MCA RESEARCH PROJECT 555

Development of Lifeboat Design

Burness Corlett - Three Quays Limited
12 - 20 Camomile Street
London
EC3A 7AS

*Tel No:	+44 (0)20 7929 2299*
*Fax No:	+44 (0)20 7929 1650*
*E-Mail:	enquiries@bctq.com*

MCA RESEARCH PROJECT 555

Development of Lifeboat Design

QUALITY STATEMENT

This document has been prepared in accordance with the Quality Assurance Procedures of Burness Corlett-Three Quays Ltd, in conformance with ISO 9001:2000.

Prepared For: The Maritime and Coastguard Agency

Date: 27 March 2006

Prepared by: Jim Peachey
Simon Pollard

Project No: 3440

Report No: 2006-011

Authorised for Issue:

0 EXECUTIVE SUMMARY

0.1 DISCUSSION

0.1.1 Burness Corlett - Three Quays Ltd were contracted by the UK Maritime and Coastguard Agency to carry out a study into the safety of lifeboats and their launching systems. The primary objective of the study was to make proposals for measures to improve the performance of lifeboats and contribute to the prevention of accidents. The scope of this study is confined to conventional, davit-mounted, side launched ships' lifeboats.

0.1.2 A second objective was to investigate the implications for lifeboat design of proposed changes to anthropometric parameters.

0.1.3 Lifeboat accidents make headline news. This is for two reasons. Firstly, the function of lifeboats is to save life, and the boats therefore need to be free of danger themselves. Secondly, most lifeboat accidents occur during tests or drills, and it therefore appears ironic that regulations intended to improve safety by requiring these drills should actually lead to injuries and fatalities.

0.1.4 By international agreement at the International Maritime Organisation (IMO), it became a requirement in 1986 for lifeboats to be fitted with on-load release hooks. The intention was to enable a lifeboat to be released from its lowering tackle, even if some tension still remained in the falls (as may occur, for example, when launching into waves).

0.1.5 The study found that lifeboat accidents occur for a number of reasons, but that most of the more serious accidents, particularly those leading to fatalities, occur because of problems with the on-load release hooks.

0.1.6 Through premature or unexpected opening of one or both hooks during a routine test or drill, the lifeboat either becomes suspended vertically or drops completely into the water, typically resulting in injury or fatality to the crew.

0.1.7 Accidents also arise from problems with other elements of the equipment used to launch lifeboats, such as winches, falls, gripes, tricing and bowsing gear, etc, but generally these types of accident have less severe consequences.

0.1.8 Previous studies, by shipping industry organisations and by the Marine Accident Investigation Branch, have examined this range of different accidents and produced recommendations aimed at addressing the various causative factors. These recommendations, often widely disseminated, sought improvements in maintenance and training, and urged design improvements by manufacturers.

0.1.9 Nevertheless accidents have continued to occur, prompting action by the IMO to reduce the level of risk. Thus, IMO Circulars have been issued in recent years regarding equipment servicing and maintenance, crew training and safety management during lifeboat drills.

0.1.10 A risk-based approach to design improvements had been proposed for the project. A generic fault tree model of a ship's lifeboat launching system was to have been constructed to examine risk contributions and to facilitate identification of design improvements. This model was to have been validated, refined and developed by a workshop of domain experts from various stakeholder groups. Unfortunately a lack of detailed design information undermined the technical basis for constructing a realistic model. However an informative and productive workshop was held at which the issues surrounding lifeboat safety and how difficulties might be overcome were discussed.

0.1.11 Anthropometric data confirms that the human species is increasing in stature and mass across the globe. In some populations the mean mass may exceed the figure required by regulation to be used in lifeboat system design. A similar problem exists with breadth of hip for seating area requirements.

0.2 CONCLUSIONS

0.2.1 Notwithstanding the contributory factors noted in the IMO Circulars, this study has found that many existing on-load release hooks, whilst satisfying the current regulations, may be inherently unsafe and therefore not fit for purpose.

0.2.2 This situation arises because some designs of on-load hook can be described as unstable, in that they have a tendency to open under the effect of the lifeboat's own weight and need to be held closed by the operating mechanism. As a result, there is no defence against defects or faults in the operating mechanism, or errors by the crew, or incorrect resetting of the hook after being released.

0.2.3 We consider this to be the principal reason for almost all of the more serious accidents that have occurred. Furthermore, we consider that the solution lies not in training or maintenance, but in radical re-design of the hook types involved. Improved maintenance, whilst desirable, is unlikely to be a sufficiently effective risk reduction measure because of the harsh operating environment and dwindling levels of skilled resource on board a ship.

0.2.4 Improved training is similarly unlikely to be a sufficiently effective measure. This is because human error is inevitable, particularly under the difficult working conditions (time pressures, language barriers, fatigue, cold, dark, wet, etc) which typically prevail on board. Given the reality of this context, it is entirely inappropriate for a safety critical system (ie an unstable design of on-load hook) to be catastrophically susceptible to single human error.

0.2.5 However, our research has clearly indicated that stable hook design is achievable. We believe that there are some designs of on-load hook currently in service which fulfil this objective, and we have seen convincing evidence of a new hook design developed explicitly to have stable characteristics.

0.2.6 Development of lifeboat design regulations has to address whether and how to ensure adequate protection for the larger populations. Should anthropometric values be applied universally or on a geographical basis? There are practical and commercial justifications for both. The study presents a method for calculating mixed population statistics.

0.2.7 Populations used to determine design anthropometric data represent a small element within the seafaring population. The populations causing concern in respect of current lifeboat designs are a small element of international seafarers.

0.2.8 If new regulations are to increase the values of human mass and hip width, the question of retrospective legislation has to be addressed. If new requirements are not to be applied retrospectively, seafarers may be put at risk. If they are to be applied retrospectively, the cost-benefit has to be justified.

0.2.9 The specific design issues controlled by regulations have been examined against anthropometric growth. Generally “overloaded” lifeboats will continue to operate within their safety factors. The principal exception is the on-load release equipment where significantly larger populations may lead to an exceedance of the proof load.

0.3 RECOMMENDATIONS

0.3.1 We recommend that unstable designs of on-load release hook are identified with the intention that they be withdrawn from service on all ships and replaced with stable designs. The necessary development of new hooks should be undertaken urgently and the transition made at the earliest possible time.

0.3.2 We believe that responsibility for developing safe and fit for purpose on-load hooks rests with the manufacturers. Accordingly, a safety performance specification for lifeboat launching systems should be developed and imposed by IMO regulation on the equipment manufacturers.

0.3.3 We further recommend that all lifeboat on-load release hooks are demonstrated to be safe and fit for purpose by means of a safety case regime. This regime should comprise a design safety case for each type or make of hook, supplemented by an operational safety case incorporating the design safety case but extended to interface with ship-specific safety management arrangements.

0.3.4 The design safety case should be submitted for independent review and approval as part of current type-approval activities for equipment. The operational safety case should be similarly submitted for independent review and approval as part of current vessel safety management system approval activities.

0.3.5 In view of the serious nature of the hazard, we consider that interim risk reduction measures are appropriate, to avoid further unnecessary fatalities during mandatory lifeboat tests and trials. In this regard, we endorse a system whereby maintenance shackles are rigged to by-pass the on-load release hook during lowering and recovery, but are disconnected at all other times.

0.3.6 Noting the difficulties with on-load release for twin fall launching systems, consideration should be given to adoption of single fall capsules for ships carrying small numbers of persons.

0.3.7 In summary we recommend that:

- All on-load release hooks should be designed and constructed to be stable, ie self-closing, when supporting the weight of the lifeboat;
- A safety case regime should be introduced specifically (and only) for lifeboat on-load release hooks, so as to achieve this aim; and
- The International Convention for the Safety of Life at Sea should be amended to include both this safety case requirement and additional safe design requirements for lifeboat launching equipment.
- An interim measure of by-passing on-load release hooks during drills should be considered.
- Single fall capsules should be considered for ships carrying small numbers of persons.

We make no specific recommendations concerning anthropometrics.

CONTENTS

1 INTRODUCTION

1.1 OPENING REMARKS

1.1.1 On 5 September 2005 the UK Maritime and Coastguard Agency (MCA) invited Burness Corlett - Three Quays (BC-TQ) to carry out a study into the safety of lifeboats and their launching systems. The invitation to tender was released in July 2005 and the contract placed in September 2005.

1.1.2 The project responds to concerns raised in 2002 by the Maritime Safety Committee of the International Maritime Organisation (IMO) and reinforced in subsequent Design and Equipment (DE) and Fire Protection (FP) Sub-Committee meetings regarding the unacceptable level of injuries and fatalities attributed directly to the use of current lifeboat arrangements.

1.1.3 BC-TQ undertook to investigate four strands of research:

- information gathering
- risk assessment
- design consequences
- anthropometric considerations.

1.1.4 The project opening meeting took place on 26 September 2005, attended by MCA and BC-TQ project team members.

1.1.5 An initial report described how BC-TQ proposed to progress the study. The report was presented to IMO (FP 50/INF.6) for discussion at the February 2006 FP meeting. The original schedule was to complete by the end of December 2005, allowing discussion with the MCA and completion of the final report by the end of January 2006 such that more detailed information might be available for discussion at FP50. However the information gathering phase of the project became increasingly protracted and MCA granted an extension to the completion dates.

1.1.6 At an initial meeting with the Marine Accident Investigation Branch (MAIB) recent lifeboat accidents and incidents were identified (to supplement the 2001 study). Contacts for marine accident investigators in other countries were provided and insights gained through discussion of relevant causational issues. Accident and incident reports, including several near-miss reports (through confidential reporting schemes) have been accessed to provide a knowledge base with the intention of constructing a fault tree model.

1.1.7 The project team witnessed a routine lifeboat drill on board a ferry to familiarise themselves with typical current practice.

1.2 INFORMATION GATHERING

1.2.1 Lifeboat accident data has been sought from a variety of sources. A general literature search and review has been undertaken, covering all relevant IMO/DE papers and current statutory requirements, together with any relevant studies and research undertaken elsewhere.

1.2.2 Wherever possible, situational and causational information has been sought, so as to generate the best possible understanding of lifeboat accidents for discussion with stakeholders and for the risk analysis. Sources approached include:

- MAIB and other official marine accident investigators
- the Health and Safety Executive (HSE) for UK offshore installation data
- hazardous incident reporting schemes.

1.2.3 Information relating to the design and maintenance of lifeboats and launching gear has been sought from manufacturers and maintenance organisations, addressing design evolution, modifications and recommended operational maintenance.

1.2.4 This accident and design data was supplemented by user-oriented information sought from shipping industry organisations such as the Chamber of Shipping, the National Union of Marine, Aviation and Shipping Transport Officers (NUMAST), the International Transport Workers' Federation (ITF), the National Union of Rail, Maritime and Transport Workers (RMT) and marine training schools.

1.2.5 We have sought strenuously to make contact with the range of stakeholder groups nominated by MCA, to obtain from them information relating to the design, operation and service experience of lifeboats and launching systems. Unfortunately the manufacturers of ships' lifeboats appeared to decide not to co-operate with the study. This had serious repercussions for the study's ability to follow its planned course and consequences for the conclusions drawn.

1.3 RISK ASSESSMENT

1.3.1 A risk-based approach was proposed because the intended outcomes of the research constituted the first steps of risk management, namely the identification of suitable risk control measures to improve lifeboat performance and contribute to the prevention of accidents. Furthermore, the project would focus on lifeboat design, rather than human factor aspects of in-service operation.

1.3.2 Of the various risk modelling techniques applicable to the design of engineered systems, fault tree analysis was considered to provide the most appropriate tool since:

- failure modes and frequencies are well understood and documented
- engineering rather than human or operational changes are being sought
- fault tree analysis embodies a logical model of the failures that can lead to an accident and enables sound estimates to be made of the effect of system changes on risk levels
- fault tree modelling generally addresses accident initiation rather than accident consequence, thereby helping to identify ways to reduce accident frequency.

1.3.3 A generic fault tree model of a ship's lifeboat system was therefore to be constructed. This model would be validated, refined and developed by a workshop of domain experts, with a view to identifying lifeboat design improvements. Workshop participants would be drawn from the various stakeholder groups, including:

- maritime regulators and accident investigators
- seagoing staff with experience of lifeboat drills and maintenance
- lifeboat system designers and manufacturers
- lifeboat systems servicing/repair staff
- ship owners and consultant engineering specialists.

1.3.4 Experience shows that the logical structure of a typical fault tree model greatly facilitates the process of identifying options for improvement. The anticipated outcome of the workshop was a series of conceptual design changes or improvements to address failure modes known to have contributed to lifeboat accidents.

1.3.5 Fault tree software was purchased and work commenced to construct the generic risk model. The aim was to structure the model to incorporate all the principal failure modes and contributory faults revealed by the accident / incident data. It would also allow for the impact of identified design improvements to be evaluated in risk terms.

1.4 DESIGN CONSEQUENCES

1.4.1 It was anticipated that a range of possible design improvements would be identified during the workshop, not all of which would be equally effective. The objective would be to categorise the options in terms of factors such as impact on risk, practicability, suitability, anthropometrics, regulatory compliance and simplicity.

1.4.2 Two complementary outcomes of the project were therefore anticipated:

- identification of preferred design improvements to defeat known failure modes
- development of appropriate design specification risk criteria for safety performance.

1.4.3 Success in respect of the first of these outcomes would be dependent on the degree of innovative thinking achieved during the risk workshop, although the systematic risk approach facilitates insight and understanding to ensure the highest level of innovation that can realistically be expected in a research project of this nature. Success in respect of the second outcome carries a greater level of confidence, the output comprising a logical statement, in risk terms, of lifeboat design objectives.

1.5 ANTHROPOMETRICS

1.5.1 The International Convention for the Safety of Life at Sea (SOLAS) requirements for lifeboats and liferafts assume an average passenger mass of 75 kg in association with defined seating areas. Population data show that the average adult mass is increasing. The consequences of this for lifeboat design were to be investigated.

1.5.2 At the project opening meeting it was agreed to concentrate on impacts and trends rather than specific data which were the subject of separate MCA research, subsequently presented to IMO (FP 50/14/1). A paper by the Canadian Administration presented to FP50 (FP50/14 and /INF.3) reinforces the need to review lifeboat design data. The issue is to define the population samples for which lifeboats are to be designed.

1.5.3 The International Life-Saving Appliance Code sets out the design criteria for lifeboat design. These criteria are addressed such that the consequences of population growth for existing designs may be identified.

2 INFORMATION GATHERING

2.1 OVERVIEW

2.1.1 Published information relating to lifeboat accidents has been reviewed. This includes information from the IMO or made available by the MCA or accessible via the internet. First hand information has also been sought from a variety of sources, including seafarers, ship owners and operators, lifeboat manufacturers and servicing organisations, a type-approval authority, the Health & Safety Executive (HSE) and MAIB. Despite certain problems (discussed below), it is considered that a sufficiently broad and up-to-date spectrum of information has been gathered to enable robust conclusions to be drawn.

2.1.2 The starting point for the information gathering exercise was the report published in 2001 by the MAIB. The MAIB report is discussed more fully below, but it is understood that its publication prompted the current consideration of the issue of ships' lifeboat safety by the IMO.

2.1.3 Over the years open wooden lifeboats with oars and sails have been superseded by mechanically propelled boats constructed in fibre reinforced plastic and nowadays required to be partially or totally enclosed. But during the course of this gathering information activity, it has become clear that generally speaking the boats themselves are not a source of concern and, with a few exceptions, neither are the davits and their attachment to the ship's structure.

2.1.4 Rather it is the rigging (hooks, falls, winches, etc) provided to enable boats to be launched, that constitutes the problem area. Leaving aside free-fall boats (which are not covered by the scope of this project), it can be said that the arrangements for launching a ship's lifeboat primarily require practical seamanship and in essence have not changed for perhaps hundreds of years. It is true that steel has replaced wood and cordage; and that gravity davits and powered winches have replaced manpower. But the basic principles of suspending the boat on hooks and falls, of swinging the boat outboard, and of lowering it to the water on running tackle remain unchanged. Herein may lie much of the problem. Whereas shipboard cargo handling (eg Ro-Ro and containerisation) has been characterised by revolutionary change, changes in lifeboat launching arrangements have been characterised by slow evolution driven by regulatory change (eg un-powered launching and on-load release). These successive regulatory developments, apparently implemented without any fundamental design reappraisal, may have led to lifeboat systems being unnecessarily complex and thereby contributing to risk.

2.1.5 One key change that is particularly relevant, however, was the introduction by IMO in 1986 of a regulatory requirement for on-load release hooks. Prior to this time, after lowering a boat into the water, it was necessary manually to unhook the boat from its falls. As boats and their launching gear became larger and heavier, and especially in a seaway with the boat subject to wave action or with the vessel underway, this task had become fraught with danger as crew tried to complete a simultaneous (fore-and-aft) unhooking process. The requirement for on-load release hooks was introduced to overcome these problems, in the expectation that launching would become significantly safer. In practice, on-load release hooks have brought their own problems.

2.1.6 It is apparent that the occurrence of lifeboat accidents is not something new. The problem has now been evident (at least in the oil and gas transport sectors of the shipping industry, see below) for a considerable period of time, with accidents being reported sufficiently frequently for a clear picture to emerge about the types of failure and range of consequences (in terms of seafarer injuries and fatalities) that typically occur.

2.1.7 The well-known nature of the problem is illustrated by the publication of two industry surveys. The first was compiled as long ago as 1994 by the Oil Companies International Marine Forum (OCIMF), based on a questionnaire distributed via the International Chamber of Shipping and selected Flag State Administrations. A total of 92 incidents were identified, 41% of which resulted in injury, with 2 incidents leading to fatalities. Significantly, OCIMF also detected a lack of confidence amongst mariners leading to a reluctance to conduct lifeboat drills. Recommendations were addressed to ship owners, manufacturers and authorities (including the IMO), and it is therefore to be assumed that these various organisations were made aware of the survey findings.

2.1.8 The second survey (in 2000) was conducted jointly by OCIMF, the Society of International Gas Tanker and Terminal Operators (SIGTTO) and The International Association of Independent Tanker Owners (Intertanko). It could be said that these organisations reflect two particularly safety conscious sectors of the shipping industry (oil and gas transportation), but nevertheless it is apparent that the issue of lifeboat safety has now been under scrutiny and understood for a considerable period of time. Both surveys effectively anticipated the MAIB 2001 study, identifying not only that most incidents occur during lifeboat drills or maintenance activities, but that the problems are associated with a variety of the components of lifeboat launching systems (including in particular on-load release hooks), and that training, maintenance and design are contributory factors. The report of the second survey notes that many of its recommendations simply reiterate those of the 1994 OCIMF survey.

2.1.9 These two surveys, the MAIB 2001 study and subsequent accident reports all make clear that most accidents to date have occurred during routine drills, maintenance and testing. During these activities, it is usually only members of the ship's crew who are at risk should an accident occur. It also appears that few lifeboat accidents in recent times have occurred during use of the lifeboat in earnest in an emergency abandon ship scenario (we are aware of only one, the Hong Kong registered ship *Ogrady*, see Annex A1.3.3). However, if this were to occur on a passenger vessel, the resulting consequence in terms of the number of lives lost would potentially be catastrophic. There is no reason to believe, because such an accident has not yet occurred, that it will not occur at some time in the future. Indeed many large scale accidents have small scale precursors.

