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Testing and evaluation of lifeboat stability

Experimental stability testing and a study of the responsibility delegation between the parties involved in the classification process of life-saving appliances

Diploma thesis in the Master Mariner Programme

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Gothenburg, Sweden 2017

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Abstract

During a lifeboat training session, the authors experienced a lifeboat to be somewhat "on the edge" with regards to its stability, and an interest to practically test lifeboats' stability and their compliance with the relevant requirements arose. This, together with the fact that one relatively newly manufactured and type-approved lifeboat was found to not fully comply with the relevant requirements in a recently performed test, despite having undergone and passed the regulated tests and evaluation in the classification process, prompted this study on stability and evaluation of lifeboat stability.

This study investigates how well three type-approved lifeboats comply with the relevant stability requirements of the Life-saving Appliances Code (LSA), and how the responsibilities are delegated between the involved parties in the classification process of life-saving appliances.

The theoretical chapter presents the relevant regulations, laws and requirements applicable to a totally enclosed lifeboat and the classification process of life-saving appliances. Furthermore, basic theory behind transverse ship stability and heel angle testing is presented.

For answering the research questions of the study, two research methods were applied; an experimental method comprised of field experiments and systematic observations for testing of the lifeboats' compliance with the stability requirements through practical heeling tests, and a documentary research method to investigate how the responsibilities are delegated within the classification process.

The results from the experimental stability tests show that one of the tested lifeboats does not fully comply with the stability requirements of the LSA-Code. The results on the responsibility delegation show, that the regulations of the International Maritime Organisation (IMO) on life-saving appliances which in turn have been transposed into the legal system of the European Union, point towards a responsibility delegation where the Notified Bodies or Recognized Organisations as the controlling party, carry the responsibility for ensuring that the life-saving appliances comply with the requirements during manufacturing, as well as on-board installation.

Keywords: ADMINISTRATION, EU, IMO, LIFEBOAT, LSA, MED, MSC, NOTIFIED BODY, SOLAS, STABILITY

Sammanfattning

Vid ett övningstillfälle i en livbåt upplevde författarna densamma som en aning rank med avseende på dess stabilitet, och intresse väcktes för att genom en studie praktiskt testa och kontrollera livbåtars stabilitet mot gällande krav. Detta, tillsammans med det faktum att en relativt nytillverkad och typ-godkänd livbåt nyligen lyckades finna en väg ut på marknaden, trots att ett senare test visade på att den inte till fullo uppfyller alla gällande krav efter att ha genomgått och klarat de reglerade tester och utvärderingar som krävs i klassificerings-processen, gav upphov till denna studie.

Denna studie undersöker hur väl tre typ-godkända livbåtar uppfyller de olika stabilitetskrav fastställda i LSA-koden, samt hur ansvarsdelegeringen mellan de involverade parterna inom klassificeringsprocessen ser ut för att livräddnings-utrustning som de facto är testad och typ-godkänd uppfyller de krav som ställs.

Bakgrundskapitlet presenterar teori genom relevanta regelverk, lagtexter och krav applicerbara på den testade, helt slutna livbåtstypen, och på klassificeringsprocessen för livräddnings-utrustning. Vidare presenteras grundläggande teori bakom tvärskeppsstabilitet och krängningsprov.

För att svara på frågeställningarna i denna studie tillämpades två metoder; en experimentell metod med tillhörande praktiska fältexperiment och systematiska observationer för att testa livbåtarnas stabilitet genom praktiska krängningsprov, och en dokumentär forskningsmetod för att undersöka ansvarsdelegeringen inom klassificeringsprocessen.

Resultaten från de praktiska stabilitetstesterna visar på att en av de totalt tre testade livbåtarna i denna studie inte till fullo uppfyller de stabilitetskrav fastställda i LSA-koden. Resultatet för ansvarsdelegeringen visar på att de regelverk av IMO som införlivats i Europaunionens lagstiftning, pekar på en ansvarsfördelning där de anmälda organen, som den kontrollerande parten, i slutändan bär ansvaret för att säkerställa att livräddningsutrustning under både tillverkning och ombord-installation uppfyller kraven.

Denna rapport är skriven på engelska.

Nyckelord: ADMINISTRATION, EU, IMO, LIVBÅT, LSA, MED, MSC, ALLMÄNT ORGAN, SOLAS, STABILITET

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Kristoffer Hagström & Mathias Nilsson

Gothenburg, 1st of March 2017

Table of content

Abstract ... **i**

Acknowledgments ... **iii**

Table of content ... **iv**

List of figures ... **vii**

List of tables ... **viii**

1 Introduction ... **1**

1.1 Purpose ... 2

1.2 Questions ... 2

1.3 Delimitations ... 2

2 Background and theory ... **3**

2.1 International Maritime Organisation (IMO) ... 3

2.1.1 Bodies and committees ... 3

2.1.2 Maritime Safety Committee (MSC) ... 4

2.2 Conventions and codes ... 4

2.2.1 International Convention for the Safety of Life at Sea (SOLAS) ... 4

2.2.2 International Life-saving Appliances Code (LSA) ... 5

2.3 Classification of life-saving appliances ... 5

2.3.1 Administration ... 6

2.3.2 European Commission (EC) ... 6

2.3.2.1 Marine Equipment Directive 96/98/EC (MED) ... *7*

2.3.2.2 EC type approval ... *7*

2.3.3 Recognized Organisation (RO) ... 8

2.3.4 Notified Body (NB) ... 8

2.3.4.1 Conformity assessment procedure ... *9*

2.3.5 Manufacturer ... 9

2.4 Totally enclosed lifeboat ... 10

2.5 Transverse ship stability ... 11

2.5.1 Acting forces/reference points ... 11

2.5.2 GM ... 12

2.6 Lifeboat freeboard and stability requirements ... 13

2.6.1 Stability ... 13

2.6.2 Heel angle & freeboard ... 13

2.7 Testing and evaluation of lifeboats ... 13

2.7.1 Procedure for determining angle of heel 14
2.7.2 Procedure for determining freeboard distance 15

3 Method 16

3.1 Research strategy 16

3.2 Data collection 16
3.2.1 Documentary research 17
3.2.2 Experiments 17

3.3 Method of analysis 18
3.3.1 Literature analysis 18
3.3.2 Observations 19

3.4 The experiments 20
3.4.1 Selection of lifeboats & locations 20
3.4.2 Step 1: Preparations 20
3.4.3 Step 2: Weight scales 21
3.4.4 Step 3: Launching 21
3.4.5 Step 4: GM 21
3.4.6 Step 5: Angle of heel 21
3.4.7 Step 6: Freeboard 22

4 Results 23

4.1 Experiments 23
4.1.1 Test 1 23
4.1.1.1 Weights 23
4.1.1.2 GM 24
4.1.1.3 Angle of heel 24
4.1.1.4 Freeboard distance 25

4.1.2 Test 2 25
4.1.2.1 Weights 25
4.1.2.2 GM 26
4.1.2.3 Angle of heel 26
4.1.2.4 Freeboard distance 26

4.1.3 Test 3 27
4.1.3.1 Weights 27
4.1.3.2 GM 27
4.1.3.3 Angle of heel 28
4.1.3.4 Freeboard distance 28

4.1.4 Compilation of tested lifeboats and test results 29

4.2 The classification process 29
4.2.1 How the responsibilities are delegated 29
4.2.1.1 Process during manufacturing 31

4.2.1.2 Classification during on-board installation *31*

5 Discussion **32**

5.1 Discussion of results 32

5.1.1 Possible sources of error during the experiments 32

5.1.1.1 Determining weights *33*

5.1.1.2 Determining GM *34*

5.1.1.3 Determining heel angles *35*

5.1.1.4 Determining freeboard distances *37*

5.1.2 The classification process 38

5.2 Discussion of method 39

5.2.1 Experiment method 39

5.2.2 Documentary research method 41

5.2.3 Presentation of data 42

5.2.4 Alternative strategies and methods 43

5.3 Validity, reliability and generalizability 43

5.4 Ethical aspects 44

6 Conclusions **45**

7 References **46**

Appendix 1 –Test 1 ..... **48**

Appendix 2 –Test 2 ..... **49**

Appendix 3 –Test 3 ..... **50**

Appendix 4 – Chalmers test report **51**

List of figures

Figure 1: IMO organisation 3

Figure 2: Illustration of MED conformity mark 7

Figure 3: Illustration of MEDs conformity assessment procedure 9

Figure 4: Illustration of a totally enclosed lifeboat 10

Figure 5: Cross section illustration of a vessel in upright and heeling condition. 11

Figure 6: Illustration of a vessel with positive GM 12

Figure 7: Illustration of a vessel with negative GM 12

Figure 9: Trigonometric heel figure 14

Figure 10: Angle of heel calculation 14

Figure 8: Illustration of how to determine angle of heel 14

Figure 12: Trigonometric freeboard distance figure 15

Figure 11: Illustration of how to determine the freeboard distance 15

Figure 13: Freeboard distance calculation 15

Figure 14: Illustration of how the weight scales were attached 21

Figure 15: Illustration of the extended steel pipe solution 22

Figure 16: Lifeboat test 1 23

Figure 17: Lifeboat test 2 25

Figure 18: Lifeboat test 3 27

Figure 19: Delegation of responsibilities in the classification process 30

Figure 20: Trigonometrical heel figure 36

Figure 21: Trigonometrical freeboard distance figure 37

List of tables

Table 1: Weight results in Kg, test 1 23

Table 2: Angle of heel results, test 1 24

Table 3: Freeboard distance results, test 1 25

Table 4: Weight results in Kg, test 2 25

Table 5: Angle of heel results, test 2 26

Table 6: Freeboard distance results, test 2 27

Table 7: Weight results in Kg, test 3 27

Table 8: Angle of heel results, test 3 28

Table 9: Freeboard distance result, test 3 28

Table 10: Compilation of tested lifeboats and test results 29

Abbreviations and definitions:

Administration: The government of the state of which a ship is entitled to fly the flag of

EC: European commission

EU: European Union

IACS: The International Association of Classification Societies

IMO: The International Maritime Organization

LSA: The International Life-saving Appliances Code

MED: Marine Equipment Directive, a consolidation of rules and standards

MSC: Maritime Safety Committee

NB: Notified Body

RO: Recognized Organisation

SOLAS: The International Convention for Safety of Life at Sea

1 Introduction

An emergency evacuation system on-board a vessel at sea offers different means of evacuation in case of an abandon ship situation. The main mean of evacuation is to abandon the ship using survival crafts (SOLAS, 2009). A survival craft is by definition stated in the International Safety of Life at Sea (SOLAS) convention "a craft capable of sustaining the lives of persons in distress from the time of abandoning the ship." (SOLAS, 2009, p. 201).

During a lifeboat training session at the maritime safety training centre at Chalmers the authors experienced the condition of one of the lifeboats to be somewhat "on the edge" with regards to its stability. Prior to this study, representatives and experts from the Institution of Shipping and Marine Technology at Chalmers and the Swedish Transport Agency performed stability testing on a fully enclosed lifeboat used by Chalmers for maritime safety training. After analysing the test results the lifeboat was deemed not seaworthy and its stability deficient.

All life-saving appliances including totally enclosed lifeboats are subject to classification during manufacturing and before commissioning to ensure that they are reliable and adequately constructed (SOLAS, 2009). If an abandon ship situation on board a vessel occurs, there should not be any doubt what so ever about a lifeboat's seagoing capabilities such as stability, structural integrity or its overall condition.

When considering this, great curiosity arose for the organisation of the concerned parties behind testing and validation of life-saving appliances as well as for the procedure for testing the stability of a lifeboat. These circumstances prompted this study on how the responsibilities are delegated between those involved in the process for classification of life-saving appliances and to perform an experiment on two fully enclosed lifeboats to analyse their stability conditions and examine whether they meet the acting stability requirements.

1.1 Purpose

The purpose of this study is to examine the acting stability requirements applicable to totally enclosed lifeboats and thereafter conduct practical stability experiments to determine how well the tested lifeboats comply with the stability requirements. Moreover, the purpose is to examine the different parties involved in the classification process of life-saving appliances, and then investigate how the responsibilities are delegated between the parties for ensuring that the regulations and requirements that apply to the life-saving appliances are fulfilled.

1.2 Questions

How well does the tested lifeboats comply the stability requirements of the LSA Code?

How are the responsibilities of the classification process for life-saving appliances delegated between the relevant authorities and organisations?

1.3 Delimitations

The tests in this study are limited to the freeboard and stability requirements for lifeboats in section 4.4.5 in the International Life-saving Appliance (LSA) code by the IMO. The requirements of the average weight per person applied in this study will be limited to lifeboats intended for use on-board cargo ships. Any lack of compulsory equipment and stores under normal operating conditions of lifeboats in section 4.4.8 of the LSA code and its impact on the test results will not be taken into account.

Stability testing will be conducted in as confined and calm waters as possible to allow for accurate measurements of freeboard and other distances from the water surface. Stability testing and calculations will be limited to transverse ship stability only.

The investigation concerning classification of life-saving appliances will be limited to appliances intended for use on-board vessels controlled by member states of the European Union.

2 Background and theory

The construction and performance of life-saving appliances needs to follow different regulations and meet certain requirements. This chapter will provide relevant knowledge of the conventions and codes in which they are stated, as well as the organisation behind them.

Furthermore it will cover the different authorities and organisations involved in the process for classification of life-saving appliances and their purposes in the process, as well as providing basic theoretical knowledge of transverse ship stability and stability testing procedures which is most essential for understanding the purpose of the study and its experiments.

2.1 International Maritime Organisation (IMO)

"IMO – the International Maritime Organization – is the United Nations specialized agency with responsibility for the safety and security of shipping and the prevention of marine pollution by ships." (IMO, 2016a). Figure 1 shows an illustration of the organisation in IMO. The concept of the IMO is that all the states who are members of the United Nations (UN) can also be members of the IMO, to partake in managing the Organisation as well as the work of its different committees, thus nurturing their own independent interests as a shipping nation (Borg & Åkerblom, 2012). As of 2016, the Organisation has 172 member states (IMO, 2016b).

