TEMPSC Structural Design Basis Determination
Part 1 – Input Data Capture and Review

Prepared by **P A F A Consulting Engineers** for the
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RESEARCH REPORT 198

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This report, part 1, covers the first phase of a three phase HSE-funded study into the structural design basis determination for Totally Enclosed Motor Propelled Survival Craft (TEMPSC). Part 2 addresses Design Events and Failure Capabilities, Part 3: Event Levels and Safety Margins. Emphasis is placed on typical TEMPSC that are currently in-service in the UK Sector of the North Sea. In this study, a generic TEMPSC has been defined as a 50-man, Glass-fibre Reinforced Plastic (GRP), side-on davit-launched craft, stationed on a fixed steel platform. Such a craft would be typical of lifeboats installed in the early to mid 1980's and therefore designed and manufactured in accordance with the pre-1986 amendments to the 1974 Safety of Life at Sea (SOLAS) regulations.

The objective of the first phase of this project is to gather and review data relevant to the structural design basis for TEMPSC.

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1. Summary

General:

This report, part 1, covers the first phase of a three phase HSE-funded study into the structural design basis determination for Totally Enclosed Motor Propelled Survival Craft (TEMPSC). Part 2 addresses Design Events and Failure Capabilities, Part 3: Event Levels and Safety Margins. Emphasis is placed on typical TEMPSC that are currently in-service in the UK Sector of the North Sea. In this study, a generic TEMPSC has been defined as a 50-man, Glass-fibre Reinforced Plastic (GRP), side-on davit-launched craft, stationed on a fixed steel platform. Such a craft would be typical of lifeboats installed in the early to mid 1980's and therefore designed and manufactured in accordance with the pre-1986 amendments to the 1974 Safety of Life at Sea (SOLAS) regulations.

The objective of the first phase of this project is to gather and review data relevant to the structural design basis for TEMPSC. Observations from this exercise are as follows:

Design & Construction:

- In general, TEMPSC are designed and constructed by a few companies using established in-house experience and expertise. Regulatory changes, competitor's products, industry feedback, and improvements in materials and fabrication methods primarily drive updated designs.

- Classification of TEMPSC is primarily based on SOLAS regulations which, in part, require each new TEMPSC design be proven against a range of tests. For structural integrity these include a side impact test, a horizontal drop test, a test to ensure water-tightness and a test to show that the TEMPSC is buoyant and self-righting. During these tests, damage can occur; however, this must not be sufficient to prevent safe operation of the TEMPSC.

- The task of obtaining data relating to GRP material, fabrication procedures and test results (particularly through to failure) for use in this study, proved to be of limited success.

Other Studies Relating to TEMPSC:

- Several probabilistic assessments have been reported of a TEMPSC being launched and escaping the platform. In general, these studies are good at determining the likelihood of a TEMPSC clearing the platform in an undamaged condition. However, less consideration has been given to the number and condition of evacuees in emergency situations where lives are at risk and personnel are likely to be in a state of panic.

- Most other publications describe the engine performance against prevailing weather conditions. These studies often employed an innovative method for aiding the escape of the TEMPSC.

Proposals:

- Structural capability of TEMPSC should be considered in parallel with consideration of impact energy characteristics and human behaviour during emergency situations. A number of such considerations are discussed in this report.

- Some authors believe that there may be an overall reduction in strength associated with damage to the TEMPSC, even following local repair. This may be significant as
  1) following the successful completion of the SOLAS tests, the prototype may be repaired and sold; and
  2) it appears that no history of damage and repair to a specific TEMPSC is held.

- A more rigorous risk-based analysis would help address a more realistic range of evacuation scenarios and assist in focusing industry resources in the most cost-effective manner.

2. Contents

3. Glossary

CSM	Chopped Strand Mat
EER	Evacuation, Escape and Rescue
EESC	Emergency Evacuation Steering Committee (predecessor to EERTAG)
EERTAG	Evacuation, Escape and Rescue Technical Advisory Group (set up by the HSE)
FSA	Formal Safety Assessment
GRP	Glass-Fibre Reinforced Plastic Resin
HSE OSD	United Kingdom Health and Safety Executive - Offshore Safety Division
IMO	International Maritime Organisation
LORS	Lifeboat Occupant Recovery System
LSA	Life-Saving Appliances
MCA	Maritime and Coastguard Agency
MODU	Mobile Offshore Drilling Units
MSA	Marine Safety Agency
OTR	Offshore Technology Research
PrOD	Preferred Orientation and Displacement System
SBV	Stand-By Vessel
Set-back	The degree to which the stern of a TEMPSC moves towards the installation reference its stowed position as the TEMPSC is lower and manoeuvred into the desired escape direction.
SOLAS	IMO Safety of Life at Sea Convention (for Life-Saving Appliances)
TEMPSC	Totally Enclosed Motor Propelled Survival Craft
TOES	TEMPSC Orientation and Evacuation System
Wash-back	The degree to which a TEMPSC moves towards the installation by the effects of wind and waves after splashdown.

4. Introduction

Since the Piper Alpha disaster (1988) and the subsequent report by Lord Cullen (1992), some consideration has been given to achieving the successful evacuation of offshore installations. In particular, this has included providing a range of evacuation methods for an installation's personnel. For fixed platforms in the North Sea, the most frequently employed alternative means of evacuation remains the lifeboat or Totally Enclosed Motor Propelled Survival Craft (TEMPSC) as it is known in the UK offshore industry.

These lifeboats come in a range of sizes and employ a variety of launching modes. However, within this report, emphasis has been placed on those capable of holding around 50 persons and launched via davits (as opposed to freefall TEMPSC). This type of lifeboat represents the most typical craft currently deployed on fixed platforms in the UK sector of the North Sea.

In various studies, risk analyses have been performed to consider the probability of successfully launching and escaping the installation, for a range of environmental conditions. It became clear that for severe environmental conditions, the TEMPSC launched on the windward side of the installation, in particular, could impact the side of the structure during descent and be driven back into the structure by wave and current action. Furthermore, there is the possibility of the craft becoming damaged or submerged due to wave action or during tow by a rescue vessel. In all such cases it is important that structural integrity is maintained.

The purpose of this project is to review the design, choice of materials, fabrication and construction of a typical 50-man davit-launched TEMPSC, so that the capacity and factors of safety can be determined for a number of selected accident scenarios. In this phase of the project, background data has been sourced and reviewed in-line with the overall project objectives.

5. Objectives

Project objectives:

The project objectives are as follows:

- To consider input data capture and review a range of 50-man (typical size) TEMPSC configurations from drawings, specifications and other literature.
- To ascertain TEMPSC construction material properties, fabrication procedures and failure assessment methodologies.
- To consider design events and failure strength.
- To identify relevant design events, such as:
  - Boat clash with jacket brace.
  - Dropping into still water or a representative wave from a prescribed height.
  - Davit hanging overload.
  - Hydrostatic immersion in the sea (upright or overturned).
  - Stand-By Vessel (SBV) towing loads prior to recovery.
- To calculate failure capacities for each design event utilising existing or new analytical techniques.
- To consider event levels and safety margins.
- To determine appropriate performance levels for each event.
- To calculate a safety factor and margin against failure for each event.
- To produce a project report for each of the three project phases:

  TEMPSC Structural Design Basis Determination

  - Part 1 - Input Data Capture and Review.
  - Part 2 - Design Events and Failure Strength.
  - Part 3 - Event Levels and Safety Margins.

The range of Totally Enclosed Motor Propelled Survival Craft considered is limited to those currently stationed on fixed platforms located in the North Sea.

While this specification includes both davit-launched TEMPSC employing vertical winch systems and freefall launched TEMPSC employing an inclined ramp, the emphasis of the project, design specifications, launch events and safety margins relate to conventionally davit-launched TEMPSC. Furthermore, it is assumed that the TEMPSC is self-powered and piloted by a coxwain following release, rather than using a system that automatically pulls the craft clear of the structure (e.g. TOES, see Section 6).

Scope of Phase 1 – Input Data Capture and Review:

The objective of the first phase of work in this project is to source literature and data relating to TEMPSC vessels and launch conditions. This data will form the basis for the structural design calculations to be performed in the subsequent phases of this project.

To meet this objective, contact has been made with industry representatives and literature searches have been performed. These contacts and searches are summarised in Section 3 of this report.

Specific data of value to the project is reviewed in Sections 4 and 5 of this report covering:

- Regulatory requirements,
- TEMPSC configurations and drawings,
- Design specifications,
- Material properties,
- Fabrication procedures,
- Integrity test results,
- Failure assessment methodologies.

In Section 9, the design events to be considered in the project are specified. The findings of this phase of the project are discussed in Section 10.