2.1.10 Against this background, it can be said that ever since the Titanic, the expectation of ships' crews, passengers and society at large has been that a sufficiency of lifeboats is available and that they will be readily operable in an emergency, affording safe means of escape from a vessel in distress. To this end (with certain exceptions), SOLAS requires ships to be provided with lifeboats, which are to be regularly tested and drilled. It is ironic that it is compliance with these regulations which provides the opportunity for lifeboat accidents to occur, through their requirement for tests and drills.

2.2 ACCIDENT INVESTIGATION REPORTS

2.2.1 The MAIB is the UK's official organisation for investigating marine accidents. In 2001, MAIB published a study of accidents involving ships' lifeboats. The study concluded that seafarers are at significant risk when using lifeboats during training exercises and testing. The study reviewed 125 incidents and accidents during the preceding ten-year period which resulted in 12 fatalities and numerous injuries (see summary in Annex A1). The MAIB study confirms that these accidents have involved problems with a variety of components, including tricing and bowsing gear, falls, gripes, winches, davits and hooks (ie the rigging). However the most serious accidents, mostly involving fatalities, involve problems with on-load release hooks and have occurred as a result of unexpected or inadvertent opening of the hook and release of the boat from its falls. Eliminating on-load release failures would substantially reduce the risk to which seafarers are currently exposed.

2.2.2 Since publication of the 2001 study, several further lifeboat accidents have been investigated by MAIB (details also included in Annex A1), indicating that such accidents are an on-going problem. As if to confirm this, a lifeboat accident occurred in early November 2005 (ie during the course of this project) in a UK port. It is understood that MAIB staff commenced their investigation, finding that winch failure led to the boat dropping about ten metres into the water causing injuries to those on board.

2.2.3 Discussions were held with MAIB staff to understand more clearly the circumstances and issues surrounding lifeboat accidents. Firstly it is apparent that within the broad categories mentioned in 2.2.1 above there is typically a wide variety of proximate causes, such that in general no particular component can be singled out as the root of the problem. If commonality of cause can be identified, then it would be 'fitness for purpose', in terms of the suitability of the lifeboat launching equipment for routine launch and recovery in a shipboard environment, in accordance with regulatory requirements. Here, fitness for purpose implies compatibility of function, design, maintenance, training and operation in the context of equipment exposed to the rigours of marine application. These rigours can include extremes of weather, a harsh operating environment, inaccessibility, reduced manning and minimal crew qualifications.

2.2.4 Information about lifeboat accidents has also been sought from official marine accident investigating organisations in other countries, including Australia, Canada and Hong Kong. A summary of some of these reported accidents is included in Annex A1. They are seen to reflect MAIB's experience of the more serious events (in terms of consequence to seafarers) being associated with on-load release hooks.

2.2.5 It is clear that the occurrence of serious accidents involving lifeboat on-load release hooks, resulting in injury to or death of seafarers, is an ongoing problem in the shipping industry.

2.3 CONFIDENTIAL INCIDENT REPORTS

2.3.1 In July 2003, the UK's maritime Confidential Hazardous Incident Reporting Programme (CHIRP) scheme was inaugurated, with the objective of receiving reports of near miss incidents and disseminating these to aid safety learning. Already, reports have been received expressing concern about the safety of ships' lifeboats. An example is included in Annex A1.

2.3.2 A similar scheme, the Marine Accident Reporting Scheme (MARS), has been run by the Nautical Institute for similar purposes since 1992. Extracts of some example reports are also included in Annex A1.

2.3.3 Such confidential incident reports highlight both the mechanical problems associated with lifeboat launching arrangements and the resulting lack of confidence amongst seafarers about their safety during lifeboat drills.

2.4 TYPES AND CAUSES OF ACCIDENTS

2.4.1 It is seen from Annex A1 that lifeboat accidents fall into several distinct categories, these being: hooks; tricing and bowsing; falls, sheaves and blocks; engines and starting; gripes; winches; davits; the weather; and other types of accident. As stated in the MAIB report, engine starting accidents are not unique to lifeboats and are therefore not considered further in this study.

2.4.2 However, it is evident from the various reports of lifeboat accidents that those involving unexpected or unintended release of the suspension hooks are likely to be the most serious accidents, often leading to fatalities. This is because they typically lead to either the entire boat dropping uncontrollably into the sea (or onto a quayside) if both hooks are simultaneously released, or one end of the boat dropping uncontrollably if only one hook is released. This category of accident has therefore been singled out for particular attention, as being the predominant contribution to risk arising from lifeboats. Preventing or minimising the occurrence of "hook" accidents would therefore make a major contribution to risk reduction.

2.4.3 The discussion of some typical hook failure accidents in Annex A1 shows that usually the failure is not so much of the hook itself but more a failure of the release mechanism. To understand the significance of this it is necessary to understand how, typically, an on-load release hook functions. Figure 2.4.3 illustrates the working parts of a typical hook design. Many other manufacturers' designs are believed to operate on equivalent or similar principles.

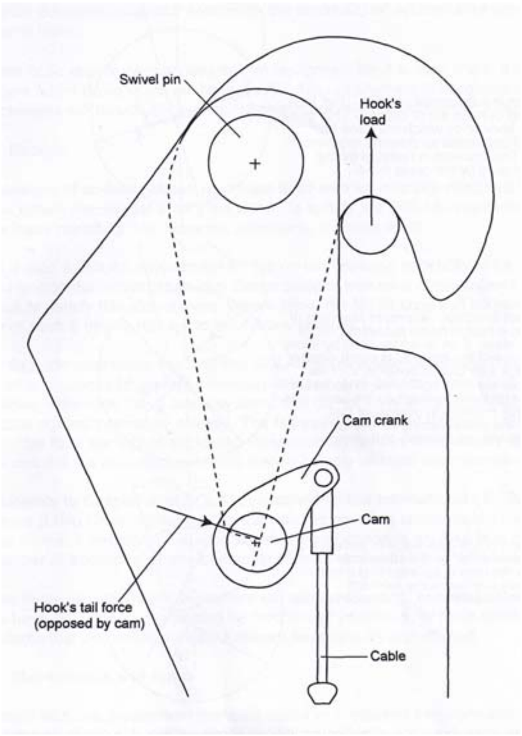


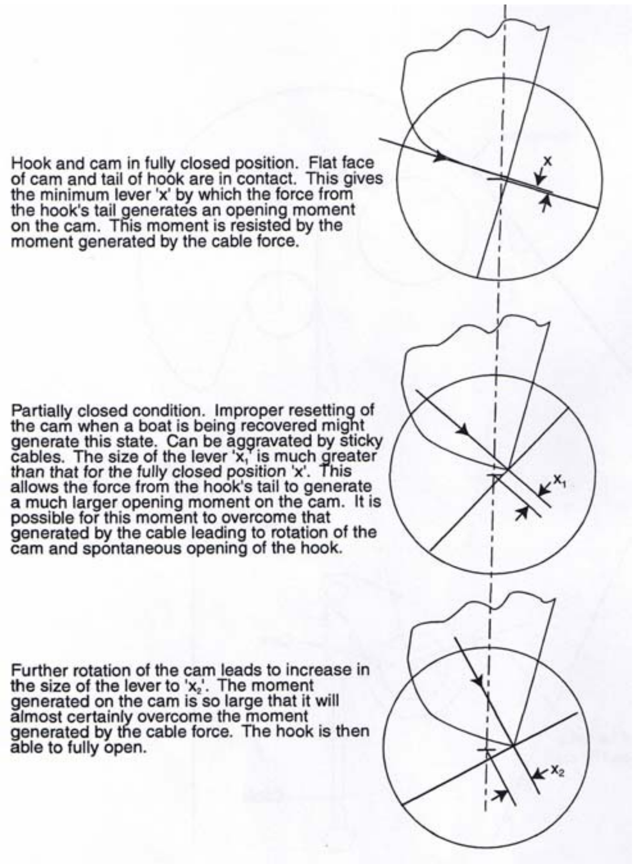
Figure 2.4.3: Typical On-load Release Hook

2.4.4 It is seen that the opening part of the hook, shown upper right and with a dotted tail, can rotate about a swivel pin. This swivel pin is supported by the two sideplates of the hook, shown by the long solid line which loops around the top of the swivel pin. The weight of the boat is supported by these sideplates, which therefore exert a downward force on the swivel pin. This is opposed by the tension in the falls, transmitted to the opening part of the hook via the suspension ring. The circular cross section of the suspension ring is seen in the bight of the hook, with an upward force arrow labelled Hook's load. Consider the opening part of the hook: the weight of the boat acting downwards at the centre of the swivel pin, together with the load in the falls acting upwards at the centre of the suspension ring, creates a couple (ie an equal and opposite pair of forces acting parallel to each other). This couple tends to rotate the hook in an anti-clockwise direction, ie to open it.

2.4.5 However, this tendency to open is prevented by the cam. The cam comprises a semi-circular shape, the flat face of which runs from about 1.0 o'clock to 7.0 o'clock as viewed in the figure (the round face being on the right). Clearly, the upper part of this cam, being in contact with the lowest part of the tail of the hook, prevents the hook rotating in an anti-clockwise direction. The cam can rotate (in the sideplates) about a centre marked + in the figure which shows also the hook's tail force pushing on the cam. There is an equal and opposite reaction force from the cam pushing on the tail of the hook. This reaction force acts in a clockwise direction on the hook, balancing the anti-clockwise tendency created by the weight of the boat.

2.4.6 It will be noticed that the lowest part of the tail of the hook lies above the cam's centre of rotation (+). Thus if the cam is rotated clockwise around this centre, until its flat face is lying in the 4.0 o'clock to 10.0 o'clock position, the cam would no longer be in contact with the tail of the hook. Under the influence of the anti-clockwise couple, the hook will open and the boat fall away. Clockwise rotation of the cam is achieved by means of a downwards pull on the cable causing rotation of the cam crank. The cable is connected to the operating lever located adjacent to the coxswain's position in the boat. This is the design intent for on-load release.

2.4.7 However, it can be seen that, because the tail of the hook lies above the cam's centre of rotation (+), the hook's tail force exerts a turning moment on the cam which tends to rotate the cam in a clockwise direction. If allowed to occur, this rotation would result in release of the hook. Only the positioning of the cam crank, as dictated by the cable and operating lever, prevents the hook forcing itself open under the action of the couple generated by the boat's weight and tension in the falls. Even when properly reset, there is a small opening moment on the cam, which has to be resisted by the cable and operating lever. If, after intentional release, the cam is not fully reset to its 1.0 o'clock / 7.0 o'clock position, a larger opening moment will exist as illustrated in Figure 2.4.7.



Hook and cam in fully closed position. Flat face of cam and tail of hook are in contact. This gives the minimum lever 'x' by which the force from the hook's tail generates an opening moment on the cam. This moment is resisted by the moment generated by the cable force.

Partially closed condition. Improper resetting of the cam when a boat is being recovered might generate this state. Can be aggravated by sticky cables. The size of the lever 'x_1' is much greater than that for the fully closed position 'x'. This allows the force from the hook's tail to generate a much larger opening moment on the cam. It is possible for this moment to overcome that generated by the cable leading to rotation of the cam and spontaneous opening of the hook.

Further rotation of the cam leads to increase in the size of the lever to 'x_2'. The moment generated on the cam is so large that it will almost certainly overcome the moment generated by the cable force. The hook is then able to fully open.

Figure 2.4.7: Effect of Incorrect Resetting of a Typical Hook

2.4.8 The above description of the hook design shown in Figures 2.4.3 and 2.4.7 appears to reflect a particular characteristic of many hook designs, which is that they are essentially "unstable". By this is meant that the weight of the boat suspended on the hook tends to produce a hook opening effect, which has to be resisted by the operating mechanism for the hook to stay closed. Thus the operating mechanism (lever, cable and cam crank) serves not only to release the boat when required, but also to maintain the hook closed at all other times. Any deficiency in the operating mechanism therefore impacts directly on the ability of the hook to remain closed and support the boat. Thus it can be said that many on-load release hooks currently in use may be inherently unsafe.

2.4.9 It is noted from the descriptions and sketches of hook designs provided in the accident reports that safety devices are generally not incorporated into the hook itself. Safety pins, and indeed hydrostatic interlocks to prevent release before a boat is waterborne, are typically provided in the area of the release handle adjacent to the coxswain's position inside the boat. Thus prevention of unintended opening of the hook is reliant solely on the integrity of the operating mechanism and safety devices / interlocks located remotely from the hooks themselves.

2.4.10 From a safety perspective, we consider these two characteristics of typical designs of on-load release hooks, ie:

- they are inherently unstable; and
- they rely on remotely located safety devices / interlocks,

to be a very undesirable situation.

2.5 MANUFACTURING AND SERVICING

2.5.1 Approaches were made to manufacturing and servicing companies seeking information relating to lifeboat launching arrangements generally, and hook design in particular. It was hoped to gain a deep understanding, from the manufacturers' perspective, of the design process and associated engineering issues. It was also considered that a full technical appreciation of existing designs and any potential susceptibilities to failure would be an essential prerequisite for developing proposed design improvements in fulfilment of the MCA's objectives for the research project.

2.5.2 However, the cooperation received from manufacturers has fallen short, by a large margin, of what we anticipated and hoped for. The output of this research project therefore falls correspondingly and significantly short, both of what we anticipated at the commencement of the project and of what the MCA should, ideally, have expected. Since the objective of the project is to identify design improvements contributing to the prevention of accidents, this shortfall in project output seems likely to delay design improvements and means that some preventable accidents are not prevented, thereby putting seafarers' lives at risk unnecessarily. Given these circumstances, we do not understand the ethics of the manufacturers' unwillingness to cooperate.

2.5.3 Our approach to manufacturing companies was first made via an international trade association for manufacturers of life-saving appliances (referred to hereafter as the Association), a body recognised as a non-governmental organisation with observer status at the IMO. A questionnaire was distributed via the Association's secretariat to all member companies. It was accompanied by a note explaining the scope and purpose of the research, a copy of the terms of reference and a letter written by the MCA confirming the authenticity of the research and assuring recipients regarding the confidentiality of any information provided.

2.5.4 This first approach generated a nil response. A second approach requested that the questionnaire be sent to a selected list of Association member companies, ie those known to be involved in the manufacture of lifeboats and launching equipment. This also generated a nil response from the manufacturers of ships' lifeboats. Finally, seven companies (including two non-Association members) were approached directly by phone and email, to request their cooperation and responses to the questionnaire. This generated one questionnaire response with some brief answers, but no design information. We were, however, able to have telephone discussions with staff of two member companies of the Association. This has provided some information on which we have relied in compiling this report.

2.5.5 Efforts were also made from the outset to involve one or more Association representatives in the project workshop event (see section 3.3) but these efforts proved unsuccessful. Following the workshop, a project timescale extension was requested and granted by the MCA, specifically to permit a further attempt to obtain manufacturers' technical design and engineering information. One company with whom we have had telephone discussions expressed a willingness to accommodate a visit by a member of the project team. But in the end, it did not prove possible to find a mutually suitable calendar window to allow the visit to go ahead prior to report delivery deadlines.

2.5.6 The questionnaire sent to manufacturers is included as Annex A2 of this report. General questions were also asked of Association members as to whether boat manufacturers or davit manufacturers are typically responsible for supplying the rigging in between, and regarding which companies also undertake servicing of lifeboats and launching equipment.

2.5.7 Based only on the single questionnaire response, it has not been possible to carry out a structured assessment of the design situation amongst the various manufacturers. Additionally, none of the manufacturers provided us with any design data (technical information, diagrams, specifications, operating instructions, etc). However, the following observations were noted during the telephone discussions mentioned above.

- In the past, formal hazard identification techniques have not generally been used as part of the design process. However, this situation may be changing, for example where this was required for a Navy project. We also understand that one manufacturer has recently completed a risk analysis for a seven-ship series.

- It appears that safety problems are rarely reported by ship owners to the equipment manufacturers. The manufacturer of a typical hook design reported having never heard of an accident involving his hooks, and that they are hardly ever called out to deal with problems.
- It was alleged that Western hook designs have been copied in the Far East, but with vital features such as tolerances not properly understood and incorporated in the copy versions.
- One manufacturer admitted that another design of on-load hook is probably more forgiving than the typical type he uses.
- There seems to be general agreement that, in the face of potential misuse at sea, it is possible to design and make a more robust and forgiving hook.
- A view was expressed that different manufacturers (and also different approving surveyors) interpret the SOLAS requirements differently, leading to some of the problems experienced on board. It was said that there are proposals being developed to iron out these different interpretations.
- A tendency was noted for seafarers to blame manufacturers for any accident or incident. However, manufacturers were keen to point out that most problems are associated with a lack of maintenance, or a lack of understanding (of the release mechanism) by the crew, or the crew not following proper procedures, or being adequately trained.
- Nevertheless, one opinion was put forward that it is unlikely that crew with enhanced seamanship skills could be anticipated in the future, and that the only route to improved safety is therefore via safer design.
- With regard to maintenance, a comment was made that during first ownership, the ship owner may often use the manufacturer's own service engineers, but that a subsequent owner is usually free to use whoever he chooses. Thus, whilst the manufacturer's service engineer may replace a degraded part, this may not be the case during subsequent ownership. (Note that, in accordance with IMO Resolution MSC.152(78) of May 2004, this situation may change with effect from July 2006, when reliance upon a service engineer authorised by the original equipment manufacturer will become mandatory). The statement was also made that a maintenance-free situation does not exist in the marine environment.
- The extent to which manufacturers currently service the lifeboats and equipment they have supplied appears to be variable. Typically it seems that maintenance and servicing is done by ships' staff or by third parties, with the manufacturers not doing a large proportion.
- It was suggested that crew often face different designs of hooks on different ships, and that these differences may not always be obvious.
- It was acknowledged that, under SOLAS requirements, a lifeboat and its launching equipment (including the hook) are primarily specified for one-off use in an emergency. The reality of a lifeboat's use, comprising regular drills involving lifting and recovery throughout the life of the ship, should therefore be better reflected in design briefs and details.
- It was also acknowledged that some hook designs can be sensitive to wear, such that even a perfectly good hook may eventually fail if repeatedly disengaged on-load. It was suggested that a hook may typically experience up to 50 releases, so that to minimize wear boats should normally be waterborne when released, and limited to (say) no more than 20 releases

on-load. The conclusion we infer is that further use may cause mating surfaces to wear out of tolerance and lead to an unsafe situation.

- One manufacturer highlighted a specific problem relating to his equipment (falling lashings), but thought the simple remedy to be not commercially viable.
- Another manufacturer appeared to be aware of accidents involving their boats, but reported there being very few problems with their hooks opening inadvertently.
- A statement was also made that hooks may look very simple, but actually they are not. There is a complex conflict between safeguards on the one hand and the need for instant release on the other.
- One manufacturer referred to the fact that regulations do not stipulate the degree of reliability to be achieved. Clearly, the use of lesser quality components (for morse cables, materials of hook construction, etc) will inevitably lead to a cheaper product. With profit margins being very low, there is little incentive for manufacturers to adopt higher construction standards, provided the hook meets minimum regulatory requirements.
- To an extent the problems are believed by manufacturers to arise from the dwindling pool of seamanship knowledge and experience onboard ships today. Unlike the old days of seafaring, when a ship's boats were used frequently, the crew on board some modern ferries may only practice using the lifeboats every other month. This presents a challenge to manufacturers to design very user-friendly equipment.
- Attention was drawn to the problem of record keeping. With as many as sixty thousand ships fitted with lifeboats, it was argued that it would be impossible for manufacturers to maintain up-to-date condition records for each hook and boat.
- In this regard, shipping was seen as having a significantly different, less safety-conscious, culture than the offshore industry (where lifeboats are similarly required on offshore oil and gas installations).
- There was an acknowledged reluctance amongst manufacturing companies to consider collaborating to jointly develop improved designs. This reluctance seems to stem from perceived conflicts of commercial interests, plus differing national cultures.
- The industry is discussing the possibility of much larger lifeboats than the current maximum capacity of 150 persons. Sizes of 250 person capacity are being considered, for use on large passenger vessels. However, this increase in size was not considered to be problematic from the point of view of on-load hook design.
- It is apparent that there is a supply chain issue between manufacturer and ship owner. In earlier times a ship builder would typically source lifeboats, davits and other components separately, subsequently assembling and testing the installation as part of the shipyard's workscope. Increasingly, however, shipbuilders are moving towards deals in which the entire lifeboat outfit is sourced as a subcontracted package. In this situation, lowest cost commensurate with SOLAS compliance wins the day. These commercial pressures are not conducive to investment in research and product development.

