Work package 4

DESSO ROPAX Design
Final report

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Preface

The project, Design for Survival Onboard or DESSO, was initiated in the summer/autumn 2003, was formally launched 2004 and completed in March 2006.

The main funding came from Vinnova, Stiftelsen Sveriges Sjömanshus and the Swedish Maritime Administration. In terms of expert man hours, the project received support from its industrial participants.

The purpose: To find solutions to the problem how to care for the survival and possible mass evacuation of passengers and crew in case of a major structural damage or fire on a ro/pax or passenger ship.

The paradigm: To study the feasibility of designing a ro/pax ship to become her own lifeboat.

The result: To be a template for future improved safety for ro/pax and passenger ships.

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The nine Work Packages (WP) of the DESSO Project
 WP 1: Project Management SSPA
 WP 2: Safety Assessment of ships. Chalmers Marinteknik
 WP 3: International Workshop. SSPA
 WP 4: RoPax Ship Design Globtech Marine AB
 WP 5: Upright and Afloat Chalmers Lindholmen
 WP 6: Decision Support Kockum Sonic
 WP 7: Fire Protection SP
 WP 8: Pax and Crew survival Chalmers Lindholmen
 WP 9: Concept Ship Display SSPA
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1 Executive Summary

1.1 Terms of reference
According to the Terms of Reference, “WP 4 is intended to be the platform, expressed in a generic model of a ro/pax, the EuRoPax 3000 - developed within the WP4 - in which the results of the other WP:s can be tested and evaluated.” The result of the tests and evaluations are summarised in the DESSO ROPAX ship which fulfils the same commercial capacities as the original EuRoPax 3000 but also the survival performance requirements identified in the DESSO Project.

1.2 For whom?
The final result is intended as a template out of which tentative owners may find ideas and solutions for improved safety.

1.3 State of the art
The generic EuRoPax 3000 ship is fulfilling present rules for damaged stability (SOLAS and MCA). The ship has a capacity of 1.500 passengers, 1.000 beds and about 3.400 lane meter trailer capacity. This capacity is typical for many European Short Sea Routes. The design is truly generic in the sense that a wide range of cargo access modes, capacities and passenger facilities can be adopted without changing the basic safety principles of the design. The same commercial capacities, flexibility and basic safety paradigms are adopted also for the DESSO ROPAX.

1.4 DESSO Targets
The DESSO targets are to develop the generic EuRoPax 3000 into the DESSO ROPAX ship concept and to give the DESSO ROPAX ship qualities to become “her own life boat”. This means – in the DESSO interpretation - that the ship shall stay upright and afloat after the following damages:
1. SOLAS damage extended to three compartments.
2. MCA damage extended to three compartments.
3. Rip-up over a length of 65% of Lpp up to, but not penetrating, the deck 1 level.

Also:
- The ship shall, after the above damages, have a certain redundancy for manoeuvrability and for extended essential functions.
- In case of damages worse than the above, the ship may sink but this shall be without excessive heel or capsizing.
- The arrangements for abandoning the ship shall be multifunctional.
- Fire shall not be a reason to abandon the ship.

1.5 Results:
The DESSO Targets have been fulfilled in the DESSO ROPAX ship concept by adopting the following principle solutions:
1. Wide and closed side casings, transversally subdivided, are arranged from around DWL and up to deck 4, thus creating a “life belt” around the ship.
   The casings are arranged “outwards” which means that the casings do not restrict the cargo capacities and passenger arrangements compared with the generic EuRoPax 3000. This arrangement makes an upright survival, after the DESSO damages, possible, as well as an upright sinking - should the damages be more extensive than the DESSO ones.
2. The engine arrangements and systems are adapted to the various damage cases which means that minimum one engine compartment is dry and functional after any DESSO damage.
3. The spatial arrangement is laid out for easy fire fighting with equipment of sustainable type (high pressure water plus redundant pump arrangement), and for easy and safe evacuation (smoke evacuation and overpressure ventilation).
4. The abandon ship arrangement can be used for “float off”, for “helicopter lift”, for davit launching or for conventional raft launching.
   The allocated area for rescue equipment can also be used for a conventional life boat arrangement.
The more significant detail solutions adopted for the DESSO ROPAX Ship, based on the above principles, are further outlined and developed in this report.

Important to note is, that for the DESSO Requirements “stay upright and afloat” after a DESSO damage, and “sinking upright” in case of a more extensive damage, the chosen solutions are of “forgiving” nature that will require no action from the crew.

For the events of less serious nature, as for survival of the ship point of view, the designs for “safety by action” are dominant.

On the “incident trigger levels”, suitable routines and training on all levels and for all involved categories are suggested to address situations of less serious nature in order to prevent from develop into significant situations.

1.6 Upcoming Rules

1.6.1 Floatability

The upcoming rules, as described in the MSC 80/3/4 Chapter II-1, are principally of probabilistic nature with complementary deterministic detail regulations.

A study, where the Generic EuRoPax 3000 and the DESSO ROPAX have been evaluated, considering the new rules, has been done within the WP 4 and WP5. The study is by definition superficial as several parts of the new rules are still under discussion regarding interpretation and application.

The study suggests that the EuRoPax 3000, with the original lifeboat/liferaft arrangement, will arrive at an attained index (A) that may not fully satisfy the required index (R).

With a 100% lifeboat capacity, the required index will be lower and the attained index will, for this reason, be sufficient to reach the required index.

The EuRoPax 3000 will – as shown in the WP5 report – capsize at most of the 3-compartment damages.

For the DESSO ROPAX, the required index demand will, due to the “liferaft alone” arrangement, be somewhat higher than for the EuRoPax 3000.

The survivability enhancements, applied to the DESSO ROPAX, will most likely only marginally improve the attained index compared to the EuRoPax 3000.

The DESSO ROPAX will – as shown in the WP5 report – survive all 3-compartment and MCA damages and she will not capsize after damages more extensive than that.

The new rules contain deterministic requirements that, in some cases, might be contradictory to the recommendations of WP4 and WP7.

1.6.2 Fire fighting

The DESSO ROPAX Ship is designed according to the upcoming rules as described in the WP7 and which are considered in line with the principles suggested for DESSO.

1.6.3 Cost aspects

In general, safety features above the rules are not rewarded, neither by the authorities nor by the industry (insurance companies, clients etc.)

At the end of this report, an attempt is made to briefly analyse the suggested DESSO features from the cost point of view and at what conditions they might be attractive for a potential owner.