2.1.1 Bodies and committees

The Organisation is governed by two managing bodies. The Assembly and the Council, both comprised of representatives of the member states. The Assembly is the executive governing body of the IMO. It is responsible for electing the Council, defining and approving the work programme as well as establishing financial arrangements and budgets. It convenes for session once every two years on regular basis (IMO, 2016c).

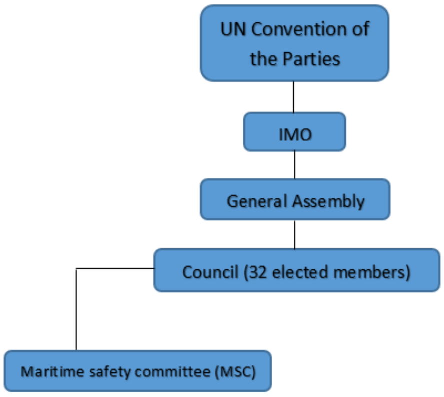


Figure 1: IMO organisation

As the head administrative Organ, the Council is responsible for the everyday management of the Organisation. It executes the duties of the Assembly during its recess period and carries out the work programme set by the Assembly (IMO, 2016c).

Under the council, the IMO has formed a number of committees and sub-committees specialized in different areas of expertise, areas such as maritime safety, marine environment protection and legal. The work of the committees results in conventions, codes, resolutions and recommendation that are then moved up the chain for approval and adoption (IMO, 2016c; Borg & Åkerblom, 2012).

2.1.2 Maritime Safety Committee (MSC)

The different committees of the IMO are tasked with certain duties and to fill specific functions in the work of the Organisation. MSC is the committee responsible for considering all relevant safety related matters within the maritime industry (IMO, 2016c).

Its functions are defined by IMO as: “to consider any matter within the scope of the Organization concerned with aids to navigation, construction and equipment of vessels, manning from a safety standpoint, rules for the prevention of collisions, handling of dangerous cargoes, maritime safety procedures and requirements, hydrographical information, log-books and navigational records, marine casualty investigations, salvage and rescue and any other matters directly affecting maritime safety”. (IMO, 2016c). Furthermore, the committee is responsible for formulating and submitting recommendations and guidelines to the Assembly for adoption (IMO, 2016c).

2.2 Conventions and codes

There are three main categories in which conventions and codes adopted by the IMO fall into. Conventions that concerns:

- Maritime safety (MSC)
- Prevention of marine pollution
- Liability and compensation (for example damage caused by pollution) (IMO, 2016c; IMO, 2016d).

For this study, merely the conventions and codes originating from MSC concerning maritime safety are relevant, those being the International Convention for the Safety of Life at Sea and the International Life-saving Appliances Code.

2.2.1 International Convention for the Safety of Life at Sea (SOLAS)

After the Titanic disaster, which resulted in the loss of more than 1500 lives, the Inter-Governmental Maritime Consultative Organization, which later became IMO, agreed to create a framework to enhance the safety at sea. The framework appeared as the International Convention for the Safety of Life at Sea (SOLAS) and it was adopted two years after the Titanic disaster in 1914 (SOLAS, 2009).

This Convention “shall apply to ships entitled to fly the flag of States the Governments of which are Contracting Governments.” (SOLAS, 2009, p. 3). This means that SOLAS becomes mandatory to all ships and its associated appliances for all member states of the IMO that have ratified the convention and implemented it into their laws.

The Convention is divided into 12 chapters where each one is targeting specific areas for ensuring safety of life at sea. Throughout the years there have been revisions of the convention and the present version was adopted by the IMO in 1974 and entered into force in 1980. Since

1974 certain annexes have been added to the convention (IMO, 2016e; SOLAS, 2009). Relevant for this study is chapter III *Life-saving appliances and arrangements,* and regulation four *Evaluation, testing and approval of life-saving appliances and arrangements* (SOLAS, 2009).

2.2.2 International Life-saving Appliances Code (LSA)

The International Life-saving Appliances Code (LSA) contains the requirements required by chapter III of the 1974 SOLAS convention for all life-saving appliances used on-board vessels that sail under the IMO. Requirements for appliances such as survival crafts, rescue boats, marine evacuations systems, lifebuoys, lifejacket, hand flares and PA-systems (IMO, 2016e).

The MSC adopted the LSA Code by resolution MSC.48(66) in June 1996 and it was entered into force first of July in 1998 by IMO. The Code is mandatory and all life-saving arrangements and appliances shall comply with its requirements as per SOLAS regulation III/3.10 and III/34 (LSA, 2010; SOLAS, 2009). Relevant for this study is chapter IV *Survival crafts,* section 4.4 *General requirements for lifeboats,* and section 4.6 *Totally enclosed lifeboats*. Furthermore the resolution regarding testing and evaluation of life-saving appliances referenced as MSC.81(70) in the code is also relevant (LSA, 2010).

2.3 Classification of life-saving appliances

Life-saving appliances intended for use on-board vessels sailing under flag states of the IMO are according to the SOLAS convention subject to certain evaluations, testing and approval before being considered to be of sufficient standard and safe to use on-board vessels (SOLAS, 2009).

Before life-saving appliances and arrangements can be approved, SOLAS requires the flag state Administration to ensure that they have undergone proper testing and either;

- meet the relevant requirements of the convention and the LSA code, as well as the recommendations of the IMO on testing of life-saving appliances by resolution MSC.81(70) and A.689(17) as stated in the convention, or;
- have undergone tests that are satisfactory to the Administration, that are equivalent to the tests in the recommendations of resolution MSC.81(70) and A.689(17) (SOLAS, 2009).

During production, the Administration is likewise required by SOLAS to ensure that the life-saving appliances are manufactured to the same standard as the prototype, by requiring it to undergo necessary production tests along the manufacturing process (SOLAS, 2009).

For the purpose of investigating how the responsibilities are delegated between those involved in the classification process, the following sections will cover the main parties involved and their functions in the process during on-board installation and manufacturing of life-saving appliances.

2.3.1 Administration

The flag state Administration is, for the purposes of the SOLAS convention, the government of the state of which a ship is entitled to fly the flag of (SOLAS, 2009), or more correctly in practice, the authority within that government assigned to handle matters concerning ships sailing under their flag.

Whereas it is the objective of the SOLAS Convention to specify minimum standards for the construction and equipment of ships, the compliance with such standards is to be ensured by the flag state Administration (SOLAS, 2009).

Statutory tests and inspections is a demanding process. It can prove challenging for a flag state Administration to accommodate the necessary amount of assets needed such as manpower, service reach, technical knowledge and to provide it globally. Therefore, the workload is often partially or completely delegated to an additional organisation that is assigned and recognized by the Administration. Such an organisation is called "Recognized Organisation" (RO) (IACS, 2011) or Notified Body (NB) (European Parliaments and Council Directive 96/98/EC on marine equipment [1996] EUT L46/25).

2.3.2 European Commission (EC)

The European commission (EC) is the body within the European Union (EU) responsible for proposing, implementing and enforcing legislation and policies in EU (EU, 2016).

Whereas the Administration is required to ensure that the equipment on board vessels comply with relevant regulations and requirements of SOLAS as the main international legal framework for safety at sea, and the LSA code, it is the opinion of EU that the testing standards of marine equipment developed by standardization bodies and the IMO allow for a margin of interpretation and discretion for the Administrations, ROs and NBs. This based on the notion that they can possess varying levels of knowledge and experience and that the rules consequently can be applied differently across EU.

To ensure high safety and performance levels of the marine equipment on board vessels, and with the aim to prevent risks of accidents caused by low performance, the EC transposed the rules and standards of IMO regarding maritime safety into the legal system of EU. This to generate a harmonizing effect of the application of rules and standards regarding testing and approval of marine equipment throughout the entire EU.

The legislative process resulted in a council directive creating an expedient and authoritative enough legal instrument for centralizing standards for testing and classification, resulting in their unitary application on all marine equipment intended to be used on-board vessels of member states of EU (European Parliaments and Council Directive 96/98/EC).

2.3.2.1 Marine Equipment Directive 96/98/EC (MED)

The Marine Equipment Directive (MED) is a consolidation of rules and standards regarding testing and approval of marine equipment intended to be used on-board vessels of member states of EU. The purpose of the Directive is, in a maritime safety context, to increase the safety at sea by stipulating uniform application of the relevant standards and conventions regarding testing and classification of marine equipment in all of EU.

The bulk of the Directive is comprised of a tabulated compilation of all the relevant testing standards, regulations, conventions and codes that together regulate proper construction, installation and testing procedures for not only life-saving appliances but for all the on-board equipment necessary for ensuring a vessel's safe operation.

The directive was adopted by the Council of the European Union 20 December 1996 and entered into force 17 February 1997. EU member state governments transposed the Directive into national laws before 30 June 1998 (European Parliaments and Council Directive 96/98/EC).

2.3.2.2 EC type approval

Marine equipment that has been approved and is in compliance with the Directive and thereof with the relevant international conventions and standards is to bear a mark that states its conformity. The mark indicating this is the ships wheel as shown in Figure 2, a mark also signifying that the equipment is type-approved.

The ships wheel mark shall be affixed onto the product by the manufacturer, together with the four digit identification number of the notified body that performed the conformity assessment procedure and what year it was performed (European Parliaments and Council Directive 96/98/EC).

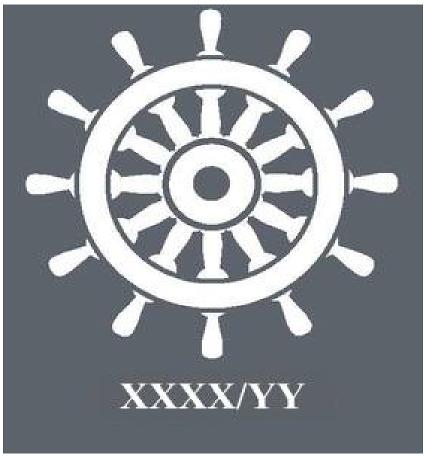


Figure 2: Illustration of MED conformity mark. ***Published with permission of SevenStar Electronics Ltd.***

2.3.3 Recognized Organisation (RO)

The administration is allowed by SOLAS and other conventions to delegate the execution of statutory testing and inspection during on-board installation to a Recognized Organisation (RO) and grant the RO with the authority to perform such testing and inspection on their behalf. The Administration is free to choose the extent of the authority granted to the RO. The authority is specified and agreed upon in a special memorandum of understanding between the Administration and the RO.

Through resolution A.739(18) and A.789(19), made compulsory by regulation 1, chapter XI-1 in SOLAS, the minimum requirements of the RO as a controlling party are specified in resolution A.739(18) as well as the specifications on the ROs functions in the process stated in resolution A.789(19), make up the framework for what the Administration are to expect from the RO. The RO, and its quality system, is to be certified by independent auditors assigned by the Administration.

Recognized Organisation is a role that has fallen to independent and self-regulation Bureaus of Classification or Classification Societies. A Classification Society provides the maritime industry with classification services on ships, constructions and technical equipment. It is an organisation that is not commercially invested in, or has any interest in shipbuilding, design, management or ownership (IACS, 2011).

2.3.4 Notified Body (NB)

In the process of manufacturing marine equipment to be used on-board vessels, an external and independent party that possess the technical knowledge needed to properly test and ensure that the products comply with the relevant standards and conventions that apply to them. For the purposes of the Marine Equipment Directive, this role is designated a Notified Body (NB).

A Notified Body (NB) is, like a RO, comprised of a classification society. Thus, the roles of the Recognized Organisation and the Notified Body are the same. In matters of classification of life-saving appliances both their purposes are to ensure that the products are of sufficient enough standard and quality. The difference between them is that they act in two different processes. The NB is rather connected to the process of classifying the actual product and the conformity assessment procedure, while the RO is involved in the classification during the on-board installation phase and re-classifications (European Parliaments and Council Directive 96/98/EC).

2.3.4.1 Conformity assessment procedure

Marine equipment covered by MED is to be manufactured and tested in accordance with the Directive. The manufacturing process's conformity with the Directive is to be assessed using the conformity assessment procedure stipulated in the Directive, which is to be performed by the NB appointed by the manufacturer.

The conformity assessment procedure consists of a number of steps, or "modules". The EC type-examination, conformity to type, production quality assurance and product quality assurance modules as shown in Figure 3, together form the conformity assessment procedure. Once the production process has been assessed through this procedure by the NB and have passed all modules it will be granted a Certificate of Conformity that signifies its compliance with MED, and thereof all the relevant international instruments such as the conventions, codes and standards that applies to it.

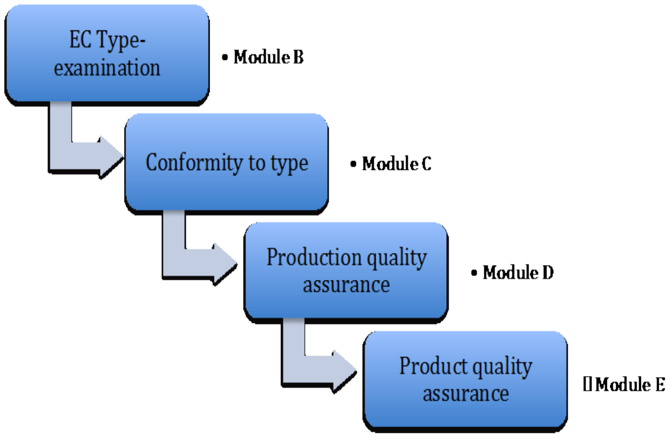


Figure 3: Illustration of MEDs conformity assessment procedure

A Certificate of Conformity issued for marine equipment is per the Directive required to be ensured by the Administration or NB acting in its behalf, to comply with the requirements of the Directive (European Parliaments and Council Directive 96/98/EC).

2.3.5 Manufacturer

During production of marine equipment the manufacturer is bound by the MED directive to fulfil certain duties. The manufacturer is per the MED directive to maintain a satisfactory quality system for the production of the equipment, and is bound to provide the classifying body with all necessary technical documentation of the production process and the products during the manufacturing.

On the specimen's path to be recognized as a type-approved product it needs to be put through an assessment process that will determine its compliance with the acting international instruments. This procedure involves certain testing and inspection is to be adduced by the manufacturer with a classification society of his choice, or a Notified Body (NB) as the controlling party (European Parliaments and Council Directive 96/98/EC).

