances which may decompose. There may not be enough oxygen inside the enclosed space to support life. The air could be oxygen-rich to the extent that it increases the chance of fire or explosion if a source of ignition is present.

NOT designed for continuous worker occupancy

Most enclosed spaces are not designed for people to work inside on a routine basis. They are designed to store a product, to enclose materials and processes, or transport products or substances. This means that occasional entry by workers for survey, inspection, maintenance, repair, clean-up, or a similar task is often difficult and dangerous because of lack of air, presence of chemicals or physical hazards.

Enclosed space entry procedure

Basically the enclosed space entry procedure consist of before, during and after entry as shown in Table-2:

Table-2. Enclosed space entry procedure [6].

Before Entry
All parties to discuss the job to be done in the space: • Hazards present in the space and mitigation methods. • Occupational hazards and mitigation methods. Risk assessment • Documentation of hazards and necessary safety measures and controls Secure the space • Evacuation of the space if necessary and take steps to prevent the space filling up: — Locking out valves and pumps; and — Placing notices forbidding their operation. — Position of space adjacent to other tanks, holds, or pipelines which if not secure could present a danger? Ventilate • Allow sufficient time for the space to be thoroughly ventilated naturally or mechanically • Guard any openings against accidental and unauthorised entry Test • Test the atmosphere in the space for oxygen content and the presence of flammable and toxic gases or vapours • Do not enter until the atmosphere has been determined to be safe Permit – complete an enclosed space entry permit to work, confirming that: • The hazards of the job and of the space have been dealt with • The atmosphere in the space is safe and ventilated • The space will be adequately illuminated • An attendant at the entrance has been appointed • Communications have been established between bridge and entry point, and entry point and entry party • Emergency rescue equipment is available at the entrance and there are sufficient personnel on board to form a rescue party • All personnel involved are aware of the task and the hazards, and are competent in their role
During Entry
• Ensure the space is suitably illuminated • Wear the right PPE • Continue to ventilate the space • Test the atmosphere at regular intervals • Communicate regularly • Be alert, and leave the space when requested or if you feel ill
After Entry
• Ensure all equipment and personnel are removed from the space • Close the access of the space to prevent unauthorised entry • Close the entry permit • Reinstate any systems as appropriate

Maritime risk assessment

According to International Maritime Organization (IMO), risk is the "combination of the frequency and the severity of the consequence", thereby articulates two components of the likelihood of occurrence and the probability of severity of the unpredictable

consequences [5]. "Safety management objectives of the company should establish safeguards against all identified risks" so has it been stated in the paragraph 1.2.2.2 of the International Safety Maritime Code (ISM) [6]. However this does not determine any particular approach to the risk management theory, and it is for the shipping company/owners/masters of ships itself to choose methods appropriate in accordance with its organizational structure, its ships and trades. The methods could vary accordingly but how ever more or less formal they are, they should be well organised and planned if assessment and responses are meant to be completed and acted upon effectively. In addition the entire exercise should be documented in drafts or amendments so as to provide evidence of the decision-making process. Risk management as defined in [7], which includes maritime risk assessment as: "The process whereby decisions are made to accept a known or assessed risk and/or the implementation of actions to reduce the consequences or probability of occurrence."

Enclosed space entry risk assessment

The methods for coping with enclosed spaces on ships and installations are in many cases are based around a risk assessment ranging from one created for every space to just one generic risk assessment created regardless of the space. The risk assessment must be suitable and sufficient and must include, but not be limited to:

- Rescue Training of the supervisor at minimum.
- Rescue Plan.
- Personal Protective Equipment (PPE)
- The suitability of the individuals undertaking the task in view of the particular work to be done. Where the risk assessment highlights exceptional constraints from the physical layout, the individual completing the risk assessment should have checked that individuals are of suitable build, and other factors such as claustrophobia, fitness to the wearing of breathing apparatus or any medical conditions which may affect an individual's suitability for the work.
- Initial, pre-entry atmospheric testing – at all levels in the enclosed/confined/dangerous space.
- Methods for continuous atmospheric testing.
- Checking of correct functioning and/or testing arrangements of emergency equipment.
- Isolations to space identified.

Hazard in general means anything that can cause harm and are workplace-generated (e.g. dangerous chemicals, electricity, working at heights from ladders, poor housekeeping). There are four main types of hazards i.e. hazardous atmosphere, configuration hazard, changing and hazardous conditions and engulfment hazard. Risk is the likelihood, great or small, that someone will be harmed by the hazard, together with the severity of harm suffered. Risk also depends on the number of people exposed to the hazard. Risk assessment is a careful examination of what, in the workplace, could cause harm to people, so that the ship owner / master can weigh up whether enough precautions has been taken or additional action should be taken to prevent harm. Controlling risk means that the shipowner /master does all that is reasonably practicable to ensure that a hazard will not injure anyone (e.g. by eliminating the hazard, enclosing it in a totally enclosed container, using general or local exhaust ventilation, implementing safe operating procedures, or providing personal protection, as a last resort).