The analysis suggests that – apart from the redundancy – the DESSO features can be obtained at moderate or low extra costs.

1.6.4 Conclusions

The DESSO Project demonstrates that a ship that has a very high survival capacity after a damage and that if she sinks does it without capsizing is possible to design and build with a marginal extra costs.

The problem is that the upcoming rules, seems not to encourage this.

The lack of focus and transparency of the upcoming rules makes them very difficult to explain to the users, especially in terms of ship’s behaviour after a damage. This must be considered a risk by itself.
2 Introduction

According to the terms of reference, "the WP 4 is intended to be the platform, expressed in a generic model of a ro/pax ship, the **EuRoPax 3000**, in which the results and findings of the other WP:s can be tested and evaluated". The **EuRoPax 3000** is described in an earlier WP 4 Report and analysed from a floatability point of view in the WP 5 Report.

Initially the **DESSO Damage Cases** are described and illustrated as an understanding of their nature is essential for evaluation of the proposals for avoiding the consequences of these damages.

In order to test, complete and evaluate these various ideas and proposals in a systematic way, the WP 4 and WP 5 jointly developed a "Evolution" Flow Chart.

As the top events are of decisive influence on the major parameters (beam, freeboard height, sectioning etc.) of the **DESSO ROPAX** ship, it was found necessary to start with problems related to the top events and work the way downwards the event levels.

With the major parameters decided and introduced in the design, the boundaries for the other required solutions were set and identification and evaluation of the proposals and suggestions was considerably facilitated.
3 Survival criteria

3.1 Present IMO Rules for floatability.

The present IMO Rules for floatability of a passenger ship or ro/pax ship are deterministic and describe certain damage cases that the ship shall be designed to survive.

1. According to SOLAS, a 1, 2, or 3 compartment damage (depending on the “criterion of service”) is required. In the very majority of Ro Pax cases it is a two compartment damage defined as a damage to two adjacent compartments, unlimited in height and with a penetration of 20% of the ship's beam (B/5) shall apply. In complement to this, “floodable length” shall also be fulfilled, granting the non submersion of the margin line, irrespective of the equilibrium heel.

2. According to MCA, a damage with a penetration up to 50% of the ship's beam (B/2), a longitudinal extension of the damage of one side compartment and an unlimited vertical extension shall also apply to withstand the floodable length requirement not usually reached by any vessel having a long compartment below the bulkheads deck.

3. According to the Stockholm Agreement, a certain amount of water on the freeboard deck shall be considered in conjunction with the SOLAS damage.

Redundancy.
- No redundancy for manoeuvrability including propulsive power is required.
- The electrical power redundancy is taken care of by an emergency generator with supply demand according to SOLAS.

3.2 Requirements according to DESSO

3.2.1 DESSO Damages

The DESSO damages, the DESSO ROPAX should survive, are more severe than those above described existing rules but considered relevant for the DESSO Project.

For upcoming rules: see chapter 8.
Damage 1
SOLAS extended to three compartments.
This means that three adjacent compartments are damaged up to B/5. No vertical limit of the damage.
Damage 2

MCA extended to three compartments. This means that three adjacent compartments are damaged up to B/2. No vertical limit of the damage.
Damage 3
Rip up to 65% of the Lpp with penetration up to but not penetrating the dk 1 level. Transversally the damage is limited to 20% of B.
3.2.2 Actual damages

Figure 1 A Panamax container ship in collision with a handymax/general cargo ship.

The penetration is almost 100% e.i. the bulk ship is almost cut in two.
The horizontal extension is moderate. The vertical extension is "unlimited. The medium and large size container ships (panamax and post-panamax) with high speed and great mass possess an enormous inertia.

Damage 2
MCA extended to two, respectively three compartments.
Damage depth: up to B/2. No vertical limit.
Figure 2 A VLCC in ballast after a collision with a fully loaded cape size bulkship. The collision angle was about 45 degrees

The penetration is up to B/2 (see also picture 1).
Generally ro/ro ships offer more resistance against penetration due to the horizontal cargo decks. An engine arrangement outside a B/5 bulkhead adds to this resistance.
Figure 3 A VLCC after a collision with an OBO in ballast. The collision angle was about 90 degrees. The penetration is about to B/5.
The collision angle was about 25 degrees. The collision started at about L/2 and ended in the superstructure aft. The bulb of the feeder ripped open on one side all the tanks from L/2 to aft.

Damage 3
Rip-up to 65% of the Lpp with a penetration up to - but not penetrating - the deck 1 level. Transversally the damage is limited to about 20% of B.

Figure 4 A product tanker after a collision with a container feeder ship.
Relatively little dynamic energy can cause damages of considerable length. In a recent example did a cape size bulk carrier slip over a sharp rock which ripped up all the tanks on one side to the full length of the ship to a depth of about 0.5 meter.
3.2.3 DESSO Fire survival criteria

Fire shall not be a reason to abandon the ship. This means that fire – wherever it occurs – shall be possible to isolate and fight. Remaining areas, outside the fire zone, shall be possible to regard as “safe areas”. The access arrangements, within the accommodation as well as the rest of the ship, shall be easy to use, logical to follow and without bottlenecks.

Figure 6 Large scale fire on Scandinavian Star

The pictures above demonstrates the problem with high located air intakes for pressurising areas around a fire zone.
3.2.4 DESSO Redundancy requirements

For the DESSO ROPAX ship, a propulsive redundancy shall remain after the DESSO damage. This means that at least one engine room shall be accessible and dry after a DESSO damage. The functions of the engine and required supply systems shall remain. Such functions are:

- Propulsion
- Electrical production and distribution
- System control
4 Irreversible Level

4.1 General

Should the DESSO ROPAX ship suffer a damage on the watertight integrity, which is more severe than the DESSO damages, the buoyancy might be lost to that extent that the freeboard deck (deck 2) will be submerged and water will enter on the freeboard deck, with a considerable loss of stability as a result. The generic EuRoPax 3000 ship will, in this scenario, lay down on its side or capsize and most likely sink.

4.2 The DESSO Requirements

The DESSO ROPAX ship is, in case of such a fatal damage, required not to heel extensively and if she sinks, sink in a reasonably upright position to facilitate an orderly evacuation.