2.5.8 Summarising the above, and focusing particularly on the issue of on-load release hooks, it is clear to us that the manufacturers' perspective appears to be that:

- Whilst problems and accidents arise primarily because of inadequate training, maintenance and procedures on board;
- It is, however, technically feasible to design and manufacture on-load release hooks that are more robust and tolerant of operational shortcomings;
- But current commercial pressures strongly discourage the development of such improved hook designs; although
- There is a decided reluctance amongst manufacturers to collaborate in developing better and safer hooks.

2.5.9 Because we were not able to source detailed design information from hook manufacturers, we are not able to say how many different designs fall into the "unstable" category described above, and how many do not. However, we understand that there are at least ten different designs of on-load release hook.

2.5.10 In our opinion, it is clear that designers and manufacturers within the industry, by virtue of their particular knowledge and experience, are most appropriately placed to undertake such design development work. For progress to be made, however, changes are required to the commercial and regulatory framework within which these designers and manufacturers operate.

2.5.11 With regard to servicing, the input we received from a company that services ships' lifeboat systems was in sharp contrast to the position taken by the manufacturing companies. This particular company manufactures boats and launching systems for the offshore oil and gas industry, but not for ships, although it undertakes servicing for both sectors. They were therefore able to provide insights into the problems experienced with ships' lifeboat systems. This company is a member of the Association, and got in touch with us after receiving our request for information via the Association's secretariat. A visit was made to the company's operating base, we were able to have extensive discussions with their technical and operations managers, and relevant technical information was made available.

2.5.12 It is noteworthy that for the offshore industry, this company manufactures survival capsules which are launched using a single fall (unlike ships' lifeboats which conventionally use twin falls). The launching arrangement uses an on-load release hook which differs significantly in concept to the arrangement typically adopted for ships' hooks (outlined in Section 2.4 above). With this hook, the weight of the capsule tends to hold the hook closed and, as long as the mechanism has been primed (by removing a hook-mounted safety pin), release occurs automatically when the capsule becomes waterborne. Alternatively, the hook can be opened manually by driving the mechanism out of its stable condition. Otherwise the hook is stable and cannot be reset in anything but a stable condition. We observed a demonstration of the hook's operation and can confirm its operating principles.

2.5.13 With regard to the servicing work this company undertakes on ships' lifeboat systems, their comments included the following.

- All manufacturers should ensure that equipment they develop fails to safe, so that if incorrectly used it will not kill or injure; only some manufacturers have actually achieved this.
- The introduction of IMO/MSC Circular 1093, which requires testing and servicing of lifeboat systems by competent persons, is a move in the right direction.
- But as it stands, Circular 1093 may have only a limited effect because owners will be tied to a particular manufacturer, with attendant concerns; 1093 needs revision to allow for independent servicing and choice.
- SOLAS requirements for periodic testing are open to interpretation such that boats and systems may be subjected to loads for which they were never designed.
- The wide variety of different hook types also means that attending class surveyors may not sufficiently understand the way each hook works and demand inappropriate tests.
- Routine renewal of maintenance pennants is an issue which should be addressed; unlike renewal and end-for-ending of fall wires, this is not currently required by SOLAS.
- Morse cables are a frequent source of trouble, for example through seizing, insecure fastening, or stretching of the cable or sheath, leading to unintended hook release.
- Similarly, human error can lead to incorrectly set hooks or incorrectly adjusted cables; in these circumstances, it is highly undesirable that the boat is reliant for support only on morse cables.
- Language difficulties occur on many ships, leading to problems for crews in properly understanding maintenance and operating instructions.
- On many ships, a high crew turnover leads to low awareness of lifeboat systems.
- Crews are unlikely to admit any lack of knowledge about how a system works in front of an attending class or flag state surveyor.

2.5.14 Two key points emerge from our discussions with this servicing company, that:

- A radically different and more safety conscious culture exists in the offshore industry compared with shipping; and
- The design of an inherently safe on-load release hook not only appears practicable, but is essential for preventing lifeboat accidents given the inevitability of human error and equipment degradation in the marine environment.

2.6 CANADIAN HOOK DESIGN

2.6.1 A Canadian report to IMO (FP50/INF.4), submitted during the course of this study, describes a series of comparative tests carried out on two different hook designs. One of these is understood to be representative of many on-load release hooks currently in service. The other comprises a new design of hook developed in Canada specifically to overcome some of the perceived shortcomings of many existing on-load hook designs. The tests suggest that the new design offers considerable advantages, through being inherently more stable and therefore much less prone to premature or unexpected opening under fault conditions.

2.6.2 We made contact with the Canadian design organization involved. They willingly provided us with relevant design information, and useful discussions ensued by phone and a face-to-face meeting during the course of the FP50 meeting at IMO.

2.6.3 We have carefully reviewed the technical information provided to us by the Canadian organization and conclude that the design does overcome the inherent unstable characteristic of the existing hook example used in the comparative tests. This is achieved via the geometry and arrangement of hook components such that the weight of the suspended boat acts in way that tends to close the hook, and that opening is achieved by driving the hook mechanism from this position of stability into a position where the hook opens automatically.

2.6.4 We understand that development of this new hook design was initiated as a result of the accidents with existing hooks being experienced worldwide. We also understand that the work was funded in part by the Canadian government (Transport Canada) and in part by Canada's offshore oil and gas industry, demonstrating again the sharp cultural difference between this industry and shipping.

2.6.5 The work focused on improving hook design because, when asked where the biggest problem with lifeboats lay, the offshore industry quickly replied "hooks". The design approach taken was not to blame the user for improper use, but to design a hook to function safely based on how it will actually be used. The prime objective was to design a hook which did not open if a mistake were made. It was also realised that operating cables are a critical structural part of the system, but are not designed for this task.

2.6.6 This information, together with that provided by the servicing company, clearly confirms two important conclusions from the information gathering work:

- That the unstable nature of some current hook designs is a direct cause of many serious and fatal lifeboat accidents; and
- That it is entirely practicable to design an on-load release hook which has stable characteristics, thus overcoming this shortcoming and substantially improving safety.

2.7 END-USER PERSPECTIVES: SHIP OWNERS

2.7.1 Through the Chamber of Shipping, and through contacts known to members of the study team, five UK-based ship owners were approached and invited to provide information to the study. All five owners expressed a willingness to assist, although two were only able to provide limited information. A questionnaire (see Annex A3) was used as the starting point for discussions. Additionally a leading shipping company's recently retired head of safety, now an independent marine consultant, agreed to provide information for the study. His input is included with that of the ship owners described below.

2.7.2 One ship owner (operating tankers) had instigated their own detailed data gathering and analysis study of incidents involving conventional lifeboats and rescue craft. A total of 58 incidents were recorded (equating to approximately 10 per year), of which 50% were classified as major. Causes were given as: design (32%); inspection and maintenance (23%); operation and procedures (21%); training (12%); and manufacture and installation (12%). A safety criticality analysis revealed that incidents with release gear have the greatest priority, on the basis that release gear failure could cause a major accident and that there is no back-up system should failure occur. Furthermore, design is identified as being the issue of greatest concern relating to release gear. Two thirds of this company's fleet have conventional side launched lifeboats, but the trouble they have experienced has led to a policy decision to specify stern launched free-fall boats on all newbuildings.

2.7.3 Another ship owner (operating coastal tankers) reported having no accidents or incidents over a 15 year period. However, only three of their vessels are fitted with davit-launched side-mounted lifeboats and these vessels were being disposed of imminently. As a deliberate policy, the company fleet will then comprise only vessels with stern launched free-fall type boats. We noted, and the company agreed, that its willingness to cooperate with research such as the present study, and its robust arrangements for crew training and servicing / maintenance of lifeboats, were consistent with its desire to be a safe and reputable owner, with the corresponding consequence of accidents being less likely.

2.7.4 A ship owner operating passenger vessels agreed that lifeboat problems are not related to the boat itself, or the davits, but are all to do with the rigging. In addition to unintended hook release incidents; this company had experienced injuries to people being hit by fall blocks, and back injuries resulting from man-handling fall blocks onto hooks, especially with enclosed or partially enclosed boats where the hooks are relatively inaccessible. In part, these problems led the company to install marine evacuation systems in place of lifeboats for a passenger ferry conversion project.

2.7.5 The same owner commented that lifeboats need to be used frequently in drills, to stop parts seizing-up. But that this frequent use led to brakes wearing out, with the manufacturers saying that brakes are not designed to be used that often. Design inadequacy was mentioned several times, this owner's opinion being that it must be possible to design equipment that is both simple to use and tolerant to human error, and therefore fit for use by the average seafarer.

2.7.6 This company stated that whilst they are happy to divulge their experience of incidents and their causes to others, other companies in the industry are not. More significantly, the comment was made that lifeboat manufacturers are generally not willing to divulge incident information.

2.7.7 Safe lowering and launching does need proficient crew, and the company prides itself in maintaining a high level of competence in both deck and hotel staff. Nevertheless, deck crew are naturally more competent in matters of good seamanship and, for drills, would sometimes prefer to do it themselves. The larger size and hence weight of passenger ship lifeboats (up to 150 person capacity), adds to the difficulty when handling gripes, fall blocks, etc, leading to the conclusion that there must be a better way.

2.7.8 Fears were expressed regarding the new situation, where SOLAS no longer requires persons to be aboard when lowering and recovering lifeboats during drills. This may necessitate crew climbing ladders to board and alight from an afloat boat, thus simply substituting one hazard for another.

2.7.9 The company is committed to good training as a vital means of achieving safety during lifeboat drills. In part this is achieved using videos and working models of the hook release mechanism (which we saw demonstrated), kept onboard.

2.7.10 An owner operating bulk carriers in the short sea trade confirmed that, even though no serious accidents have been experienced, staff on board have lost faith in lifeboat launching mechanisms. Problems have been experienced with conventional davit-launched boats relating for example to hanging-off pennants and winch brake failures leading to minor accidents. A key issue for this company, operating under the pressures of the short sea sector, is the lack of time available for training.

2.7.11 The fifth of the five owners we approached operates in the public sector. Over a six year period, they recorded ten accidents involving lifeboats (although it is understood that some unreported accidents also occurred). The range of components involved appears typical, comprising winches, gripes, blocks, falls, bowsing and hooks. The instance of hook failure involved premature release of on-load hooks, resulting in the boat dropping into the water and causing 7 injuries. There was one other instance of the boat dropping into the water, and four instances when boats were left suspended vertically (causing injuries), or at an acute angle.

2.7.12 This owner also commented that, apart from these accidents, other problems have arisen such as the size / position of access hatches at the forward and aft ends, which preclude easy access to the falls. Also cited is the difficulty of defect rectification when the original manufacturer is no longer in business.

2.7.13 As part of this owner's safety management arrangements, accidents are investigated and the findings promulgated around the fleet. Servicing and repair are undertaken by external contractors, but maintenance (currently carried out by ships' staff) will also be contracted out when MSC Circular 1093 takes full effect.

2.7.14 Design, manufacture, maintenance, servicing and operational use are all considered equally to blame for the problems being experienced, although in a number of the accidents design is thought to have played the major part. Maintenance was also an issue in another accident, where brake pads had just been renewed.

2.7.15 Pressure of work and time constraints for conducting drills and maintenance affect this owner in much the same way as in most commercial companies.

Likewise, operational complexities and competence of personnel play a major part.

2.7.16 Finally, this owner commented as follows.

- We are very aware of, and concerned with, the number of reported incidents in recent years.
- A feasibility study is therefore underway to consider replacing lifeboats with alternative evacuation systems. A decision whether to proceed is expected by the end of March 2006.
- If the decision is to replace lifeboats, this will commence as early as December 2006 and take place over the next five years on certain vessels, including newbuildings.
- Even so, it could take 10-15 years to reduce the hazards on all ships in the fleet, a period of time which not everyone considers acceptable.
- The greatest problem now is the perception that crews currently have of lifeboats; no longer do they save lives, rather they cause accidents.
- Due to the concern over incidents, boats are now lowered / recovered with only the launching crew onboard. In some cases, no personnel are in the boat at all.
- Lifeboat crews and other personnel are not therefore getting the experience of being in a boat, let alone the formal training. This unfamiliarity can only lead to further incidents when personnel are finally forced to be involved, and thus the mistrust increases. On a recent occasion personnel were refusing to board the boat. This whole perception could now be beyond a point of recovery.

2.7.17 The marine consultant who provided information for the study was formerly head of safety for a shipping group which included ferries. His comments included the following.

- It is naive to think that equipment will get looked after well and used properly on board ship in a marine environment.
- It is notoriously problematic to lower a lifeboat from within (using a remote winch control wire).
- Also, whilst this may be appropriate for a coaster with a small crew (the last-man-off argument), it is not appropriate for vessels with large numbers of people on board and equipped with both rafts and boats.
- It should be feasible to design a foolproof on-load release system (this comment was made with the “rotating cup” system in mind), although there is not necessarily a robust engineering solution to every problem.
- One of the typical hook designs is inherently dangerous and should be banned.
- Lifeboat systems are designed to meet IMO regulatory and code requirements, but do not seem also to be designed for safe recovery after drills; and
- The question needs to be asked: “Why are lifeboats required, and why are we required to be drilled monthly in their use? Ultimately, lifeboats are not designed to be recovered”.

2.7.18 Summarising the ship owners' viewpoints set out above, it is concluded that:

- Some owners have conducted their own studies and are adopting radical changes to reduce risk;
- There is real conflict between the desirability of conducting drills to maintain proficiency, and the associated risk of accidents;
- Whilst owners recognise the importance of training and maintenance, design inadequacy is also a key issue and needs to be addressed;
- The design of lifeboat launching equipment can and should take realistic account of the context of use aboard ship; and
- Ultimately, radical abandonment solutions may be a better answer.

2.8 END-USER PERSPECTIVES: SEAFARERS

2.8.1 It was considered especially important to seek information and opinion on the issue of lifeboat safety directly from seafarers, who are at risk of injury or fatality should an accident occur. Seafarers are the users of lifeboats; it is they who maintain and operate the lifeboats and launching equipment on a day-to-day basis on board their vessels. Without any doubt, this routine usage predominates over the rare occasions when the boats may be used in an emergency.

2.8.2 Furthermore, and subject of course to the inevitability of modern commercial and time pressures, it is suggested that because lifeboats are there for their safety, it is unlikely that seafarers will knowingly and intentionally shirk their role in maintaining both the serviceability of boats and launching arrangements and their own competence in their use. Tedious though lifeboat drills may sometimes be, they are probably secretly welcomed by the majority of mariners.

2.8.3 We therefore sought to obtain the seafarers' perspective via their trade union organisations. We approached the officers' union (NUMAST), the ratings' union (RMT) and the International Transport Workers Federation (ITF). This latter umbrella organisation is a non-governmental organisation with observer status at the IMO. As with other consultees, a questionnaire (see Annex A4) was used as the starting point for information gathering. The objective was to seek both a consensus view from the unions, and individual opinions from seafarers. All three organisations expressed a keen willingness to assist, although the practicality of obtaining individual inputs from serving seafarers at sea soon emerged as a problem.

2.8.4 NUMAST commented as follows.

- Lifeboat safety is currently a major issue, and is under discussion by NUMAST's professional and technical panels.
- The need to practice by routinely lowering / launching boats is questioned; liferafts are not routinely drilled in this way and it is only a drill not a real abandonment; system tests may therefore suffice; but
- Seafarers need good and competent training; there needs to be a process within drills that teaches without exposing people to risks.

- A few years ago NUMAST instigated a process in which boats are lowered to and from the water with no-one on board; the crew climb down, hook on and climb back. Alternatively, the boat can be lowered with no more than two crew on board, holding the man ropes if possible.
- This process emerged from lengthy discussions in safety forums and was promulgated as instructions to members via the organisation's newsletter.
- Although almost ubiquitous now, on-load release hooks are more trouble than they are worth; the older off-load type were much simpler, one just had to ensure the after hook was released first.
- Manufacturers probably feel frustrated, in that they make equipment according to prescribed SOLAS standards, but then it's not properly maintained.
- There needs to be a cultural change, so that maintenance is done by properly qualified staff ashore.
- A big problem is that, as crew move around from ship to ship, not only are the lifeboat arrangements on every ship different but operation and maintenance manuals are difficult to understand.
- The recent IMO guidance is considered helpful, especially about being cautious when conducting drills.
- Taking all the factors into account, maybe a totally new concept for ship abandonment is required.

2.8.5 Unfortunately, and despite expressing a keen willingness to assist, RMT were not able to provide a detailed response to the questionnaire during the timeframe of our information gathering work. We understand that this was due to exceptional and unconnected pressures being experienced by RMT officials at the time. However, an RMT representative was able to attend the workshop event on 13th January (see section 3.3). His participation and constructive contribution are gratefully appreciated.

2.8.6 The ITF commented as follows.

- We strongly dispute the manufacturers' claim that the problems lie with the seafarers; the manufacturers should take a greater responsibility.
- We agree that seafarers are often not fully conversant with the equipment, but nowadays seafarers do not have time on board to become fully familiar.
- Launch and release equipment on different ships frequently differs markedly, but ought to be same or similar to facilitate familiarity.
- During ISM surveys, seafarers of course say "everything is fine", the reality being challenges to their job security.
- Also, crew are often fatigued, socially isolated, stressed and overworked.
- Under STCW, an AB (able-bodied seaman) is trained primarily in watch-keeping duties, not maintenance of lifesaving equipment; and
- Typically there is no longer a carpenter or bosun on board having the requisite experience to take responsibility for maintenance of lifeboats.
- As equipment on board gets progressively more complex, and the pool of skills on board reduces, proper maintenance becomes more difficult.
- In some countries, the ship owners' approach is strongly tending towards minimum qualifications on board, thus exacerbating this problem.

- In less pressured times, the crew would often lower the boat and motor ashore; this generated familiarity but does not happen any more.
- On-load release hooks are a big issue; safe operation needs very fine tolerances, which typically cannot be achieved in a ship-board context.
- Manufacturers do not seem to accept that an on-load release hook is a sensitive piece of equipment; they should instead invent equipment that is difficult to operate incorrectly.
- Ships do not usually report problems to manufacturers, because often the original manufacturer is not readily accessible.
- Whilst generally against over-regulation, the situation demands a very tight list of manufacturing requirements, not simply the on-load requirement.
- There should be much greater standardisation, perhaps a maximum of only two or three different designs of lifeboat launching arrangements; this is far from the case at present.
- This would also overcome another problem, which is ships being supplied with a "standard" manual when in fact the equipment on their particular ship differs from the standard, creating operating and maintenance difficulties.
- There is a marked difference in culture between the aviation and maritime sectors; there is no justification for mariners having to put up with lower standards.
- The organisation has been mandated by its safety committee to pursue the issue of lifeboat safety vigorously and not to accept the current situation.