2.4 Totally enclosed lifeboat

On-board merchant vessels of today, the main mean of evacuation in case of an abandon ship situation is by the use of survival crafts (SOLAS, 2009). Survival crafts include inflatable life rafts, rigid life rafts, partially enclosed lifeboats, totally enclosed lifeboats and free-fall lifeboats (LSA, 2010). SOLAS regulations states that passenger ships shall carry partially or totally enclosed lifeboats and that cargo ship shall carry totally enclosed lifeboats, thus making the totally enclosed lifeboat to one of most common type of lifeboats in the industry today (SOLAS, 2009).

A totally enclosed lifeboat as illustrated in Figure 4, shelters the persons in distress from weather and other external hazards by its rigid superstructure. Other characteristics of a totally enclosed lifeboat are that it shall have rigid watertight enclosures with hatches that can be opened from both sides, which fully encloses the lifeboat.

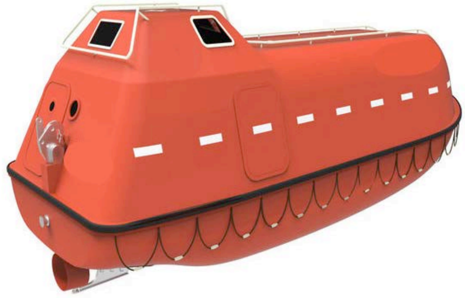


Figure 4: Illustration of a totally enclosed lifeboat. ***Published with permission of Norsafe.***

General requirements for all types of lifeboats are that they shall have a highly visible exterior colour and windows or panels to let in sufficient daylight. It shall be possible to row the boat and the atmospheric air pressure difference between the inside and the outside shall not exceed 20hPa.

The lifeboat shall be equipped with a safety belt for each assigned seating position capable of ensuring that a person of a mass up to 100kg remains in its seat in case of capsizing. If the boat capsizes in fully enclosed condition the water influx shall be without significant leakage and it shall re-right automatically to its normal upright position when partially or fully loaded (LSA, 2010, p. 48).

2.5 Transverse ship stability

Transverse stability is a term that refers to a vessels ability to sustain or return to an upright position after being affected by external forces and the heeling moments that they entail. The forces and weights that have been put on-board the vessel and the size of their resultant needs to be accounted for to be able to ascertain the stability of the vessel (Borg & Åkerblom, 2012).

2.5.1 Acting forces/reference points

There are a number of terms within the science of transverse ship stability that are vital in understanding how a vessel is affected by the forces it is exposed to. Figure 5 illustrates a cross section of a vessel and the acting forces/reference points in upright and heeling condition.

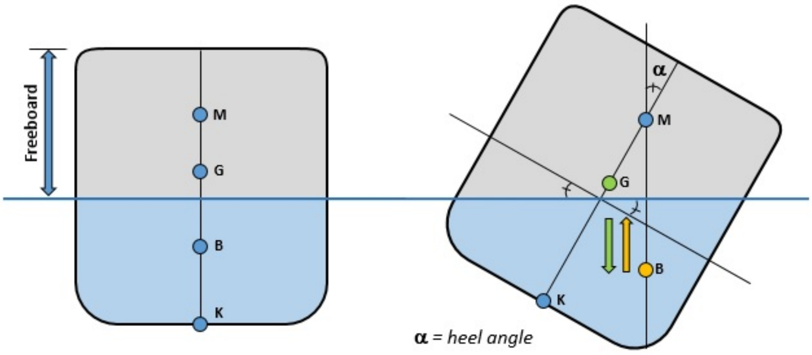


Figure 5: Cross section illustration of a vessel in upright and heeling condition.

Centre of gravity (G) – is the point in which all the mass of a vessel is concentrated and the force of gravity acts vertically downwards towards the earths centre. Its position depends on where the different weights and forces are placed on-board the vessel (Derrett, 2006; Jovanoski & Robinson, 2015).

Centre of buoyancy (B) – as the resulting force *G* immerses a vessel into the water, a reacting force appears acting opposite to *G* creating an equilibrium. The underwater pressure which depends on the draft of the vessel, presses on the hull creating the buoyancy force *B*. Its position depends on the shape of the vessel's hull (Borg & Åkerblom, 2012; Jovanoski & Robinson, 2015).

Metacentre (M) – is the point of intersection between the centre line of a vessel and the vertical line from the centre of buoyancy. Its position depends on the shape of the vessel's hull (Van Dokkum, 2016; Jovanoski & Robinson, 2015).

Base line/keel (K) – is a reference point used for stability calculations. The position of G and M is determined relative to *K*. It is located at the lowest possible point of a vessel, inside the keel plating (Van Dokkum, 2016).

Centreline – is an imaginary line along the longitudinal centre of the vessel, dividing it into two equal sized sides (Van Dokkum, 2016; Derrett, 2006; Bačkalov , et al., 2016).

Heel angle (α) - is the angle between the vessel's centreline and the vertical plane (Jovanoski & Robinson, 2015).

Freeboard – is for the purpose of this study and the lifeboat stability requirements in the LSA code, the distance "measured from the waterline to the lowest opening through which the lifeboat may become flooded," (LSA, 2010, p. 39).

2.5.2 GM

When masses such as cargo, ballast, bunkers and stores are applied onto a vessel, each of their weight and position have a contributing effect on the vessels centre of gravity. Ergo, the position of the centre of gravity is ultimately under the operator's control.

Masses, each with their own individual centre of gravity that are placed low inside the vessel will generate a moment that will lower the vessel's centre of gravity resulting in a greater stability and vice versa. Masses that are placed on either side of the vessel's centreline will also generate a moment resulting in a lateral movement of the centre of gravity towards the same side, causing the vessel to heel. Essentially, the centre of gravity of the vessel will move directly towards the centre of gravity of any weight added (Derrett, 2006).

The vertical position of the centre of gravity *G* relative to the position of the metacentre *M* is directly proportional to the initial stability of the vessel. The distance between them constitutes the metacentric height, *GM*. (Borg & Åkerblom, 2012)

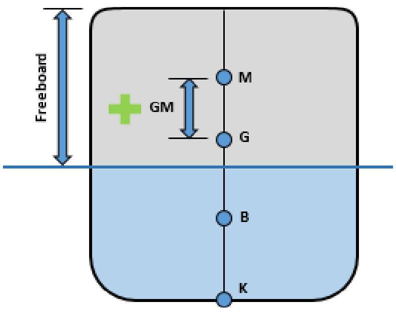


Figure 6: Illustration of a vessel with positive GM

A vessel in stable equilibrium, namely with its centre of gravity *G* located below the metacentre *M*, is a vessel with positive *GM* as shown in Figure 6. On the contrary, a vessel with its centre of gravity *G* located over the metacentre *M* is a vessel in unstable equilibrium, thus a vessel with negative *GM* as shown in Figure 7 (Borg & Åkerblom, 2012).

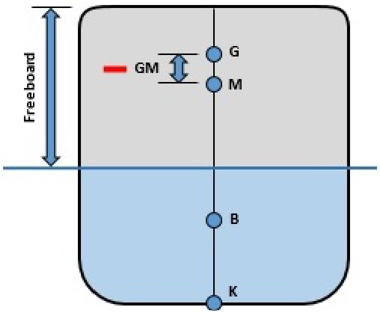


Figure 7: Illustration of a vessel with negative GM

A vessel with negative *GM* will continue to heel to the point where its centre of gravity *G* is once again positioned below the metacentre *M*, which will be once the vessel has capsized and turned upside-down. Consequently, a vessel with positive *GM* will maintain its heel without any increase in angle (Bačkalov, et al., 2016; Borg & Åkerblom, 2012).

2.6 Lifeboat freeboard and stability requirements

SOLAS refers to the “Code” regarding the requirements of life-saving appliances, which is the LSA Code (SOLAS, 2009). Lifeboat freeboard and stability requirements are stated in paragraph 4.4.5, section 4.4 *General requirements for lifeboats*, in chapter IV *Survival craft* in the LSA Code (LSA, 2010).

2.6.1 Stability

All lifeboats shall have a positive GM value and be stable when the boat is filled to 50% of the maximum allowed amount of persons in each assigned seat on the same side of the lifeboats centreline (LSA, 2010, p. 38). The average mass per person is 82,5 kg in accordance in the LSA code (LSA, 2010, p. 37).

2.6.2 Heel angle & freeboard

Under the same loading condition all lifeboats without side openings near the gunwale shall not achieve an angle of heel exceeding 20 degrees. The freeboard distance, measured from the water surface to the lowest opening where water may flood into the lifeboat shall be at least 1,5% of the lifeboats length over all or 100mm, whichever is the greatest (LSA, 2010, pp. 38-39).

2.7 Testing and evaluation of lifeboats

The stability and freeboard requirements for lifeboats are regulated in the LSA Code, and compliance with such requirements is to be determined through certain testing and evaluation (LSA, 2010; European Parliaments and Council Directive 96/98/EC). The Code includes MSC resolution MSC 81.(70), which is MSC’s own recommendations on how testing and evaluation of lifeboats is to be performed (LSA, 2010).

MSC 81.(70) covers the testing procedures for basically all vital elements such as material tests, overload tests, seating strength tests, freeboard tests and stability tests (LSA, 2010, p. 79). However, a testing procedure for evaluating a lifeboats compliance with the LSA code’s specific requirement on the maximum allowed angle of heel is not specified in this resolution.

It is stated in MSC 81.(70) that; “tests for requirements referred to in the LSA Code, which are not included in this Recommendation, should be to the satisfaction of the Administration” (LSA, 2010, p. 79)

The procedure for determining the lifeboats’ GM in this study derives from the ship stability theory established in section 2.5.2, while the procedure for determining the freeboard distances originates from those specified in MSC 81.(70) (LSA, 2010, pp. 141-142).

2.7.1 Procedure for determining angle of heel

For the purpose of determining whether the tested lifeboats meet the LSA Code's requirement on the maximum allowed heel angle, this is determined based on the procedure applied during the test performed by Chalmers in co-operation with the Swedish Administration Transportstyrelsen, which is thereby by definition satisfactory to the Administration (LSA, 2010, p. 79).

To determine the angle of heel the procedure illustrated in Figure 8 and 9 below is used. The blue line refers to the water surface and reference point *A* is determined by where the water level is notching the rubber list. Reference point *B* is placed as close to the edge on the opposite side of the lifeboat as point *A* and the distance *c* is measured.

To ensure that the corner *C* is perpendicular, a lace with a weight attached on one end is fixed in point *B* with the weight hanging into the water. The distance *a* is then measured between the water surface and point *B*. When reference points are decided and distances are measured the angel of heel ∝ can be calculated through basic trigonometry as shown Figure 10.

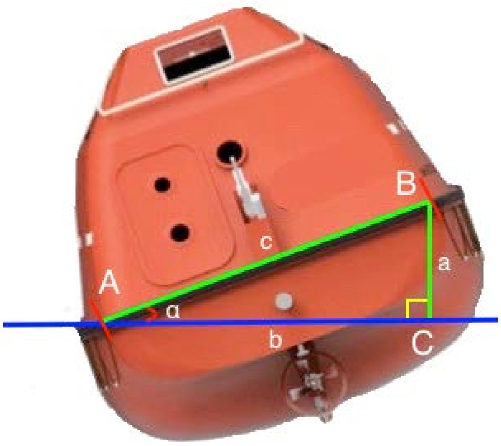


Figure 8: Illustration of how to determine angle of heel. ***Published with permission of Norsafe***

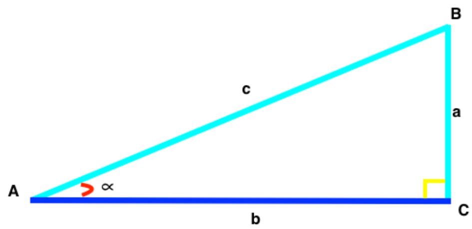


Figure 9: Trigonometric heel figure

$$Sin \propto = \frac{a}{c}$$

$$\propto = sin^{-1}(\frac{a}{c})$$

Figure 10: Angle of heel calculation

2.7.2 Procedure for determining freeboard distance

The freeboard is the vertical distance *b* measured from the water surface up to the lowest opening where water can flow into the lifeboat, which in this case is the lower doorframe of the lifeboat's side door. This means that the distance *b* illustrated in Figure 11 and 12 below is between reference point *A*, the lower doorframe and the reference point *C* that is perpendicular to the water surface (LSA, 2010, pp. 141-142).

The distance *c* is to be manually measured from reference point *B* to point *A*, which is done by measuring the distance adjacent to the lifeboat's structure from the water surface up to point *A*. The determined angle ∝ is the angle of heel and the freeboard distance is calculated through basic trigonometry as shown in Figure 13.

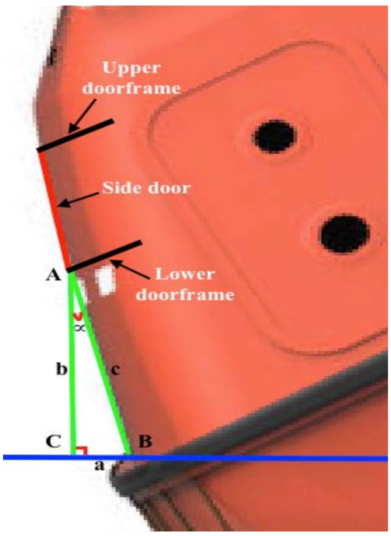


Figure 11: Illustration of how to determine the freeboard distance. ***Published with permission of Norsafe***

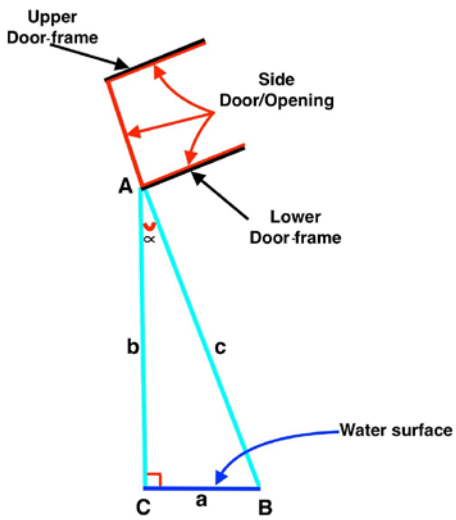


Figure 12: Trigonometric freeboard distance figure

$$Cos \propto = \frac{b}{c}$$

$$b = c \bullet \cos \propto$$

Figure 13: Freeboard distance calculation

3 Method

This chapter covers the chosen research strategies for this study and the chosen methods for collecting secondary data and producing primary data, as well as the methods for analysing the collected data. Furthermore it describes the experiments through a step-by-step explanation of how they were conducted.