4.3 Sinking upright

The following alternatives to achieve the DESSO requirements for “sinking upright” are investigated:

1. To down flood the water from the freeboard deck into the undamaged compartments below, thus improving the stability during the sinking. The development of the capsizing scenario may however be very rapid (within minutes), and the time required for positive and well considered actions as well as prompt access to the systems required for the down flooding might be unpredictable and most likely completely insufficient. (see the Vossnack Report). Also present interpretation of the freeboard regulations will make a down flooding arrangement difficult.

2. To improve the stability with a combination of closed side casings and transverse bulkhead (doors) on the freeboard deck. A widening of the side casings corresponding to an increased ship’s beam to 30,12m above the freeboard deck (originally on the EuRoPax 3000 equal to 28,5m) and adding two transverse bulkhead doors, will increase the stability and limit the free water surface on deck 2 sufficiently to ensure an upright sinking. (see WP 5) The bulkhead doors will however create obstacles for the cargo handling and the side casings will not be big enough to offer alternative space for technical installations and accesses.

3. To improve the stability with closed side casings wide enough (min 3.75m) to handle the sinking upright problem without any additional transverse bulkhead doors.

For the DESSO ROPAX ship, this alternative is chosen.
Figure 8 DESSO ROPAX design with wide closed side casings
4.3.1 Arrangements for the DESSO ROPAX ship for sinking upright

The basic philosophy to arrange for fulfilment of the DESSO requirements is as follows:

- In case of loss of reserve buoyancy, the waterline inertia shall increase with the increased draft to that extent that sufficient stability remains. This is achieved by an increased beam above the waterline.

![Figure 9 Increased beam above the waterline](image)

- Should a damage be that extensive that the freeboard deck is flooded, reserve buoyancy is obtained by connecting the web flanges so a complete inner hull is created from the freeboard deck and up to below the lowest passenger deck.

The ship is thus supported by the double hull side walls as for a floating dock.

![Figure 10 The ship is supported by the double hull side walls as for a floating dock](image)
In case of a damage of such a magnitude that also the "dock walls" are severely damaged, the two lower passenger decks may offer a certain reserve buoyancy that prevents capsizing during the sinking. This is assuming that a reasonable watertight integrity of the superstructure is maintained.

![Figure 11 Reserve buoyancy in passenger decks](image)

The side casings, widened to 3.8m each, giving a ship’s beam of 32.12m above the freeboard deck and maintaining approximately the original beam of 28.5m in the waterline are found sufficient to fulfil the DESSO requirements. These wide side casings offer alternative spaces for various technical installations (boiler, silencer, air condition units, ventilation arrangement, access etc) that otherwise would have occupied commercial space. The wide side casings do also provide wider areas on the passenger decks for commercial use and facilitate the creation of an ultimate reserve buoyancy in the passenger accommodation.

In order to limit the heeling during the sinking it is assumed that the compartments of the side casing are fully interconnected all the way up to the deck 4 (lowest accommodation deck) so minimum asymmetry is created.

![Figure 12 Cross flooding to minimize asymmetry](image)

Longitudinally fore and aft of the damage, undamaged compartments offer spare buoyancy that will assist to keep the ship upright and slow down the sinking.

When the sinking has progressed to that level where water reach the air intakes, located in undamaged sections, that leads to the engine room or lower holds, water may enter and fill the undamaged sections. As the ship at this stage may have a list of about 20 degrees, this water may initially worsen the heeling considerably over a certain period of time.
To avoid this and thus maintain the buoyancy in the undamaged parts, the ventilation ducts are designed in such a way that they create a watertight passage from the outside of the hull to the area they are ventilating, thus leaving the space they are passing, dry.

Figure 13 Ventilation duct arrangement to minimize flooding

The section shows an undamaged transverse zone.
4.4 Uncontrolled fire

4.4.1 Accommodation

Upcoming SOLAS requirements call for “safe areas” within the accommodation in order to minimise the need for abandon the ship in case of fire.

A “safe area” – according to the SOLAS definition – is an “area in the context of a fire casualty, from the perspective of habitability, any area outside the main vertical zone(s) in which a fire has occurred, such that it can safely accommodate all the persons onboard to protect them from hazards to life or health and provide them with basic services”.

The above means that the “safe area” can be any space outside the main vertical zone(s) affected by fire.

Should abandoning of the ship be needed, shall, according to the SOLAS rules, “adequate means of egress/escape to life saving appliances be provided from each area identified or used as a safe area, taking into account that a main vertical zone may not be available for internal transit”.

(for a full definition and detail description of "Safe Areas" see the WP7 Report)

Arrangements for the DESSO ROPAX ship facilitating evacuation

For the DESSO ROPAX ship, this is provided for by arranging the accommodation decks to simplify orientation and provide easy access to the stair cases to the assembly stations. These are arranged, with one for each fire zone, as "safe areas" with direct access along the ship’s side to the outdoor gangway on which the life rafts are located. The arrangement does also provide for an outdoor passage from one area to another "bypassing zones lost by fire".

Figure 14 Evacuation deck

Within the blocks of passenger cabins, the corridors are arranged in the longship direction. The arrangement makes it possible to "seal off" a corridor with a cabin on fire (and not necessarily the whole block of cabins), thereby facilitating both evacuation and fire fighting.

Longship corridors are also easier to walk, in case of excess heel, than transverse ones.

Figure 15 Within the blocks of passenger cabins, the corridors are arranged in the longship direction
Provisions for supply of fresh air and evacuation of smoke and toxic gases is necessary for a safe evacuation and for the habitability. The DESSO solutions are described in detail in the WP7 Report. Normally, (like on the generic EuRoPax 3000 ship) the arrangements for ventilation and air condition, including the intakes for air, are located on the upper decks. This may create problems for finding air intakes that not run the risk of sucking gases and smoke instead of fresh air into the areas in question.

For the DESSO ROPAX ship, the wide side casings (necessitated by the floatability requirements), are used to accommodate the units for air condition and ventilation and related intakes for air on a low deck level (dk 3), starboard and port in pairs for each fire zone. This arrangement, together with the DESSO redundancy for manoeuvrability and extended supply of electricity will facilitate substantially to care for the supply of fresh air and extraction of smoke also in the “irreversible” scenarios.