2.8.7 One particular submission from an individual seafarer stands out. It is from a ship's master (see also MARS report 200603), and extracts are as follows.

- I have been sailing on ships with lifeboats fitted with hydrostatic interlock for ten years, but have never come across any officer who understands this simple mechanism properly. So I never allow my officers to do anything to the mechanism without my prior approval; in fact I do the maintenance / inspection myself, taking them with me and explaining the system to them. Throughout my career I have seen circulars from MARS, Flag State, P&I, Class, IMO/MSC, MAIB, etc warning of injuries and fatal accidents. I think the main reason for accidents is incorrect hook re-engagement after lowering and manoeuvring the boat in water, and lack of understanding of hydrostatic interlocks. Also, hooks are constructed so it is difficult to see if they are properly engaged, instruction plates are ambiguous and manuals are never clear.
- I never allow a boat to be lowered with people inside, unless maintenance shackles are rigged to by-pass the on-load release hook: Thus before lowering, we connect these to the floating block of the falls; when the boat is just above the water we stop lowering and remove the shackles before lowering into the water and operating the on-load release; then we follow a reverse procedure when recovering the boat out of the water into its stowed position.

2.8.8 Another individual seafarer's contribution is noteworthy, in stating categorically that on safety grounds conventional davit-launched lifeboats ought to be banned. Liferafts would suffice for ships with a crew of only 3 or 4 people, otherwise free-fall or float-free lifeboats should be provided. With existing davit-launched lifeboats this contributor questions the need for drills to include driving the boat in the water, because this can be better covered in a training school context. This would avoid the routine operation of disengaging gear which is designed primarily to be used only in an emergency, thus reducing the opportunity for incorrect hook resetting (with the consequent possibility of a subsequent accident), and avoiding the need for having people in the boat during drills (hence substantially reducing risk).

2.9 HEALTH & SAFETY EXECUTIVE

2.9.1 Lifeboats are required by regulation on offshore oil and gas installations in UK waters. Whereas modern installations are usually provided with free-fall boats (as is the case with ships), earlier installations were equipped with conventional falls-launched boats similar to those on many ships. HSE was therefore approached to ascertain whether the offshore industry had also experienced lifeboat accidents.

2.9.2 There have been 3 accidents on UK installations in the period 1992-1996, involving 2 fatalities.

2.9.3 In pursuing these enquiries it became obvious that a significantly different, more proactive and safety conscious, culture exists within the offshore industry compared with shipping. For example, within 10 days of the most recent UK accident in 1996, a Safety Alert had been issued by HSE to all operators, with a variety of follow-up safety initiatives later that year. Subsequently, updated guidance was issued in April 2003 following a comprehensive risk assessment by the industry's own "Step Change" initiative forum.

2.10 OTHER INFORMATION

2.10.1 As part of our information gathering work, maritime training schools were contacted. They have experienced no problems or accidents, though admit that their launching equipment is fully maintained, and that teaching and drills are carried out under supervision by very experienced training staff fully familiar with the equipment and its mode of operation. However, they acknowledge that in places launching procedures can be awkward, and there are aspects where students leave the course but do not necessarily follow the procedures they've been taught.

3 RISK ASSESSMENT

3.1 RISK LEVELS AND TOLERABILITY

3.1.1 Risk is the combination of the likelihood (or probability) of an accident occurring, coupled with the severity of its consequence. For accidents involving small numbers of people (and lifeboat accidents typically fall into this category), individual risk (IR) is conventionally taken as the measure of risk level. Individual risk is the probability of fatality per year of a hypothetical person in a representative hazardous situation. In the UK, guidance figures for the acceptability of individual risk in the workplace have been provided by the HSE, as follows:

Risk level	**Acceptability**
Lower than 10^{-5}	Broadly acceptable
Between 10^{-5} and 10^{-3}	Tolerable
Higher than 10^{-3}	Intolerable

NB: 10^{-5} corresponds to a 1 in 100,000 chance per year;
similarly, 10^{-3} corresponds to a 1 in 1,000 chance per year.

3.1.2 If a risk is deemed broadly acceptable, HSE consider that no further action is necessary. If a risk is assessed as being tolerable, efforts should be made to reduce the risk to the extent that it is reasonably practicable to do so. If a risk falls into the intolerable category, the activity giving rise to that risk should not be undertaken (except in exceptional circumstances), or measures should be put in place (irrespective of cost, time and trouble) to reduce the risk to be within the tolerable region.

3.1.3 It was not part of the purpose of this research to establish the actual risk level associated with lifeboat accidents. This is because IMO has effectively already decided that risks are too high and need to be reduced. It is not clear to us whether this decision was based on the actual level of risk, or simply because it results from a regulatory requirement. Nevertheless because the risk arises as a direct result of a mandatory activity, it can be considered to be preventable. It is probably for this reason therefore, and the fact that lifeboats are intended to save lives, that IMO concluded that the risk from lifeboat accidents is unacceptably high.

3.1.4 All the same, we have attempted to estimate the actual risk levels associated with lifeboat accidents. This is not straightforward because data is needed regarding both the numbers of accidents of different types and the population of ships, lifeboat drills, etc which gave rise to those accidents. Although some data is available in the former category, data in the latter category (consistent with the available accident data) is rather difficult to source.

3.1.5 However, two of the ship owners we approached made some data available to us. One owner experienced 10 incidents on 9 ships over a six year period. This equates to 0.185 incidents per ship per year. The incidents resulted in 19 injuries but no fatalities. There are two ways of estimating the likely fatal injury rate. Firstly, the classic work of Frank, Bird & Heinrick suggests a broadly constant statistical ratio between minor and serious consequences. Assuming a 20 to 1 ratio for lifeboat accidents indicates a fatality rate for this owner of 0.009 per ship per year. Alternatively, the data in the MAIB 2001 study (12 fatalities in 125 incidents, see Annex A1) suggests a ratio of 0.096 fatalities per incident, equating to a fatality rate for this owner of 0.018 per ship per year (ie twice as high). However, it is likely that MAIB data is biased towards more severe accidents.

3.1.6 The second owner experienced 58 incidents in a total of 178 ship years of operation. Of these 42 (ie 72%) took place during lifeboat drills and 9 (16%) during testing and maintenance. This equates to 0.326 incidents per ship per year. But only 6 of the 58 incidents involved injury (and there were no fatalities), so the injury incident rate was 0.034 per ship year. The MAIB study (12 fatalities in 125 incidents, see Annex A1) suggests a ratio of 12 fatalities to 80 injuries, indicating a fatality rate for this owner of 0.006 per ship per year.

3.1.7 Thus, based on these limited data sets and very approximate estimates, the individual risk (IR) from lifeboat accidents may be of the order of 0.006 to 0.020 per ship per year (ie 6×10^{-3} to 20×10^{-3}). If correct, these figures (of the order of about one in 100 per year) place risk levels well into the intolerable region, fully justifying seafarers' concerns.

3.2 PROPOSED FAULT TREE MODEL

3.2.1 As set out in our project proposal, the principal objective of the workshop was to have been focused on a fault tree model of lifeboat accidents. The plan was to prepare this model beforehand and then, during the course of a workshop attended by a wide range of stakeholder interests, to:

- review and refine the fault tree model;
- validate the model for design development work; and
- use the model to identify possible options for design improvement.

3.2.2 In the event, however, it was not possible to prepare the fault tree model beforehand, and consequently not possible to refine the model and use it during the workshop as a basis for discussing potential design improvements.

3.2.3 The reason for this was the reluctance of manufacturers to provide detailed design information to the project team which could be associated with accident information as a basis for constructing a realistic fault tree model. This was despite strenuous efforts to encourage manufacturers to participate in this research study, as described in section 2.5. Regrettably development of the fault tree model could not therefore be pursued. We also sought to secure participation in the workshop by manufacturers' representatives, but these attempts were also unsuccessful.

3.2.4 For the benefit of participants, the fault tree approach was described in outline during the workshop and a simple illustration discussed. However, fault tree modelling has not been taken further. The workshop went ahead comprising only discussion of the issues surrounding lifeboat safety and how they might be overcome. From this point of view, it must be said that the workshop was an informative and productive event, with willing and constructive participation by all those present.

3.3 WORKSHOP EVENT

3.3.1 The one-day workshop took place on 13th January 2006, at the offices of Burness Corlett - Three Quays in London. The agenda for the workshop is included as Annex A5. Participants comprised:

- Two representatives of the MCA;
- A representative of the MAIB;
- A representative of the seafarers' union RMT;
- Representatives of two ship owning companies;
- Two representatives of a lifeboat servicing company;
- A representative of a marine design company*;
- A classification society surveyor;
- A marine safety consultant; and
- Three members of the research contractor's team.

* Designers of the on-load release hook featured in IMO paper FP50/INF.4.

3.3.2 It was noted that IMO/MSC Circular 1049 issued in May 2002 stated that most accidents fall into the following seven categories:

- Failure of on-load release mechanism;
- Inadvertent operation of on-load release;
- Inadequate maintenance of lifeboats, davits and launching equipment;
- Communication failures;
- Lack of familiarity with boats davits, equipment and controls;
- Unsafe practices during lifeboat drills and inspections; and
- Design faults other than on-load release.

3.3.3 It was agreed that key current requirements of the regulations which contribute to why accidents happen include:

- Lower at least one boat every month (but no requirement for crew to be on board);
- Launch every boat every 3 months with assigned crew on board (therefore also recover);
- On-load release gear required (from no load to 1.1 times full load);
- Lifeboats always ready for use in emergency; and
- On-load release gear overhauled/tested at 1.1 times full load every 5 years.

3.3.4 On the other hand, it was noted that regulations do *not* require:

- A *maximum* embarkation height above sea level (although the davit head height is not to exceed 15 metres, "as far as practicable");
- Twin falls;
- On-load release for single falls arrangement; or
- A proven recovery arrangement.

3.3.5 Relevant IMO/MSC circulars were agreed as being:

- 1049 (May 2002): Safety management system (SMS) principles to be applied to design, construction, maintenance and operation;
- 1093 (June 2003): Servicing and maintenance to be by original equipment manufacturer (OEM) or authorized organisations (1093 will be implemented from July 2006); and
- 1136 (Dec. 2004): On-board procedural guidance for safety during drills.

3.4 WORKSHOP OUTPUT

3.4.1 On the basis of the above, the group discussed a series of key questions. The objectives were to encourage a deeper understanding of the issues, stimulate creative thinking, test the boundaries of the problem, and inform compilation of our state-of-the-art review. These questions, and the group's answers to them, are set out in Annex A6 and A7.

3.4.2 The first set of questions sought to identify current problems, the changes needed and obstacles to change. Participants' opinions can be summarised as follows.

- Identified problems closely reflect the comments of end users set out in sections 2.7 and 2.8 above, but also include the lack of relevant research and development and the requirements currently embodied in IMO regulations.
- Necessary changes need action by IMO and shipping regulators on the one hand, and by designers and manufacturers on the other; and
- Obstacles to change were seen as relating to costs and safety culture, but not technology.

3.4.3 The second set of questions sought to raise fundamental issues regarding the provision of lifeboats and their launching arrangements. Participants' opinions can be summarised as follows.

- It remains an open question as to whether lifeboats are the most appropriate means of abandonment for all types of vessel in all circumstances; but
- Given that lifeboats are provided, crews need practice to be proficient in their use.
- In principle, on-load release and a twin-falls arrangement are desirable features for lifeboat use in emergency situations.
- Actual use of lifeboats, however, comprises routine drills for which equipment is not necessarily designed.
- Design for frequent safe launching and recovery, including standardisation of the operating mechanism, is therefore also desirable; and
- Given the trend towards minimum manning, it is becoming less practicable for ships' crew properly to undertake lifeboat maintenance work.

3.4.4 The workshop closing session considered five further questions. The brief answers given below should be considered as being very subjective, and based on the perceptions and aspirations of the workshop participants. Nevertheless, they are indicative of the group’s expectations for safer ships’ lifeboats in the future.

- Is it possible to design a system in which the parts only fit together the right way? Answer: Probably yes.
- Is it possible to design and engineer a truly fail-safe twin-falls release gear? Answer: Probably yes.
- Is it possible to eradicate "single point failure", yet have single point on-load release? Answer: Possibly yes.
- Do the problems actually lie with SOLAS? Answer: SOLAS requirements ought to be amended to ensure safer system design.
- Is "rocket science" needed to achieve a truly fail-safe design of launching equipment? Answer: Probably not.

3.5 THE SAFETY CASE APPROACH

3.5.1 It is clear from the information discussed in section 2, and from the output of the workshop described in section 3.4 above, that for seafarers involved in mandatory lifeboat drills and others involved in testing, maintenance, etc:

- The majority of risk stems from on-load release hooks which are not fit for purpose; and
- Design changes for hooks are therefore necessary for risks to be significantly reduced.

3.5.2 It is also clear that confidence needs to be generated that new hook designs will result in improved safety. An appropriate and effective way of both demonstrating safety improvement and thereby building confidence is by adoption of a safety case regime for lifeboat on-load release hooks.

3.5.3 A safety case can be described as a structured argument supported by a body of evidence that provides a compelling and valid case that a ship or piece of equipment is safe for use in a given operating environment. A safety case typically comprises a document containing:

- A description of the equipment, its purpose and operating environment;
- An identification of the associated hazards and assessment of resulting risks; and
- A demonstration that risks have been reduced to be as low as reasonably practicable (ALARP).

3.5.4 The ALARP principle embodied in UK health and safety law, together with the tolerability criterion (see 3.1.2 above), provide a rational and defensible basis for judging when risks have been reduced to be acceptably low. They form an integral part of a safety case regime.

4 DESIGN CONSEQUENCES

4.1 FOCUS FOR CHANGE

4.1.1 It has been seen that a wide variety of lifeboat accidents can occur, involving components such as on-load release hooks, falls, sheaves, blocks, winches, tricing and bowsing gear, gripes, etc.

4.1.2 Regrettably, with a system that involves transferring a lifeboat, by use of man and machine, from its stowed position on a ship into the water and subsequent recovery, some accidents are perhaps inevitable. Clearly, factors such as training, experience, appropriate supervision, good instructions in the user's language, freedom from undue haste or fatigue, etc are all operational means of reducing the likelihood and consequence of an accidental event. Typically, recommendations promoting such measures appear frequently in the many published accident investigation reports and do not need repeating in detail here.

4.1.3 However, the occurrence of accidents resulting from inadvertent or unintended release of a boat from its falls, leading to the boat dropping into the sea or onto a quayside, is altogether a different matter. These accidents have the potential for fatal injury, as has occurred on several occasions. It follows that the prime focus for change to improve lifeboat safety is design improvements to reduce the likelihood of hook related fatal accidents. In particular, we consider that on-load release hooks should be designed to fail-to-close rather than fail-to-open as seems to be the case with many current designs.

4.1.4 It has been put to us that maintenance, or rather the lack of adequate maintenance, is a key causative factor in hook related accidents. However, we believe that it is unrealistic to expect high standards of maintenance in a shipboard environment, and that hook designs should reflect this inevitability and be more tolerant of the harsh operating conditions at sea. As one interested commentator remarked: There is no point expecting there to be first class seafarers on board with PhDs in lifeboat maintenance; instead lifeboat designs need to be made seafarer-proof.

4.1.5 Responsibility for this reality of minimum manning and competency lies in part with the IMO and has led to a decline in the total pool of skills available on board, and a resulting inadequacy of maintenance opportunity and capability. This situation is not consistent with the level of maintenance and operational competence that manufacturers appear to depend on for fault free operation of their launching equipment throughout the life of the ship.

4.1.6 The principal focus for change, therefore, should be in the design of on-load release hooks, the objective being for the hook to be inherently stable and therefore not prone to inadvertent or unintended opening during drills, maintenance and tests.

4.2 DESIGN SPECIFICATION

4.2.1 Currently on-load release hooks, and indeed all parts of a lifeboat's launching arrangements, are designed to fulfil the requirements of SOLAS Chapter III and the Life Saving Appliances Code. These requirements focus primarily on functional performance for emergency use, covering for example structural performance, impact and drop tests, stability requirements, operation of release gear, engine starting, etc. A requirement to recover a lifeboat after launching is included, but without detailed functional performance criteria.

4.2.2 Whilst detailed and explicit requirements relevant to emergency use of a lifeboat are clearly essential, rarely if ever will a lifeboat on most ships be used in an emergency. But use on a routine basis for the purpose of lifeboat drills and tests is inevitable. Appropriate functional performance and safety performance requirements are therefore needed, to supplement existing SOLAS requirements and ensure that lifeboats are operable and safe during normal, as well as any emergency, use.

4.2.3 The following design requirements are therefore proposed in respect of on-load release hooks and lifeboat launching systems.

- The purpose should be specifically defined to include operation during routine drills as a primary function.
- A realistic operating profile should be established, covering intended functions (including deployment, launch, recovery and lifting back on board into stowage), frequency of use, inspection periods, etc.
- Hook behaviour should be stable, such that all foreseeable mechanical faults or human errors leave the hook in a closed (and therefore safe) condition.
- Safety performance should be explicitly established as a design objective through incorporation of design risk criteria in the equipment specification.
- These risk criteria should apply to the lifeboat launching system as a whole, and reflect (or improve on) the HSE tolerability criteria set out in 3.1.2 above.
- No single failure should lead to catastrophic consequences (these being defined as loss of control of the system, or incidents exposing operating staff or others to risk of injury).
- Safety performance metrics should be identified to demonstrate through tests and analysis that intended performance can be achieved.
- These metrics should include frequency rates for different failure modes and consequences, so as to demonstrate performance relative to risk acceptance criteria.
- The design should be such that simultaneous opening of both hooks of the twin-fall system will occur when required with a sufficiently high reliability for specified risk criteria to be achieved.
- Appropriate safety assessment techniques, including hazard identification, risk assessment and cost-benefit analysis should be used in design.
- For example, failure modes, effects and criticality analysis techniques (FMECA) could be adopted to identify all possible fault and failure modes,

including material failures, mechanical failures, human error and procedural violations.

- Consideration should be given in the design to ergonomic aspects of the man-machine interfaces involved in launching and recovering lifeboats, and to the need for visibility and accessibility of components for inspection purposes.
- Realistic allowances should be included in design for in-service degradation through corrosion, erosion, vibration, electrolytic action, wear, etc.
- Geometrical compatibility of fit between components which are not intended to be compatible should be prevented.
- Safe systems of work should be established for all intended operations, taking account of manual handling aspects, operating limits, weights, etc.
- Competence requirements for operation, inspection, servicing and maintenance should be established.

4.2.4 The requirements set out in 4.2.3 constitute a draft risk-based design specification for on-load release hooks and lifeboat launching systems. They are intended to supplement existing SOLAS requirements. Further development and finalisation of this outline specification should be undertaken by an appropriate sub-committee and drafting group of the IMO's Maritime Safety Committee.

4.2.5 Additionally, the mode of operation of levers, etc controlling the means of release of a lifeboat from its falls, and its subsequent re-engagement, should be standardised, so that every seafarer knows exactly what action gives rise to what effect. This will facilitate seafarers being fully conversant with arrangements on their ship, particularly during an emergency, perhaps in the dark and in a state of distress.