6. Summary of Information Received

General:

Organisations including Government bodies, Classification Societies, the International Maritime Organisation (IMO) and Affiliates, Designers, Manufacturers and Consultants were contacted and data sought. Emphasis was placed on those organisations with expertise with TEMPSC based in the UK sector of the North Sea. A full list of contacts approached and replies received are given in Appendix A.

In this section, a brief summary is made of the reports relating to evacuation by davit-launched TEMPSC, along with their relevance to this study into the structural behaviour of TEMPSC.

Regulations from the International Maritime Organisation (IMO), the British Maritime and Coastguard Agency (MCA) – formally the Marine Safety Agency (MSA), Government bodies and Certification Authorities or Classification Societies are covered in Section 4 of this report.

UK Health and Safety Executive Reports:

Most of the information regarding the operation and safety of TEMPSC has been funded, or part-funded, by the HSE. Consequently, there are a number of publications that have been issued via the HSE. The following summaries are not exhaustive, but give emphasis to reports of direct relevance to TEMPSC design and to reports issued since 1988.

OTH series (reports from OTR - formally published)

OTH 88 285 "ESCAPE II: Risk Assessment of Emergency Evacuation of Offshore Installations", prepared by Technica.

This report describes the enhancement of a computer program ESCAPE that makes quantified assessments of the methods of emergency evacuation from offshore installations. The program requires input data relating to:

- the environmental conditions;
- the type of structure (fixed, floating, and member bracing arrangement);
- the number, location and dimensions of TEMPSC and alternative helicopter evacuation;
- specification of event probabilities, for example 80% likelihood that the coxwain will be unable to release the winch in storm conditions, etc.

Based on user input a three-dimensional path is plotted for the TEMPSC following launch. For a particular collision between the TEMPSC and the structure, predefined tables relate the degree and location of damage and consequently the number of fatalities that would be expected to occur. The program can then analyse the full range of anticipated outcomes for a given evacuation scenario and assign percentage survivability of the platform's personnel in such a case.

It was noted that the estimates of TEMPSC damage in the collision and consequent risk to life were based on crude estimates, with damage $\propto$ (impact velocity)^2. It was reported that

'*In fact, knowledge of the impact resistance is not well advanced. The existing IMO standard test bears little relation to the likely impact; it also only tests the fender and its support.*'

It was therefore recommended that

"*Consideration should be given to a research project that will check whether the magnitude of the horizontal impact forces in breaking wave conditions is sufficiently large to warrant concerns about the structural strength of the hull. If the results of this study are borne out then ways of increasing the hull resistance to such forces should be considered*."

Contact has been made with DNV Technica to determine whether the ESCAPE program is still in use and what developments have been made to the program since 1988. However, DNV Technica has not been able to establish the status of this program.

OTO series (Reports from OTR- Not formally published)

OTO 96 001 "Computer Models of Vessel Seakeeping Behaviour", prepared by BMT Offshore Limited.

The purpose of this study was to review seakeeping modelling computer programs. The study identified: the main classes of seakeeping behavioural problems and classifications, the main computer programs used to predict wave forces and responses, and the ability of each program to represent particular seakeeping problems.

It was concluded that strip theory programs were the most appropriate for predicting the seakeeping response of TEMPSC. This method appeared to be able to model vessel motions in severe weather conditions, beyond the anticipated limits of the formulation.

OTO 96 007 "Review of Current Free-fall Lifeboat Literature and Recommendations for Needed Research and Development", prepared by Clemson University, South Carolina.

While this report is specifically aimed at freefall TEMPSC, two issues also of importance for davit-launched TEMPSC are raised.

Firstly, it was noted that

"*Current prototype testing of free-fall lifeboats can only demonstrate that the lifeboat is of adequate strength to withstand the tests to which it is subjected. These tests are conducted in calm water. The reserve strength of the boat cannot be determined from these tests because the boat is not tested to failure. Furthermore, damage to the boat occurs fairly often during these tests which tends to indicate that: 1) the loads acting on the boat are not well enough defined to allow a thorough structural analysis and design to be constructed, and 2) the actual reserve strength is less than anticipated. Yet, the reserve strength of the lifeboat must be known so that the "operating window" of the boat can be determined and the overall safety of the evacuation can be assessed*."

Secondly, it was noted that studies of freefall lifeboats suggested that

"*environmental effects do not have a significant effect upon the strength of the fibreglass construction, while repeated launches over time can cause the strength of the lifeboat to deteriorate*" (by perhaps 50% following several hundred training launches). While freefall lifeboats are, in general, subjected to greater forces during a typical calm weather launch than a davit-launched TEMPSC, clearly any historical minor damage may lead to deterioration in the strength of the hull.

OTO 96 706 "LORS Lifeboat Occupant Recovery System", prepared by Husky/Bow Valley East Coast Project.

The Lifeboat Occupant Recovery System (LORS) was developed to enable the safe recovery of occupants from a TEMPSC onto a rescue vessel. The system assumes that the TEMPSC has been successfully launched and cleared the platform. The need for such a system was in-part due to the failures and fatalities that had occurred in transferring crew to the rescue craft or in towing the TEMPSC; and in-part due to the increased limits on environmental conditions within which the TEMPSC could be launched following the development of systems such as PROD (see OTO 96 707). It was concluded that the LORS system would increase the likelihood of a successful evacuation of an offshore installation.

OTO 96 707 "UK PrOD Trials"

The PrOD (Preferred Orientation and Displacement) System comprises of a boom extending horizontally out from the platform attached via a tag line to a davit-launched TEMPSC. Following splashdown, the tension created in the tag-line is sufficient to turn the TEMPSC away from the platform and give the TEMPSC an initial acceleration that will assist the TEMPSC avoid wash-back.

36 PrOD and 6 non-PrOD launches are reported from a drilling rig, from heights of 18 m and 24 m. Non-PrOD launches in around 20 knot winds and 1.0 m maximum wave heights towards the rig, would generally lead to a maximum stern set-back of 4 m, around 7 m at right angles to the point of splashdown. In one instance the TEMPSC had a minor collision with the rig but no damage was reported.

OTO 97 009 "Design, Construction, Commissioning and Testing of the Seascape Systems Ltd. Emergency Evacuation System"

This report describes full-scale tests of the Seascape TEMPSC launching frame. The system was found to perform in a satisfactory manner, although the full-scale trial did highlight some areas where modifications would be of benefit to the system. Since the Seascape frame is an alternative to traditional davit-launch, the report is not applicable to this study.

OTO 97 016 "Davit-launched TEMPSC Performance Project", prepared by BMT Fluid Mechanics Limited.

This report describes the scope for a proposed £250K joint industry funded project to optimise the operational performance of davit-launched TEMPSC. The project aims include a review of the operation of TEMPSC from launch to escape and include model tests and possibly full-scale tests of TEMPSC to determine their manoeuvrability. No consideration of structural behaviour is to be considered within the scope of this project.

OTN series (Reports from OTR - Company Confidential)

OTN 95 135 "Review of Tools and Data for the Assessment of Launch of Freefall and Conventional TEMPSC", prepared by BMT Offshore Limited.

This report presents a literature review of freefall and davit-launched TEMPSC from the boarding phase to escape. The majority of the data gathered relate to freefall TEMPSC. In addition, questionnaire responses from manufacturers, software suppliers and test houses were collated and assessed.

The report states that

"*The TEMPSC designers and manufacturers rely heavily on specific model tests and full scale trials of their systems, and do not claim to rely much on computer software, except for structural design. The reliability of the structural design depends, however, on the reliability of the input loads, and the source and reliability of this information is not clear*."

Overall, a number of interesting opinions were made, however, in most cases these were either unsubstantiated or not referenced to other studies thereby justifying the point made.

MaTSU (Confidential in Confidence)

Report MaTR/142 "Review of the Probable Performance of Offshore TEMPSC" (undated).

This report reviews the conclusions and recommendations of 22 reports relating to the use of TEMPSC for the evacuation of offshore installations, formally issued between 1983 and 1993. The conclusions and recommendations were divided into those endorsed by the DEn Emergency Evacuation Steering Committee (EESC), 3 reports, and the remaining 17 reports that were presented to the EESC. See Appendix B for a list of organisations belonging to EESC (now called EERTAG).

This report gives a useful overview of areas in EER that require research effort, the areas of operation that are of the highest risk and comparisons of the relative merits of improved design against increased training. Apart from dividing conclusions and recommendations into those formally endorsed by EESC and those not, priorities have not been identified. With regard to TEMPSC design strength, Appendix 2, Section I, Part D5, specifically addresses the 'Hull Strength of TEMPSC'.

The specifications for future work are taken directly from OTH 88 285 - ESCAPE II, reported above, with further consideration to the use of alternative materials and hull shapes. There is one clause taken from a study by Hollobone, Hibbert & Associates Limited (OTO 84 018) that states "*At Beaufort No. 7, the maximum horizontal load on a TEMPSC due to breaking waves is about 7100kN. The maximum load due to vertical waves is only about 3040kN*."