3.1 Research strategy

To answer the research question on how the responsibilities are delegated in the classification process and for researching the acting stability requirements applicable to a totally enclosed lifeboat, a documentary research strategy was applied as the strategy method for obtaining the relevant information.

To answer the research question regarding how well the tested lifeboats meet the acting stability requirements, a study design in form of an experimental strategy method comprised of practical field experiments and direct observations was implemented in this study.

3.2 Data collection

The data collection methods used in this study are comprised of the documentary research, as well as direct observations form the practical field experiments. Data gathered by the documentary research was obtained solely through secondary data, which consequently implies that no new research is conducted for the purpose of this study in that respect (Eriksson & Kovalainen, 2008). However, the obtained secondary data in the research on how the responsibilities are delegated in classification process was processed and is presented as primary data based on that no previously research regarding this matter was found and was then considered to be of the new research category (Denscombe, 2016). The data gathered from the experiments in this study have however produced primary data, thus new research was conducted for that purpose of this study (Eriksson & Kovalainen, 2008).

3.2.1 Documentary research

Documentary research refers to research that is conducted by using written texts, visual sources such as videos and pictures as well as digital communication such as social media and websites (Denscombe, 2016). “A documentary research often includes an interpretation of the documents and a search for hidden senses and structures.” (Denscombe, 2016, p. 319), which has been applied to the research regarding the structure of the involved parties and delegation of responsibility in the classification process for life-saving appliances in this study. The advantage of using a documentary research is that it creates opportunities for the authors to select relevant data within the limitations of the study (Denscombe, 2016). The documentary research has been applied to this research by using written texts such as books in form of regulatory instruments together with the laws of EU and official documents produced by the classification societies.

To gather a wide initial range of relevant information for the study the authors divided the documentary research into three main areas. Those were the regulatory instruments comprising the acting regulations and requirements applicable to life-saving appliances, scientific references and other literatures related to the study.

Regulations and requirements such as, SOLAS chapter III *Life-Saving appliances and arrangements* and LSA code chapter IV *survival craft* as well as the official website of the International Maritime Organization (www.imo.org) were used as main sources, together with the maritime equipment directive (MED), the standards of the International Association of Classification Societies (IACS) and resolutions such as MSC.81(70).

Relevant scientific references for a wide initial knowledge were found through search engines such as Summon and Google scholar. Summon is a database available for students via Chalmers library. In order to find relevant literature, keywords were used in the database. These included, lifeboat, lifeboat stability, ship stability, classification society, requirements for lifeboats, freeboard, GM, GZ, SOLAS, LSA-Code, Flag state administration, European commission, Marine Equipment Directive, Recognized Organisation, Notified Body, Maritime Safety Committee and lifeboat test. Furthermore search was done in the references of the scientific references and other relevant literatures were selected with assistance of the staff at Chalmers library Lindholmen.

3.2.2 Experiments

The experimental phase of this study was carried out using an experimental strategy method, utilizing field experiments to perform practical trials and observations. An experiment can be described as a factual based study, designed to analyse specific characteristic and conditions of factors under controlled circumstances (Denscombe, 2016). The purpose of using experiments in this study was to practically examine and test pre-existing theories in the form of regulations and requirements stated in the LSA Code.

Practical field experiments were chosen for this study to conduct the experiments. This created opportunities to identify important key factors, which generated data findings through observations and measurements that allowed authors to determine key factors and present the observed results (Denscombe, 2016).

3.3 Method of analysis

A literature analysis and observations during the experiments are methods chosen for assembling and analysing data, which are presented in the result chapter. The purpose of analysing data is to get a deeper understanding through a thorough analysis of what has been studied. The intention of the analysis is to describe the components, explain how they work and interpret what they mean (Denscombe, 2016; Eriksson & Kovalainen, 2008).

3.3.1 Literature analysis

Literatures obtained through the documentary research were selected primarily from public documents associated with IMO such as convention, codes, directives and resolutions. Stated facts in these documents were selected to associate with the selected topics of this study without questioning their credibility due to that today's merchant shipping industry is built up on these regulations and requirements (IMO, 2016a). Other sources such as scientific references and books were carefully selected and critically reviewed to ensure that the stated facts in this study are to the best of the authors' knowledge as scientific and true as possible. The method for analysing these sources included reading, screening, structuring and credibility assessments (Denscombe, 2016).

Data collected through the documentary research and the literature analysis generated qualitative data, which refers to data in form of words written or spoken and visual pictures with the advantage that this data provides a detailed and deep comprehension within a relatively limited area (Eriksson & Kovalainen, 2008; Denscombe, 2016). Qualitative data is often associated with comprehensive transcriptions of interviews to be able to organise the gathered data into subsections related to a research (Denscombe, 2016). However, it was implemented in this study during collection of information from associated documentary sources such as regulatory instruments, which then were gathered and organized to present the responsibilities of the classification process for life-saving appliances and how it is delegated between the relevant authorities and organisations, as well as the requirements applicable to totally enclosed lifeboats

3.3.2 Observations

The lifeboat stability experiments were performed and analysed using observational research combined with a method called direct observation. The advantages of this method is that observed data can be recorded continuously during the tests through systematic observations by using observation schedules. Others can then repeatedly perform the experiment under similar circumstances with equal results. This method is very effective because it has the advantage to collect a large amount of data in a relative short time (Denscombe, 2016).

Direct observations are often used in psychological and sociological experiments to observe responses on human beings. This study applied this method to observe what actually happens to a lifeboat when weights are added to one side of the lifeboat's centre line. By using systematic observations, most of the major observation differences that could occur when different observers are looking at the same thing may be minimized (Denscombe, 2016). To ensure that the method is being systematic, observation schedules were used. In this study the observation schedules attached in appendix were used to make the analysis of the test results a step-by-step procedure, which should minimize the observation errors caused by different observers (Denscombe, 2016).

During the experiments the authors closely observed different outcomes, which were recorded with pictures taken by a private camera after permission from the responsible person on site. Measurements of relevant distances were taken and noted in the observation schedules, to be able to compare the results with requirements stated in the LSA code. The findings from the stability test performed by representatives from Chalmers and the Swedish Transport Agency are also included in this study and are presented in the results.

Data collected through the experiments generated quantitative data, which refers to data primarily associated with experiments in form of numbers gathered with mathematical principles or as for this study through measurements and observations from the experiment (Denscombe, 2016). The advantages of using quantitative data are that the study conveys a scientific appearance and that the analysis of the results is generated during the tests (Denscombe, 2016).

3.4 The experiments

The method for executing the field experiments was obtained from the test report of the previous lifeboat stability test conducted by the representatives of Chalmers University of Technology and the Swedish Transport Agency 2016-08-25. The summary of the test report is attached in appendix 4 and the findings from the test is included and presented in the result of this study.

This method was slightly adjusted to suit the circumstances of the field experiments and to adapt with the chosen method of this study, while still ensuring that the method remained similar enough so that the results of all the tested lifeboats could be compiled and compared to each other.

The execution of the field experiments is described using a step-by-step explanation in order to simplify the procedure if a similar test is to be performed again.

3.4.1 Selection of lifeboats & locations

The lifeboat used in the test performed by representatives from Chalmers and the Swedish Transport Agency was one of the tested lifeboats in this study. Associated with this study, two additional lifeboats were tested. One lifeboat at the maritime safety centre Remmaren at Chalmers, Göteborg and one at Öckerö Maritime Center, Öckerö.

3.4.2 Step 1: Preparations

In the first step of conducting the experiments the following equipment was prepared:

- **Lifeboat –** *The lifeboat to be tested*
- **Davit –** *The structure to support and launch the lifeboat*
- **Dinghy –** *A smaller boat to take measurements and to observe the lifeboat from the seaside*
- **Weight scale x2 –** *Capable of supporting the entire weight of the lifeboat including added weights*
- **Water bags –** *To simulate the weight of persons, including the water filling arrangement*
- **Measuring tape –** *To measure relevant distances*
- **Lace –** *With a weight attached on one end to create perpendicular angles*
- **Observation schedule –** *Including a camera for documentation*

3.4.3 Step 2: Weight scales

In the second step of conducting the experiments weight scales were attached as illustrated in Figure 14. Water bags were then placed in each assigned seat on the same side of the lifeboats' centreline. The number of bags varied depending on each lifeboat's amount of assigned seating positions, for example if the lifeboat had a total of 22 assigned seating positions, 11 water bags were placed in the seating positions on the same side of the centreline. The weight scales outputs were noted in the observation schedules both when the lifeboat was empty with only its original stores on-board and when the bags were filled with water to simulate the people's total weight in accordance with the LSA Code.

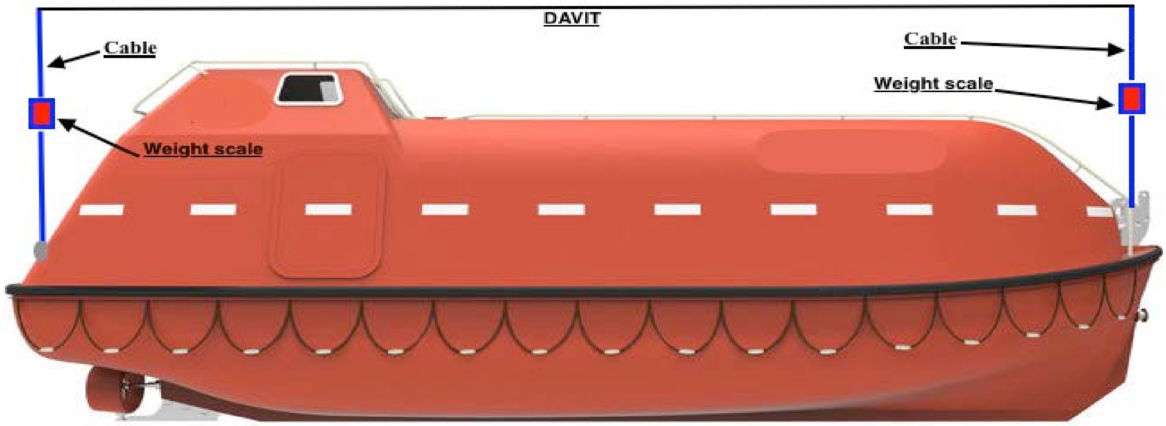


Figure 14: Illustration of how the weight scales were attached. ***Published with permission of Norsafe.***

3.4.4 Step 3: Launching

In the third step of conducting the experiments the lifeboats were slowly and safely launched into the water with the water bags still placed in the assigned seats. The lifeboat was slowly launched into the water until the tension was released from the davit cables. While the lifeboat was launched it was closely observed to ensure that the lifeboat was in a stabile equilibrium and that it had sufficient stability for the test to be continued.

3.4.5 Step 4: GM

The fourth step of conducting the experiments was to determine whether the lifeboats had a positive or negative GM. The theory on how to determine GM is presented in section 2.5.2.

3.4.6 Step 5: Angle of heel

The fifth step of conducting the experiments was to determine the lifeboats' heel angles using reference points, measured distances and a trigonometrical calculation as described in section 2.7.1.

Due to the rounded stern on the lifeboats in test 1 and test 2, the distance *c* had to be longer than the width of the boats. The reference point A had then to be moved further out from the side of the boat until it reached the water surface as shown in Figure 15. In order to do this, and at the same time enabling reference point B to be placed on the opposite side to ensure a perpendicular angle in reference point C between the water surface and distance *a*, the lifeboats stern was extended using a horizontally placed steal pipe on the aft deck.

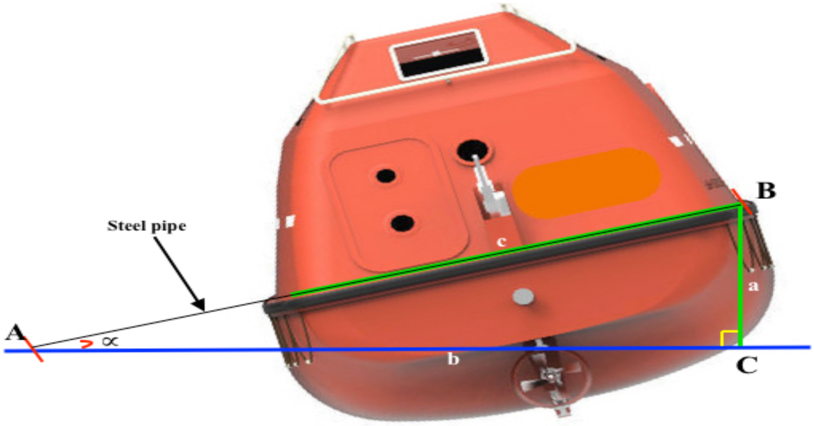


Figure 15: Illustration of the extended steel pipe solution. ***Published with permission of Norsafe***

3.4.7 Step 6: Freeboard

In the sixth step of conducting the experiments the lifeboats' freeboard distances were determined using the lifeboats' heel angles generated by step 5 together with reference points, measured distances and trigonometrical calculation as described in section 2.7.2.

4 Results

The results of this study are divided into two main sections. Firstly, the part regarding the experiment and the results on how well the tested lifeboats meet the stability requirements in the LSA Code, and secondly, the part regarding the results on how the responsibilities are delegated in classification process.

4.1 Experiments

The results from the experiments on the lifeboats' compliance with the requirements in the LSA Code are presented in four parts. Those are Test 1, Test 2, Test 3 and a compilation. Each include the most relevant results from the experiments, and additional specific information and data from each test is to be found in the observation schedules attached in appendix.

The presented results from test 3 come from the experiment conducted by the representatives of Chalmers University of Technology and the Swedish Transport Agency. Additional information and data is to be found in the summary of the original test report attached in appendix.