4.2.6 It is proposed that such a standard should be required by regulation, but developed by manufacturers in the industry after consultation with end users.

4.2.7 It is envisaged that considerable engineering research and design development will be necessary to fulfil the specification requirements outlined in 4.2.3. We consider that those best placed to undertake this design and engineering development include organisations currently involved in lifeboat systems manufacture, since these organisations are likely to have relevant knowledge and experience. However, other organisations with an interest in safety at sea may equally be competent to undertake the work.

4.2.8 We note a conclusion from the anthropometric aspects of this study that in many of the sample populations evidenced by UK and North American administrations the on-load release capability of existing lifeboat systems may be working outside the design limits.

4.3 PROPOSED AMENDMENTS TO SOLAS

4.3.1 The foregoing has identified proposed design changes for making lifeboats safer. The changes focus primarily on on-load release hooks, because it is considered that some existing designs of hook contribute significantly to risk.

4.3.2 Given the nature and level of the risks arising from lifeboat accidents, and the prevailing culture within the shipping industry, we consider that regulatory action is needed for the proposed design changes to be implemented. New regulatory requirements should therefore be initiated by the IMO. However, the approach we propose should help contribute to a progressive cultural change for the better in the industry.

4.3.3 A proven and established approach to securing an acceptable level of safety is by adoption of a safety case regime. It is considered that this is an appropriate way forward for ships' lifeboat safety and would provide the needed stimulus for change. We therefore propose that IMO should introduce a safety case requirement for lifeboat on-load release hooks. Our proposals are set out in more detail in the conclusions section.

4.3.4 We anticipate that considerable time will be needed to complete the necessary engineering development work. In view of the high level of risk which appears to be associated with lifeboat accidents, interim measures should therefore be introduced.

4.3.5 One such short term measure which could be considered is never to allow a boat to be lowered during a drill with people inside, unless maintenance shackles are rigged to by-pass the on-load release hook. As proposed to us, the shackles are connected to the floating block of the falls before lowering. Then, when the boat is just above the water, lowering is stopped and the shackles removed before lowering into the water and operating the on-load release. A reverse procedure is followed when recovering the boat out of the water into its stowed position. The maintenance shackles are disconnected at all other times. In view of the serious nature of the hazard, we endorse this way of avoiding further unnecessary fatalities during mandatory lifeboat drills.

4.4 OTHER OPTIONS

4.4.1 Consideration of other options for improving lifeboat safety falls outside the scope of this study. These options include, for example, free-fall boats, safe haven concepts, amended drill requirements and adoption of single-fall capsules (for which simultaneous release is not a requirement).

4.4.2 This latter option may be the right solution for some smaller cargo ships with relatively small numbers of people on board. For such vessels we see no reason why a single fall solution should not be adopted. These appear to work well in the offshore industry with capacities of 30 to 50 persons, so would be quite adequate for most modern merchant vessels. Furthermore, on-load release with single fall arrangement without risks arising from unstable hook design is entirely practicable. The arguments in favour of twin falls, which in any case apply only in real emergency situations and need not apply to routine drills, are of less importance than avoiding the risks associated with present designs of twin-fall on-load release systems.

4.4.3 However, for passenger vessels, and for larger cargo vessels with larger crews, an inherently more stable and therefore safer on-load release system may be the only answer.

5 ANTHROPOMETRICS

5.1 BACKGROUND

5.1.1 For many years it has been apparent that the stature of most populations in the developed world is increasing steadily. This appears to be a function of dietary and exercise habits and may be defined as the temporal mean shift of the population. Previous work by MCA and others provides evidence of the increase in mass of worldwide populations, such that the human mass specified for lifeboat design is exceeded in many parts of the world.

5.1.2 Shipboard populations are unlikely to be homogeneous in that they are formed from combinations of ethnicity, gender and age. The statistics of weight variation among such combined populations are complex, requiring an extension from simple statistical inference based on unimodal distributions. A method is suggested to estimate sample weights for groups of various sizes taken from typical shipboard populations which may be defined as the intrinsic variation of the combined population.

5.1.3 The consequences of population growth on regulatory compliance are addressed in this section.

5.1.4 An example of the increase in body mass between 1960 and 2002 for Americans showing the influence of gender and age is given in Table 5.1.4 [Mean Body Weight, Height and Body mass Index, United States 1960 – 2002. US Centre for Disease Control and Prevention, 2004].

Population Gender and age		Mean body weight (kg)		
		1960	2002	Increase
Male	20 - 74	75.3	86.5	+11.2
Female	20 - 74	63.5	74.4	+10.9
Male	15	61.4	68.1	+6.7
Female	15	56.3	60.9	+4.6
Male	10	33.6	38.5	+4.9
Female	10	35.1	40.3	+5.2

Table 5.1.4: Increase in Body Mass of American Population, 1960 - 2002

5.1.5 Following a number of air casualties involving smaller aircraft, the FAA in August 2004 revised its average adult passenger weight from 63.4 kg to 78.8 kg, assuming a 50:50 mix of men and women in summer clothing. This was based on a large sample across the continental USA [Federal Aviation Authority Advisory Circular 120-27D, 2004].

5.1.6 Similar considerations encouraged Transport Canada to re-evaluate the standard passenger weights as follows:

Males (12 years of age upwards)	90.7 kg
Females (12 years of age upwards)	74.8 kg
Children (2 – 11 years of age)	34.0 kg

5.1.7 The aircraft-related studies which have been carried out worldwide were firstly concerned with small sample statistics, where, for example, on a 9 seater aircraft significant deviations between the sample mean and the population mean can arise, whereas on a jumbo jet the means would be expected to be more or less coincident. At the same time it emerged that the population means were, in fact, also increasing.

5.1.8 In the last few years these considerations have come to be applied to small marine craft, such as small pleasure craft, lifeboats and other survival craft, where the total passenger weight is a substantial proportion of the all up weight of the craft. The MCA work referenced above illustrates how sample sizes rapidly approach the mean values such that numbers involved in lifeboat design, for example say greater than 30 people, are close to the mean value.

5.1.9 There are other concerns in lifeboat design evidenced by various administration reports. A Canadian Transportation Safety Board report into a lifeboat accident [report MOO W0265 Accidental Release of Lifeboat from Bulk Carrier Pacmonarch] noted how wearing lifejackets in a lifeboat along with the shape of the lifeboat canopy and padded headrests forced occupants to bend their necks forward at awkward angles with the consequent risk of neck injuries when bracing against lifeboat motion.

5.1.10 The same report noted that the lifeboat seatbelts were insufficiently long to secure a large person wearing a standard lifejacket.

5.1.11 Similar incidents have been noted in the UK [MAIB report 9/2005 into lifeboat release gear test from RFA Fort Victoria]. A separate call to industry for research into lifesaving appliance compatibility has been issued by MCA.

5.1.12 Aside from the papers specifically referenced in this section, background data has been gleaned from the following:

- Physical Status: The Use and Interpretation of Anthropometry. Technical report Series 854. Geneva, WHO, 1995
- Statistics for a Composite Distribution in Anthropometric Studies. M.H. Al-Haboubi, Ergonomics, Vol. 40, 1997
- Statistics for a Composite Distribution in Anthropometric Studies: The General case. M.H.Al-Haboubi, Ergonomics, Vol.42, 1999.

5.2 DATA SOURCES

5.2.1 SOLAS requirements for lifeboats and liferafts presently assume an average mass per occupant of 75 kg. They assume also a hip width for seating area of 430 mm.

5.2.2 This section of the report considers a sample of the mass of worldwide data which is available relating to weights of individual populations. Much of the published data is in terms of Body Mass Index (BMI – kg/m^2) which relates body weight (kg) to height (m); this is a useful measure for medical purposes but not directly useful in the present study, except to note that for virtually all groups with easy access to nourishment the BMI measures are increasing. This suggests that whereas average heights and other measures of stature within populations are increasing, average weight is increasing more rapidly – a measure of body fat increase, or obesity. Hence the concern over seating area in boats.

5.2.3 A number of relevant data sources have been found and these are summarised in Table 5.2.3.

5.2.4 In this context, 'relevant data sources' means that the data includes people likely to be encountered frequently onboard ships as crew or passengers. It excludes disabled persons, people from developing nations and children of all populations, not that individuals from these populations cannot be found onboard, but simply that they will not change the underlying statistics significantly.

5.2.5 The influence of nationality mix within the international seafaring population is clearly significant. References for good ergonomic design show how important it is to appreciate the target population. The same is true for gender issues.

5.2.6 A report by Process Contracting Limited [Bridge Ergonomics – Some anthropometric considerations for ISO TC8/SC5 – May 2004] describes how anthropometric data is used to define particular European design standards. The top ten nationalities in the estimated world fleet in 2002 are quoted from the Seafarers International Research Centre database in Cardiff and reproduced in Figure 5.2.6.

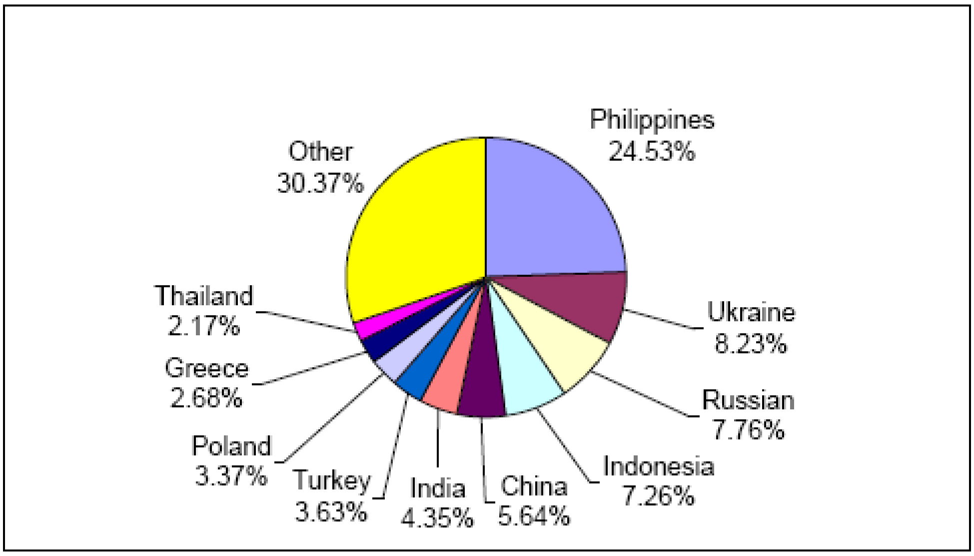


Figure 5.2.6: Proportions of Nationalities in the Seafaring Population

The populations used to determine design anthropometric data represent a small element within the seafaring population. The populations causing current concern at IMO and the subject of this particular study also form a small element of seafarers.

5.2.7 From the information presented above, it is difficult to justify increasing design standards on a worldwide basis, ie a global population. A casual inspection of the tabulated data, whilst statistically not reliable, shows that the average mass of a population made up equally from the primary geographical areas identified is less than 70 kg.

5.2.8 However the need to address concerns where the geographical population has larger physical characteristics is clear although it is difficult to justify differing standards across the world. One therefore needs to consider whether to combine various populations according to their influence or to design for the largest.

5.2.9 The brief of this study was not to answer these questions but to examine the issues. Some calculation methods for defining target anthropometric values are therefore outlined below.

Weight Data for Various Populations (current values) (Sources: various)			
Population	Weight (kg)		
	Mean	Standard Deviation	95%
US adult mixed population	78	14.6	102
US adult males (white)	78	18.2	108
US adult males (black)	79	22.4	116
US adult males (Hispanic)	77	15.2	102
US adult females (white)	65	19.5	97
US adult females (black)	76	22.5	113
US adult females (Hispanic)	66	19.5	98
British adult mixed population	75	11.6	94
European adult mixed population	75	12.2	95
Middle east young adults	65	12.0	85
Chinese workers (H.K.)	60	9.1	75
Japanese adults	60	8.5	74
Latin America & Caribbean	61	9.1	76
Canadian offshore workers	88	17.1	116
South & SE Asia mixed population	50	6.7	61
Polynesia & Micronesia	73	11.0	91
China mixed population	53	4.3	60
India mixed population	48	10.3	65

Table 5.2.3: Weight Data for Various Populations (current values)

5.3 ESTIMATION

5.3.1 Some statistical definitions related to anthropometrics:

- *Population* – Any large collection of individuals such as ‘French’, ‘Men’, ‘Students’, etc. A *parameter* is any summary number which describes the population, such as the mean. Generally, the population parameter cannot be determined, but a *sample* of the population can be used to estimate the parameter of interest.

- *Sample mean,* x_m – is the average of all the values in the sample.

- *Population mean*, μ – is the average of all the values in the population

- *Standard deviation,* σ – The standard deviation is a measure of how tightly grouped the population data are about the mean value. It uses the mean as a reference point and then measures the variability by considering the distance between each value and the mean. Nearly 100% of observed values (99.87%) lie within 3 standard deviations of the mean in a normally distributed population.

  $\sigma = (\Sigma\ (x\text{-}x_m)^2 / (N\text{-}1))^{1/2}$

  where N is the number of members in the sample.

- *Percentiles* – A percentile describes how far an observation is from the mean as a function of the standard deviation. For example, in a normal, bell-shaped, distribution of weight in a population, 95% of all measured values will be less than 1.65 times the standard deviation from the mean. Thus:

  If the mean were 75 kg and the standard deviation 13.6 kg, then 95% of all members of the population would be expected to be less than (75 + 1.65*13.6) or 97.44 kg.

  Very frequently in anthropometrics, the 95% percentile level is used as the design upper limit, giving a probability of exceedance of 5%. If lower levels of exceedance were required then the ‘multiplier’ for the standard deviation would become as follows:

  97.5% percentile multiplier = 1.95
  99.0% percentile multiplier = 2.33
  The generalised set of values for the multiplier are usually expressed as ‘z tables’.

5.4 SINGLE POPULATIONS

5.4.1 If the population consists of a single defined group, such as offshore workers, then the calculation of a mean sample body weight, w_{sm}, for use in lifeboat or liferaft design (and the associated lifting appliances) is simple, once the population statistics are known. This also assumes that weight in the population is normally distributed, which for the present purposes is a robust assumption.

5.4.2 The calculation of mean body weight for a sample size of N members in order not to exceed the 95% percentile level is as follows:

$$w_{sm} = 1.65\ (\sigma / \sqrt{N}) + \mu$$

5.4.3 Example:

A lifeboat and its associated lifting equipment are to be designed to accommodate 25 persons and the permissible exceedance level for the standard or design ‘person’ is set at the 95% percentile level.

The sample, in this case, is considered to be drawn from a single normally distributed population of, say, North American adult males where the population mean is 78 kg and the standard deviation 18.2 kg. The mean body weight for use in design can be calculated as:

$$w_{sm} = 1.65\ (18.2/\sqrt{25}) + 78$$

or,

$$w_{sm} = 84 \text{ kg.}$$

5.4.4 In general, the influence of sample size falls off rapidly beyond 40 or 50 persons in the LSA, becoming asymptotically the same as the population mean above that number of persons. This illustrates the ‘small aeroplane problem’ alluded to above, where the number of persons the craft is intended to carry influences the design weight.

5.4.5 On larger craft it may be considered appropriate to adopt the population mean as the design standard, having due regard due to uncertainties in interpreting the population statistics. Influences such as the type and weight of clothing assumed to be worn when the weights are measured and the constitution of the population being among these uncertainties. The value adopted for design should take these into account.

5.5 COMBINED POPULATIONS

5.5.1 When sampling persons in a lifeboat, there will usually be more than one underlying population. For example, there may be North European officers and South east Asian crew, or, on a cruise ship, North American adults with Latin American or Chinese crew.

5.5.2 The general principles remain the same as those for the single population case but the combined population statistics need to be determined, knowing the individual population distributions.

5.5.3 There are complex computational procedures which could be adopted to arrive at the combined population if precision were necessary, but for the present purposes a simple graphical method is suggested which gives good results for two or more combined populations and which will work for skewed distributions.

5.5.4 The method uses Normal Probability plotting paper which can be downloaded from the internet if none is to hand. Assume that the combined population is made up of 85% North American males aged 50 and 15% Hispanic males aged 25 with the population distributions shown in Table 5.5.4.

	Percentiles				
	5%	40%	50%	60%	95%
	Weights in kg				
North American males	63	80	83	87	116
Hispanic males	56	69	73	76	102

Table 5.5.4: Weight Distributions of Populations

5.5.5 These two distributions are plotted onto Normal Probability paper (see Figure 5.5.5) and may be seen to be skew, in that they are not straight lines when plotted on this type of paper. This does not materially affect our analysis.

5.5.6 From the table, it can be seen that 50% of the North American males (NAs) are less than 83 kg, that is, 42.5% of the composite population (ie 0.85 x 50%) weigh less than 83 kg. By inspection of the plotted distributions we can determine that 77% of the Hispanics (Hs) are less than 83 kg. Thus (0.15 x 77%) or 11.6% of the composite population are also less than 83 kg. The combined percentages, (42.5% and 11.6%) or 54.6% are less than 83 kg. This gives us our first data point to be plotted on the graph, Figure 5.5.5.

5.5.7 The second point is found in the same way: in the population of Hs, 50% are less than 73 kg this represents (0.15 x 50%) of the combined population, or 7.5%. At the same time, it can be seen from the plot of NAs that 15% of that population is less than 73 kg, or (0.85 x 15%) of the combined population; 12.75%. The combined percentage (20.25%) can now be plotted on the graph.

5.5.8 If the distributions are normal, two points will be sufficient to draw the combined distribution. If the original populations were not normally distributed then they will be curved and the calculations above can be repeated for a number of points, or alternatively, a good approximation can be drawn through the two points by inspection.

5.5.9 If necessary, the process can be repeated for any number of combined populations by simply applying the method successively.

5.5.10 The resulting combined distribution will provide the combined mean, the 95% percentile and therefore a good approximation to the standard deviation, as described earlier. These values can then be used to determine design weights, as for the single distribution case.