ARK Safety

ARK Safety has recently completed a comprehensive review of this subject, which has been performed in four phases.

Offshore Evacuation by TEMPSC Review.

Part 1 Regulatory Requirements and Code Recommendations

Part 2 Design Review

Part 3 Safety Critical Elements

Part 4 Performance Standards.

These documents have yet to be formally issued within the HSE's reporting system; two are reviewed.

"Part 1 Regulatory Requirements and Code Recommendations", HSELR/30, September 1999.

This report provides a comprehensive summary of regulations relating to TEMPSC, in particular the IMO's International Convention for the Safety of Life at Sea (SOLAS) and corresponding International Life-Saving Appliance (LSA) Codes. These codes cover a wide range of issues including construction, capacity, access, buoyancy, freeboard and stability, propulsion, fittings, equipment, markings, enclosure, capsizing and re-righting, protection against acceleration and protection against fire.

The aspects of these regulations of direct relevance to this study are summarised in Section 7. One area of particular relevance to this project concerns the testing requirements to prove the TEMPSC has sufficient structural strength to meet the SOLAS regulations. These were in the process of being revised during the production of the ARK Safety - Part 1 Report, but have now been issued as IMO.81(70). These are included in the review of regulations in Section 7.

It is important to note that this report includes a summary of previous regulations having an influence on TEMPSC that may still be in service.

"Part 2 Design Review", HSELR/030/2, October 1999.

This report describes the design process for TEMPSC. This process was subdivided into ten steps of which the first two steps form the bulk of the structural modelling, while subsequent steps are concerned with detailed design and type approval. The ten steps of the design process are described as follows:

- "*Step 1* *Draft the preliminary design concept/ layout.*

  This is the production of a master layout, where the complete conceptual design has been investigated in line with the design specification. At this stage a preliminary simple draft lines plan would be produced. This layout would be supported by preliminary draft design calculations/estimates, such as weights, centres of gravity, hydrostatic curves, and power predictions.

- *Step 2* *Design review.*

  This is a detailed review of the preliminary design layout and calculations to evaluate whether the design has the potential to meet the design specification, *thus permitting the detailed design process to be undertaken. It may also identify whether additional investigation work is required. e.g. the commissioning of tank testing to assist power prediction, etc.*

- *Step 3* *Detailed design and production of data required to permit manufacture and testing of the prototype product.*
- *Step 4* *Design review prior to Step 5.*
- *Step 5* *Preliminary submission for approval.*
- *Step 6* *Issuing of material to permit prototype build.*
- *Step 7* *Monitoring of design in build. Checking of calculated weights vs manufactured weights. Monitoring of manufactured parts, sub and final assemblies, addressing design modifications as required.*
- *Step 8* *Testing and updating the design "As fitted and tested".*
- *Step 9* *Submission approval of product.*
- *Step 10* *Acceptance.*"

The first two steps of this Design Process are described in detail in the report: those sections of the report relevant to this study are summarised in Section 8.

Norwegian Petroleum Directorate Reports

Report No. ARF/96A74, "Evacuation and Rescue Means – Strengths and Weaknesses Pre-Project Report", Revision 1, Preliminary Draft – Issued for Comment, 2nd December 1996.

This report gives a comprehensive assessment of the current state of evacuation from offshore installations in the North Sea. The purpose of the report is to give a 'state-of-the-art' review of evacuation and rescue prior to further sponsorship of projects. This covers all potential methods of evacuation and escape from helicopters to stairways and ladders. Consequently, TEMPSC form only one part of the assessment, and within that section davit-launched TEMPSC forming one small part. This lack of emphasis reflects the preference for freefall TEMPSC over davit-launched TEMPSC in Norwegian waters, especially from new platforms. The emphasis of NPD's approach is very much towards a risk-based rather than code-based assessment and this is reflected in the layout of the report.

The report also gives a comprehensive review of historical accident data, in particular noting that more than 90% of fatalities occurred during the escape, evacuation and rescue phases. This is one of the few reports that considers how human behaviour may affect the successful evacuation of the installation and relates this aspect to major incidents in the past. No specific reference to design strength of TEMPSC is made and there is only brief reference to the dangers of wash-back with davit-launched TEMPSC.

UK Offshore operators association (UKOOA)

OTC Paper No. 6629, "The Response to Piper Alpha: Recent Offshore Safety Developments in the UK", May 1991.

This paper represented the operator's response to the findings and recommendations of Lord Cullen's report into the Piper Alpha disaster. With regards to evacuation and escape it was noted that

"*in the majority of emergencies there is time to evacuate non-essential personnel while the extent and seriousness of the emergency is assessed. In this circumstance, helicopters are the most convenient way of evacuating an installation but in addition every platform has its own dedicated evacuation system which is completely independent of external help….. TEMPSC provide this means of help*."

With regard to the response to Piper Alpha, it was considered that there was a risk that the reaction to a specific disaster could result in a piecemeal rather than comprehensive improvement in safety. Therefore UKOOA supported the use of a Formal Safety Assessment (FSA) approach to safety, as was in use for onshore installations at the time. This approach was described as a four-stage assessment:

- Hazard identification;
- Definition of accident prevention measures;
- Specification of accident consequence mitigation measures;
- Definition of a safety management system.

This FSA approach is in-line with the risk-based safety case approach adopted by the UK offshore industry. More recently FSA has been broken into a five-stage process, incorporating an important Cost Benefit Analysis element.

Consultant Engineers

ARK Safety

See HSE Reports in Section 3.

WS Atkins

WSA Report No. AM2944-D02 "Evacuation, Escape and Rescue West of Shetland", Draft Issue 2, November 1996

This report concerned the key factors influencing emergency response that are likely to be used for a range of production platforms that may be sited to the West of the Shetland Islands. For a conventionally launched TEMPSC from a fixed platform it is noted that "*A generally proposed limit for conventional launch from a fixed platform is Beaufort 6/7 or significant wave heights of up to 4m*".

The report concentrates on the provision of helicopter rescue from a FPSO production platform and is of limited value in this project.

EM&I (Company Confidential Reports Summarised by Kind Permission)
"Report on the Current Status of the TOES System", Report No. TOES/UPDATE/001, April 1996.

This report gives a summary of the improved probability of a successful TEMPSC launch and cost-effectiveness of including the TEMPSC Orientation and Evacuation System (TOES). In addition, papers covering the TOES rope selection and TOES reliability analysis were attached, as prepared by Reading Rope Research and Pentech Consulting Engineers, respectively.

"Ninian North Prototype TOES System Risk Analysis – A Study for EM+I", Report No. p272/DNN/hw/Rev 1, March 1994.

The probabilities of an unsuccessful Whittaker No.4 type 50-man TEMPSC capsule launch, were specified in four environmental conditions: calm, moderate, gale and storm, each weighted in accordance with the likelihood of occurrence. The steps and operations that could lead to an unsuccessful launch were each allocated a probability for each environmental condition, and the results combined to give an overall probability of success. The predicted rates for a successful evacuation were based on the DnV Technica model, see Section 3.1.1 OTH 88 285. These probabilities are reproduced below for a standard non-TOES launch and launch including the TOES system. Full details of failure probabilities without the TOES system are reproduced in Table 1.

	Non-TOES	Inc. TOES	Probability of wind strength
❑ Calm	88%	98%	23.7%
❑ Moderate	60%	97%	61.0%
❑ Gale	36%	81%	14.8%
❑ Storm	22%	70%	0.5%
❑ **Overall**	**63%**	**95%**	