![Figure 16 HVAC units in side casings gives low located air intakes.](image)

### 4.4.2 Engine areas and cargo areas

For the purpose of facilitating abandoning of the ship, necessary adoption of the arrangements, according to the recommendations in the WP 7 Report, can be done within the existing principle layout of the cargo decks and observing the redundancy requirements for the machinery functions that are dealt with later in this report. The major access/escape way from the engine rooms and cargo holds is via an A-60 trunk with inclined stairs that goes directly to the safe areas/assembly stations. In addition to that are the normal emergency escapes that are connected, via air locks, to the passenger escape ways. In addition to this access way, the cargo holds and engine areas have emergency escapes according to the rules.
4.5 Abandoning of the ship

Above a certain level of damage (see WP5 and WP7 Reports), the ship is most likely impossible to keep afloat or habitable. Consequently the ship has to be abandoned. An imperative requirement to do this in an orderly fashion is that the ship is in a reasonably upright condition at any time during the sinking and abandoning operation.

In case of fire, redundancy for electrical supply and partly manoeuvring capability is required by DESSO. The former to keep the systems needed for the prime movers (main engine) running, assist to operate the abandon ship equipment and keeping the evacuation areas free from smoke and toxic gases. The latter is to assist, by suitable manoeuvring, to keep the evacuation areas free from smoke and engulfing flames.

4.5.1 Arrangements for abandoning of the DESSO ROPAX ship

Regarding the choice of abandon ship equipment, several proposals have been investigated. (see WP8 Report). The most radical one is to let part or parts of the superstructure become a “safe haven” that can be disconnected from the ship and float away in the case the ship sinks. Various types of free falling types of lifeboats have also been contemplated as possible solutions. None of the above proposals are however presently on a sufficient stage of development or have the desired capacity. They will therefore be dealt with on principle basis only. (see WP8 Report).

For the purpose of the DESSO ROPAX ship, it is decided to base the system for abandoning of the ship on inflatable rafts - possible to launch loaded - with a capacity of 100 persons each and fast rescue boats only. No conventional lifeboats will be used.

Presently a raft, possible to launch loaded has a maximum capacity of 48 persons. The major suppliers see no difficulties to enlarge the concept to the desired capacity.

The rafts will be located on the gangways outside the public areas on deck 6.

The areas in the gangway are sufficient to arrange for 100% raft redundancy - should this be deemed necessary.

Should so be desired, the raft arrangement can be replaced by conventional lifeboats without further alterations of the accommodation.

![Figure 17 The life rafts will be located on the gangways outside the public areas on deck 6](image)

The public areas are designed to serve as assembly stations (safe areas) and direct access to the rafts is arranged.

The rafts are possible to inflate in situ and can either be launched:

- by crane, loaded
- by helicopter, loaded
- “float away” loaded
- conventionally with inflation in the water and embarkation by slide
Figure 18 The rafts can be launched by crane

Figure 19 Lifted away by helicopter.

The Russian MI 26 is reported to have a takeoff weight of 56 tons, a light weight of 28 tons which leaves a dead weight of 28 tons including fuel. The rafts are estimated to have a weight of approx. 14 tons with 120 persons onboard.
Note:
In the upcoming probabilistic rules, the required index is increasing with decreasing number of life boats in relation to the passenger number. This means that a life boat capacity for the full number of passengers and crew gives a lesser required index than rafts alone. (see the WP 5 Report)

**Fast Rescue Boats**
The fast rescue boats will be located in the side casings, in a recess, on the level between deck 2 and deck 3. This location ensures a short pendulum arm.
5 Significant Level

5.1 General
The further occurred incidents are allowed to develop uninterrupted, forming chains of events leading to a significant level, the more difficult it is to prevent the chains to develop a final disaster. Consequently, safety in situations that have reached a significant level must – to a great extent - be conceptual and forgiving.
This means that the design of the DESSO ROPAX ship must contain such qualities in it’s basic design that the ship is capable – up to a defined level - to forgive and absorb the human mistakes or whatever that has taken the ship into the significant situation.
On the other hand - prompt and qualified actions with access to relevant means - can always, and at any stage, improve a given situation and even reverse a potential disastrous chain of events to a less harmful level.

5.2 The DESSO damages on the watertight integrity.
For the DESSO ROPAX ship, the damage cases which are identified as significant and capital are:

1. A SOLAS damage extended to three compartments.
2. MCA extended to three compartments.
3. Rip-up over a length of 63% Lpp up to but not penetrating the deck 1 level.

These damage cases are previously detailed described in this report and also in WP 5.

The above DESSO damage cases contains elements of uncontrolled free surfaces, loss of residual stability, loss of spare buoyancy, significant fire and shift of centre of gravity and may be the top of a wide range of chains of event of various origins.
The more typical of these origins are headlined on the levels below the “significant level” in the initially described “Accident Assessment Flow Chart”.

5.3 The DESSO survival standards
The DESSO ROPAX ship has been given an inherent capability to survive these damages upright and afloat and with maintained redundancy for propulsion and electrical power.
The DESSO ROPAX ship shall also have an inherent standard so fire shall not be a reason to abandon the ship.

5.4 Upright and afloat after a DESSO damage on the watertight integrity
The generic EuRoPax 3000 has, according to the rules, a capacity to survive a structural damage corresponding to MCA + 2 comp. according to SOLAS and this without any propulsive redundancy.

For the DESSO ROPAX, the decisive DESSO damage requirements for "upright and afloat" are the cases 2 and 3 as described earlier under chapter 3.2.1 DESSO Damages.

5.5 Arrangements for "upright and afloat” for the DESSO ROPAX ship
To fulfil the requirements for “upright and afloat”, widened and closed side casings corresponding to a B=32.12m are adopted (as for the “sinking upright” requirement). The subdivision for this casing is up to deck 4 the same as for that below deck 2 (the freeboard deck).
(see WP5 Report)

To facilitate the "propulsive redundancy" requirement, the aft engine rooms are separated with a longitudinal WT arrangement. The longitudinal separation of the aft engine rooms will, in case of a damage, create a certain undesired asymmetry of the flooding and consequently a heeling of the ship. This is considered acceptable as the redundancy adds so much to the "safety by action" capacity including the correction of the heel it causes.
However, certain restrictions in the geometry must be observed in order not to create an unacceptable large heeling moment. (see also “Redundancy” next chapter)

The longitudinal separation of the forward and aft engine rooms is done to facilitate access arrangements both for personal and for redundant cable routing.
In order to limit the risk for excessive heel in case of flooding both an aft engine room and a fully utilised heeling tank pair, the heeling tanks are split up in a forward pair and an aft pair on minimum two compartments distance from the aft engine rooms.