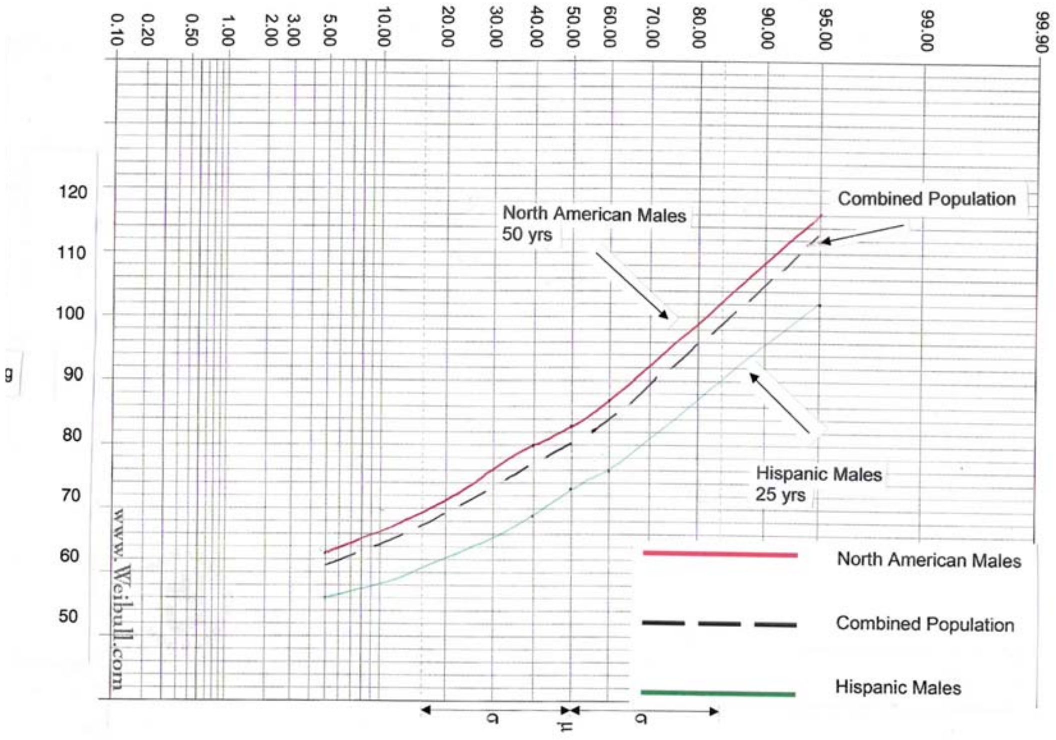


Figure 5.5.5: Population Plot showing Development of Combined Population

5.6 INTERNATIONAL LIFE-SAVING APPLIANCE CODE

5.6.1 LSA Code Requirements - Chapters IV, V and VI Design of Survival Craft, Rescue Boats and Launching Appliances
Specific implications of an increase in the physical size and mass of an adult person are examined after each of the relevant clauses in the Code. However discussion with manufacturers suggests that lifeboats and their associated equipment are designed down to rule. International commercial competition allows manufacturers little margin for adoption, for example of larger body mass in their design calculations. It may be seen therefore that an increase in body mass will immediately diminish the design margins inherent in the Code requirements.

5.6.2 Para. 4.4.1.1
General requirement that lifeboat is stable and has sufficient freeboard when loaded with full complement. Detail requirements for stability and freeboard are given in para. 4.4.5.

Implications: Code requirements are based on an average body mass per person of 75 kg. A mass increase on this average will impact on the stability and freeboard of a lifeboat certified to the current requirements. Typically, an increase in passenger mass will have a net impact on the laden boat mass as shown in Table 5.6.2.

Increase in Passenger Mass		Laden Boat Mass
kg	%	%
3.8	5.0	2.8
5.0	6.7	3.6
7.6	10.0	5.4
10.0	13.3	7.1
15.0	20.0	10.7

Table 5.6.2: Effect of Increased Passenger Mass on Laden Boat Mass

(The table addresses overladen current designs. It does not allow for new boats where increases in the self weight would likely be required to satisfy the various design requirements.)

5.6.3 Para. 4.4.1.2
Requires each lifeboat to have a certificate of approval, endorsed by the Administration. Certificate to include number of persons lifeboat is approved to carry and total mass when fully equipped and fully manned.

Implications: Lifeboats certified to current requirements may be overloaded. Lifeboats may not accommodate the certified number of persons where their anthropometric characteristics exceed the regulation standard. This has consequences for compliance with Chapter III of SOLAS, particularly if new requirements are to be applied retrospectively.

5.6.4 Para. 4.4.1.3
Addresses lifeboat strength for launching and towing.

Implications: Whole lifeboat design is affected by enhanced passenger mass requirements.

5.6.5 Para. 4.4.1.5
Concerns strength of the seating, based on 100 kg per person (static load) for each space which complies with para. 4.4.2.2.2.

Implications: 100 kg (static load) is presumed to be based on a statistical normal distribution, with a mean mass of 75 kg. An increase in the mean mass should be reflected by an equivalent increase in the static load for seat strength.

5.6.6 Para. 4.4.1.6
Concerns sufficient strength of the lifeboat to withstand a load of 1.25 times (for metal boats) the total mass when fully loaded, without residual deflection upon

removal of the load. For non-metallic hulls, the test load is 2 times. These two figures are effectively safety factors.

Implications: The safety factors inherent in these requirements are diminished by increased passenger mass but not exceeded within the limits of Table 5.6.2.

5.6.7 Para. 4.4.1.7
Concerns sufficient strength to resist impact damage when being launched under fully loaded conditions.

Implications: An increase in average body mass per person will increase the inertia of the lifeboat above that which was experienced in the impact and drop tests performed as per 6.4 in Part 1 of the Code's prototype test requirements. Therefore, the force exerted on the hull at point of impact with the ship's side and water will be greater than experienced in the tests, possibly resulting in damage which affects the lifeboat's efficient functioning.

5.6.8 Para. 4.4.2.2
Provides parameters for determining the number of persons permitted to be carried. Number to be the lesser of:

Para. 4.4.2.2.1: The number of persons having an average mass of 75 kg (no other physical dimensions given), all wearing lifejackets and seated in a normal position, without interfering with means of propulsion or operation of the boat's equipment; or

Para 4.4.2.2.2: The number of spaces that can be provided in accordance with standard spatial dimensions of the occupants. A standard "human footprint" is given in the Code, in terms of body width (430 mm) and required free clearance in front of each occupant (635 mm, with 150 mm maximum overlap).

Implications: If the certified number of occupants are to be "squeezed" into the lifeboat, it is likely that there will be an adverse impact on the means of propulsion and the efficient operation of the boat's equipment, in addition to physical discomfort. Alternatively, the lifeboat carries less people than it is certified for and compromises the requirements of Chapter III of SOLAS.

It follows that as body mass has increased, so have the body dimensions. Particularly of relevance here are width across the shoulders/upper arms and the trunk/hips. The data shows that height is also increasing. Hence, the standard "human footprint" given in the Code needs revising.

5.6.9 Para. 4.4.3
Concerns access into lifeboats.

Implication: Access arrangements need to be reconsidered for larger crew and passengers.

5.6.10 Para. 4.4.4
Concerns inherent buoyancy. Requires that additional inherently buoyant material equal to 280 N per person is provided. This figure is related to the given average body mass of 75 kg (or 736 N) per person.

Implication: Greater amount of additional inherently buoyant material may be required to support higher mass persons where out of the water.

5.6.11 Para. 4.4.5.1 Stability
Para. 4.4.5.2 Freeboard

Implications: See discussion in 5.6.2 above.

5.6.12 Para. 4.4.6.8
Requires that speed through calm water is a minimum of 6 knots and that there is sufficient fuel for at least 24 hours (at 6 knots).

Implications: “Overladen” existing lifeboats may not achieve 6 knots and/or may consume too much fuel to complete the specified endurance. New designs may require larger engines and fuel capacities with attendant overall weight increases.

5.6.13 Para. 4.4.7.6.2.2
Requires on-load release mechanism to operate when the lifeboat is loaded with a load of 1.1 times the design total mass of the boat when fully loaded.

Implication: A total mass greater that the design value reduces the safety factor. From Table 5.6.2 it may be inferred that the safety factor is exceeded for a mean passenger mass of approximately 85 kg. Thus in many of the sample populations evidenced by UK and North American administrations the on-load release capability of existing lifeboat systems may be working outside the design limits.

5.6.14 Para. 4.4.7.6.4
Requires that the design of the structural connections of the release mechanism in the lifeboat is based on a safety factor of 6.

Implication: Safety factor will be diminished.

5.6.15 Para. 4.4.7.7
Adequate painter connection

Implication: Depending on designer’s strength selection, painter attachment may be inadequate for an overladen boat.

5.6.16 Para. 4.6.2.6
A totally enclosed lifeboat when capsized to be capable of supporting *inter alia* its full complement of persons.

Implication: Higher mass persons require higher buoyancy characteristics.

5.6.17 Para. 4.6.3.1
Requires that the strength of the safety belt (and harness for free-fall boats) at each seat position is designed for a body mass of 100 kg.

Implication: As the discussion in 5.6.5 above, an increase in the population mean mass should be reflected in the extreme values. Belt length is not defined and this needs to reflect other anthropometric values.

5.6.18 Para. 4.6.3.2
Totally enclosed lifeboat to be self-righting when fully loaded.

Implication: Overloaded lifeboat may not be self-righting – a stability issue (see 5.6.2 above).

5.6.19 Para. 4.6.3.3
Damaged lifeboat to be capable of supporting its complement.

Implication: Overloaded lifeboat may have insufficient residual buoyancy – see 5.6.2 above).

5.6.20 Para. 4.6.4
Requirements for propulsion system in the event of capsize of totally enclosed lifeboat.

Implication: As discussed above, residual buoyancy characteristics of overladen boat may preclude compliance.

5.6.21 Para. 4.6.5
Concerns sufficient strength to resist impact damage when being launched under fully loaded conditions.

Implications: As 5.6.7 above.

5.6.22 Para. 4.7.2
Carrying capacity of a free-fall lifeboat.

Implication: The same general comments apply to freefall lifeboats as 5.6.8 above.

5.6.23 Para. 4.7.3 to 4.7.6
Performance and construction requirements of a free-fall lifeboat.

Implication: The same general comments apply in that overladen boats will have different characteristics which may affect their ability to launch and perform safely in accordance with the requirements.

5.6.24 Para. 5.1.1.3.2
Rescue boats to carry at least five seated persons and a person lying on a stretcher.

Implication: Whilst there are no specified anthropometric data for rescue boat capacities, designers may be influenced by the lifeboat data.

5.6.25 Para. 6.1.1.5
Launching appliance and its attachments other than winch brakes to withstand a static proof load of 2.2 times the maximum working load.

Implications: The safety factors inherent in this requirement is diminished by increased passenger mass but not exceeded within the limits of Table 5.6.2.

5.6.26 Para. 6.1.1.6
Structural members to have a factor of safety of 4.5. Running gear and related attachments to have a factor of safety of 6.0.

Implications: The safety factors inherent in these requirements are diminished by increased passenger mass but not exceeded within the limits of Table 5.6.2.

5.6.27 Para. 6.1.1.9
Rescue boat recovery arrangements for boat and full complement at rate not less than 0.3 m/s.

Implications: Should rescue boat capacities designers be influenced by the lifeboat anthropometric data, *in extremis* recovery may be slowed or unachievable.

5.6.28 Para. 6.1.2.5
Winch brakes to withstand static proof load of 1.5 times maximum working load and dynamic proof load of 1.1 times maximum working load.

Implications: The safety factors inherent in these requirements are diminished by increased passenger mass. The static test is not exceeded within the limits of Table 5.6.2, but the dynamic text load may be.

5.6.29 Para. 6.1.2.6
Maximum lowering speed defined by S = 0.4 + 0.02H.

Implications: Braking arrangements may result in faster lowering or *in extremis* uncontrolled lowering.

5.6.30 Section 6.1.4
Launching appliances for free-fall lifeboats address the free-fall element and a back-up element. Regulations refer back to earlier requirements.

Implications: The same general comments apply as for davit launched systems in that overladen boats will have different characteristics which may affect their ability to launch and perform safely in accordance with the requirements.

5.7 TESTING AND EVALUATION OF LIFE-SAVING APPLIANCES

5.7.1 Lifeboats installed on board on or after 1 July 1999 should meet the applicable recommended test requirements of the Code. However, lifeboats which satisfactorily pass the tests where an average body mass of 75 kg is an intrinsic factor, may not pass these tests should the average body mass be increased. Consideration should therefore be given to the impact that an increase in the average body mass will have on the required tests. These tests are summarised below. However, the implications are as set out above.

5.7.2 Part 1: Prototype Tests
Overload, impact & drop, seating strength, seating space, freeboard & stability, release mechanism, towing a liferaft, fuel consumption, towing of the lifeboat itself, painter release at speed when being towed, davits & launching appliances.

5.7.3 Part 2: Production and Installation Tests
Release, lowering speed (plus lowering brake test) and recovery.

5.8 DISCUSSION

5.8.1 Anthropometric data confirms that the human species is increasing in stature and mass across the globe. In some populations the mean mass may exceed the figure required by regulation to be used in lifeboat system design. A similar problem exists with breadth of hip for seating area requirements.

5.8.2 Development of the regulations has to address whether to increase the values to ensure adequate protection for the larger populations and how to do so. Should the values be applied universally or on a geographical basis? There are practical and commercial justifications for both. The study reports population data against which to form a view and presents a method for calculating mixed population statistics.

5.8.3 Populations used to determine design anthropometric data represent a small element within the seafaring population. The populations causing concern in respect of current lifeboat designs are a small element of international seafarers.

5.8.4 Assuming new regulations are to increase the values of human mass and hip width, the question of retrospective legislation has to be addressed. If new requirements are not to be applied retrospectively, are persons being put at risk? If they are to be applied retrospectively, is there a cost-benefit in so doing?

5.8.5 The study reports the design issues controlled by regulations. Generally "overloaded" lifeboats will continue to operate within their safety factors. The principal exception is the on-load release equipment where significantly larger populations may lead to an exceedance of the proof load. The consequences for free-fall boats are not definable within the remit of this study.

6 CONCLUSIONS

6.1 GENERAL

6.1.1 The expectation of ships' crews, passengers and society at large is that lifeboats will be readily operable in an emergency, affording safe means of escape from a vessel in distress. To this end SOLAS requires ships' lifeboats to be regularly tested and drilled.

6.1.2 The scope of this research study is confined to conventional, davit-mounted, side launched ships' lifeboats.

6.1.3 The occurrence of accidents involving this type of lifeboat, resulting in injury to or death of seafarers, is an ongoing problem in the shipping industry.

6.1.4 The industry as a whole has been aware of this problem for at least 11 years, although it is considered likely that individual ship owners and lifeboat manufacturers have been aware for longer than this.

6.1.5 Ship lifeboat incidents and accidents continue to occur, there being at least one in the UK during the course of this research project.

6.1.6 Both cargo ships and passenger ships experience lifeboat accidents (although nowadays many cargo ships are fitted with free-fall boats and many ferries are also fitted with inflatable lifesaving systems, both of which are outside the scope of this study).

6.1.7 It can be argued that lifeboat launching arrangements essentially require practical seamanship and have not changed for centuries (despite steel replacing wood and cordage; electric power replacing manpower, etc). By contrast, shipboard cargo handling (eg ro-ro and containerisation) has seen revolutionary change. Herein may lie much of the problem. Successive regulatory developments, apparently implemented without any fundamental design reappraisal, may have led to lifeboat systems being unnecessarily complex and thereby contributing to risk.

6.2 DESIGN REVIEW

6.2.1 Information and opinions have been sought from a variety of stakeholders, including individual seafarers and their union representatives, ship owners and operators, accident investigators, a ship surveyor, an equipment designer, lifeboat manufacturers and servicing organisations, and regulatory bodies (especially concerned with lifeboat type approval, inspection and testing).

6.2.2 With the exception of one stakeholder group, all those approached have readily cooperated. Grateful thanks are due to them for their time and contributions.

6.2.3 Many of these stakeholder representatives have first hand experience or close awareness of lifeboat problems or incidents, despite not being selected specifically on this basis. It is noteworthy that almost universally these contributors expressed real concern about the risk associated with ships' lifeboats.

6.2.4 This concern reflects the discussions that have taken place at the IMO in recent years, which have led to the conclusion that risk levels are unacceptably high. It is understood that this conclusion is based largely on the number of recorded accidents, although in a formal risk assessment the frequency of accidents (ie taking account of the exposed population), rather than the number of accidents, would be the determining factor.

6.2.5 An attempt has been made to estimate accident frequency and resulting risk levels. Consistent event and population data are not readily available, but based on limited data and very approximate estimates, the individual fatality frequency for seafarers during lifeboat drills may be as high as about one in 100 per year. This estimate, if correct, places the risk level well into the intolerable region, fully justifying seafarers' concerns.

6.2.6 This is a very high value in risk acceptance terms and arises as a direct result of a mandatory activity. It is probably for this reason, and the fact that lifeboats are intended to save lives, that IMO concluded that the risk from lifeboat accidents is unacceptably high.

6.2.7 Published investigation reports show that the incidents and accidents arise for several reasons. These include:

- International regulatory requirements for lifeboats to be periodically tested and ships' crews routinely drilled in their operation;
- Design shortcomings, such that launching equipment may not be fit for purpose in a realistic shipboard environment;
- Design variability between types and manufacturers, and inadequate or misleading manuals on board, leading to misunderstandings and confusion amongst shipboard end users;
- Inadequate or improper maintenance on board, leading to degradation over time of performance and design intent; and
- Progressive erosion with time of a suitably skilled resource on board to undertake maintenance, and to a certain extent, drills and tests. This resource shortfall results from pressures towards minimum manning, experience and certification across all shipboard ranks.

6.2.8 In general, accidents are rarely due to a single cause. Thus corrective action in respect of just one of these problem areas is unlikely to suffice. Effective safety management usually entails addressing a variety of contributory factors. We can therefore anticipate that design, operational and regulatory changes will be needed to significantly reduce lifeboats accidents.

6.2.9 In certain respects, maintenance issues have been addressed by the IMO through MSC Circular 1093. Significant concerns have been raised, however, that as currently formulated, the arrangements do not permit independent scrutiny of safety critical features of lifeboat launching systems.

6.2.10 As with other types of accident, both in the marine world and elsewhere, human error is often blamed as a cause. This superficial approach fails to recognise the systemic nature of accidents, diverting attention from the introduction of effective preventative measures.

6.2.11 From a safety perspective, ships' lifeboats are a special case because human operator(s) are integral to system integrity. Safe operation is therefore particularly susceptible to human error. Since human error is inevitable, safe system design is especially challenging.

6.2.12 Without significant change, the historical (and still current) pattern of accidents is likely to continue for many years into the future, as owners operate ships to the end of their economic lifespan.

6.2.13 There has been a wide variety of types of accident involving ships' lifeboats. These include accidents due to failures or problems with:

- On-load release hooks;
- Falls, sheaves and blocks;
- Winches;
- Tricing and bowsing gear;
- Gripes; and
- Inter-compatibility of parts having different functions.

6.2.14 To an extent, these accidents result from the adoption of a twin-fall system for launching lifeboats with the added system complexities this brings in comparison with a single-fall arrangement. The reasons for preferring a twin-fall system (primarily for stable suspension and orientation of the boat during loading, lowering and entry into the water) were therefore considered during the study, and also discussed during the stakeholder workshop.

6.2.15 The clear conclusion is that a single-fall arrangement would not be suitable, and therefore that twin-falls are an essential functional requirement for conventional lifeboats. However, where only a small number of persons onboard are involved, adoption of a survival capsule on a single fall launching arrangement may be appropriate.

6.2.16 Whilst any accident is unwelcome, accidents which may result in fatalities warrant special attention. The historical evidence clearly indicates that accidents involving on-load release hooks are most likely to lead to fatalities.

6.2.17 Even within the category involving on-load release hooks, there is a variety of basic causes or initiating events, including for example:

- Premature or inadvertent operation of the release lever;
- Incorrect re-setting of the hook;
- Wear and corrosion of components within the hook;
- Incorrect re-setting of the inboard operating mechanism;
- Corrosion, failure or seizing of the operating cables;
- Problems associated with the hydrostatic interlock; and
- Corrosion of the hook-to-boat structural connection.

6.2.18 Nevertheless, the result of most hook events is the premature or unexpected release of the boat. If this occurs at any significant height above the water, and especially if one end of the boat releases alone or before the other, significant injuries and/or fatalities can and do occur to the operating crew.

6.2.19 The benefit or otherwise of on-load release hooks was one of the issues considered during the project and discussed during the stakeholder workshop. Whilst there appears to be some support for the simpler off-load type (thereby avoiding almost all the problems set out at 6.2.17 above), the size and weight of modern lifeboats and falls blocks, coupled with the hazards introduced in a seaway, weighed heavily in favour of the on-load capability.