Table 1
Failure probabilities for the launch of a 50-man Whittaker capsule

WHITTAKER No.4 : 50-man Capsule		**FAILURE PROBABILITIES**			
		Calm	**Moderate**	**Gale**	**Storm**
		23.7%	**61.0%**	**14.8%**	**0.5%**
STEP 5	**CRAFT PREPARING FOR LAUNCH**				
5.1	Engine cannot be started	0.0000	0.0050	0.0100	0.0100
5.2	Seawater cocks jammed	0.0000	0.0000	0.0000	0.0000
5.3	Damage to craft/launch mech.	0.0000	0.0000	0.0020	0.0020
		0.0000	**0.0050**	**0.0120**	**0.0120**
STEP 6	**EMBARKATION**				
6.1	Descent before loading complete	0.0020	0.0020	0.0020	0.0020
6.2	Craft access blocked	0.0020	0.0020	0.0020	0.0020
		0.0040	**0.0040**	**0.0040**	**0.0040**
STEP 7	**CRAFT DESCENT BEGINS**				
7.1	Cable jammed on sheaves/tube	0.0020	0.0020	0.0020	0.0020
7.2	Release pin jammed	0.0020	0.0020	0.0020	0.0020
7.3	Brakes jammed by obstruction	0.0020	0.0020	0.0020	0.0020
7.4	Falls drum obstructed	0.0004	0.0004	0.0004	0.0004
		0.0064	**0.0064**	**0.0064**	**0.0064**
STEP 8	**CRAFT DESCENDS TO NEAR SEA LEVEL**				
8.1	Launch mechanism hit by debris	0.0004	0.0004	0.0004	0.0004
8.2		0.0000	0.0000	0.0000	0.0000
8.3	Release hook opened	0.0030	0.0030	0.0150	0.0150
8.4		0.0000	0.0000	0.0000	0.0000
8.5	Winch/brake mechanism seized	0.0020	0.0020	0.0020	0.0020
8.6	Winch fails to control descent	0.0004	0.0004	0.0004	0.0004
8.7		0.0000	0.0000	0.0000	0.0000
8.8	Fall wire, attachments etc brake	0.0020	0.0020	0.0020	0.0020
8.9	Craft hits structure due to wind	0.0000	0.0000	0.0000	0.0000
		0.0078	**0.0078**	**0.0198**	**0.0198**
STEP 9	**DESCENT COMPLETED**				
9.1	Wave impact damages craft	0.0000	0.0000	0.0500	0.1000
9.2	Falls wires not long enough	0.0020	0.0020	0.0020	0.0020
		0.0020	**0.0020**	**0.0520**	**0.1020**
STEP 10	**RELEASE GEAR ACTIVATED**				
10.1	Failure of ratchet, lock, etc.	**0.0004**	**0.0150**	**0.1400**	**0.1400**
STEP 11	**DEPARTURE FROM PLATFORM**				
11.1	Hits structure - coxswain error	**0.1000**	**0.2000**	**0.3000**	**0.4000**
11.2	Hits structure - wind/waves	**0.0000**	**0.2182**	**0.3054**	**0.4400**
11.3	Craft capsized	**0.0000**	**0.0000**	**0.0500**	**0.1000**
11.4	Hits structure - tide	**0.0000**	**0.0000**	**0.0000**	**0.0000**
11.5	Propeller/drive shaft fail	**0.0020**	**0.0020**	**0.0020**	**0.0020**

SUCCESS RATE IN EACH CONDITION	**88%**	**60%**	**36%**	**22%**

OVERALL SUCCESS RATE = 63%

Note: Success Rate = Product of (1-Prob. of element failure) where elements are in **BOLD**

e.g. Calm conditions = (1-0.0000)*(1-0.0040)*(1-0.0064)*……*(1-0.0020) = 0.8798

Noble Denton Consultancy Services Limited

OTC Paper No. 6929, "Lifeboat Launch Simulation and Its Application to Safety Assessment", May 1992.

This paper describes a computer program SESCAPE developed by Noble Denton to mathematically model the davit launch of a TEMPSC from either a fixed or floating platform. The variable parameters of a TEMPSC launch are:

- Platform type;
- Severity of the environment;
- Vertical lowering speed;
- Disconnection time;
- Lifeboat heading.

Within the text, some equations describing the pendulum motion during lowering and the motion response of the lifeboat following splashdown are presented. However, it was noted that

"*the present analysis only assesses the risk of lifeboat/platform collision instead of the risk of damage because a collision under a limited impact (small impact velocity) does not necessarily result in damage to the lifeboat and the simulation should be allowed to continue. This aspect has not been incorporated in the analysis and is subject to further investigation*."

This program is still used by Noble Denton, although it does not appear to have been further upgraded from this reported version. Consequently, the purpose of the program is to determine collision probabilities and only impact velocities are determined for each collision scenario.

Offshore Design Associates Limited

"Comparative Physical Model Study of Offshore Evacuation Systems", March 1997.

This report summarises 182 deployments of 1:15 scale TEMPSC launches using davit, freefall, PROD and SEASCAPE systems, from a floating drilling and production unit. It was concluded that, while all systems worked in calm conditions,

"*the davit system was clearly unacceptable. It exhibited large pendulum motions during deployment and even when the release mechanisms operated flawlessly, the TEMPSC was not able to get away from the rig in the specified time. Actually the TEMPSC was flung against the columns and the underside of the deck on several occasions.*"

The level of damage that could be inflicted on a davit-launched TEMPSC was only surmised.

Quasar Consultants

"Lifeboat Launching Study", for Phillips Petroleum, Report No. O-75-91-1, 26th July 1991.

The objective of this study was to compare the probability of collision between a lifeboat and the structure from which it is launched. This was performed using the computer program LBL. A range of vessel concepts were studied:

- Existing configuration [probably side-on davit-launched]
- Upgraded boat [no details presented on type of upgrade]
- Bow out (industry standard)
- PrOD system
- Vertical drop (free-fall)
- Skid launched (free-fall)

In this report, details are given on the launching phase, with collision probabilities calculated during descent and once at-sea. Unfortunately, the report is an extension to earlier work on the existing configuration and upgraded boat, which were not specifically referenced in this report and therefore is not currently available for review. Therefore, for the most part, this report examines in-detail the launch of free-fall TEMPSC. Some probability distributions are illustrated for each of the launch types. However, some important details, such as the distance between the platform and the davits, are not stated in this report.

RNLI/Newcastle University

Marine Technology Paper. Vol. 36, No. 4, "A Practical Formal Safety Assessment System for the Marine Design Environment", Winter 1999.

The authors of this paper based in the Marine Department of Newcastle University have developed a Formal Safety Assessment methodology and accompanying software for use in the marine industry. This assessment tool was applied in considering safety aspects in the design of rescue vessels used by the RNLI.

It was noted that

"*in marine design safety, decisions are based largely on the experience of the designers, expressed in a semi-formal way. Dangers are inherent in this approach, in that there is possibility of overlooking catastrophic failure scenarios. This paper investigates a procedure dedicated to design for safety and describes its practical application to the marine design process*."

7. Regulations:

General:

In this section, reference is made to the regulatory requirements on the structural design and performance of davit-launched TEMPSC. In general, Certification Authority (CA) or Classification Society requirements for offshore platforms is limited to the launching devise – seen as being a fixed part of the platform's topside – while the lifeboat itself requires Type Approval as a special category Passenger Carrying Craft. Consequently, CA regulations make little reference to evacuation requirements and for lifeboats and liferafts defer to the IMO's Safety of life at Sea (SOLAS) and Life Saving Appliance (LSA) codes, see section on Certification Authorities below.

A full review of the development and specification for TEMPSC is given in the HSE Report "Phase 1 Regulatory Requirements and Code Recommendations", HSELR/30, September 1999. In addition, the recently completed IMO "Revised Recommendations on Testing of Life-saving Appliances", IMO.81(70) or MSC 70/23/Add.1, Annex 6, Section 6 Lifeboats - gives a comprehensive specification for testing that should be performed on a prototype TEMPSC to prove fitness-for-purpose. In Section, Safety of life at sea (SOLAS) / life saving appliance (LSA) codes below, the IMO's structural requirements for TEMPSC are summarised. For more detailed information, reference should be made to the HSE summary document, HSELR/30, or the original codes.

ARK Safety note that "*the philosophy applied to LSA regulations, developed by the IMO, has been to lay out the requirements as to what the equipment must be able to do and then provide supporting regulations for the testing and approval of the product. It has always been left to the designers to use their own skills, design experience, appropriate design methods and standards to produce products which can fulfil the requirements."*

Certification Authorities

Lloyd's Register of Shipping

No reference to lifesaving appliances was made in the Lloyd's Register of Shipping (LRS) Rules and Regulations for the Classification of a Floating Offshore Installation at a Fixed Location (1999). Following discussions, it was clarified that LRS follow the SOLAS requirements in full and do not require any additional requirements to be met.

With regard to the design process, it was stated by LRS that there is liaison between the designer, manufacturer and CA, but the CA would not perform a full independent structural assessment of the TEMPSC. Rather the CA would ensure that the safety critical areas were adequately designed, full specifications and drawings were archived and controlled, that the prototype TEMPSC met SOLAS requirements and that subsequent TEMPSC were constructed in accordance with the proven prototype.

Bureau Veritas

Bureau Veritas (BV) Rules for the Classification of Offshore Units, Part III – Facilities, Chapter 7 – Equipment and Safety, Section 7.1.2 - Statutory Requirements (1998 edition) states:

"*7-1.2.1 International Regulations*

Attention is directed to the International Regulations that equipment of units may have to comply with in addition to requirements of the present Rules, such as:

- *IMO Code for the Construction and Equipment of Mobile Offshore Drilling Units (MODU code), in particular for drilling units;*

- *International Convention for the Safety of Life at Sea (SOLAS), in particular for self-propelled units.*"

Germanisher Lloyd

Germanisher Lloyd (GL) Rules for Classification and Construction – Offshore Technology, Part 2 – Offshore Installations, Chapter 3 – Specific Types of Units and Equipment, Section 7 – Life Saving Appliances and Equipment (1990 edition) states:

"*3. Approval, Tests, Surveys*

3.1 Generally the dimensioning and testing of survival craft with their launching devices and of other life-saving appliances are not part of the certification or classification procedure.