4.1.1 Test 1

Lifeboat: Totally enclosed lifeboat, built 1984
Dimensions (L x W): 8,0m x 3,0m
Capacity: 50 Persons
Location: Öckerö Maritime Centre
Date, duration: 2016-12-20, 08:00-17:00
Weather: +6°C, S 3m/s, very calm sea
Initial heel: 0°

Figure 16: Lifeboat test 1

4.1.1.1 Weights

Implementation of the experimental method described in step 2 gave rise to the following results presented in the weight results Table 1. Due to the lifeboat capacity of 50 persons, 25 water bags each with the weight of 82,5kg was placed in each assigned seat on the same side of the centreline. This resulted in a total mass of 2063kg to be added. Based on weight scale outputs and by adding the forward and aft weight scale values, the total mass of the lifeboat without any added weight was 3660kg. The total mass with added weight was 5720kg, which resulted in an actual added mass of 2060kg, a difference of -3kg.

Table 1: Weight results in Kg, test 1

Weight per person	82,5
Person capacity/2	25
Weight to add	**2063**
Without add. Weight	3660
With added weight	5720
Actual weight added	**2060**
Diff.	**-3**

4.1.1.2 GM

Determination of each lifeboat's GM was performed in accordance with step 3 and 4 in the experimental method, chapter 3. In this procedure, the following questions were asked and answered to determine whether the lifeboat's GM was positive or negative:

- *Does the lifeboat heel over during launch?* **YES**
- *Does the heeling moment stop at a certain heel angle?* ***YES***
- *Is the lifeboat in stable equilibrium?* ***YES***
- *Is the lifeboats´ GM positive or negative?* ***POSITIVE***

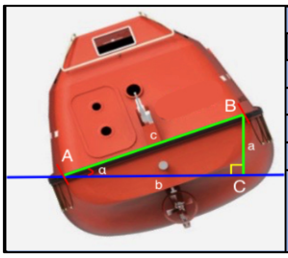
This test reports a positive GM value, which means that the lifeboat complies with the GM requirement of the LSA-Code and that its stability was sufficient for the test to proceed. (LSA, 2010, p. 37).

4.1.1.3 Angle of heel

Implementation of the experimental method described in step 5 gave rise to the following results presented in the angle of heel result Table 2. When the lifeboat was launched the specified reference points and distances were acquired while the external conditions were as calm as possible and the lifeboat was as stable as possible. The distance *c* between point A and B was measured to 4265mm and the distance *a* between point B and C was measured to 1215mm. With these values the angle of heel α was calculated to an angle of 16,6°.

This test reports an angle of heel of 16,6°, which means that the lifeboat complies with the requirement of the LSA-Code within the range of maximum 20° (LSA, 2010, pp. 38-39).

Table 2: Angle of heel results, test 1



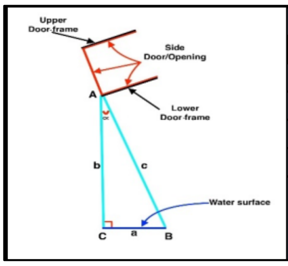
Distance & angle values				Calculation
Distances (mm)		Angles (°)		
a	1215	α	16,6	$Sin\propto = a/c$
b	N/A	B	N/A	$\propto = sin\text{-}1\,(a/c)$
c	4265	C	90	
Comments				

4.1.1.4 Freeboard distance

Implementation of the experimental method described in step 6 gave rise to the following results presented in the freeboard distance result Table 3. When the lifeboat was launched the specified reference points and distances were acquired while the external conditions were as calm as possible and the lifeboat was as stable as possible. The distance *c* between point A and B was measured to 430mm, and together with the heel angle α 16,6° the vertical distance *b* from the water surface up to the lower doorframe was calculated to 412mm.

This test reports a freeboard distance of 412mm, which means that the lifeboat complies with the requirements of the LSA-Code within the range of minimum 100mm or minimum 1,5 % of the lifeboat's length (LSA, 2010, pp. 38-39).

Table 3: Freeboard distance results, test 1



Distance & angle values				Calculation
Distances (mm)		Angles (°)		
a	N/A	α	16,6	$Cos\alpha = b/c$
b	412	B	N/A	$b = c \bullet \cos\alpha$
c	430	C	90	
Comments				

4.1.2 Test 2

Lifeboat: Totally enclosed lifeboat, built 1985
Dimensions (L x W): 7,4m x 2,7m
Capacity: 35 Persons
Location: Chalmers Safety Centre
Date, duration: 2016-12-15, 09:00-17:00
Weather: 0°C, S 3-4m/s, calm sea
Initial heel: 0°

Figure 17: Lifeboat test 2

4.1.2.1 Weights

The lifeboat capacity of 35 persons, gave that 18 water bags each with the weight of 82,5kg was placed in each assigned seat on the same side of the centreline. This resulted in a total mass of 1485kg to be added. Based on weight scale outputs and by adding the forward and aft weight scale values, the total mass of the lifeboat without any added weight was 4020kg. The total mass with added weight was 5510kg, which resulted in an actual added mass of 1490kg, a difference of +5kg as shown in Table 4.

Table 4: Weight results in Kg, test 2

Weight per person	82,5
Person capacity/2	18
Weight to add	**1485**
Without add. Weight	4020
With added weight	5510
Actual weight added	**1490**
Diff.	**5**

4.1.2.2 GM

The following questions were asked and answered to determine whether the lifeboat's GM was positive or negative:

- *Does the lifeboat heel over during launch?* **YES**
- *Does the heeling moment stop at a certain heel angle?* ***YES***
- *Is the lifeboat in stable equilibrium?* ***YES***
- *Is the lifeboats´ GM positive or negative?* ***POSITIVE***

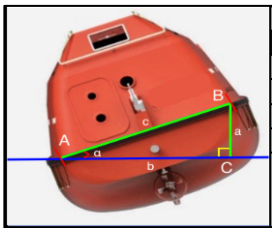
This test reports a positive GM value, which means that the lifeboat complies with the GM requirement of the LSA-Code and that its stability was sufficient for the test to proceed (LSA, 2010, p. 37).

4.1.2.3 Angle of heel

When the lifeboat was launched the specified reference points and distances were acquired while the external conditions were as calm as possible and the lifeboat was as stable as possible. The distance *c* between point A and B was measured to 4630mm and the distance *a* between point B and C was measured to 1230mm. With these values the angle of heel α was calculated to an angle of 15,4° as shown in Table 5.

This test reports an angle of heel of 15,4°, which means that the lifeboat complies with the requirement of the LSA-Code within the range of maximum 20° (LSA, 2010, pp. 38-39).

Table 5: Angle of heel results, test 2



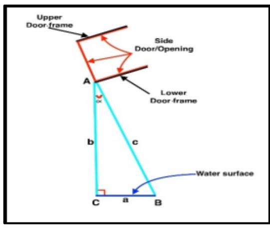
Distance & angle values				Calculation
Distances (mm)		Angles (°)		
a	1230	α	15,4	$Sin\propto = a/c$
b	N/A	B	N/A	$\propto = sin\text{-}1\ (a/c)$
c	4630	C	90	
Comments				

4.1.2.4 Freeboard distance

When the lifeboat was launched the specified reference points and distances were acquired while the external conditions were as calm as possible and the lifeboat was as stable as possible. The distance *c* between point A and B was measured to 470mm, and together with the heel angle α 15,4° the vertical distance *b* from the water surface up to the lower doorframe was calculated to 453mm as shown in Table 6.

This test reports a freeboard distance of 453mm, which means that the lifeboat complies with the requirements of the LSA-Code within the range of minimum 100mm or minimum 1,5 % of the lifeboat's length (LSA, 2010, pp. 38-39).

Table 6: Freeboard distance results, test 2



Distance & angle values				Calculation
Distances (mm)		Angles (°)		
a	N/A	α	15,4	$Cos\alpha = b/c$
b	453	B	N/A	$b = c \cdot \cos\alpha$
c	470	C	90	
Comments				

4.1.3 Test 3

Lifeboat: Totally enclosed lifeboat, built 2014
Dimensions (L x W): 5,3m x 2,3m
Capacity: 22 Persons
Location: Chalmers Safety Centre
Date, duration: 2016-08-25, 13:00-14:20
Weather: +26°C, S 4m/s, calm sea
Initial heel: 0°

Figure 18: Lifeboat test 3

4.1.3.1 Weights

The lifeboat capacity of 22 persons, gave that 11 water bags each with the weight of 82,5kg was placed in each assigned seat on the same side of the centreline. This resulted in a total mass of 908kg to be added. Based on weight scale outputs and by adding the forward and aft weight scale values, the total mass of the lifeboat without any added weight was 2250kg. The total mass with added weight was 3160kg, which resulted in an actual added mass of 910kg, a difference of +2kg as shown in Table 7.

Table 7: Weight results in Kg, test 3

Weight per person	82,5
Person capacity/2	11
Weight to add	**908**
Without add. Weight	2250
With added weight	3160
Actual weight added	**910**
Diff.	**2**

4.1.3.2 GM

The following questions were asked and answered to determine whether the lifeboat's GM was positive or negative:

- *Does the lifeboat heel over during launch?* **YES**
- *Does the heeling moment stop at a certain heel angle?* ***YES***
- *Is the lifeboat in stable equilibrium?* ***YES***
- *Is the lifeboats´ GM positive or negative?* ***POSITIVE***

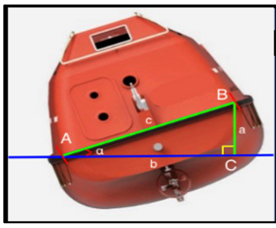
This test reports a positive GM value, which means that the lifeboat complies with the GM requirement of the LSA-Code and that its stability was sufficient for the test to proceed (LSA, 2010, p. 37).

4.1.3.3 Angle of heel

When the lifeboat was launched the specified reference points and distances were acquired while the external conditions were as calm as possible and the lifeboat was as stable as possible. The distance *c* between point A and B was measured to 1900mm and the distance *a* between point B and C was measured to 1310mm. With these values the angle of heel α was calculated to an angle of 43,6° as shown in Table 8.

This test reports an angle of heel of 43,6°, which means that the lifeboat does not comply with the requirement of the LSA-Code within the range of maximum 20° (LSA, 2010, pp. 38-39).

Table 8: Angle of heel results, test 3



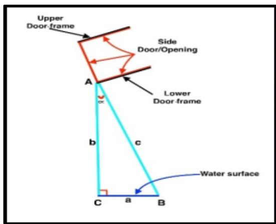
Distance & angle values				Calculation
Distances (mm)		Angles (°)		
a	1310	α	43,6	$Sin\alpha = a/c$
b	N/A	B	N/A	$\alpha = sin\text{-}1\ (a/c)$
c	1900	C	90	
Comments				

4.1.3.4 Freeboard distance

When the lifeboat was launched the specified reference points and distances were acquired while the external conditions were as calm as possible and the lifeboat was as stable as possible. The distance *c* between point A and B was measured to 120mm, and together with the heel angle α 43,6° the vertical distance *b* from the water surface up to the lower doorframe was calculated to -87mm as shown in Table 9.

This test reports a freeboard distance of -87mm, which means that the lifeboat does not comply with the requirements of the LSA-Code within the range of minimum 100mm or minimum 1,5 % of the lifeboat's length (LSA, 2010, pp. 38-39).

Table 9: Freeboard distance result, test 3



Distance & angle values				Calculation
Distances (mm)		Angles (°)		
a	N/A	α	43,6	$Cos\alpha = b/c$
b	-87	B	N/A	$b = c \bullet \cos\alpha$
c	120	C	90	
Comments				

4.1.4 Compilation of tested lifeboats and test results

Table 10 compiles the results of the tested lifeboats and then compares them to the LSA Code requirements. If the test result comply with or lie within the margin of compliance with the Code it is indicated green. If not, it is indicated red. The horizontal headlines separately show each tested lifeboat and the vertical headlines separately show each requirement, within the brackets are the LSA Code requirements (LSA, 2010, pp. 38-39).

Table 10: Compilation of tested lifeboats and test results

Requirements *(LSA requirements)*	Test 1 50 Persons	Test 2 35 Persons	Test 3 22 Persons
GM *(Positive)*	Positive	Positive	Positive
Angle of heel *(≤ 20°)*	16,6°	15,4°	43,6°
Freeboard *(≥ 100mm)*	412mm	453mm	-87mm
	Appendix 1	*Appendix 2*	*Appendix 3 (Chalmers)*

Analysis of the table shows that the lifeboats in test 1 and test 2 fully comply with the LSA-Code requirements while the lifeboat in test 3 complies the requirement for having positive GM, but does not comply with the requirements regarding angle of heel and freeboard distance.

4.2 The classification process

For the purpose of examining the parties that carry responsibilities for ensuring that life-saving appliances are fulfilling the requirements and comply with the international instruments that apply to them, and of investigating how those responsibilities are delegated between those involved in the classification process, this section will cover the findings of that research.

4.2.1 How the responsibilities are delegated

The SOLAS convention and the LSA code, set by the IMO, are the regulatory instruments for life-saving appliances (IMO, 2016d). In addition, IMO have produced a number of recommendations on how compliance with these regulations and requirements can be evaluated in forms of resolutions and testing standards. All these instruments, together with additional relevant testing standards brought forth by other acknowledged NBs and ROs, have been gathered and implemented by EC into the European Union’s legal system through MED (European Parliaments and Council Directive 96/98/EC).

The process for classifying and certifying life-saving appliances implies a substantial amount of tests and inspections. As shown in the Figure 19, the process can be pictured as two separate processes. The tests and inspections that are performed during manufacturing, and those performed during on-board installation.

The process during the manufacturing of a product results in the product obtaining a type-approval per ECs Marine Equipment Directive, and the process during on-board installation results in the product being classified for on-board use (European Parliaments and Council Directive 96/98/EC; IACS, 2011).