There are many ways of conducting a risk assessment. The ship owner/company should provide guidance on how to carry out risk assessments and any hazard identification (HAZID) techniques that must be used. One of the outcomes of a risk assessment should be a hazard register [6]. The hazard register records all the hazards that have been identified by the various HAZID techniques, showing representative causes, consequences and safeguards for each. It is sensible to maintain a portfolio of hazard registers specific to tasks or operations on your ship, including entry into enclosed spaces. When a non-routine or particularly hazardous activity is to be conducted, the register can be referred to in order to see which hazards apply and the safety measures to be put in place.

Whilst not all of the hazards may be present on each occasion, there may be additional hazards that have not previously been identified. The register is therefore a guidance document to be consulted, and should not replace an assessment of the risks on each occasion. There is a move with some authorities requiring a register of safeguards to be produced rather than hazards, since these have more specific management requirements. HAZID techniques are well suited to identifying safeguards, especially safety-critical ones, as well as hazards. Such registers should be 'living documents' – continually reviewed and updated. The following Table-3 is an example of a list of typical enclosed space entry hazards, methods for controlling the hazards and mitigating measures – steps that can be taken that should reduce the impact of any incident.

Table-3. Typical enclosed space entry hazards, methods for controlling the hazards and mitigating measures [6].

Incident	**Person entering collapses in the space**
Cause	Poor atmosphere
Preventative Measures	• All lines leading into the space secured • Space emptied • Space remotely cleaned prior to entry if possible, i.e.Crude oil washing (COW) of oil tanks or filling tanks with water then pumping out. • Atmosphere tested and found safe prior to entry • Atmosphere tested at regular intervals • Continuous ventilation of the space
Mitigating Measures	• Personnel entering the space trained in enclosed space entry procedures • Attendant at entrance – contact with bridge • Regular communication between attendant and entry personnel • Emergency signal established • Entrants wearing personal monitors • Rescue equipment on stand-by including breathing apparatus, harness, and lifeline

Incident	Fire/explosion in the space
Cause	• Dust cloud • Flammable atmosphere • Hot work • Equipment failure • Oxygen-rich atmosphere • Hydrogen rich
Preventative Measures	• Monitor atmosphere • Use only intrinsically safe equipment in potentially flammable atmospheres i.e. fuel oil tanks • Follow hot work procedures • Do not use defective equipment • Do not ventilate with pure oxygen
Mitigating Measures	• Sufficient personnel on board to form a fire party • Training and drills in fire-fighting • First aid equipment available
Incident	Slip/trip
Cause	• Poor lighting • Poor housekeeping • Inadequate PPE • Hazardous structural arrangement • Worker fatigue • Slippery surfaces • Poor visibility from dust/smoke/mist, etc.
Preventative Measures	• Good lighting arrangements • Monitor and maintain good housekeeping • Relevant PPE worn as appropriate • Briefing/awareness of space arrangement before entry • Assessment of personnel before entry and throughout. Proper rest periods and rehydration • Good ventilation and dust prevention measures
Mitigating Measures	• Stretcher and first aid kit available • Drills in first aid incidents, including procedures for communication to shore-side assistance

Planning and conducting of hazard identification, risk assessment and risk control (HIRARC)

Basically the purpose of HIRARC is to list down activities carried out on board ships, identifying what might go wrong and deciding upon what should be done in order to prevent it. The areas referred to are:

- To identify all factors that may cause harm to seafarers and others (identification of hazards);
- To consider what the chances are that harm actually befalling anyone in the circumstances of a particular case and the possible severity that could come from it (the risks); and
- To enable ship owners / Master to plan, introduce and monitor preventive measures to ensure that the risks are adequately controlled at all times.

The process of HIRARC [9] requires four (4) simple steps as follows (Figure-1):

- Classify the work activities
- Identify the hazards involved
- Conduct risk assessment (analyze and estimate risk from each hazard), by calculating or estimating:
  - Likelihood of occurrence and
  - Severity of hazard
- Decide if risk is tolerable and apply control measures (if necessary)

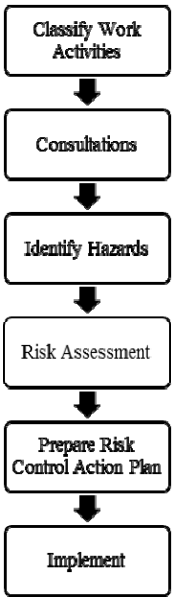

Figure -1. Flowchart of HIRARC process.