However, approval of the structure in way of the launching devices, taking into account the forces from the above appliances, is included in the certification/classification.

3.2 Also, the inspection of the life-saving appliances and their launching devices with regard to their proper condition and functioning may be carried out within the scope of the periodical (classification) surveys.

1) Reference shall be made to the

IMO Code for the Construction and Equipment of Mobile Offshore Drilling Units ("MODU CODE") 1989,

1983 Amendments to SOLAS 1974 Volume I, Chapter III,

IMO Resolution A 521(13) adopted on the 17th November 1983. Recommendation on Testing of Life-saving Appliances,

GL Regulations for Life-saving Launching Appliances, 1986."

Safety of life at sea (SOLAS) / life saving appliance (lsa) codes

General:

Refs:- International Convention for the Safety of Life at Sea (SOLAS), 1974. (including 1996 Amendments)

International Life-Saving Appliance Code (LSA Code). Resolution MSC.48(66), 1997.

Revised Recommendations on Testing of Life-saving Appliances, IMO.81(70), 1999.

Reg. 4 Evaluation, Testing and Approval of Life-saving Appliances and Arrangements

Before being given approval by the Governing Body, a prototype TEMPSC must have successfully undergone tests to confirm that it complies with the IMO's requirements. The range of tests must, as a minimum, be substantially in accordance with the recommendations of the IMO on the testing of life-saving appliances.

Reg. 5 Production Tests

The Governing Body shall require production tests be conducted to ensure the TEMPSC manufactured is to the same standard as the approved prototype.

Requirements for Davit-launched GRP TEMPSC

The relevant sections in LSA code are Chapter IV: Survival Craft, Section 4.4 General Requirements for Lifeboats and Section 4.6 Totally Enclosed Lifeboats, equivalent to SOLAS Regulations 41 and 44 respectively.

1. Construction

Form and stability

This regulation specifies that TEMPSC must be properly constructed, have ample stability in a seaway and have sufficient freeboard when fully loaded. All TEMPSC must have rigid hulls and be capable of maintaining positive stability when in an upright position in calm water, when loaded with their full complement of persons and equipment, and holed on any one location below the waterline, assuming no loss of buoyancy material and no other damage.

Strength

Lifeboats are to be of sufficient strength to enable them to be safely launched into the water when loaded with their full complement of persons and equipment, and be capable of being launched and towed when the ship is making headway at a speed of 5 knots in calm water.

Fall wire launched lifeboat overload strength

GRP TEMPSC shall be of sufficient strength to withstand a launching load without residual deflection on removal of that load. This load is twice the total mass when fully loaded.

Fall wire launched lifeboat impact and drop strength

GRP TEMPSC shall be of sufficient strength to withstand, when fully loaded and with skates or fenders in position, a lateral impact against a concrete wall or block, at a velocity of at least 3.5 m/s, and also into the water from a height of at least 3 m.

Enclosure

Every TEMPSC shall be provided with a totally watertight enclosure such that:

- Hatches allow launching and recovery operations without occupants having to leave the enclosure;
- In the capsized position, with hatches closed and without significant leakage, the fully laden TEMPSC can support its mass.

Protection against acceleration

Notwithstanding the Item covering ‘Fall wire launched lifeboat impact and drop strength’, a TEMPSC shall be constructed and fendered such that it provides protection against harmful accelerations resulting from impacts with the structure during launching. These impacts are to be simulated by a fully loaded test and have an impact velocity of not less than 3.5 m/sec.

Relevant tests:

IMO 81(70) Section 6.3 Lifeboat Overload Test

The unloaded craft is either placed on blocks or suspended from its lifting hooks. The craft is then loaded to represent its full compliment of personnel (W=100%) and then in overload conditions 1.25W, 1.50W, 1.75W and 2.00W, where W represents the total weight of the TEMPSC.

Measurements are made of:

- keel deflection (amidships),
- change in length between the top of the stem and the stern posts,
- change in breadth over the gunwale at the quarter length forward, amidships and the quarter length,
- Change in depth from the gunwale to the keel.

The keel deflection (amidships) and change in breadth over the gunwale at the quarter length forward, amidships and the quarter length aft should not exceed 1/400th of the TEMPSC length at 1.25W. At 2.00W they should be in proportion to those at 1.25W.

The TEMPSC should be returned to its unloaded state and after at least 18 hours remeasured. No significant residual deflections should be noted.

IMO 81(70) Section 6.4 Lifeboat Impact and Drop Test

The TEMPSC should be loaded to represent a full complement of personnel (100 kg weights should be secured to test the safety harness strength). Skates or fenders should be in position, if required. The TEMPSC should then be drawn back from its free hanging position so that when released to impact a fixed rigid vertical surface, the velocity at impact is 3.5 m/s.

Acceleration forces should be measured to establish the most severe exposure to acceleration for any occupant on the TEMPSC.

The fully loaded TEMPSC should then be dropped a distance of 3 m from its lowest point into calm water.

The TEMPSC should then be emptied and examined for any damage that may have occurred. An operational test should then be performed – IMO 81(70) Section 6.10 referenced in Item 6. Propulsion.

These tests are considered a success if:

- No damage has been sustained that would affect the lifeboat's efficient functioning;
- Any damage caused by the impact and drop tests has not been significantly increased following the operational test;
- Machinery and other equipment has operated to full satisfaction;
- No significant ingress of water has occurred;
- Accelerations measured during the impact test are in compliance with specifications detailed in Section 6.17 Evaluation of the Dynamic Response Model.

2. Carrying capacity

Main text - Not relevant.

Relevant tests:

IMO 81(70) Section 6.1 Definitions

The average mass of one person is taken to be 75 kg. Where required, the CoG of this weight is 300 mm above the seat pan on the seat back.

IMO 81(70) Section 6.6 Lifeboat Seating Strength Test

The seats should be loaded with 100 kg with no permanent deformation or damage.

IMO 81(70) Section 6.7 Lifeboat Seating Space Test

A full compliment can board within 3 minutes and be in-place without interfering with the TEMPSC's operation.

3. Access

Not relevant.

4. Buoyancy

Inherent buoyancy

This requires the TEMPSC to have inherent buoyancy, or shall be fitted with inherently buoyant materials, which must not be adversely affected by seawater or oil products. It shall be sufficient to float the lifeboat and all its equipment when open to the sea. Additional material shall be fitted equal to 280 N of buoyancy force per person. Buoyancy materials provided to meet these requirements shall not be fitted external to the hull.

Capsizing and re-righting

- Safety belts can hold a person of 100kg in-place in a capsized position.
- The TEMPSC is inherently or automatically self-righting when fully or partially manned, provided all hatches are closed and all persons are seated securely and belted in place.
- The fully laden TEMPSC shall be capable of supporting a full compliment when holed in one location and its stability in the event of capsizing shall be such that there will be above-water escape route for its occupants. When the TEMPSC is in a stable flooded condition, the water level shall not exceed 500 mm above the seat pan at any seat position.
- The engine exhaust pipes, air ducts and other openings shall exclude water from the engine when the TEMPSC capsizes.

Relevant Tests: IMO 81(70) Section 6.14 Additional Tests For Totally Enclosed Lifeboats

Self-righting test – The TEMPSC should be incrementally rotated about its longitudinal axis to angles of heel up to and including 180 degrees on its longitudinal axis and released. After release it should always return to the upright condition without assistance. This should be done in the fully loaded and light conditions. At the beginning of these tests the engine should be running in a neutral position and unless arranged to stop automatically when inverted, should continue to run when inverted and for 30 minutes following righting. If the engine has been arranged to stop automatically, then it should be easily restarted in the righted position and continue to run for 30 minutes.

Flooded capsizing test - The TEMPSC including all equipment but disregarding personnel mass should be placed in the water and made open to the sea until the craft can contain no more water. All entrances and openings should be secured open during the test. The TEMPSC should be rotated on its longitudinal axis to 180° and then released. After release the craft should attain a position that provides above water escape for personnel.

5. Freeboard and stability

All TEMPSC shall be stable and to have a positive GM Value when loaded to 50% capacity, in their normal positions on one side of the centreline.

Each TEMPSC, with side opening near the gunwale, shall have a freeboard, measured from the waterline to the lowest opening through which the lifeboat may become flooded, of at least 1.5% of the lifeboat's length, or 100 mm, whichever is the greater.

Each TEMPSC, without side openings near the gunwale, shall not exceed an angle of heel of 20° and shall have a freeboard, measured from the waterline to the lowest opening through which it can become flooded, of at least 1.5% of the lifeboat's length or 100 mm, whichever is the greater.