**Figure 22** Aft pair of heeling tanks situated more than 2 compartments away from aft engine room in order to minimize asymmetry in case of a 3 compartment damage

### 5.6 Upright and afloat at an uncontrolled free water surface scenario

Uncontrolled free water on the freeboard deck or the decks above, may rapidly develop into scenarios with significant and capital loss of stability, with consequent risk of capsizing of the ship. (see descriptions of the Herald of Free Enterprise and the Estonia in the WP2 Report). The capsize of the Normandie, due to trapped water from a fire fighting operation, is classic.

**Arrangements for control of free water on the DESSO ROPAX ship**

For the DESSO ROPAX ship, the freeboard is 3.0m on the design draught and 2.8m on the scantling draught. The chosen solution to free the freeboard deck and above from harmful water - may it be from structural damage or from fire fighting - is to arrange remote operable freeing valves along the ship’s side; two forward and one aft per side. The area of each valve has an area of about 0.5m2 which is deemed sufficient to prevent clogging from debris. Above valves lead directly overboard and are intended for emergency use only.

**Figure 23** Freeing valves from main deck
Harmful amount of water on the freeboard (dk 2) level can also in emergency and under certain conditions be discharged overboard via the stern ramp/door. For this purpose – and also for the purpose of closing the deck in case of fire – the ramp/door is made remote and wirelessly operated.

The previously mentioned increased side casings give a powerful righting leaver curve that will lessen excessive heel.

5.7 Upright in case of shift of Centre of Gravity

Unexpected shift of CoG can occur due to events like shift of cargo in heavy weather or due to human error (see “Zenobia”, ”Vinca Gorthon” and “Jan Heweliuz” in the WP2 Report).

**Arrangements for limiting a shift of cargo on the DESSO ROPAX ship.**

Due to the “straight lane concept” in the cargo area of the DESSO ROPAX design, pillars in between the cargo lanes are not an obstacle for the cargo handling and can therefore be accepted. The pillars are used to form an efficient limitation of excessive heeling moment after a cargo shift and to limit the weight of the deck structure.

The DESSO ROPAX ship has, because of the side casings, a forgiving righting leaver curve limiting the initial heel and facilitating corrective ballast pumping.

Asymmetric loading will only be able to compensate for by the heeling tanks and not by the ordinary ballast tanks which are symmetrically located. The reason for this is that otherwise lack of careful loading might be balanced by excessive use of ballast, which in turn means a risk of excess heel if ripped open in an accident.

The two pairs of heeling tanks are located fore and aft respectively in order not to be damaged both or together with the aft engine room in case of a 3-compartment damage.

The straight lane concept for the cargo areas makes symmetrical loading easy and uncomplicated.

5.8 Fire fighting arrangement for the DESSO ROPAX

The basic philosophy is that all spaces of the ship shall be protected by the same type of system. The choice of system for the DESSO ROPAX is high pressure water mist. For the detail description references are made to the WP 7 Report.

A fire fighting system with water of high pressure deluge type or high fog type do also limit the transfer of heat from a zone on fire compared with CO2. The systems are also perpetual as long as the pipes and pumps are operable.

In order to assure requested DESSO redundancy the fire pumps and systems are located symmetrically one in each of the aft engine rooms.

For the manual fire fighting equipment, the WP 7 gives detailed recommendations. Regarding the spatial location of the fire main line and the fire stations in the cargo holds, this is arranged with the fire main as a ring line outside the B/5 and with branches up to the upper decks in the emergency escapes and regular access ways.

The fire stations are located at the respectively deck levels inside the access and escape ways and in the corridors (see also WP7 report).
5.9 Evacuation from accommodation fire zones in case of a "significant fire"

An overriding DESSO requirement is that “fire shall not be a reason to abandon the ship”. The detail requirements for fulfilling this are formulated in the WP7 Report.

The arrangement of the passenger areas and crew quarters are arranged for simple orientation and easy and safe access to the evacuation zones (safe areas), with stairways, at the end of each corridor.

Each group of passenger cabins contains three parallel and separate corridors. The separation of the corridors facilitates the limitation of cabins directly affected by smoke and toxic gases in case of fire. The stairways in the evacuation zones lead directly to the internal safe areas/assembly stations at the deck above the accommodation areas.

The ventilation arrangement is capable of active smoke control which means that the smoke is extracted from the escape routes in a possible fire area while the surrounding areas and stairways are kept under overpressure to prevent smoke from spreading into these areas. This arrangement improves safe evacuation and facilitates manual fire fighting.

Figure 24 Smoke gas evacuation
5.10 Fire limitation arrangements

The cargo hold on deck 2 and 3 are provided with two fire curtains each to limit the areas for a possible fire. (see also the WP7 Report)

Figure 25 Fire curtains on deck 2 and 3

The WP 7 recommends extended fire insulation above the rules under the accommodation and between the cargo decks. The arrangement suggested in the DESSO ROPAX, offers no obstacles to this. For the fire insulation between the cargo decks (A60) this can alternatively be achieved by water from the sprinkler system.

5.11 Dangerous cargo

The arrangement of the EuRoPax3000, with the open sides on deck 4, was not considered due to the fire fighting and dangerous cargo point of view. From the residual stability and residual buoyancy point of view the arrangement, with a non watertight deck 4 volume, provides no contributions and is deleted in the DESSO ROPAX. An open deck space is arranged on the DESSO ROPAX on deck 4 aft of the superstructure. The arrangements on this deck concerning fire fighting, armatures etc are in accordance with the IMDG rules for what is allowed to be carried on an open deck (see also WP8 report).
6 Secondary and Primary Consequences Levels

6.1 General

On these levels, incidents from the level below (Incident Triggers) have resulted in the development of potentially dangerous chain of events. One of the major targets for the DESSO ROPAX ship design is to create natural breakers in the potentially dangerous chain of events, thus preventing them from developing their potential into “significant” or “irreversible” levels.

The chain breakers can be of conceptual design nature like
- compartmentation with regards to water tightness or fire,
- spatial arrangements
- improved fire insulation
- etc

They can also be of “safety by action” nature where means are built into the conceptual design that allow the crew to detect and to act to stop or even reverse the development of the chain of undesired events.

Examples of this category of chain breakers are:
- Well designed early alarm systems
- Decision support systems
- Well designed and logically arranged manual fire fighting equipment
- etc

6.2 Collision, grounding or stranding

Collision, grounding or stranding may all result in structural damages. Structural damages may also be caused by other reasons like wave impact, loose cargo, technical malfunctions etc. Unless the above events result in damages beyond the “irreversible” level (a damage more extensive than a DESSO damage), the DESSO ROPAX ship is conceptually designed to forgive and stay afloat.