6.2.20 With regard particularly to premature or inadvertent operation of the release gear, one of the key factors which emerged from discussions with end users is the variability between different designs and manufacturers of the actual means and mechanism for release. Standardisation in this respect, irrespective of manufacturer, could therefore be beneficial.

6.2.21 An argument against standardisation is that it might stifle innovation and improvement. However, this argument is not accepted because:

- There are many instances of differing designs all meeting a common standard (eg domestic electric plugs and motor vehicle pedal layout); and
- A safety benefit is obtained.

6.2.22 It is proposed that such a standard should be required by regulation, but developed by manufacturers in the industry after consultation with end users.

6.3 RISK ASSESSMENT

6.3.1 Good safety management practice emphasizes a hierarchy of risk reduction strategies:

- Firstly, avoidance or substitution of the hazard; then
- Preventative measures to reduce the likelihood of an accident; and lastly
- Mitigative measures to reduce the consequences of the accident.

6.3.2 Furthermore, passive measures are preferable to measures which require human intervention, and reliance on PPE or human actions are least favoured.

6.3.3 Since the accidents occur during drills and tests, it might be argued that regulations should be changed to remove the hazard. In this regard it is understood that from July 2006 it will be allowable to lower and recover lifeboats without persons being on board. However, removing persons from the hazard in this way could be seen only as a mitigative measure.

6.3.4 Additionally, it is not clear that suitably safe alternative means exist for persons to gain access to the lowered boat in the water, to test the engine etc and re-connect the boat for recovery, and for the safe return of these persons on board.

6.3.5 The requirement by regulation for routine lifeboat drills was another issue considered during the project and discussed during the stakeholder workshop. There is no doubt that it is appropriate for these regulatory requirements to continue in force. Regular drills not only demonstrate functioning and serviceability of a lifeboat and its launching arrangements, but also encourage crew familiarity with the equipment and afford practice in its use.

6.3.6 Notwithstanding the above, anecdotal evidence was received from various sources that mandatory drills are sometimes skipped (despite log entries to the contrary) because of seafarers' safety concerns. Accident statistics would tend to support the validity of such assertions.

6.3.7 It follows that the prime focus for change to improve lifeboat safety is design improvement to reduce the likelihood of hook related fatal accidents.

6.4 DESIGN DEVELOPMENT

6.4.1 Several of the causes of hook failure outlined above reflect what appears to be a particular characteristic of many hook designs, which is that the hook is essentially unstable, ie that the weight of the boat suspended on the hook tends to produce a hook opening effect.

6.4.2 It can therefore be said that many on-load release hooks currently in use may be inherently unsafe. This is a very undesirable situation.

6.4.3 In principle, if the opposite were the case, ie that the weight of the boat produced a closing effect on the hook, factors such as incorrect re-setting of the hook, wear and corrosion of components within the hook, incorrect re-setting of the inboard operating mechanism and corrosion, failure or seizing of the operating cables would no longer be so hazardous.

6.4.4 In other words, a design objective for the hook should be for the hook to resist opening, by requiring a positive force or moment to overcome this resistance. A failure or problem within the hook itself or its operating system then leaves the hook in a safe condition, with the weight of the boat keeping the hook closed and the boat securely suspended.

6.4.5 In principle, therefore, one can envisage a different sort of hook in which instead of the release mechanism holding the hook closed against the weight of the boat, the weight of the boat holds the hook closed and the release mechanism has to overcome the resulting resistance in order to open the hook.

6.4.6 Despite continued and persistent attempts throughout the duration of this project, we were not able to obtain detailed design data from any manufacturer of in-service ships' lifeboat launching equipment, or to have substantial informative discussions with any such manufacturer.

6.4.7 This reluctance on the part of manufacturers to provide detailed information could be due to a number of factors, including concerns about:

- Divulging proprietary design or engineering details;
- Potential exposure to commercially damaging consequences; and
- The possibility of litigation should equipment be proved not fit-for-purpose.

6.4.8 In seeking to fulfill the aims of the project, it was intended to establish a correlation between particular accidents and their causes, and the design of the equipment involved. However, without cooperation from manufacturers, it has not been possible to establish such a correlation.

6.4.9 Anecdotal evidence suggests that accident investigating organisations may have experienced similar difficulties in dealing with manufacturers.

6.4.10 The lack of cooperation by equipment manufacturers has resulted in severe limitations on what, realistically, could be achieved by this project in terms of identifying improvements in the most important area of on-load hook design. This is because without detailed knowledge of equipment / accident correlations, specific design shortcomings cannot be identified.

6.4.11 At the outset, an explicit intention of the project was to use fault tree analysis as a means of structuring design and accident information so as to examine risk contributions and facilitate identification of design improvements. Unfortunately, development of a fault tree model as envisaged has not proved possible, due to the absence of detailed manufacturers' information.

6.4.12 Of particular interest in this respect is the hook design originating from a design house which does not yet have its design in widespread production and use. Unlike the manufacturers of in-service ships' lifeboat launching equipment mentioned above, this design house willingly made design details and information available.

6.4.13 Crucial to the design philosophy adopted by this design house is the fundamental requirement for the hook to remain stable with a predominant tendency to be self-closing. Tests, reported by Canada to FP50 at IMO, clearly demonstrate such characteristics for this particular design.

6.4.14 Furthermore, we were made aware of another design of on-load release hook used in single fall applications for survival capsules on offshore installations. The manufacturer of these hooks, unlike the manufacturers of twin fall systems intended for ships' lifeboats, also willingly made available design details and information.

6.4.15 We observed a demonstration of the way in which this single fall on-load release hook functions, and are able to confirm its stable and self-closing characteristics.

6.4.16 It therefore appears practicable, both in principle and as evidenced by these two examples, to engineer an on-load release hook with significantly superior safety characteristics than hooks currently in service. On board adoption of such a hook design should therefore greatly reduce the fatal accident rate associated with in-service use including routine testing and drills with ships' lifeboats.

6.4.17 Development of a new on-load hook design requires both:

- Compilation of a suitable design specification, covering functional and safety performance aspects; and
- An investment in design and engineering development to create a new hook design which fulfils these specification requirements.

6.4.18 An outline design specification has been drafted as part of the scope of work of this project and is included in this report. This draft specification includes an explicit statement of safety objectives covering routine drills, as well as emergency lifeboat operations, and reflects the requirement for stable hook characteristics.

6.5 RULE DEVELOPMENT

6.5.1 It is envisaged also that IMO regulatory requirements should be amended to reflect the inclusion of safety goals for routine lifeboat tests and drills. Finalisation of a suitable design specification should therefore be undertaken by an appropriate sub-committee and drafting group of the IMO's MSC.

6.5.2 Those best placed to undertake the necessary design and engineering development include, but are not necessarily limited to, organisations currently involved in lifeboat systems manufacture, since these organisations are likely to have relevant knowledge and experience.

6.5.3 It has already been noted, however, that little appears to have changed during the past decade, although the causes and occurrence of lifeboats accidents were known and documented. An additional stimulus is therefore required for the industry as a whole to embark on the development and introduction of safer on-load release hooks.

6.5.4 Such stimulus could come from either:

- Lifeboat system manufacturers themselves, but on the basis of their record to date and their general unwillingness to contribute to this study, this appears unlikely; or
- External entrepreneurial competition, as perhaps illustrated by the development work leading to the Canadian report to FP50 at IMO; or
- Ship owners as purchasers of lifeboat systems, but this appears unlikely because of the commercial pressures and widespread compliance culture existing within the industry; or
- Through regulation requiring either manufacturers or ship owners or both to adopt a more proactive approach.

6.5.5 This last option is considered to be the most likely to succeed, given the prevailing culture within the shipping industry. Nevertheless, the approach outlined below should help to contribute to a progressive cultural change for the better in the industry. Additionally, the proposed approach is likely to encourage, rather than stifle, entrepreneurial competition.

6.5.6 A proven and established approach to securing an acceptable level of safety is by adoption of a safety case regime. It is considered that this is an appropriate way forward for ships' lifeboat safety and would provide the needed stimulus for change.

6.5.7 The essence of the safety case approach is that a comprehensive assessment of risks is undertaken, that sufficient safety measures are implemented within a safety management system, and the whole is documented as a justification that risks are controlled to be as low as reasonably practicable.

6.5.8 For ships' lifeboats, therefore, the safety case would demonstrate that throughout the life of the ship, lifeboat drills and tests, as well as any actual routine or emergency use, will be acceptably safe.

6.5.9 Because both design and operational changes for lifeboats are anticipated, a typical two-stage safety case can be envisaged.

- Stage 1: As an integral part of the hook design process, a design safety case should be developed and submitted for independent review and approval. There need only be one such safety case for each make / model / size of hook, and the independent approval process would parallel current type approval activities.
- Stage 2: As an integral part of each ship's safety construction certification, an operational safety case should be developed and submitted for independent review and approval. This operational safety case would incorporate the design safety case but be extended to include and interface with ship-specific safety management arrangements. The independent approval process would parallel current SMS approval activities.

6.5.10 Importantly, a safety case regime facilitates identification of a duty holder, ie a person or body corporate responsible in law for the content of the safety case. This helps give real substance to the safety benefits being achievable.

6.5.11 It is proposed that the hook manufacturer be identified as the duty holder for the Stage 1 design safety case, responsible for identifying hazards, assessing risks and achieving independent approval of his associated demonstration that risks are acceptably low.

6.5.12 Clearly, the process of developing this design safety case should reflect the design specification as set out in 6.4.17 and 6.4.18 above. Various alternative approaches are possible, including:

- Individual manufacturing companies could develop the design safety case for their own design of hook;
- A number of manufacturers could collaborate, jointly developing the design safety case for a common design of hook;
- An independent organisation could develop a new design of hook and, in collaboration with a manufacturer, develop the design safety case.

6.5.13 These arrangements need not compromise the corporate independence of manufacturers or other design organisations, nor adversely impact upon their commercial competitiveness, since the boats, davits, winches and many other components of a lifeboat system would not be part of the proposed safety case regime.

6.5.14 It is proposed that the ship operator (owner or manager as appropriate) be identified as the duty holder for the Stage 2 operational safety case, similarly responsible for achieving independent approval of his demonstration that risks in operation are acceptably low.

6.5.15 In large part the operational safety case would rely on the design safety case, but with appropriate additional hazard identification, risk assessment and documented justification as part of the operator's safety management system.

6.5.16 The duty holder's responsibility would transfer to any subsequent operator of the ship.

6.5.17 This focused approach, embodying a safety case regime specifically for on-load release hooks, is intended to address the key issue so far as fatal lifeboat accidents are concerned, ie the need for stable hook characteristics throughout the operating lifetime of the ship.

6.5.18 The As Low As Reasonably Practicable (ALARP) principle embodied in UK health and safety law, together with a tolerability criterion, provides a rational and defensible basis for judging when risks have been reduced to be acceptably low. These should form part of the safety case regime.

6.6 APPLICATION

6.6.1 With regard to existing ships, consideration needs to be given to retrospective application of the changes proposed above. In respect of on-load release hooks, a key consideration is that retrofitting (ie like-for-like replacement) should be entirely practicable. A schedule of implementation dates, taking account of a ship's age and the timescale needed for development, approval and production of new hook designs, should be agreed at IMO.

6.6.2 Such retrospective application is considered entirely reasonable, given the unacceptable level of risk associated with current regulatory requirements for lifeboat tests and drills.

6.6.3 For new ships, as a minimum, a safety case regime for lifeboat on-load release hooks should be introduced according to a schedule established by IMO and taking account of the timescale needed for development, approval and production of new hook designs.

6.6.4 In the longer term for new ships, more radical design approaches may be feasible, superseding methods rooted in antiquity. These might take the form of modern mechanical handling solutions for transferring a safe habitat between the ship and the sea.

6.6.5 Consideration of such radical change was specifically excluded from the scope of this study. Nevertheless, the design specification described above, covering functional and safety performance aspects, could form a sufficient basis for developing innovative abandonment solutions. Certainly, the changes proposed should not preclude such innovation.

7 RECOMMENDATIONS

7.1 HOOK DESIGN

7.1.1 All on-load release hooks should be designed and constructed to be stable, ie self-closing, when supporting the weight of the lifeboat.

7.2 REGULATION

7.2.1 A safety case regime should be introduced specifically (and only) for lifeboat on-load release hooks, so as to achieve this aim.

7.2.2 SOLAS should be amended to include both this safety case requirement and additional safe design requirements for lifeboat launching equipment.

7.2.3 In the meantime, consideration should be given to by-passing on-load release hooks during drills by the use of maintenance pennants and shackles.

7.2.4 Consideration should be given also to adoption of single fall capsules for ships carrying small numbers of persons.

7.3 ANTHROPOMETRICS

7.3.1 Regulators have to address whether they wish to continue to require lifesaving appliances to suit an average world population or whether they wish to require them to suit the larger members of the population.

7.3.2 It is feasible to permit alternative designs to suit different populations, with associated permits to operate in particular theatres of operation. Whether this is a sustainable philosophy is outside the remit of this study.

ANNEX A1: ACCIDENT REPORTS

A1.1 GENERAL

A1.1.1 This annex reviews a few of the available lifeboat accident reports. It focuses on the more severe types of accident; those associated with on-load release hooks. Other accident types, for example involving winch brakes and clutches, remote winch controls, gripes, etc are not addressed because it appears to us that previous studies and many individual accident reports comprehensively identify the causative factors and provide appropriate recommendations. Those recommendations cover such topics as the adequacy of operating manuals, provision of clear visual instructions adjacent to winches and release levers, the importance of training, precautions against corrosion, etc. This report focuses on what is considered to be the principal contribution to risk for seafarers (ie accidents arising from on-load release hooks) and the examples below reflect that focus.

A1.2 MARINE ACCIDENT INVESTIGATION BRANCH

A1.2.1 The MAIB 2001 study report includes a categorisation of the recorded lifeboat accidents which can be summarised in the following table:

	Numbers of:			
Category	**Incidents**	**Fatalities**	**Injuries**	**Equivalent fatalities §**
Hooks	11	7	9	7.9
Tricing and bowsing	10	2	5	2.5
Falls, sheaves & blocks	12	2	19	3.9
Engines & starting †	18	0	15	1.5
Gripes	12	0	10	1.0
Winches	32	0	8	0.8
Davits	7	0	0	0.0
Free-fall ‡	2	0	1	0.1
Weather	2	0	0	0.0
Not otherwise classified	19	1	13	2.3
Totals	**125**	**12**	**80**	**20.0**

† The MAIB report notes that such accidents are not unique to lifeboats; they are therefore not considered further in this study.
‡ Free-fall lifeboats are outside the scope of this study.
§ Assuming 10 injuries are equivalent to one fatality.

It is immediately apparent that the majority of fatalities arise from the “Hooks” category. Two illustrative examples from this category are as follows:

A1.2.2 Hook failure: MV Ivory Ace: MAIB's report of this investigation was produced before 1998 and so was not published on the web. It is understood, however, that whilst the vessel was being surveyed for renewal of its safety equipment certificate, the boat had been lowered into the water, its engine tested, and the boat then recovered to its fully stowed position. Shortly afterwards, both hooks released simultaneously, causing the boat to drop into the water, injuring the 2 crew members still aboard. The unexpected release occurred because, after hooking-on and before lifting from the water, a locking pin in the operating mechanism adjacent to the coxswain's position had been incorrectly re-inserted. There were two locations for this pin, one being a stowed location, the other being for hook re-setting. The procedure for changing from one location to the other had not been followed, but MAIB concluded that crew competence was not to blame. Instead, the report cited design complexity, poor operating instructions and poor visibility around the locking pin, postulating that reliable operation of the release gear was beyond the capability of the average seafarer, no matter what his nationality and experience. It will be noted that the accident was not a failure of the hook itself, but a failure in the mechanism for releasing the hook.

A1.2.3 Hook failure: MV Hoegh Duke: MAIB's report of this investigation was produced on behalf of the Flag State Administration. During a routine drill with 12 crew members aboard, the lifeboat was being lowered into the water. The aft hook separated from the falls, allowing the boat to swing and then fall vertically as the forward hook failed. Six of the people aboard were killed and the other six injured. MAIB's report concludes that the after on-load release hook had not been properly reset because the after operating cable was seized and the resetting lever was stiff. However, because the hook had not been properly and fully reset, the design of the hook was such that a force was created in the hook which overcame the resistance of the seized cable, allowing the hook to open. The report identifies serious neglect of maintenance and ignorance of safe operation as giving rise to this situation. Again it will be noted, however, that the accident was not directly a failure of the hook itself, but a failure in the mechanism for releasing the hook.

A1.2.4 After hooks, the next most significant category is seen to be "Falls, sheaves & blocks". An illustrative example from this category is as follows: During lifeboat drill on the Ro-Ro passenger ferry Pride of Hampshire, a suspension link joining the aft lifeboat hook to the falls broke catastrophically. The lifeboat fell, pitching people into the water and resulting in 16 crew members suffering injury. MAIB found that the alloy steel suspension link had not been suitably heat treated for the marine environment and had become weakened due to stress corrosion cracking. This type of failure, like engine starting accidents, is not considered unique to lifeboats and therefore not considered further in this study.

A1.2.5 Since publishing their 2001 study report, MAIB have investigated several further accidents involving lifeboats. These include:

- MV Galateia - both hooks unexpectedly released;
- European Highway - hanging-off pennants incorrectly attached;
- St Rognvald - snagging of self-lowering control wire;
- RFA Fort Victoria - release gear activated before boat was seaborne;
- Pride of Bilbao - suspension ring mistakenly connected to wrong hook;
- Pride of Calais - winch clutch failure resulting from use of incorrect lubricant; and
- Marine Explorer - winch brake failure due to incorrect re-assembly.

These recent events serve to illustrate the variety of types of accident that can occur with lifeboat launching systems. All of them underline the importance of good manuals, adequate training, proper maintenance, etc, as highlighted in many of the accident investigation reports. Two of them (European Highway, Pride of Bilbao) emphasise the desirability of designs that preclude components being inadvertently interconnected. However the first accident, on MV Galateia, warrants further consideration in the context of this study.

A1.2.6 Hook failure on MV Galateia: MAIB's report describes how the accident happened during a lifeboat drill, immediately after the boat had been re-connected to the falls and raised to the embarkation level. Both hooks simultaneously opened, allowing the boat to drop, striking the deck as it fell and ending up partially capsized in the water. One of the three crew on board suffered serious injury, the other two minor injuries. The reason was essentially the same as in the Ivory Ace accident, in that a locking pin in the operating mechanism adjacent to the coxswain's position had not been correctly reinserted after hooking-on the boat. Once again it is seen that the accident was not directly a failure of the hook itself, but a failure in the mechanism for releasing the hook.

A1.3 OTHER OFFICIAL ACCIDENT INVESTIGATORS

A1.3.1 The Australian Transport Safety Board (ATSB) have published a number of reports of lifeboat accidents, including for example:

- Tanker *Port Arthur*: Both on-load release hooks disengaged allowing the boat to fall vertically into the water, seriously injuring one of the crew. The accident occurred because the hooks had not been correctly reset after the last time the boat was lowered.

- Bulk carrier *Ma Cho*: Whilst lowering the boat during a drill, the aft on-load release hook suddenly disengaged, leaving the boat suspended vertically by the forward falls. Investigation revealed that the after hook had not been fully reset because the clamp for its operating cable was loose.