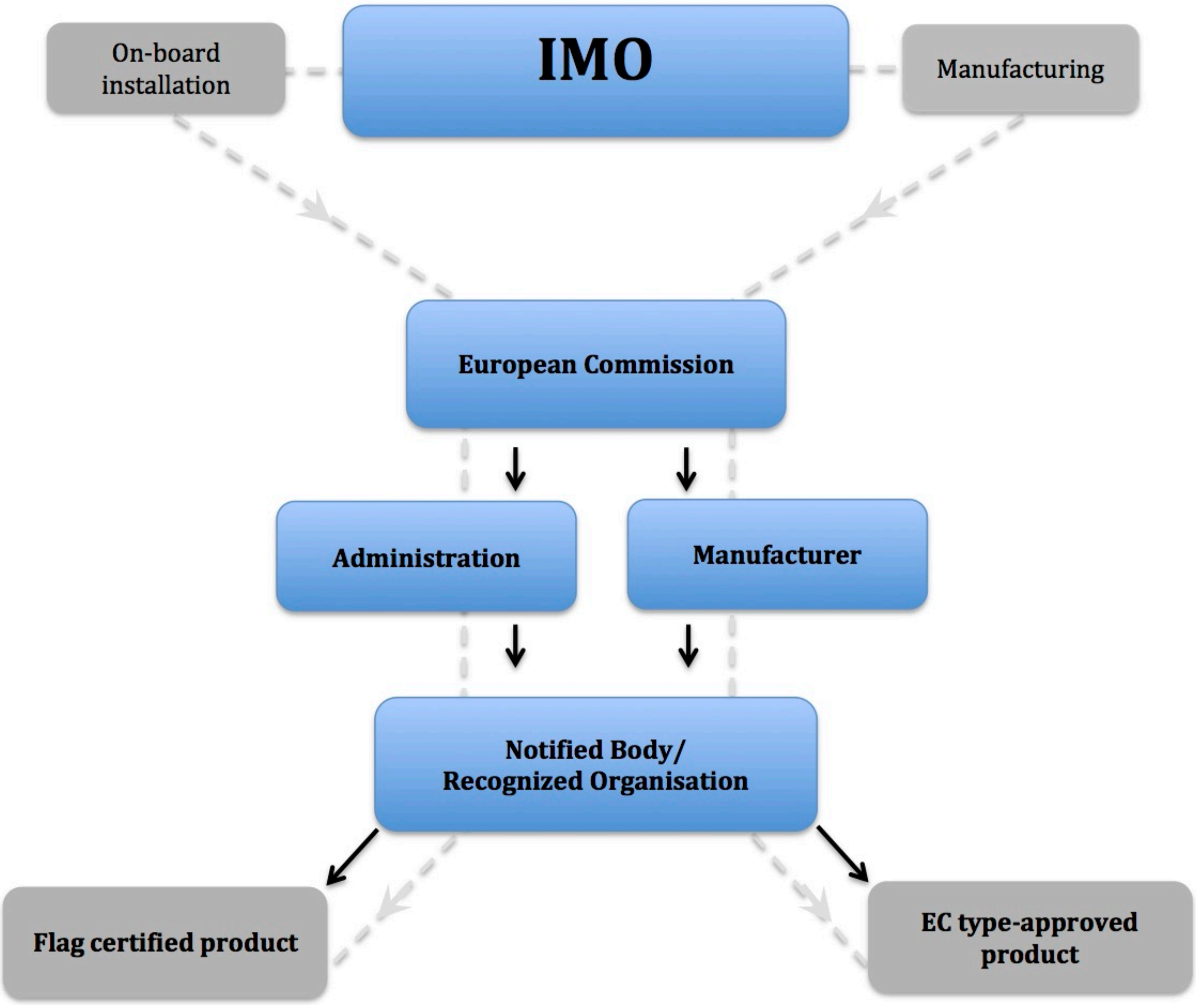


Figure 19: Delegation of responsibilities in the classification process

4.2.1.1 Process during manufacturing

As illustrated in Figure 19, the EC imposes responsibilities onto the manufacturer during the manufacturing process according to the MED directive. The conformity assessment procedure presented in section 2.3.4.1 is to be adduced by the manufacturer and performed by a NB appointed by the manufacturer (European Parliaments and Council Directive 96/98/EC).

According to MED, the surveillance of the conformity assessment procedure during manufacturing of life-saving appliances is the NBs responsibility. (European Parliaments and Council Directive 96/98/EC).

4.2.1.2 Classification during on-board installation

The regulatory instruments of IMO and consequently, the laws of EU, impose responsibilities onto the Administration for ensuring that the life-saving appliances comply with the relevant regulations and requirements (European Parliaments and Council Directive 96/98/EC; SOLAS, 2009; LSA, 2010).

In case the Administration delegate the task of testing and evaluating the equipment to a RO, the responsibility for the equipment complying with the regulatory instruments when it has undergone and passed the necessary tests, is transferred to the RO. The International Association of Classification Societies states that; “the RO is responsible and accountable for the work it carries out on the behalf of the Administration” (IACS, 2011).

5 Discussion

In this chapter the results of this study and the methods used for achieving those results together with their respective implications and limitations will be discussed in relation with the theoretical chapter and previous research. The study has shown that one of the tested lifeboats did not comply with all the requirements despite being approved and classified. This matter will be discussed with regards to the classification process and all the tests and evaluations that it implies. Furthermore, the validity, reliability and generalizability of the research as well as the ethical aspects and their implications on the study will also be discussed.

5.1 Discussion of results

The result discussion is divided into two main parts. The first part covers the discussion of the results on how well the lifeboats meet the requirements of the LSA code, whereas the second part covers the discussion of the results on how the responsibilities are delegated between the parties involved in the classification process.

As shown in Table 10, the results of the lifeboats in test 1 and 2 have noticeable similarities regarding all three stability requirements, while the results of the lifeboat in test 3 regarding heel angle and freeboard distance deviate from the other two lifeboats significantly.

Besides than merely establishing that this is the case, this study cannot be the judge of any specific cause for this. The cause, and any possible contributing factors for this to be, cannot in anyway be deduced from the findings of the study which means that this is something that can only be speculated on. Some fundamental and apparent differences between the tested lifeboats that could have a contributing effect on the lifeboats' deviating performances during the tests are simply the shape configurations and sizes of the lifeboats, which do have an effect on their individual stability characteristics.

Other possible contributing factors could be the sheer condition and age of the lifeboats, how generously they have been operated over the years and whether or not they have sustained any structural damage impossible to notice visually but still great enough to affect the lifeboats' performances. These factors though, should not have even the slightest effect on the lifeboat in test 3 which did not pass the test, based on the fact that it was commissioned straight out of the factory and was only 2-3 years old. In contrast to the significantly older lifeboats in test 1 and 2, this lifeboat was basically new and sparingly used. In this case, the inadequate performance of the lifeboat could rather point to irregularities during manufacturing, and consequently, during the classification process since the lifeboat was in fact classified and approved.

5.1.1 Possible sources of error during the experiments

Certain implications and limitations arises depending on how the theory is applied to achieve certain results, how experiments are carried out with regards to the accuracy of measurements and how the findings are presented (Denscombe, 2016; Eriksson & Kovalainen, 2008). With this in mind, the results are discussed and critically reviewed.

When a stability test is performed on a vessel there are a number of uncertain parameters, or sources of error, which can be hard to ascertain and what impact they could have on the test's result. Wherever measurements are taken, the output values' accuracy and their impact on the result is directly related to the accuracy of measurements themselves. The accuracy when weighing of weights and measuring distances and angles while the vessel is immersed into the water could decrease as a consequence of that the vessel seldom remains stationary at the induced heel angle due to the environment in which the test is performed. External conditions such as wind and sea state can have an impact on the accuracy of the measurements taken. The accuracy of any measuring instruments used during the procedure and whether or not they have been properly calibrated could have an impact on the results, as well as the proficiency of the operators when the measurements are being taken.

For the purpose of the four main elements; weights, GM, angle of heel and freeboard distance that have been determined, the possible sources of error which may have had an impact on those measurements will be discussed in relation with the theoretical chapter and the presented results.

5.1.1.1 Determining weights

All weights placed on-board a vessel affects the vessels stability as described in section 2.5.1. Depending on where the weight is positioned, or more importantly where its centre of gravity is located, it will affect the lifeboat's stability accordingly. The location of the centre of gravity of each water bag that was placed inside the lifeboats to simulate persons during the experiments of this study was not definitively determined. This due to the sheer complexity of physically acquiring the centre of gravity of a water mass inside an unsymmetrical and constantly shape-shifting bag.

If human beings would have been used during the tests, the centre of gravity of each human being in seated position, would probably have been located near the sacral region of the beings in every assigned seat. Consequently, the centre of gravity of the water bags may have deviated from the location of where the centre of gravity of a human body would be. This may have been of significance for the extent of the heeling moments, which in turn would have had an effect on the lifeboats' GM and consequently resulted in a larger or smaller heel angle and freeboard distance.

Any lack of compulsory equipment and stores located in the lifeboats that are used under normal operating conditions such as fuel and survival packs, was not taken into account in this study. However if it were, it could possibly have contributed to an increase of the GM distance and improved the stability as the equipment and stores normally are located in the lower part of a lifeboat. Although, due to the difficulties of placing all the necessary water bags in the predetermined assigned seats, some bags where placed on the floor, which most likely resulted in the centre of gravity of the lifeboats being lowered and an increase of the GM distance. This factor was assumed to somewhat counterbalance the effect occurring from any lack of compulsory equipment and stores.

The outputs from the weight scales with added weight, which are presented separately in the observation schedule for each test in appendix, show that there is a weight difference between the forward hook and the aft hook. This difference indicated that the weights were not evenly distributed longitudinally in the lifeboat, which in turn was revealed as the lifeboats were slightly trimmed by the stern or by the head as they were launched into the water. This was not taken into account as it was deemed not to have any significant influence on the results. The possible influence that it although could have on the results of such tests performed in this study is however addressed in a research on sources of error associated with heeling tests of ships, which acknowledges the fact that it may have an influence on the outcome but that it is probably small (Sjöling, 1995).

Analysis of the weights sections in the result chapter reveals that the largest difference between the calculated weight to be added and the actual added weight was 5kg. Its influence on the results was not taken into account because a maximum difference of 5 kg was considered to be relatively small and thereof of little significance for the result of this study, as well as that the weight scales were calibrated to round off to the nearest ten kilograms.

5.1.1.2 Determining GM

The determination of whether the GM of the lifeboats was positive or negative in this study was based on the assumption that if the lifeboat remained stationary at the induced heel angle, the lifeboat was in a stable equilibrium and therefore had a positive GM. This assumption is well-founded on the bases of the theory behind transverse ship stability as described in section 2.5.2, and is a good enough method for determining whether or not a vessel has a positive GM, but it is based solely on observing the vessel's behaviour during the test and not on mathematical calculations.

A vessel with an induced heel in an unstable equilibrium, residing in an environment in the absence of any external forces such as wind or waves, could very well appear to have a positive GM. It could remain stationary at a certain heel angle as long as it is not affected by any form of motion. Once the vessel is affected by an external force, which will generate an additional heeling moment that will be applied onto the vessel, it can continue to heel over and capsize, and return to a stable equilibrium and a positive GM.
Thus, it is only once a lifeboat has been exposed to an external force and still remains or returns to its initial induced heeling position that is can be considered to have a positive GM. This method is of course followed by the obvious risks of lowering a lifeboat into the water with an

induced heel and an unknown stability condition, and to properly determine if the GM is positive the tension on the davit cables needs to be fully released.

An alternative, and possibly safer method for determining GM could have been to do so through a calculation of a specific GM value. However, that method implies a number of additional variables needed, for which the gain would not have outweighed the effort for the purposes of this study. Furthermore, since the launch of the lifeboat was performed with great caution, and based on the fact the LSA code does not state any specific value in its requirement for GM, only that it shall be positive, the observation method was deemed sufficient and safe enough for the purposes of this study.

5.1.1.3 Determining heel angles

The method chosen for determining the heel angle of the lifeboats was based on the application of a trigonometrical model on which a trigonometrical calculation was performed. This method implied a number of implications which may have had an impact on the result. The trigonometrical model was set-up outside the stern of the lifeboats, and measuring of all distances were done from the outside using a dinghy. Due to the lifeboats' heeled condition, the possibility for the observers to take accurate measurements while residing on the lifeboats themselves was limited and would have been difficult. Working from the seaside enabled the authors to take measurements without affecting the lifeboat, as well as enabling the authors to observe the trigonometrical model from a correct perspective. This to minimize as many sources of error as possible that could be caused by the observers.

A dinghy was not the most stable working platform to take measurements from. It was intermittently affected by external forces such as wind and waves. The swell from other passing boats also affected the dinghy which in turn complicated the observers' ability to take accurate measurements. The wind, waves and swell from other passing boats likewise caused the lifeboat itself into a gentle rocking motion which also complicated the measurements.

An alternative method for determining the heel angle could have been to utilize a protractor together with a lace on which a weight would have been attached, to indicate the heel angle on the protractor. This would possibly have enabled a more accurate indication of the angle of heel, due to that the values would not have been related to a water mass under constant movement, but only by the external forces acting on the lifeboats themselves.

However, this method would imply the weight of an additional person on-board the lifeboats which probably would have affect the outcome. Also, the difficulty and the risks of residing inside the lifeboat during the procedure would not have been beneficial, thus, the method of taking the measurements from outside the lifeboats was chosen as the best alternative.

The hands-on measurements of the distances in the trigonometrical model were taken manually. This of course implies certain sources of error which also may have affected the result. The difficulties of measuring and determining the distance *c* were firstly to adjust the length of the steel pipe representing distance *c* so that it was of sufficient length to reach the water surface to create reference point A, and to join the sides of the triangle as shown in Figure 15.

Secondly, the determination of reference points' A and C location proved to be difficult due to the sea state, as the water surface was constantly in motion. The way to perform this method and its measurements is difficult to practically improve. However, the accuracy of the measurements could be improved by eliminating the disturbance from waves during measuring. This could be achieved by performing the experiment in a more laboratorial setting, were the effects of external forces are minimal.

Despite this, we estimate that the measurements accuracy of each distance lie within a margin of ± 30 mm. Based on the values from test 1, the following example shows the maximum impact on the result when adding and subtracting 30 mm from the distances *a* and *c*. Figure 20 illustrates a trigonometrical figure to clarify the distances in question.