It is however imperative that the watertight integrity is maintained as designed and not put out of action by open access ways that should be kept closed or by non-compliance modifications etc. Failures in the above respects may cause undesired/unexpected cross flooding with fatal consequences as a result.

Due diligence in the design of access-ways, in the broad sense of the word, will contribute considerably in increased safety in this respect. Protection against consequences that may not seriously jeopardise the safety of the ship are also considered, simply for that reason that damages after an accident can be kept limited.

6.3 Arrangements of access ways

In the following sections, the arrangement principles of the access ways for normal and for emergence operation, as adopted on the DESSO ROPAX ship, are described. The descriptions are made out of the viewpoint "avoiding accidental progressive flooding of water" and "avoiding transmission of fire, smoke and toxic gases". Where applicable, the access ways are located within the same vertical WT zone and the same fire zone respectively.

Cargo Access Arrangement (CAE)

The existing rules and regulations determining the design, functions and scantlings are considered relevant and covering in most of the DESSO damage cases.

The additional DESSO demand is for the ramp covers on the free board deck (dk 2) which on the EuoPax DESSO are designed to withstand a water pressure from below. The pressure head is taken from the rip-up damage case when the ship is assumed to float in an equilibrium with deck 2 as the new “tank top”.

The ramp cover and the stern ramp/door can be remotely operated in order to enable closing of the cargo areas in case of fire. (see "Silver Ray" in the WP2 Report). It is noted that remote operation of CAE is prohibited in the upcoming rules MSC 80/3/4 regulation 13-1/4.

Access Arrangements for Passengers

In the EuRoPax DESSO, the access to the passenger and the crew accommodation is arranged amidships and athwartships SB and P on deck 6 which is the Public Area deck.

A possible – but not shown – alternative for a Mediterranean style –mooring situation, is to arrange for access from aft via the wide side casings up to deck six where a reception area is arranged.
The ordinary access ways between the passenger accommodation decks are arranged as double stairs in the centreline and double stairs and lifts athwartships SB and P. 

The centre line stairs are located one in each of the fire zone cofferdams plus one out door aft. 

The athwartship stair/lift arrangement is amidships in the embarkation area. This arrangement is extended downwards to deck 2 and deck 3 to provide access for drivers from these decks. This access is arranged in an A-60 isolated WT trunk with WT doors to deck 2 and 3 and with arrangement for overpressure in case of fire. 

The trunked WT and A-60 emergency escapes goes vertically from the cargo areas via airlocks to the accommodation accesses and further to the assembly stations (=public areas) on deck 6.

**Access Arrangements for crew**

The normal entrance to the accommodation quarters for the crew on deck number 7 is via the same main entrance as for the passengers.

The access from the crew quarters to the navigation bridge is straight forward through the central corridor.

The access to the mess rooms on deck number 5, galley and stores on deck number 4, is via a dedicated crew stair and lift arrangement.

The emergency exits are the same as from the passenger accommodation.

The access to the engine rooms and cargo areas is arranged SP and P in the engine casing, where dedicated lift and stairs are arranged from the deck 7 (crew quarters) and down to the engine workshop areas. Exits are arranged at the deck number 2, number 3 and number 4 levels.

This access is arranged in an A-60 isolated WT trunk with WT doors to deck 2, 3, 4, 5 and 6 and with arrangement for overpressure in case of fire.

Emergency escapes from the cargo holds are arranged according to the same principles.

**General, emergency**

In all access ways, where WT doors are arranged, these are swinging inwards to avoid progressive flooding in case of submerging.

**Access for provision and stores**

The access openings for handling of the provision and stores are, on the DESSO ROPAX ship, arranged within the same fire zone as they areas (galley and serving counters etc.) that they serve.

The handling principle for the stores, provision, laundry, garbage etc. is that it is unitised in 20’ ISO units that are transported to deck 3 under the store-rooms on a trailer and then lifted, through a WT hatch in deck 4, into the store-room.

From the provision store and preparation area, the food goes via a lift to the galley and from there – also by lift – to the serving stations.

To the shops the goods is transported by lift and trolley.

**Access for engine spare parts and for engine maintenance**

**General**

Experiences show (see WP 2 and “Stena Nautica”) that unauthorised open access ways between WT compartments may severely worsen the consequences of damages on the WT integrity.

The reason for the unauthorised open access ways may vary but a very common reason is “necessary for access for maintenance and transport of spares”.

Thus it is of highest importance that strict routines for permissible access through WT bulkheads are laid down but equally important that the ship has a spatial lay-out that unauthorised opening of WT passages simply is not needed. Necessary maintenance must be able to perform efficiently without shortcuts in the safety routines.

As the DESSO ROPAX is capable to survive an MCA damage extended to three WT compartments, and in some cases even extended to four compartments, the following policy for the WT doors between the engine/workshop compartments is suggested:

“ Either the forward door or the aft door of the workshop is allowed to be open for passage and for work at sea – but never both simultaneously”.

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Access for spare parts

The majority of the components that require access for heavy spare parts and their handling auxiliaries, are located in the four main engine compartments.

For damage survival reasons, the two forward engine compartments are cross connected.

For the same reasons, the engine rooms are in longship direction separated with a WT compartment which is cross connected.

The two aft engine compartments are, for redundancy reasons, separated SB and P.

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Figure 26 Access for spare parts

The WT compartment, in between the two engine room pairs, is allocated for workshops, spare part stores, engine office (which is not the same as engine control room – see “redundancy”) and change room.

The access arrangement for access for personnel to the workshop etc area and to the engine rooms is shown on the General Arrangement.

The principle for the arrangement is that should a flooding occur in the engine room or workshop, the door to the other compartment will be more firmly closed by the water pressure even if all the cleats are not properly locked.

In the lift, which has a lifting capacity of 1 ton, minor spares can be transported from the deck 2 level.

For the access of heavier spare parts to/from the engine rooms/workshop, bolted doors are arranged in the bulkheads between the compartments.

For access from shore to workshop and to the engine rooms, bolted doors are arranged in the longitudinal bulkhead to deck 1.

The above openings are for shore operation only and need not and must not be opened at sea.

Other mayor components for outside the engine rooms (like steering gear, ventilation, boiler rooms etc, are arranged with access doors/hatches – WT or not, as case may be.