Relevant Tests: IMO 81(70) Section 6.8 Lifeboat Freeboard and Stability Tests

Flooded stability test – The TEMPSC should have a positive stability when flooded due to becoming holed in any one location below the waterline assuming no loss of buoyant materials or other damage. Several tests with holes in different areas may be required. During each test, the TEMPSC shall be fully loaded with the weight of all equipment and personnel who will not be in the water, and hence buoyant.

Freeboard test – The freeboard should be measured for the fully equipped TEMPSC, loaded to 50% capacity with all persons seated to one side of the centreline. The acceptance criteria is that the freeboard should be not less than 1.5% of the lifeboat length or 100 mm, whichever is the greater.

6. Propulsion

Engine starting

The engine and starting aid (if required) must be able to start the engine at an ambient temperature of –15°C within 2 minutes.

Engine operation out of water

The engine shall be capable of operating for not less than 5 minutes after starting from cold with the lifeboat out of the water.

Engine operation in the partly flooded condition

The engine shall be capable of operating when the lifeboat is flooded up to the centreline of the crankshaft.

Lifeboat speed, towing and fuel requirements

The speed of the lifeboat shall be a minimum of 6 knots in calm water fully loaded and all auxiliary equipment operational. It shall also be able to tow a 25-man liferaft at 2 knots when fully loaded. Sufficient fuel is to be provided for 24 hours at 6 knots in the fully loaded condition.

Additional requirements for totally enclosed lifeboats

- The engine and its installation shall be capable of running in any position during capsize and continue to run following uprighting, or the engine shall automatically stop on capsize and be easily restarted on return to upright. No fluid loss shall occur during capsize.

Relevant Tests:

IMO 81(70) Section 6.10 Lifeboat Operational Test

Operation of engine and fuel consumption test – The TEMPSC should be fully loaded and manoeuvred for at least 4 hours. It should be demonstrated that it can tow a fully laden 25-man liferaft at 2 knots or demonstrate that it has at least an equivalent towing force. The towing fitting shall be attached to a stationary object and the TEMPSC engine operated at full speed for a minimum of 2 minutes without damage to the fitting.

Cold engine starting test – The engine and attachments should be placed in a chamber at –15°C. The test begins when it has been shown that the temperature of all oils and fluids do not exceed –15°C. The engine should be started three times and allowed to run. Following the first two tests the engine should be returned to the chamber temperature, while the final test should run for at least 10 minutes with all gear positions operated.

Engine-out-of-water test – The engine should operate for at least 5 minutes at idling speed under normal storage conditions with no damage.

Submerged engine test - The engine should operate for at least 5 minutes while submerged in water to the level of the centreline of the crankshaft with the engine in a horizontal position with no damage.

IMO 81(70) Section 6.11 Lifeboat Towing and Painter Release Test

Towing test – It should be shown that the fully laden TEMPSC can be towed at a speed of not less than 5 knots in a calm sea and on an even keel with no damage.

Davit-launched lifeboat painter release test – See Item 7 Fittings.

IMO 81(70) Section 6.14 Additional Tests For Totally Enclosed Lifeboats

Engine Inversion test – The engine and its fuel tank should be mounted on a frame to permit 360° of rotation. Detailed procedures are provide with regard to starting, running and stopping the engine associated with the degrees of rotation which must be made to the engine.

7. Fittings

Release mechanism

Every TEMPSC shall be fitted with a release mechanism complying with the following requirements:

- ❑ The mechanism shall be so arranged that all hooks are released simultaneously;
- ❑ The mechanism shall have two release capabilities as follows:
    - a normal release capability which will release the lifeboat when it is waterborne or when there is no load on the hooks; and
    - an on-load release capability that will release the lifeboat with a load on the hooks. This release shall release the lifeboat loading ranging from no load with the lifeboat waterborne to a load of 1.1 times the full laden condition. This release capability shall be adequately protected against accidental or premature use.
- ❑ The fixed structural connections of the release mechanism in the lifeboat shall be designed with a calculated factor of safety of 6 based on the ultimate strength of the material used, assuming the mass of the lifeboat is equally distributed between the falls.
- ❑ Where a single fall and hook system is used for launching a lifeboat or rescue boat in combination with a suitable painter, the second requirement above for two release capabilities need not apply. In such an arrangement, a single capability to release the lifeboat or rescue boat only when it is fully waterborne will be adequate.

Painters

Every TEMPSC shall be fitted with a device to secure it near the bow, and when being used it shall be safe and stable when being towed by a ship in calm water up to 5 knots. Except for free-fall boats, the device shall have internal operation to release when being towed at 5 knots in calm seas.

Relevant Tests:

IMO 81(70) Section 6.9 Release Mechanism Test

The TEMPSC loaded to 1.10 x its fully laden weight should be suspended just above the ground or water and released simultaneously from each fall with no damage to the TEMPSC or release mechanism. This test should be repeated, again at 1.10 x full load, when waterborne and in the light condition. The release mechanism should then be mounted on a tensile strength testing devise and loaded to six times it working load without failure.

Finally, it should be demonstrated that the release mechanism releases a fully laden TEMPSC when being towed at speeds up to 5 knots. In lieu of a waterborne test this may be performed in the following manner:

- At the force necessary to tow the TEMPSC at a speed of 5 knots applied to the hook in a lengthways direction at 45° to the vertical. This should be conducted in the aftward as well as the forward directions depending upon the hook design.

- At a force equal to the safe working load of the hook in an athwartship direction at an angle of 20° to the vertical on both sides of the TEMPSC.

- At a force equal to the safe working load of the hooks in a direction halfway between the above two tests and within the ellipse segment formed by these two tests. This test should be conducted in four positions.

IMO 81(70) Section 6.11 Lifeboat Towing and Painter Release Test

Towing test – See Item 6 Propulsion.

Davit-launched lifeboat painter release test - It should be shown that the painter release mechanism releases the painter on a fully laden TEMPSC towed at a speed of not less than 5 knots in a calm sea. This should be performed for painter release mechanism releasing in a number of distinct directions, preferably as specified in Section 6.9 Release Mechanism Test above.

8. Equipment

Not relevant.

9. Markings

Not relevant.

8. Data Relevant to this Project

General:

ARK Safety noted that "*Due to the relatively small market, in global terms, there has never been any pressure to publish and release engineering design standards. It should be noted that it has not been in the designer's, or his company's interest to do so. LSA builders have not found it to be in their interest to provide knowledge and experience to other parties that have not invested in the costly business of designing and developing LSA to meet ever changing standards. In their view, this could provide the potential for a boat builder to become a lifeboat manufacturer with little investment or experience*."

Many Companies with expertise in the area of TEMPSC were approached and data sought, see Appendix A. However, in-line with the above remarks, it was difficult to obtain detailed information on the design and construction of TEMPSC. In general, there was concern that this study would result in potential criticism of TEMPSC design and construction methods and, consequently, lead to recommendations for significant changes in existing practice.

Specifications of a Typical 50 MAN Davit-Launched TEMPSC

Umoe Schat-Harding

ARK Safety noted the need to consider two design regimes:

- Regime A for craft produced to meet the pre-1986 amendment to SOLAS 1974, upgraded, where practical, to meet the new specification.
- Regime B for craft produced to meet the post-1986 amendment to SOLAS 1974.

In accordance with these specifications, drawings were supplied for TEMPSC under both Regimes. For Regime A, these drawings concerned the Watercraft 8.0 m XL 50 person craft while Regime B the drawings primarily concerned the Watercraft MK V 7.3 m 38 person craft. Full details of the design methodology and structural drawings are referenced in ARK Safety report HSELR/030/2.

Regime A (50-person)

- The basic dimensions are: 8.00 m length, 2.70 m breadth, 2.80 m height, and a keel to hook height of 1.84 m.
- The weight of the craft is 3,850 kg with a davit load of 7,600 kg and hook spacing of 7.00 m.

Regime B (38-person)

- The basic dimensions are: 7.30 m length, 2.25 m breadth, 3.10 m height, and a keel to hook height of 1.94 m.
- The weight of the craft is 3,120 kg with a davit load of 5,970 kg and hook spacing of 7.05 m.

Norsafe

- The Norsafe 7.4 m Totally Enclosed Motor Lifeboat (TELB) has a capacity for 50 persons.
- The basic dimensions are: 7.52 m length, 2.82 m breadth, 3.10 m height, and a keel to hook height of 1.95 m.
- The weight of the craft is 3,500 kg with a davit load of 7,250 kg and hook spacing of 6.87 m.

- The craft is designed and built to 1986 amendments to SOLAS 1974, Classification Society and National Authority requirements.

- The hull, superstructure, buoyancy tanks, water and provision containers are made from fire-retardant GRP.