> If 30mm is added to the value of distance *a*, and 30mm is subtracted from the distance *c*, this will result in an increase of the heel angle of 0,5°. When added to the angle of heel of 16,6° presented in the result, this would have resulted in an angle of 17,1° which is still inside the margins for compliance with the requirements when the maximum possible error is accounted for.

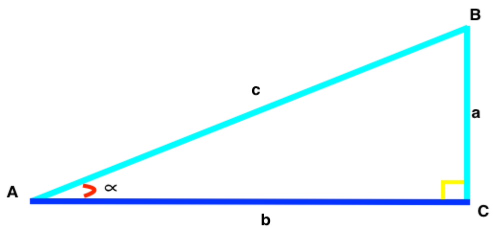


Figure 20: Trigonometrical heel figure

5.1.1.4 Determining freeboard distances

When determining the lifeboats' freeboard distances, similar complications arose as during the determination of the heel angle. Both the lifeboat and the dinghy were affected by the same external forces such as wind, waves and swell from other passing boats, which in turn could have had a similar effect on the measurements of the freeboard distances.

Another factor which could have affected the result of the freeboard distance measurement was the trim of the lifeboats. Since the parameters of the lifeboats' trim were not accounted for, the freeboard distance was measured from the point on the lifeboats closest to the water surface were water could enter into the lifeboats. This point was determined solely as an estimation through observation and might due to that not have been entirely accurate, but close enough for ensuring a reliable result.

The heel angle value generated through the heel angle calculation played a vital part in the step for determining the freeboard distance. As it is used in the following trigonometrical calculation for the freeboard distance, the result of that calculation is directly related to the accuracy of the heel angle value. If the heel angle value is off to a certain degree, the freeboard distance value will be affected. As discussed in the previous section, we estimate that the measurement accuracy of the distance lies within a margin of ± 30 mm. Based on the values from test 1, together with an additional 0,5° heel angle error generated in the previous example, the following example shows the maximum impact on the result when subtracting 30 mm from the distance *c*. Figure 21 illustrates a trigonometrical figure to clarify the distance in question.

> If 30mm is subtracted to the value of distance *c*, this would result in a decrease of the freeboard distance *b* by 30 mm. When subtracted from the freeboard distance of 412 mm presented in the result, this would have resulted in a freeboard distance of 382 mm which is still inside the margins for compliance with the requirements when the maximum possible error is accounted for.

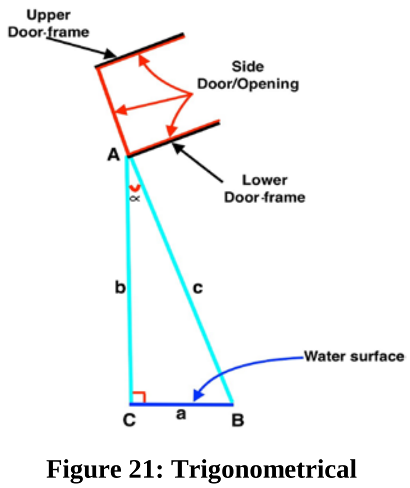


Figure 21: Trigonometrical freeboard distance figure

It is stated in the LSA code that the freeboard distance shall be of minimum 100 mm or at least 1,5% of the lifeboat's total length, whichever is the greater (LSA, 2010). If the freeboard distance is to be great enough, and the requirement of 1,5% is to be the applicable, the lifeboats' length would need to exceed 6,6 m. For this to be an applicable limitation close to the freeboard distance of 412 mm presented in the results of test 1, a total lifeboat length of approximately 27 meters would have been necessary, which is was not. Due to this, the study solely applied the minimum 100 mm requirement of the freeboard distance.

5.1.2 The classification process

The task of creating a clear picture of how the responsibilities are delegated based on the regulatory instruments was very challenging due to the complexity of the process. As established in the results of this study, the responsibilities for ensuring that life-saving appliances that have been tested and classified actually comply with the regulatory instruments that apply to them, are delegated between the different parties involved in the classification process. According to the regulatory bodies and their related instruments, the delegation of responsibility can be done so through a certain flow as illustrated in Figure 19 in the results.

When trying to correctly ascertain the situation of how responsibilities are delegated, it was vital that all the involved parties and more importantly, their roles and responsibilities were accounted for in correct way. The configuration of the key players in the process, based on a subordinated perspective, was determined and founded solely on the regulations of IMO and laws of EU, together with statements of IACS as the official voice of the classification societies, due to the complete lack of any previous, more academic sources such as peer-reviewed scientific articles. Such sources could imply a more profound scientific touch, but it is however our opinion that this does not compromise the credibility of the research as the industry and those involved in the classification process operate according to the regulations established by the industry rather than placing any value in scientific articles in this respect.

As established in the results, the assessment of regulation compliance in the classification process is progressed through two different phases succeeding one another. This, and all the testing that is embedded in the two different phases, reflects the substantial amount of tests and inspections the entire classification process implies for assessing the life-saving appliances compliance with the acting regulations.

Whilst the substantial collection of regulated tests and evaluations on the equipment's path to finally becoming installed and operated on-board, is obviously proven to be a sufficient tool for ensuring that life-saving appliances comply with the regulations, one lifeboat still managed to find its way through this process despite not complying with the relevant regulation according to the results of this study.

The scope of this study was not to determine the exact cause for how this could occur, or if and in that case where any irregularities might reside in this process. The sheer complexity of the process with regards to its many different regulatory instruments and the many different parties involved could be of significance for any obstacles being created in the process. Any varying technical knowledge and experience of the controlling parties, the ROs and NB, could also be of significance and have an effect on the level of reliability of the assessments performed in the classification process.

5.2 Discussion of method

The methods used in this study were chosen to in the best possible way adapt to the purpose of the research within its limitations in order to produce credible answers to the research questions. An experimental strategy method was the method used for answering the question regarding how well the tested lifeboats meet the stability requirements of the LSA Code. A documentary research method was chosen for obtaining the information regarding stability requirements applicable to lifeboats, as well as for producing primary data for answering the research question of how the responsibilities of the classification process for life-saving appliances are delegated between the relevant authorities and organisations.

These methods were chosen to present a research as good, credible and interesting as possible. However, these methods initially have some theoretical advantages and disadvantages depending on in which context they are used as well as how they are implemented (Denscombe, 2016). When the chosen research strategies, data collection methods and the analysis methods were implemented into this specific study, certain additional limitations arose which are presented and discussed in this section. Furthermore, the methods chosen for presenting data together with an alternative choice of method are discussed.

5.2.1 Experiment method

The lifeboats that were selected for the experiments in this study were chosen as they were located in the vicinity of Gothenburg and thereby easily accessible, due to time and geographical limitations.

Whereas the purpose of using experiments in this study was to practically examine and test pre-existing theories in the form of regulations and requirements stated in the LSA Code, the choice of using an experimental strategy method to produce primary data was made over any other strategy because they were found not possible to apply onto this study.

Practical field experiments were chosen over experiments in an orchestrated laboratory environment because of the available lifeboats' locations and the logistical difficulties of transporting them to a laboratory setting, for example a large indoor saltwater pool. The advantages of performing the experiments in an orchestrated laboratory environment could probably have resulted in more accurate results because of that the sources of error, such as impacts from the external conditions discussed in section 5.1.1 – 5.1.1.4, would have been minimal. However, the presented result in this study is considered not to be of significant difference compared to a test conducted in such orchestrated laboratory environment as the field experiments were carried out in as calm waters as possible.

The main advantage of an experimental strategy method is that it is considered to be the most credible and scientific approach within the area of experimental research and the outcome from such an experiment produces impartial and objective results (Denscombe, 2016). We consider this to be of great importance to this study, as such a serious shortcoming that a seemingly approved and classified lifeboat was not fulfilling all the LSA Code requirements.

The main disadvantages with an experimental strategy method are often argued to be that if the experiment is conducted in an artificial environment such as an orchestrated laboratory environment, the results will be negatively influenced and not as credible due the operators' ability to control relevant variables that normally would randomly reside outside an artificial environment (Denscombe, 2016). These disadvantages are however not an issue for the experiments in this study as they were carried out in the field and in the presence of such variables. The limitations on the outcome for the experiments in this study was rather the small selection of tested lifeboats. They could have been more randomly selected with regards to size, manufacturer and age if the amount of the lifeboats to be tested would have been larger. This to present a wider scope of results, which probably also could be generalized in relation to a more comprehensive presented result.

The implementation of the observational method using direct observations and observation schedules presented in the method chapter proved to significantly simplify the execution of the experiments. The use of observation schedules enabled a very effective and systematic execution of the experiments, which most likely minimized many of the possible sources of error during the execution which probably could have had a greater impact on the outcomes without this systematic approach. Despite the difficulties of fabricating well-functioning observation schedules, it was after hand considered a great tool of assistance when the experiments were carried out.

The main advantages of using systematic direct observations are especially that the data is gathered instantly during the experiments as well as that the quantitative data recorded in the observation schedules are already organized and structured (Denscombe, 2016), unlike qualitative data that need to be processed to produce similar materials which then can be analysed and presented in the result. The benefits of using quantitative data in this research are that the study conveys a scientific appearance and that it has a solid foundation on which to prove and defend its presented result (Denscombe, 2016).

The main disadvantages of using systematic direct observations are that the process could to some extent become too simplified, which implies to that the procedure for achieving the intended results may very well contain inadequate and insufficient amount of information to enable other researchers to perform the same experiment once again (Denscombe, 2016). The lack of adequate and sufficient amount of information could also be applied to the observation schedules, however, based on repeated use of the observation schedules in this study during the execution of the lifeboat stability tests, they are in the authors' opinion considered to be adequate and sufficient enough, but it cannot be guaranteed until it is used by a third party. The drawbacks of using quantitative data is that the data could be of insufficient quality in the results due to sources of error of which are discussed in sections 5.1.1 – 5.1.1.4, as well as a presentation of too much unrelated and irrelevant data (Denscombe, 2016). It is however the authors' opinion that this has been minimized in the results of this study.

5.2.2 Documentary research method

For the purpose of obtaining credible data on the stability requirements applicable to totally enclosed lifeboats, and on how the responsibilities in the classification process are delegated, a documentary research method based on qualitative literature analysis was applied. The advantage of applying a documentary research method is that it enables the authors to select relevant and applicable sources of data within the scope of the study (Denscombe, 2016). The advantages with these collected qualitative data are that they provide greater detail and depth within a relatively limited areas as well as it simulates a reflection of the real world (Denscombe, 2016).

The data was primarily obtained through sources such as international conventions and codes from IMO, together with laws of the European Union and official documents of IACS as the official voice of the classification societies. Likewise, the data obtained from the scientific references and books were carefully selected and critically reviewed because of the use of these secondary data to produce primarily data. Due to the difficulties of producing relevant and credible data from the collected scientific references and books, the aforementioned conventions and codes, laws and official documents were selected in first hand to ensure the quality of the new primary data produced. This to reduce the negative impact on the results by using secondary data which often could display another authors own interpretation of the reality as this data is often originally produced for other purposes (Denscombe, 2016), and may then come into conflict with the purpose of this study. Based on this, it is the authors' opinion that the credibility of the documentary research and the literary analysis regarding the classification process in this study is not compromised when using secondary data to produce new primary.

The main advantages of using qualitative data gathered, which were applicable to this study through the documentary research are that the data provided implies to a detailed and wide scope of relevant information within a relatively limited area, as well as that the analysis is based upon the researchers' interpretation skills in contrast to only present gathered or generated values (Denscombe, 2016; Eriksson & Kovalainen, 2008). These benefits were proved to simplify the approach regarding the classification process in this study. The main disadvantages of using the gathered qualitative data were the amount of time and effort required to gather and organize the data applicable to this research to reach a credible result, as well as any possible imperfection in the authors' objectivity assessments that were carried out during the literature analysis while reading, screening, structuring and credibility assessing the literature (Denscombe, 2016).

5.2.3 Presentation of data

For the purpose of presenting the results of the experiments, the findings were presented using tables together with associated written clarifications. It is the opinion of the authors that tables was a well suited tool for presenting the quantitative data produced by the experiments in this study. By presenting data in this study through tables, the authors goal was to present relevant and sufficiently comprehensive data in a flexible and distinct way, and at the same time screen out other more superfluous information that could be obscuring and interfere with the reader's comprehension. Although, this can only be achieved as long as that the tables are not too advanced and poorly designed. An unstructured appearance, together with too much information will make them difficult to read and will have a negative effect on the reader's ability to comprehend the information (Denscombe, 2016). It is considered that these effects have been minimized in the results of this study.

The secondary data obtained for determining the configuration of the involved parties and how their responsibilities are delegated in the classification process, was presented in the results as primary data as it was obtained through the authors' own interpretation of the stated facts in the literatures. Due to this, the results is supported by references to the specific literature with the purpose to justify the authors' interpretation, which was considered to be the best possible solution. Furthermore, with the goal to consolidate the process in a clear and structured way as well as trying to visualize this rather complex process and who is transferring its responsibility onto whom in a hopefully simplified way, the result was supplemented by Figure 19.

An alternative way of providing the reader with a description of how this process is composed could have been to present the result solely through such hard facts in text form with references to paragraphs and section of the relevant regulations and requirements, however, this could have counteracted the authors' intention of providing the reader with simplified picture of how the process is composed.

5.2.4 Alternative strategies and methods

The research strategies and methods that were chosen for this study are in the authors' opinion considered to be the best applicable ones to fulfil the purpose and answering in the questions of this study. With that being said, they cannot with certainty be considered to produce the best possible results within the scope of the study. Alternative strategies and methods could possibly have produced similar results. However, with regards to the experimental part of this study, any alternative to the experimental method chosen to conduct the experiments was never considered to be applicable due to the purpose of practically examining and testing pre-existing theories in forms of the regulations and requirements in the LSA Code.

Regarding the study's question on how the responsibilities are delegated in classification process, an alternative research strategy could however been applied. A combined method research strategy, which implies a more modern strategy of combining different methods which then together can be adapted to strengthen the accuracy of the findings regarding a specific question (Denscombe, 2016). This could have been applied on this study by combining the already implemented documentary research method with an interview research method, to enable the authors to interview persons involved in the process and obtain a deeper understanding of how the responsibility delegation is composed in the classification process from a real world perspective. This could possibly have strengthened the accuracy of the findings when combined with the documentary research.