Access for bunkers and other fluids, (pilot access)

The access stations for bunker and fluids (like fresh water, lub-oil, hydraulic oil, urea, sludge, black/grey water etc.) are located SB and P between frames # 95-99.
The stations are located in WT recesses in the double hull, each with a WT door in the ship’s side and with WT access to the crew access-way (stairs and lift) between the engine room and superstructure.

This makes the bunker door also suitable as pilot access.

The piping from the station goes vertically down to the engine workshop area from where it is branched out to the various tanks and treatment stations.

The bunker doors can be remotely closed in case of fire.

**Outlet for exhaust gases**

The wide side casings are used for arranging of boilers, exhaust boilers and silencers below the passenger accommodation levels. The arrangement means better possibilities for the passenger area access ways and layout.

**Access for Air**

Passenger and crew accommodations.

Active and passive smoke control is arranged for.

Passive smoke control is arranged according to present rules which means that in case of fire all ventilation shall be stopped and all fire dampers shall be closed.

The philosophy behind an arrangement for active smoke control is that stairways, escape routes or other areas shall – in case of fire - be kept under overpressure by the ship's ordinary HVAC system.

From fire zone shall the smoke and toxic gases evacuated by a separate and normally closed down system.

The HVAC system is arranged below the passenger accommodation in the wide side casings with low located inlets. The arrangement is symmetrically SB and P and air can - in case of fire - be taken low down and from the windward side.

The smoke extraction system is equally located in the wide side casings but with high located outlets. The arrangement is symmetrically SB and P and smoke can - in case of fire - be discharged on the leeward side.

The air intakes/outlets are provided with WT fan dampers of gas puff absorbing type. (This means that they are capable to retrieve their function after a having blown open by a gas puff).

![Figure 27 Gas puff proof ventilation dampers](image)
Ro/Ro Cargo decks

The roro cargo decks are provided with a ventilation system for use in port, based on longitudinal exhaust forward, and with natural supply via the stern ramp/door and ramp covers. At sea the ventilation is based on longitudinal exhaust/supply. In addition derivent fans will secure avoiding of badly ventilated pockets due to various cargo configuration. Each deck is provided with its own separate ventilation ducts. The fan dampers are of the gas puff absorbing type. The stern ramp/door and the ramp covers are possible to close remotely.

The deck 1 ventilation trunks have WT automatic gates at the passage of the longitudinal B/5 bulkhead in the lower hold.

Engine rooms

The air supply to the engine rooms are arranged in the wide side casings and with natural exhaust via the funnel. Both the supply fans and the natural exhaust ways are provided with dampers of the same type and function as for the cargo holds.

6.4 Redundancy

Purpose of improved redundancy

At the DESSO Seminar in mid 2004, it was concluded that a maintained redundancy for electrical power and for manoeuvrability, is of high importance for “safety by action” in case of damage on the WT integrity, in case of fire and in case of abandoning the ship.

Manoeuvrability means possibilities to lessen the impact of waves, to avoid grounding in close to shore situations, to avoid collision in close to ship situations, to reach sheltered waters etc. In case of fire, manoeuvrability means possibilities to lessen the impact of smoke and flames and in case of abandon ship it means possibilities to a more controlled operation. Redundancy in case of fire does also mean possibility to have hydraulic power to remotely close CAE and fire dampers.

Present Regulations for Redundancy (2005)

According to the present rules and regulations (SOLAS Reg. 42), an emergency generator supplying energy to a number of well defined emergency functions of category illumination, communication, navigation, emergency bilge, emergency fire fighting, shall be installed. No emergency system support to propulsive power or emergency propulsion is required.

The Reg. 42 says that “the location of the emergency source of electrical power … shall be such as to ensure to the satisfaction of the Administration that a fire or other casualty in the spaces containing the main source of electrical power … will not interfere with the supply, control and distribution of emergency electrical power.”

It was considered questionable weather this is possible after a “significant” SOLAS damage. An MCA damage will be capable – according to it’s definition – to knock out the entire emergency source wherever located and/or isolate the rest of the ship from the main el-suppliers weather workable or not.

Arrangements for propulsive redundancy for the DESSO ROPAX ship

For the DESSO ROPAX, a propulsive redundancy shall remain also after a 3-compartment SOLAS + MCA damage and for a rip-up damage penetrating the double bottom but transversally limited. (Damage cases 2 and 3)

To achieve this, following spatial alternatives have been investigated:
Figure 28 Possible engine room arrangements and redundancy
The table shows that in order to have one engine room dry and accessible for operation after the DESSO damages, alternative 2 is the one to be chosen.

Seen from a pure DESSO Redundancy requirement point of view, a longitudinal separation of the engine rooms is not required as the DESSO redundancy relay entirely on “opposite side aft” engine room. However, any damage of regular SOLAS 2-compartment type would without this separation flood three engine rooms instead of two.

**Engine room auxiliaries**

For a proper function of the propulsive prime movers, gears and shafting, the auxiliary systems like fuel, lubrication, cooling water etc. and a free flow of exhaust gases must be arranged for. The operation of the equipment must be possible “on the engines” as well as on a central computer system (CCS) with a multitude of possible operation stations.

Two capital operations centres are arranged; the bridge and the alternative operations centre aft on the deck 7.

A central engine control room is considered superfluous and even not desirable.

The main engine auxiliaries - like pumps for fuel, lub oil, water etc - do requires electrical power. For this purpose the main engine rooms will have their own source of independent electrical supply.

The arrangement of the generators is as follows:
- In the aft engine rooms is located the gear box with a shaft generator each with their own distribution board.
- The two forward engine rooms will have a common set of generator rooms located in between the two engine rooms.
There will be three generators each in a comfort and fire insulated compartment. The distribution board will be in common for the three generators.

A consequence of this arrangement is that a substantial redundancy also for the supply of electrical power is created which might make the traditional emergency generator superfluous.

**Electrical distribution system**

The layout for the power cables and signal cables is done considering a 50% redundancy as far as practical, after a DESSO damage.

The basic principle for the arrangement is that the cabellage is done SB and P in fire insulated and watertight trunks in the engine casings, leading straight upwards to the deck 7 level where it is branched forward an aft to the two operation centres.

From these main lines, power and signals are branched off as they pass the consumer areas/areas with equipment to be controlled.

**Note 1.**
The arrangement of the aft engine room is – due to the requirement of limited asymmetric flooding – very cramped if the “margin line” shall not be submerged.