Analysing and estimating risk

Risk is the determination of likelihood and severity of the credible accident/event sequences which is used to determine the magnitude and to priorities identified hazards. The qualitative analysis is used whereby words are used to describe the magnitude of potential severity and the likelihood that those severity will occur. As mentioned in [10], these scales can be adapted or adjusted to suit the circumstances and different descriptions may be used for different risks. This method uses expert knowledge and experience to determine likelihood and severity category. Table-4 shows the values likelihood of an event occurring and is based on workers experience, analysis or measurement.

Table-4. Likelihood of an occurrence.

Likelihood (L)	Example	Rating
Most likely	The most likely result of the hazard / event being realized	5
Possible	Has a good chance of occurring and is not unusual	4
Conceivable	Might be occur at sometime in future	3
Remote	Has not been known to occur after many years	2
Inconceivable	Is practically impossible and has never occurred	1

Severity is based upon an increasing level of severity to an individual's health, environment or to property and is shown in Table-5.

Table-5. Severity of hazard.

Severity (S)	Example	Rating
Catastrophic	Numerous fatalities, irrecoverable property damage and productivity	5
Fatal	Approximately one single fatality major property damage if hazard is realized	4
Serious	Non-fatal injury, permanent injury	3
Minor	Disabling but not permanent injury	2
Negligible	Minor abrasions, bruises, cut, first aid type of injury	1

Risk assessment calculation

Once the assignment of likelihood and severity of hazards is complete, a risk matrix can be used as a mechanism for assigning risk by using a risk categorization approach. The risk is calculated using the following formula:

L x S = Risk , whereby L is the likelihood and S is the severity.

The calculated risk is then presented in a matrix form (Table-6) whereby it is a very effective way of communicating the distribution of the risk in an enclosed spaces. Each cell in the matrix corresponds to a specific combination of likelihood and severity of hazard. The steps involved in using this risk matrix are as follows:

- First find the severity column that best describes the outcome of the risk.
- Next, follow the likelihood row to find the description that best suits the likelihood that the severity will occur.
- Finally, the risk level is given in the box where the row and column meets.

Table-6. Risk matrix.

	Severity (S)				
Likelihood (L)	1	2	3	4	5
5	5	10	15	20	25
4	4	8	12	16	20
3	3	6	9	12	15
2	2	4	6	8	10
1	1	2	3	4	5
	High Risk				
	Medium Risk				
	Low Risk				

The risk values obtained earlier are then summarized / prioritised to three ranges as shown in Table-7. Hazards assessed as "High Risk" clearly indicates substantial efforts should be made to reduce the risk. Risk reduction measures should be implemented urgently within a defined time period and it might be necessary to consider suspending or restricting the activity, or to apply interim risk control measures, until this has been completed. Considerable resources might have to be allocated to additional control measures. Arrangements should be made to ensure that controls are maintained, particularly if the risk levels are associated with extremely harmful consequences and very harmful consequences.

Table-7. Risk value priority.

Risk	Description	Action
15 - 25	High	A **HIGH** risk requires immediate action to control the hazard as detailed in the hierarchy of control. Actions taken must be documented on the risk assessment form including date for completion.
5 -12	Medium	A **MEDIUM** risk requires a planned approach to controlling the hazard and applies temporary measure if required. Actions taken must be documented on the risk assessment form including date for completion.
1 - 4	Low	A risk as **LOW** may be considered as acceptable and further reduction may not be necessary. However, if the risk can be resolved quickly and efficiently, control measures should be implemented and recorded.

As for medium risk, consideration should be as to whether the risks can be lowered, where applicable, to a tolerable level and preferably to an acceptable level, but the costs of additional risk reduction measures should be taken into account. The risk reduction measures should be implemented within a defined time period. Arrangements should be made to ensure that controls are maintained, particularly if the risk levels area associated with harmful consequences. Finally, low risk requires no additional controls unless they can be implemented at very low cost (in terms of time, money, and effort). Arrangements should be made to ensure that the existing controls are maintained.

CONCLUSIONS

The aim of the risk assessment process is to remove a hazard or reduce the level of its risk by adding precautions or control measures, as necessary. By doing so, we can create a safer and healthier workplace. Risk assessment carried out for enclosed spaces on board ships should be continual, flexible, reviewed regularly to improve safety and preventing pollution. This will assist the ship owner to imply priorities and exploit its scarce resources for greatest effect. Since 'risk' is never a constant or concrete entity, the divergence of the nature of perception and anticipation the level of danger from the risk undertaken is resolved by experience, training and disposition.

Human behaviour towards issues, general awareness, and constant vigilance of those involved, all play a vital role in the organisation's decision-making process in the risk assessment in ship operations. All parties involved in the shipping industry such as ship owners, shipyards, and maritime organizations are equally responsible in implementing measures aimed at improving

the identification of all dangerous and potentially dangerous spaces and increasing compliance with safe working practice required in enclosed spaces.

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