- Bulk carrier A*lianthos*: The aft on-load release hook opened unexpectedly during a training exercise. The boat was left suspended vertically on the forward fall, resulting in the forward davit being buckled. ATSB concluded that the hooks were not fully reset after the previous launching and that the after hook opened spontaneously when the davit made harder than normal contact with its end stops whilst lowering the boat.

A1.3.2 Similarly, The Transportation Safety Board of Canada (TSB) have published a number of reports of lifeboat accidents, including for example:

- Bulk carrier *Iolcos Grace*: During a lifeboat drill, the forward hook released prematurely, with the operating lever still in its stowed position. The boat then swung vertical and the after hook also released, allowing the boat to fall into the water and resulting in several injuries and a fatality. The investigation found that the forward hook had not been correctly reset the last time the boat had been released.

- Product carrier *Farandole*: After lowering the lifeboat into the water during a drill, some difficulty was experienced operating the control lever to re-engage the on-load release hooks. The boat was then hoisted back to boat deck level. First the forward, then the aft, on-load release hooks opened and the boat fell into the water causing injury to its 4 crew.

A1.3.3 A report published by the Hong Kong Marine Department gives details of a lifeboat accident on board the Hong Kong registered ship *Ogrady*. During lowering of the boat for emergency use (following a collision), the hooks suddenly released and the lifeboat dropped into the sea, causing two fatalities. The primary cause was believed to be inadvertent release of the boat, due to a lack of understanding of the equipment by the crew member, inadequate safety training and the absence of clear operating instructions for the on-load release mechanism.

A1.3.4 A common thread linking these and other similar reports is the susceptibility of on-load release hooks of different designs to open unexpectedly, thereby plunging the boat into the water and potentially injuring anyone aboard. The reasons, or initiating events, that trigger the hook to open in this way are varied and include: improper resetting of components within the hook the last time it was used, improper resetting of the operating mechanism; mechanical problems associated with the operating mechanism; improper operation of the release gear; etc.

A1.4 CONFIDENTIAL REPORTING SCHEMES

A1.4.1 The UK's maritime CHIRP scheme was inaugurated in July 2003, with the objective of receiving reports of near miss incidents, etc and disseminating these to aid safety learning. An extract of one such report (unintended hook release) highlights the inadequacy of some instruction manuals: "The manufacturer immediately blamed the crew for not reading the instruction manual properly. Lifeboats are just too complicated for ordinary seafarers to use. Even I, who took a university honours degree in Nautical Studies, find the manuals confusing".

A1.4.2 A similar scheme, MARS, has been run for many years by the Nautical Institute, an international body for professionally qualified seafarers. The aim of MARS is to help improve safety by collecting and disseminating information about accidents and near misses, without fear of litigation. Often MARS simply publishes information from official accident investigations, but observations submitted confidentially by Nautical Institute members are also on the MARS database. Extracts of some typical examples of the latter include:

- "Lifeboat remote release wires are really dangerous. I am aware of the danger after some near miss incidents. Fortunately, so far no serious accidents have happened. I have been wondering why many ships are still built with traditional lifeboat davits. This system is very sensitive to all kinds of problems with many wires running through rollers, making sharp turns etc. Davits suffer from continuous corrosion and are not easily accessible for maintenance. Davits only work well when the sea is calm. In my opinion, the problem is not only remote release wires but boat and davit design." (Report No. 200141).
- "During a training exercise a lifeboat descended uncontrollably to sea level. We were very fortunate that no crew were inside. It was clear that the remote control wire for releasing the winch brake was under strong tension. This prevented the brake being applied and stopping the boat. It is logical to expect the brake control wire to pay out at the same rate as the boat is lowered, but it was found not to be the case. As the control wire became shorter, its triangular handle came into contact with the boat deckhead and the boat lowered itself." (Report No. 200062).
- "During a routine drill the brake lever arm dropped to its stops and there was no braking effect whatsoever. The boat ran down to the water and was dragged alongside at 16 knots. The painter was ripped free, the forward falls torn away, and the boat was struck by the propeller. Fortunately there were no injuries. An investigation revealed that two locking nuts on the end of the brake shaft were slack, which had effectively rendered the brake useless. Prior to the drill, the brake lever was checked and found to be correctly adjusted. This is another unfortunate case of the failure of a lifesaving device now more noted for mechanical problems, injuries and deaths, rather than lifesaving." (Report No. 200140).

A1.4.3 In each of these incidents, had there been injuries it is likely that they would have given rise to an official accident report. Instead, these MARS reports serve to highlight the sort of mechanical failures that can occur and the resulting lack of confidence in ships lifeboats.

A1.5 SUMMARY

A1.5.1 A picture emerges from the above that, as a generality, on-load release hooks are typically unstable. By this is meant that any fault or problem in the operating mechanism, or any error in its use, leads almost inevitably to release of the hook. As such, on-load release systems could be said to be prone to single point failure, whereby a single failure in the system can cause the system to fail, resulting in an accident. Such systems cannot be considered robust in safety terms, since they are not tolerant of defects, failures or human errors. It will additionally be noticed from the reports exampled above, that more than one type of fault or failure in the release system can lead to hook opening and hence a lifeboat accident. Typically, therefore, on-load release systems could be said to be prone to multiple single point failure modes.

A1.5.2 Viewed from this perspective, and considering the large number of lifeboat drills carried out aboard ships as required by regulations, it is perhaps remarkable that there are not more lifeboat accidents. The record of accidents would appear to demonstrate that in general considerable care is taken by ship owners and ships' crews properly to maintain and service lifeboat launching equipment and carefully to conduct lifeboat drills, despite the rather unforgiving nature of the marine and shipboard environment.

ANNEX A2: MANUFACTURERS QUESTIONNAIRE

A2.1 GENERAL

A2.1.1 The following eight questions were initially circulated via the Association secretariat, but subsequently communicated directly to manufacturing companies (including some non-Association members). It was intended that the information gleaned should provide an introduction for more informative discussions between the project team and companies experienced in the design and manufacture of lifeboats and their launching systems.

A2.1.2 The questionnaire explained that the project is confined to conventional davit-launched lifeboats, and seeks primarily to address the more serious types of accident highlighted by the MAIB study, ie accidents resulting from problems with rigging (hooks, tricing, bowsing, falls, sheaves, blocks, gripes and, to some extent, winches).

A2.2 The questions sought information from the equipment manufacturers relevant to these types of accident, as follows:

A2.2.1 **Design:** To what extent have you used FMEA or other hazard identification techniques, during the design process?

A2.2.2 **Development:** What design changes have taken place that would lead to a change in the likelihood of problems occurring?

A2.2.3 **Feedback:** Do ship-owners report problems to you, or do servicing agents report problems to you, or does information only come to you via accident investigations?

A2.2.4 **Analysis:** What sorts of problems are reported, and what analyses of these problems do you undertake?

A2.2.5 **Specifics:** Which of the different types of problem mentioned above (hooks, tricing, bowsing, falls, etc), are relevant to your particular design(s) of lifeboat launching equipment?

A2.2.6 **Root cause(s):** Are these problems inherent in the specified SOLAS requirements (and LSA Code), or do they result from servicing arrangements, or from operational use (or misuse)?

A2.2.7 **Corrective action:** What action have you taken (or are you planning to take) to overcome problems particular to your equipment?

A2.2.8 **Design data:** Please provide sufficient technical information (ie relevant diagrams, specifications, operating instructions, etc) to allow a full understanding of the above.

ANNEX A3: SHIP OWNERS QUESTIONNAIRE

A3.1 INTRODUCTION

A3.1.1 The following questions, supported by background information regarding the scope and purpose of the project, were posed to the ship owner organisations we approached:

A3.2 QUESTIONS

A3.2.1 Has your company experienced any accidents or near-miss incidents involving a lifeboat, especially during launch / recovery / maintenance / servicing / testing?

A3.2.2 If so, please provide details of the circumstances, what happened and what action was taken.

A3.2.3 What problems, if any, do you experience with lifeboat launching, recovery, maintenance, etc (for example relating to the equipment itself, operating instructions, accessibility of parts and controls, etc)? Please mention the type of equipment involved.

A3.2.4 Are such incidents and problems reported to the manufacturers or dealt with internally?

A3.2.5 How is this experience reflected in your company's safety management and training arrangements?

A3.2.6 Is servicing undertaken internally by your company, or by outside contractors? What specifications and controls are in place governing the competence / quality of organisations undertaking maintenance and servicing?

A3.2.7 Are problems primarily related to design and manufacture, or to maintenance and servicing, or to operational use on board?

A3.2.8 What are the practical difficulties involved in safely testing, launching, recovering and maintaining lifeboats onboard?

A3.2.9 In general, what is your company's perception of the seriousness of the problem, the likely reasons for accidents and the desirable changes (design, operation, maintenance, regulation, etc) to avoid accidents? Who should make these changes?

ANNEX A4: SEAFARERS QUESTIONNAIRE

A4.1 INTRODUCTION

A4.1.1 The following questions, supported by background information regarding the scope and purpose of the project, were posed to seafarer trade union representatives.

A4.2 REQUESTED INFORMATION

A4.2.1 A union opinion covering: the perceived seriousness of the problem; the likely reasons for these accidents, the desirable changes (design, operation, maintenance, regulation, etc) to avoid accidents, and who should make these changes.

A4.2.2 Responses from some individual union members to the following questions.

- Have you personally experienced an accident or near-miss incident involving a lifeboat, especially during launch / recovery / maintenance / servicing / testing?
- If so, please describe the circumstances, what happened and what action was taken.
- What problems, if any, do you experience with lifeboat launching / recovery (for example relating to the equipment itself, operating instructions, accessibility of parts and controls, etc)? Please mention the type of equipment involved.
- From your point of view, what are the practical difficulties involved in safely testing, launching, recovering and maintaining lifeboats onboard?
- In your opinion, what changes would make lifeboats safer?

ANNEX A5: WORKSHOP BRIEFING AND AGENDA

Workshop on Ships' Lifeboat Safety, Friday 13th January 2006

1. Invitation: I confirm my invitation to attend the workshop to be held on Friday 13th January 2006, at the London office of Burness Corlett - Three Quays (BC-TQ, see http://www.bctq.com for a map), starting at 09:30 for 10:00. We expect to finish at about 17:00 hours. The workshop is an integral part of the UK MCA's research project aimed at preventing lifeboat accidents. A buffet lunch and coffee, etc will be provided. Thank you for agreeing to participate.

2. Objectives: The MCA's research project is confined to conventional davit-launched lifeboats, and aims to identify improvements in lifeboat design that will help to prevent accidents, particularly during lifeboat testing and drills. The focus will be on the more serious types of accident highlighted by the MAIB's study in 2001, ie accidents resulting from problems with "rigging" (hooks, tricing, bowsing, falls, sheaves, blocks, gripes and winches). The specific objectives of the workshop are as follows:

a) To review and refine a risk model of lifeboat accidents, by considering failure modes and causes; and
b) To identify potential options for design improvement that would circumvent or inhibit the failure modes known to have occurred in the past.

3. Agenda: The outline agenda for the day is as follows. Breaks will be taken as appropriate.

a) Welcome and introductions
b) Background to the MCA Research Project
c) Key questions regarding ships' lifeboat safety
d) Introduction to a risk model of lifeboat accidents
e) Detailed consideration of first accident type, causes and options for improvement
f) Detailed consideration of second accident type, etc
g) Concluding summary of the day

4. Approach: We need an open and constructive discussion to maximize the insights gained and facilitate identification of practical options for safety improvement. The discussions will therefore be confidential. Where sensitivities arise, for example regarding past incidents or aspects associated with particular manufacturers or operators, please be assured that requests for confidentiality and non-attributable status will be respected. Alternatively you may prefer to raise the issues with us privately so that we may introduce them anonymously.

BC-TQ: 12-20 Camomile Street
London EC3A 7AS
+44 (0)20 7929 2299

Jim Peachey
9th January 2006

ANNEX A6: WORKSHOP OUTPUT (1):

A6.1 PROBLEMS, CHANGES NEEDED & OBSTACLES TO CHANGE

A6.1.1 The following table summarises the group's discussion regarding problems, the changes needed and obstacles to change.

Problems	Changes needed	By whom	Obstacles to change
Adequacy of maintenance and training, given reduced crewing.	Easier, simpler and clearer ways to operate lifeboats.	Legislators to make policy; designers to implement.	- - - -
Crew lack of familiarity with equipment.	Assess human factors during design; designers to adopt safety management approach.	Designers.	- - - -
Drills typically done shortly after joining ship, but working patterns do not allow sufficient time.	Better maintenance and training guidelines.	MCA should oversee (NB: Enhanced status of MSC Circ 1093 from 1/7/2006).	MCA's resources.
Ship crews have no faith in launching mechanism. Insufficient time available for training due to pressure in short sea trades. Competition in shipbuilding market; very expensive for owner to buy more than SOLAS minimum.	- - - -	- - - -	- - - -
On-load release hooks. Drills omitted (despite log book entries) due to crew fear for safety. Insufficient crew on board for adequate maintenance.	Reconsider need for on-load release. Make the equipment maintenance-free between major overhauls (ie 5 years).	- - - -	Maintenance-free equipment is primarily an engineering (and cost) issue.
Inadequate safety culture (& money for safety) in shipping, compared with offshore industry. Seafarers do not understand meaning of "on-load" release. Crew from some countries will not admit to ignorance (nationality traits). Currently, no means of collating data on how many lives are saved by lifeboats.	Changes to MSC Circ 1093, such that manufacturers do not have monopoly of service provision (and thus cannot keep problems secret). Manufacturers to design equipment to "fail to safe", not fail to danger.	MCA to initiate changes to MSC Circular 1093. Manufacturers.	Manufacturers obstructing change; will not ask, listen to, or take advice from independent service agents. Senior managers in manufacturing companies have a poor approach to health and safety matters.
If servicing only undertaken by manufacturers, possible to conceal design faults. Activating on-load release with many TOR and Titan hook designs can lead to hook being out of tolerance after only 2 cycles; manufacturers only sell replacement hooks, not parts.	Equipment needs to be made safe for use during regular training drills.	- - - -	- - - -

A6.1.1 (continued): Problems, changes needed and obstacles to change.

Problems	**Changes needed**	**By whom**	**Obstacles to change**
Complete absence of research on evacuation from ships and offshore rigs. The system of regulation. IMO standards are set at bare minimum to get consensus agreement.	Fix the hook problem for twin-fall systems (demanded by the offshore industry).	Regulators at IMO.	Shipping economics; *not* technology - design problems can be overcome. International nature of shipbuilding (86% ships built in Far East)
Approximately 25 manufacturers, but UK schools all have only one type for training. The hook / release mechanisms (boats themselves are not a problem). Requirements for visual indication of hook re-setting only recently introduced.	Simplified hook mechanisms (which need not be rocket science). Making ISM Code more effective than it is (eg re adequate maintenance).	- - - -	Economics; ship owners must be prepared to pay for appropriate training. The existing regulations are obstacles to change.
Typically the extended time period (up to 2 years!) between completing formal training and actually being in a lifeboat again. On ferries (and similarly on passenger vessels?), hotel staff may not be routinely involved in drills which are undertaken by deck crew. Formal onshore training may be seen as a paper exercise simply to ensure sufficient numbers of "ticketed" crew are aboard. Lifeboat launching equipment too unwieldy for female hotel staff to cope with.	- - - -	- - - -	- - - -
Unsafe practices on board due to language barriers (senior officers / junior officers / crew). Too difficult to see current status of Mills Titan release gear.	Need to debate whether off-load release is required. Simplify the whole system, because one cannot "engineer-out" the human factor.	- - - -	The manufacturers, and their stranglehold on the industry.
Poor safety culture in shipping by comparison with offshore and aviation for example. Many seafarers frightened to drill with boats on board; scared of potential consequences (and of seasickness). Typically, seafarers will train with one hook system, and then find something different on their ship (and again on their next ship).	Need for performance based standards. Need to design a fit-for-purpose system.	- - - -	- - - -

ANNEX A7: WORKSHOP OUTPUT (2):

A7.1 KEY QUESTIONS

A7.1.1 Questions regarding ***Purposes of Lifeboats***:

Question	**Answer**
Why conventional lifeboats at all? On what ships, in which circumstances?	Travelling public expects them; they work; are better than "cork mats". Legislation requires them. Liferafts not suitable for open ocean. Lifeboats more suitable than rafts for disabled persons access / capability. But for cargo ships in coastal waters, helicopters would be first choice for evacuation.
Why practice using them? (who practices with aircraft escape slides?)	Generates familiarity for crew; they need to know system works. Aircraft evacuation trials show value of drills. But risk of practicing needs to be recognised; whole team needs to understand.
Why have any people on board during practice lowering and recovery?	Ships' boats need to be launched for crew to practice manoeuvring. Following launching; people need to be aboard to recover boat. This is a dangerous activity, but would be more dangerous to do anything differently (eg board crew once boat is afloat). Nevertheless, offshore boats are not lowered with people aboard; training objectives are achieved differently.
Why were the lifeboats not used on Sally Star (25th August 1994)?	(See quotes from 1995 MAIB report). "Opinion should not be based on a single incident". Lifeboat accidents are documented, but successful evacuations by lifeboat tend not to be.

A7.1.2 Questions regarding ***Lifeboat Equipment***:

Question	**Answer**
Why is on-load release needed?	To release boat from falls when fully waterborne, especially in a seaway (waves) or tideway (current). Need to disconnect very quickly if launched into rough seas. Note: If not fully waterborne, additional actions are required to release boat. The on-load release requirement stemmed from offshore accidents (Alexander Kjieland).
Why twin falls?	Agree there is no regulatory requirement for twin falls. But, twin falls inherently provide longitudinal stability (eg against broaching). Reliance on a single fall questionable for large (150-person) lifeboats. Novel deployment systems, eg using a boom (PROD), have not been particularly successful offshore (see OPITO records).
Why are there different types of release gear, not one standard type?	Agree that a standardised approach is not impossible to achieve. Also that SOLAS / LSA Code provides a standard, but is not sufficiently well defined. Ideally, standardisation should be initiated by the manufacturers, but is more likely to require legislation.
Why are there often different manufacturers for boats, hooks, davits, etc?	For commercial reasons. To retain design flexibility. Better to have a single manufacturer, but providing components are compatible, more than one should not be a problem. The only key interface is the hook / lower ring of falls; if these are geometrically compatible, there is no other significant interface issue between the boat plus hook (one system), and the davit/winch/falls (separate system).

A.7.1.3 Questions regarding ***Use of the Equipment***:

Question	**Answer**
Why the need to lower from within the boat?	A regulatory requirement. The "last-person-off" issue. Hence an important requirement for cargo ships, but may not be for passenger ships. Note: Freefall lifeboats are only launched from inside.
Is the equipment designed to recover the boat?	No! But of course the ship owner's expectation is to do so (for obvious commercial reasons). Recovery of the boat is not part of stipulated lifeboat drills. Likely that a recovery requirement will emerge from the work of FP50.
What competences are required on board for safe maintenance / training / drills?	Inherent in STCW competency requirements, ISM requirements and Safe Manning Certificate.
Is it "reasonable practicable" to provide these competences, and the needed time, on board?	If high level competencies are necessary, probably not. If only low level competencies are necessary, then yes. Typically, crews on board nowadays are doing less maintenance. Expecting crew on board to audit / check the work of service companies may not be realistic.
Can user/maintenance manuals be written using only icons and a 500-word vocabulary?	Yes - this is realistic and achievable. FP50 has developed guidelines on this issue, which if approved will become MSC Circular.