5.3 Validity, reliability and generalizability

It is the authors' general opinion that the validity of the results of the tested lifeboats' performances in this study is very good. This based on the fact that there could not be any doubt about which specific criteria that were to be tested, as they were clearly stated by their respective requirement in the LSA Code. Although the reliability may not be as high, the data generated through all the measurements taken during the tests were however of sufficient accuracy for the authors to safely argue that the results are highly credible.

It is the authors' general opinion that the validity regarding the results on how the responsibilities are delegated in classification process is also very good. This based on that the fact that the data gathered from the documentary research and the literature analysis are considered to be of high authenticity through its association with IMO and its regulatory instruments, which also indicated that these literatures contain representative and a credible content (Denscombe, 2016). Although the reliability may not be as high, as the presented data in the result of this research is mostly based on interpretation of the literatures, which may be influenced by misinterpretations and the objectivity of the authors. However, due to carefully and impartial assessments of these literatures the authors can safely argue that the results are highly credible.

The generalizability of the findings from the research regarding the delegation of responsibility in the classification process is considered to be high. This based on the fact that the presented results are obtained through the only acting regulatory instruments that cover provisions for responsibility delegation in the classification process, which means that these provision are to be applied in every case whenever any responsibility is to be delegated. The generalizability of the findings from the stability tests although may not be as high. This due to that the results from the tested lifeboats cannot be generalized because of the selection of only three lifeboats is considered to be too small. For a generalization to be possible, the selection would need to have been significantly larger than three lifeboats.

5.4 Ethical aspects

Several ethical aspects were taken into consideration in this study. When specific equipment and its performance is tested in a study like this, and if it is found that the equipment performed poorly, the findings may be perceived to implicate any shortcomings of the manufacturer or the controlling parties in question. It needs to be pointed out that is however neither the purpose of the study nor the authors' intention.

Ethical aspects were taken into consideration by the authors when using water bags instead of people. This primarily to ensure safety and to get the most accurate results as possible but also to not having to expose people with questions regarding their weight, which could appear as offensive in some cases. Furthermore, any pictures of the lifeboats taken during the stability tests were taken solely for noting purposes and will not be published, except for the picture on the cover of the study. The pictures of lifeboats included in this study were presented with the permission from Norsafe, and used solely as illustrations and they do not have any significance to the study other than as a illustrative tool.

6 Conclusions

The results of the practical stability experiments in the study show that the lifeboats in test 1 and test 2 fully comply with the stability requirements of the LSA Code by presenting positive GM values, heel angle values not exceeding 20° and freeboard distances no less than 100 mm. The results of the experiment on the lifeboat in test 3 shows that it complies with the requirement regarding GM but it does not comply with the requirements regarding angle of heel and freeboard distance.

The lifeboat in test 1 presented a positive GM value, a heel angle value of 16,6° and a freeboard distances of 412 mm, whereas the lifeboat in test 2 presented a heel angle value of 15,4° and a freeboard distance of 453 mm, as well as a positive GM value. The lifeboat in test 3 however presented a heel angle value of 43,6° and a negative freeboard distance of -87 mm, while still presenting a positive GM value.

Delegation of the responsibilities in the classification process is done in both the manufacturing and the on-board installation process of life-saving appliances, thus involving different parties. During the manufacturing process the European Commission imposes responsibilities onto the manufacturer through the MED directive. The manufacturer's responsibilities for the conformity assessment procedure is delegated to a Notified Body appointed by the manufacturer. Furthermore, the responsibility for surveillance of the conformity assessment procedure during manufacturing on behalf of European Commission is delegated to a Notified Body.

During on-board installation, the regulatory instruments of IMO and consequently the European Commission, impose responsibilities onto the Administration. In case the Administration decide to delegate the task of testing and evaluating the equipment to a Recognized Organization, the responsibility is transferred to the RO, as the RO is responsible and accountable for the work it carries out on the behalf of the Administration. If not, the responsibility stays with the Administration.

On the subject of the not approved lifeboat in this study, it was not the scope of this research to determine any cause for its deficient performance and it cannot in anyway be deduced from the findings of the study. Therefore the authors encourage further research on this subject, to produce a more profound presentation of the classification process. As a suggestion, a case study could serve as a well-suited applicable approach enabling a closer research on how, and in that case, where any flaws or irregularities could reside within the process that could be the cause for the worrying performance of the lifeboat in test 3 of this study.

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Appendix 1 –Test 1

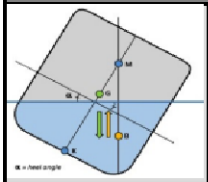
Observation schedule lifeboat Test 1

Present	Lifeboat particulars		Place	Öckerö Maritime Center
Kristoffer Hagström: Author	Type	Totally enclosed lifeboat	Date	2016.12.20
Mathias Nilsson: Author	Year built	1984	Time	08:00-17:00
Henrik Andreasson: ÖMC	Capacity	50 persons	Duration	9h
Ronny Johansson: ÖMC	Lenght	8,0 m	Wind	S 3 m/s
	Width	3,0 m	Temp	+6°C
			Seastate	Very Calm
			Start heel	0°

Weights (kg)

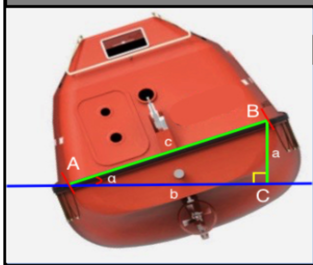
Without added weights	Fwd hook	1650	Weight per person	82,5	Diff.	-3
	Aft hook	2010	Person capacity/2	25	Comments	
	Total	**3660**	**Weight to add**	**2063**		
With added weights	Fwd hook	2680	Without add. Weight	3660		
	Aft hook	3040	With added weight	5720		
	Total	**5720**	**Actual weight added**	**2060**		

GM



Observation questions	Answers	Comments
Does the lifeboat heel over during launch?	YES	If **GM** is *negative* further steps will not be taken.
Does the heeling moment stop at a certain angle of heel?	YES	
Is the lifeboat in stable equilibrium?	YES	
Is the lifeboats´ GM positive or negative?	POSITIVE	

Heel angle calculation



Distance & angle values			
Distances (mm)		Angles (°)	
a	1215	α	16,6
b	N/A	B	N/A
c	4265	C	90

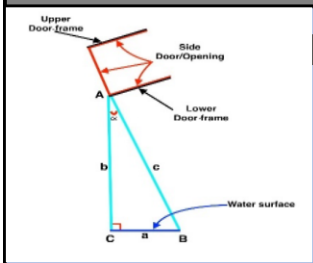
Comments:
-Rounded stern

Calculation

$$Sin\propto = a/c$$

$$\propto = sin\text{-}1\ (a/c)$$

Freeboard calculation



Distance & angle values			
Distances (mm)		Angles (°)	
a	N/A	α	16,6
b	412	B	N/A
c	430	C	90

Comments:

Calculation

$$Cos\propto = b/c$$

$$b = c \bullet \cos\propto$$

Results	Heel calculation (°)			Freeboard calculation (mm)		
	Heel angle	16,6	PASSED Acc. LSA 4.4.5.2.2	Freeboard distance	412	PASSED Acc. LSA 4.4.5.2.2

Appendix 2 –Test 2

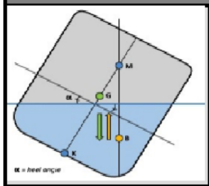
Observation schedule lifeboat Test 2

Present	Lifeboat particulars		Place	Chalmers Safety Center
Kristoffer Hagström: Author	Type	Totally enclosed lifeboat	Date	2016.12.15
Mathias Nilsson: Author	Year built	1985	Time	09:00-17:00
	Capacity	35 persons	Duration	8h
	Lenght	7,4 m	Wind	S 3-4 m/s
	Width	2,7 m	Temp	0°C
			Seastate	Calm
			Start heel	0°

Weights (kg)

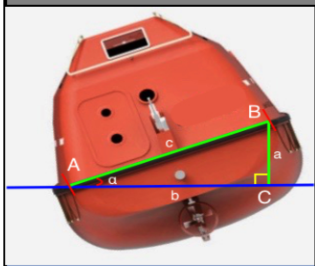
Without added weights	Fwd hook	1760	Weight persons	82,5	Diff.	5
	Aft hook	2260	Person capacity/2	18	Comments	
	Total	**4020**	**Weight to add**	**1485**		
With added weights	Fwd hook	2530	Without add. Weight	4020		
	Aft hook	2980	With added weight	5510		
	Total	**5510**	**Actual weight added**	**1490**		

GM



Observation questions	Answers	Comments
Does the lifeboat heel over during launch?	YES	If **GM** is *negative* further steps will not be taken.
Does the heeling moment stop at a certain angle of heel?	YES	
Is the lifeboat in stable equilibrium?	YES	
Is the lifeboats´ GM positive or negative?	POSITIVE	

Heel angle calculation



Distance & angle values				Calculation
Distances (mm)		Angles (°)		
a	1230	α	15,4	
b	N/A	B	N/A	
c	4630	C	90	

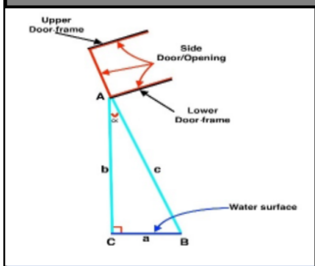
Comments:
-Rounded stern

Calculation:

$$Sin\propto = a/c$$

$$\propto = sin\text{-}1\,(a/c)$$

Freeboard calculation



Distance & angle values				Calculation
Distances (mm)		Angles (°)		
a	N/A	α	15,4	
b	453	B	N/A	
c	470	C	90	

Comments:

Calculation:

$$Cos\propto = b/c$$

$$b = c \bullet \cos\propto$$

Results	Heel calculation (°)			Freeboard calculation (mm)		
	Heel angle	15,4	PASSED Acc. LSA 4.4.5.2.2	Freeboard distance	453	PASSED Acc. LSA 4.4.5.2.2

Appendix 3 –Test 3

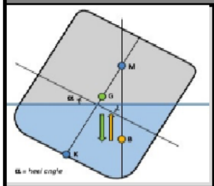
Observation schedule lifeboat Test 3

Present	Lifeboat particulars		Place	Remmaren, Chalmers
			Date	16-08-25
Martin Lindberg: Transportsyrelsen	Type	Totally enclosed lifeboat	Time	13:00-14:20
Mats Iaaksson: Chalmers	Year built	2014	Duration	1h 20min
Kjell Saebbö: Chalmers	Capacity	22 persons	Wind	S 4 m/s
Lars Telestam: Chalmers	Lenght	5,3 m	Temp	26°C
	Width	2,3 m	Seastate	Calm
			Start heel	0°

Weights (kg)

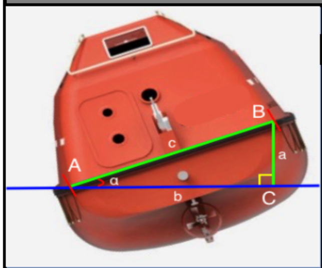
Without added weights	Fwd hook	1010	Weight persons	82,5	Diff.	2
	Aft hook	1240	Person capacity/2	11	Comments	
	Total	2250	Weight to add	908		
With added weights	Fwd hook	1640	Without add. Weight	2250		
	Aft hook	1520	With added weight	3160		
	Total	3160	Actual weight added	910		

GM



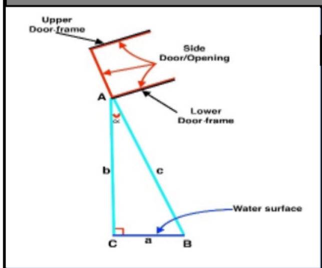
Observation questions	Answers	Comments
Does the lifeboat heel over during launch?	YES	If **GM** is *negative* further steps will not be taken.
Does the heeling moment stop at a certain angle of heel?	YES	
Is the lifeboat in stable equilibrium?	YES	
Is the lifeboats´ GM positive or negative?	POSITIVE	

Heel angle calculation



Distance & angle values				Calculation
Distances (mm)		Angles (°)		
a	1310	α	43,6	$Sin\alpha = a/c$
b	N/A	B	N/A	$\alpha = sin\text{-}1\,(a/c)$
c	1900	C	90	
Comments:				

Freeboard calculation



Distance & angle values				Calculation
Distances (mm)		Angles (°)		
a	N/A	α	43,6	$Cos\alpha = b/c$
b	-87	B	N/A	$b = c \bullet \cos\alpha$
c	120	C	90	
Comments:				

Results	Heel calculation (°)			Freeboard calculation (mm)		
	Heel angle	43,6	NOT PASSED Acc. LSA 4.4.5.2.2	Freeboard distance	-87	NOT PASSED Acc. LSA 4.4.5.2.1

Appendix 4 – Chalmers test report

Kontroll av livbåts stabilitet i enlighet med krav i LSA-koden 4.4.5.2.2.

Livbåt [redacted]		serial nr: [redacted]		BV cert.nr [redacted]
	Datum:	160825, kl.13.00-14.20		
Ägare:	Chalmers Tekniska Högskola		**vind:**	S 4 m/s
			temp:	26 grader
Närvarande:		**slagsida olastad**		0 grader

Martin Lundberg	Transportstyrelsen
Mats Isaksson	Chalmers Tekniska Högskola
Kjell Saebbö	Chalmers Tekniska Högskola
Lars Telestam	Chalmers Tekniska Högskola

Resultat;
Dörrkarm 87 mm under vattenytan
krängningsvinkel 43,6 grader

vägning		
	fulla förråd utan vattensäckar	förlig livbåtskrok 1010 kg akterlig livbåtskrok 1240 kg totalt: 2250 kg
	som ovan med säckar:	förlig krok 1640 kg akterlig krok 1520 kg totalt: 3160 kg

erforderlig vikt motsvarar 11x82,5 kg=907,5 kg, 11 sittplatser, 82,5 kg/person.

Säckar jämnt fördelade längs sidan, vikt : 3160
2250
910 kg