- The hull and superstructure are moulded into one unit. Together with the inside GRP structure the design forms a double skin craft preventing water from flooding the cabin in the event of the outer hull becoming damaged.

- The boat is equipped with on/off load lifting hooks, which are controlled from a release handle mounted at the steering position. Hooks will release simultaneously when the craft is fully waterborne. Emergency release is possible but the system is secured against accidental release.

Material Properties (GRP)

Material properties have been sought from Umoe Schat-Harding Limited, but were not received.

ARK Safety report that "*the basic required performance of lifeboat laminates has been met using polyester resins and E glass reinforcements. The use of more sophisticated and expensive resin systems and/or high performance reinforcements, such as Kevlar and carbon fibre, has not been found necessary.*

The base materials commonly used under both regimes are:

a) Gel coat: Specially formulated polyester resin to provide a protective outer coating for the base laminate.

b) Basic laminate components:

- *Polyester Resin*

- *E Glass chop strand mats and woven roving type reinforcements.*

Typical mechanical properties for a polyester resin - E glass mat laminate, having a glass content in the order of 30 %.

Tensile strength 85 - 90 MPa

Flexural strength 180 - 200 MPa"

Material data has been sourced from a number of references as follows:

- Gelcoat external resin data sheet, as produced by Vetroresina SpA;

- Scott Bader Crystic 302 polyester resin data sheet;

- Matweb – The online Materials Information Resource;

- Engineering Design Properties of GRP by A. F. Johnson;

- Design of Marine Structures in Composite Materials by C. S. Smith.

Assuming around 30% chopped strand mat (CSM) GRP material properties are specified as listed in Table 2. Further details about the material properties and design assessment method employed in this study will be given in the Part 2, Project Report.

The test specimens are moulded and therefore are affected by the moulding and operating conditions inherent in their preparation. The moulded product will ordinarily also be subjected to stress, cold flow, creep, chemical attack, ageing, and changes in environment not reproducible under testing procedures. In selecting a plastic material the product designer should have a thorough understanding of the specimen preparation, specimen conditioning, and test method. With this understanding the designer will select the material most suitable for the product itself as well as the environmental effects.

Table 2
Mechanical Properties of GRP

Mechanical Properties	Units	Gelcoat G600	Matweb	Johnson	Smith	In This Project
% Fibre by weight	%	25%	Average	30%	30%	≈30%
Tensile strength	MPa	70	100	100	95	100
Flexural strength	MPa	145	160	173	165	170
Compressive strength	MPa	-	210	140	140	140
In-plane shear strength	MPa	-	-	81	74	80
Interlaminar shear strength	MPa	-	-	25	25	25
% elongation at break	%	1.9	1.5	1.5-2.5	-	
Tensile modulus	GPa	5.9	22.5	7.8	-	7.8
Flexural modulus	GPa	4.0	17.5	6.4	-	6.4
Shear modulus	GPa	-	-	2.8	-	2.8
Poisons ratio - tension		-	-	0.42	-	0.42
Poisons ratio - comp.		-	-	0.32	-	0.32
IZOD impact strength	KJ/m²	50	-	50-80	-	65
Barcol hardness	°Barcol	45	71	40-55	-	45

Tensile Properties

The tensile test measures the strength of a material in resisting being pulled apart. Both ends of the specimen are firmly clamped in the jaws of a testing machine, a force (stress) is applied pulling the sample from both ends, while gauge marks are used to measure the elongation (strain) of the specimen. Both are plotted on graph paper reflecting a stress-strain diagram.

Plastic materials, in contrast to metals and ceramics, respond differently when under load. Metals are true elastic materials and act like a spring when a load is applied below their elastic limit, returning to their original shape without deforming. Plastics, however, always undergo deformation (permanent strain) when a load is applied. In designing plastic products, the materials selected should have allowable loading well within the material's elastic limit. The plastic product is designed so that the applied force does not exceed 75% of the material's elastic limit.

Izod Impact Test

The Izod Impact test is one of many tests developed to measure a material's sensitivity to cracking and is related to the material's overall toughness. The test procedure is to clamp a notched specimen into a heavy base pendulum-testing machine so that the specimen is vertical and facing the impact pendulum. The pendulum is held at a prescribed height; when it is released it swings down and breaks the specimen, then swings past it to a point were the energy in the pendulum reaches zero. The force exhibited in breaking the sample is calculated from the height that the pendulum reaches on the follow-through.

The Izod Impact specimen is created with a prescribed notch to facilitate the measurement of a plastic material's toughness in relation to cracks. All plastic materials are notch sensitive. This means that plastic parts will normally fail at surface cracks. Thus, plastics require the elimination of sharp corners, filled radiuses, and rounded threads in any product design. A plastic material that contains glass fibre to improve its strength will exhibit brittle properties due to the inability of the materials to absorb impact.

Hardness Tests

The Rockwell Hardness test measures a material's resistance to the indentation of a steel ball whose size and load specification are determined in relation to the hardness of the material.

The Durometer Hardness, sometimes referred to as shore hardness, measures a soft material's resistance to the indentation of a flat 0.79 mm or a pointed 0.100 mm instrument. The distance that the point penetrates the materials is indicated on the apparatus dial one second after loading.

Barcol Hardness is a measure of surface hardness made with a Barcol Impressor instrument in accordance with ASTM D-2583. The hardness value can be used as an indication of the degree of cure of FRP laminates.

Fabrication Procedure

Most TEMPSC are manufactured from GRP, which is able to produce economically a product of the required shape and structural performance. GRP can provide the required structural properties and good energy absorption characteristics with low production and maintenance costs. The GRP method of construction permits not only additional material to be easily incorporated in areas which are required to carry greater loads, but also the ability to provide increased structural performance by the addition of high performance reinforcements and related resin ratios.

In many cases it has been found to be more efficient and economic to use a greater thickness of a lower grade laminate than less thickness of a higher grade. This is because of the following issues:

- The overall structural design of lifeboats has more stiffness problems (retaining shape) than strength problems.
- Increasing the thickness of the laminates has an overall cubic effect on the stiffness, whereas changing the E value of the material can only have a direct linear effect on the stiffness factor.
- The basic design needs to have the required stiffness, whilst retaining the ability to flex and absorb energy, which are induced into the structure, due to impacts.
- A lightweight high performance laminate with a heavy stiffening system is not as efficient in absorbing energy, without damage.

The chop strand type reinforcement and a measured proportion of polyester resin is applied to the mould (after gel coating has taken place) as a prefabricated mat, made from short random orientated chopped strands of fibreglass, held together with a soluble resin binder. Where additional strength and tear resistance is required, the basic mat laminate characteristics can be improved by the introduction of fabric or woven roving reinforcements. This material provides higher strength and stiffness than chopped strand mat.

Chop strand mat laminates have lower glass content than woven roving laminates with resultant lower strength and modulus of elasticity. Therefore, chop strand mat laminates must be thicker, in order to have equivalent properties.

- ❑ A typical max. glass content for CSM laminates would be in the order of 30%.
- ❑ A typical max. glass content for CSM woven-roving laminates would be 40%.
- ❑ A typical max. glass content for Woven-roving laminates (special processes) would be 50%.

Failure Assessment Methodologies

Structural failure of the TEMPSC is considered to have occurred if either the hull/canopy is sufficiently damaged that the craft can no longer provide protection and must be evacuated, or if the structural failure has resulted in the propulsion/steering/towing system becoming inoperable, requiring the TEMPSC to be rescued by another craft.

In Section 6 of this report, it was shown that most published reports and papers relate to the probability of the TEMPSC being successfully launched and escaping the installation. In general, this exercise begins by assuming that a full, or partial, compliment of personnel has boarded the TEMPSC and terminates when the craft is clear of the installation. Consequently, the probabilistic studies tend to address the success or otherwise of a TEMPSC launch rather than considering the likelihood of evacuating all the installation's personnel.

As reported by NPD (see Section 6), the Ocean Ranger and Ocean Express disasters highlighted the danger to life following the successful escape of the lifeboat during the transfer of personnel to the rescue craft. While in the cases of Ekofisk B, West Vanguard and Ocean Odyssey, personnel were left behind due to early launch of the lifeboats. Therefore, it should be remembered that the launch and escape of the TEMPSC is only one part of the evacuation process and should not be considered to be independent of other phases of the evacuation. For example, it is generally assumed that a trained coxwain will be operating the TEMPSC, however, consideration should be given to the possibility of there being no able-bodied coxwain available.

The RNLI and MCA have been responsible for initiating risk-based Formal Safety Assessments (FSA) of Lifeboats and High-Speed Passenger Craft, respectively. The purpose of this assessment method being to focus resources on areas which are safety critical and which are most cost-effective. Similarly, the Norwegian Petroleum Directorate has undertaken risk-based studies on evacuation from offshore installations, although this was in a less structured manner. One important distinction considered by NPD was the different types of evacuation, each having different types of risk associated:

- ❑ Training and maintenance exercises;
- ❑ Precautionary evacuation;
- ❑ Emergency evacuation.

With regard to the structural assessment of TEMPSC, structured safety assessment could be performed. However, such an exercise would not only require more detail about potential impact effects on the TEMPSC, but also consideration of accelerations and impact effects on the personnel enclosed. For example, increasing the strength and stiffness of the TEMPSC will result in less structural damage but could increase injury to the TEMPSC's occupants.

9. Project Phases 2 and 3

The following Failure Events will be investigated in phases 2 and 3 of this project, which are concerned with determining the strength of the TEMPSC in the following events, the safety margins over the design requirements and the likelihood of such events occurring:

- Davit overload;
- Swing onto leg due to wind and oscillatory actions;
- Dropped into water (still, 6 m wave and 10 m wave) due to winch/hook failure or release;
- Immersion in water (upright/overturned);
- Collision with jacket due to wave/current action following release;
- Damage/submersion during towing.

Unlike other seagoing craft, TEMPSC spend the majority of their life suspended in the davits, out of the water. Maximum loading conditions are found to occur during the launch and escape phase and not in the open water condition.

In performing a structural assessment, the first high stress condition is identified as being when the craft is fully loaded and being launched using the fall wires, with maximum forces occurring in the keel and the gunwales. Consequently, the first design consideration is the amidships section of the hull, where the designer must ensure sufficient section. Following this, high stresses are noted in the canopy top, which is a greater distance from the neutral axis and tends to be made thinner than the hull. The SOLAS swing and drop test energy is primarily absorbed by the hull structure, so in terms of direct impact resistance, the canopy has less strength than the hull, if it were to receive that same impact.

With the post 1986 designed craft having buoyancy in the hull and the canopy, the resultant design is essentially double skinned, making it additionally strong and stiff, as well as being well insulated.

10. Observations

This report is aimed at providing background information relating to the design specification for davit-launched TEMPSC. This data will be employed in subsequent reports to determine the capacity and reserve strength of a typical 50-man TEMPSC, currently employed in the North Sea, for a range of accident scenarios.

Structurally, the TEMPSC is required to meet a range of strength and buoyancy criteria specified by the IMO's SOLAS requirements. Testing a prototype TEMPSC, verifies the craft to these SOLAS criteria by ensuring that no significant damage occurs that may prevent it operating in a safe manner during the evacuation and escape phases. Since these tests rarely, if ever, lead to complete failure, there is little information on the reserve strength of a TEMPSC although, it has been noted, that some damage can occur during these tests. The range of structural tests is limited to a side impact at 3.5 m/s and dropping the TEMPSC from a height of 3 m into calm water for a craft in its fully laden condition. While additional tests are performed to verify the strength of the davits, buoyancy of the craft, engine performance, etc. these tests assume that the TEMPSC is under well-controlled environmental conditions. For a davit-launched TEMPSC from an offshore platform, the most likely in-water collision would be stern-on, leading to the probable loss of propulsion and steerage capabilities.

In SOLAS, there is no requirement to consider any fatigue damage history. From other industries employing GRP and from repeated launches of freefall TEMPSC, there is evidence of a loss of strength following one or more impact events. Therefore, there should be concern over a reduction in the capacity of a TEMPSC that has been involved in minor collisions and locally repaired. In particular, the prototype TEMPSC will have been subjected to the impact and drop tests and repaired prior to it being put into service. This craft will be the oldest and potentially the weakest in its class.

In general, experienced designers and manufacturers have developed the form of the GRP TEMPSC hull and canopy over a number of years. While some engineering calculations and computational modelling are performed for new craft types, the size and shape of the TEMPSC is primarily based on the proven design of earlier generations of TEMPSC. The industry is understandably concerned that details of the design and manufacturing are not made public, thereby allowing competitors relatively easy entry to the market. Furthermore, there is a feeling by some in the industry, both manufacturers and offshore operators, that the current designs 'work' and therefore raising concerns over the current design of TEMPSC that may lead to changes in structural requirements would be expensive and somewhat unnecessary. Consequently, very little good data and engineering methods are available that can be used to determine the strength and safety margins for alternative accident scenarios.

Previous studies concerned with the behaviour of TEMPSC have primarily been based on the likelihood of the TEMPSC being successfully launched and escaping from the offshore platform or vessel. Many of these studies have highlighted the lack of structural data and therefore have made only simplistic estimates of damage to the craft and consequent injuries and fatalities on-board. Nearly all of these risk-based studies are concerned with the probability of a successful launch and escape. From the HSE's point-of-view this is not always the same criteria as a successful evacuation - whereby all personnel are safely removed from the platform with only minor injury or discomfort. For example, the engine may fail, i.e. an 'Unsuccessful Launch', but the craft is retrieved without incident or, as has tragically happened, a 'Successful Launch' was followed by significant loss of life during transfer of the personnel onto the rescue vessel.

While the need to assess the structural capability of TEMPSC is an important factor in considering the successful evacuation of offshore facilities, there remain a number of important issues that need to be addressed in parallel.

For example:

- Would a stronger more rigid exterior be of benefit to the occupants or would it increase the probability of severe injury to the occupants, c.f. motor vehicles that are designed to absorb impact energies by significant deforming during collision?

- Is it always best practice to immediately turn the TEMPSC away from the structure as this will expose the propulsion and steering mechanisms to maximum likelihood of damage?

- In the event of fire, under current guidelines personnel would be directed to the leeward side of the facility, however, this would probably be the area with highest temperatures – would this lead to confusion and panic?

- Previous studies generally assumed that a trained coxwain would be on-board the TEMPSC. However, in a major incident this is unlikely for all craft. What would the evacuees do and what would be the consequence?

- In a major incident, how long would the occupants wait for the TEMPSC to fill-up prior to demanding that the craft be launched?

A full safety assessment including some consideration of human behaviour in different evacuation conditions would help target areas that could improve successful evacuations from offshore installations. This may or may not indicate that the strength of existing TEMPSC is a major area of concern.

Appendix A

List of Contacts Made and Replies Received:

Contact	Contact Type	Follow up	Reply
Government Agencies			
Health and Safety Executive (HSE)	Phone	Letter	OTH, OTN and OTO reports. Misc. reports/drawings.
International Maritime Organisation (IMO)	Web	Phone	Details of SOLAS and test specification status
The Maritime and Coastguard Agency (MCA)	Email	Phone	Recommended contacting ILAMA Copy of IMO test specification.
Certification Authorities			
Lloyd's Register (LRS)	Phone	Phone	LRS Rules and survey requirements for TEMPSC.
Germanisher Lloyd (GL)	Email	Email	GL regulations for TEMPSC.
Det Norske Vertitas (DNV)	Phone	Phone	DNV Technica – Status of ESCAPE program
Other Agencies			
The British Rig Owners Association (BROA)	Fax	Web	None
The Chamber of Shipping (COS)	Fax	Web	No information. Recommended manufacturers
International Association of Drilling Contractors (IADC)	Fax	Web	None
International Life-Saving Appliance Manufacturers Association (ILAMA)	Fax	Web	None
International Lifeboat Federation (ILF)	Fax	Web	None
International Marine Contractors Association (IMCA)	Fax	Web	None
Offshore Contractors Association (OCA)	Fax	Web	Recommended contacting UKOOA
UK Offshore Operators Association (UKOOA)	Fax	Phone	Suggested visiting their website

See next page

Contact	Contact Type	Follow up	Reply
Consultants			
Aker McNulty	Fax	-	None
ARK Safety	Phone	Email	HSE reports
J. Buchan & Sons	Fax	-	None
EM&I	Phone	Letter	Reports on TOES system failure probabilities and Rope Strength
Mulder & Rijke	Fax	Phone	None
Noble Denton	Phone	Fax	Offered to run analyses of launch/ escape using the SESCAPE program
Norsafe	Fax	Email	None
NOR Survival Systems	Fax	-	None
Robert Gordon Institute of Technology (RGIT)	Phone	-	None
Seaworthy Marine (Scotland) Ltd	Fax	Visit	Company information brochure. Data on resins and bow-thruster.
Selantic UK Ltd	Fax	Visit	Subcontractor of Norsafe. Company information brochure.
Umoe Schat-Harding Ltd	Phone	Letter	Offered to supply material data relating to older craft. None received

Appendix B

EERTAG (formally EESC) Membership:

British Rig Owners Association (BROA)

International Association of Drilling Contractors (IADC)

Maritime and Coastguard Agency (MCA), formally the Marine Safety Agency (MSA)

Offshore Safety Division, Health and Safety Executive (OSD, HSE), formally the Department of Energy, DEn.

Trades Union Council (TUC)

United Kingdom Offshore Operators Association (UKOOA)

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