The margin line requirement, which comes from SOLAS, has with the DESSO side casing arrangement no practical meaning. The Swedish Maritime Administration allows a transversally stepped freeboard deck as defined in the present rules to cope with this problem.

**Note 2.**
Should a twin engine arrangement be preferred – instead of the present four engine arrangement – a certain degree of redundancy can be achieved with the following arrangement:
- The forward main engine room is kept as is in principle but the engine size and power and consequently the length is adopted as required.
In case of damage both engines are flooded.
- The aft engine room including separating tanks are kept as is but without any engines. Only the gearbox with shaft generator (now also arranged for propulsion drive), distribution board etc are kept. The longitudinal extension is made shorter accordingly.
- The generators are arranged as previously but in WT cages and with separate distribution boards in WT rooms.

In case of flooded forward engine rooms it is possible to have one of the generators driving a shaft generator/motor for propulsive redundancy.
7 Incident triggers

7.1 General
In the analysis of disasters in the WP 2, as well as in the in the other WP reports, the presence of the human factor as initiator of disastrous chains of events and incidents is clearly visible. Human shortcomings are found to be the origin of the events as well as the reason for inability to identify or to execute suitable remedies to break the disastrous chain of events.

Very seldom, completely unexpected events (a freak wave, meteorite hit etc.) are to be blamed.

To cure the “human factor” problem it is often asked for
- more rules
- more training
in that order.

7.2 Non compliance
A study of the events, referred to in the WP 2 and other WPs, suggests that not a small number of the disasters is emanating from lack of compliance with, or cheating of existing rules.

Examples of disasters, where lack of compliance with existing rules, has played a decisive role are:
- Estonia
- Sundancer
- Scandinavian Star

Examples of rule cheaters are:
- Zenobia
- Rocknes

Example of cargo non compliance:
- Silver Ray

In the above examples, the shortcomings are suggested not to be on the seafarers side but ashore.

The examples from the first group suggest that lack of appreciation, from those issuing the relevant certificates or permissions to sail, is at hand.

The examples from the second group suggest that lack of appreciation, from those who designed the actual ships, and from those who did the approval, is at hand.

The example from the third group suggests that those who allowed the actual car (with fire works onboard) to be loaded on the Silver Ray did not understand the importance of checking what is allowed to carry and why.

Lack of appreciation and training is suggested to explain the frequent inability to cope with the problem to break a disastrous chain of event that is under progress.
This goes both for those who are designing the tools and those who are using them.

7.3 Interaction between the actors on the sea transport scene
With the assistance of Class Rules and International and National Regulations and modern design tools, there are excellent possibilities for the industry to create ships that are both efficient and safe.

However, fulfilment of the rules and regulations is no guarantee that the ship is suitable for its purpose or “safe” according to the state of the art.

Also, Contradiction between enhanced safety and existing rules as well as upcoming rules exists.
The rules for survival capability at decisive damage does sometimes draw the attention from solutions that may prevent a minor damage to develop into a decisive one.

The ISM Code sets forth important rules for the seafaring and gives the safety at sea a considerable lift. But - the Code is not entirely free from principle objections regarding the placing of the ultimate burden for safety onboard on the master of the ship.
- A ship is a product composed with little or no influence from those who carries this ultimate responsibility for its safe operation.
- A master is obliged to see to that his ship complies with the status assumed in the certificates. But that the original certificate certify technicalities, that are in compliance with relevant and required rules, has appeared being not allowed to be trusted. (Sundancer, Estonia).

7.4 Training for "Safety by Action", Simulator Training

Severe accidents are fortunately rare. Experiences gained from one ship or types of ship in emergency situations are neither frequent nor directly applicable to other ships or to other types of ships without a rather extensive analysis in between. Training for nautical situations and manoeuvring is frequently done at our nautical colleges in very advanced simulators.

Analysing of accidents or incidents is by far less done – if at all - at our nautical colleges or at our technical universities and this is also the case when it comes to training for possible actions to break a disastrous chain of events.

Worthwhile to notice is that major ferry and liner operators are using, for the in house training, suitable and advanced programs to an increasing extent. How to handle damage on the WT integrity is an important part of that.

Within the DESSO Project, analysis of a few significant disasters is done. (see WP2 Report) The findings suggest that all of them have started with something rather trivial. This might be within the field of design, maintenance, status control or operation. An initial trivial event has been allowed to develop in an undisturbed chain of events into the final disaster.

The WP2 findings also point at the incapability of the operators to handle the situations as they develop

7.4.1 DESSO Proposal

A continuous collection and analysis of event chains that have ended up in disasters or potentially disasters is organised at the Maritime universities.

The purpose of the DESSO Proposal is to create a living Data Base within the field of Adopted Maritime Safety (human behaviour, technical solutions, decision support etc.) with the aim to create a better understanding of the anatomy of disasters. The Data Base shall be made up in such a way that it can be used for:
- Education and training of ships officers, operative personnel, naval architects and administrators for a better understanding in the anatomy of disasters.
- Development of simulator technologies for training of sea going and other relevant personnel.
- Continuous and ongoing identification of areas for research and development.

7.4.2 Decision support

Any successful safety by action activity must be based on an appreciation of the situation – the more complete the better. The WP8 has described a system based on collection of information regarding the situation in various parts of the ship after a damage. It is however important that any onboard decision support system is workable when needed – namely after a damage of that extent that DESSO has defined.
8 Upcoming rules

8.1 Floatability

The upcoming rules, as described in the MSC 80/3/4 Chapter II-1, are principally of probabilistic nature with complementary deterministic detail regulations.

A study, where the Generic EuRoPax 3000 and the DESSO ROPAX have been evaluated, considering the new rules, has been done within the WP 4 and WP5. These studies are by definition superficial as several parts of the new rules are still under discussion regarding interpretation and application.

The studies suggest that the EuRoPax 3000, with the original lifeboat/liferaft arrangement, will arrive at an attained index (A) that may not fully satisfy the required index (R).

With a 100% lifeboat capacity, the required index will be lower and the attained index will, for this reason, be sufficient to reach the required index.

The EuRoPax 3000 will – as shown in the WP5 report – capsize at most of the 3-compartment damages.

For the DESSO ROPAX, the required index demand will, due to the “liferaft alone” arrangement, be somewhat higher than for the EuRoPax 3000.

The survivability enhancements, applied to the DESSO ROPAX, will most likely marginally improve the attained index compared to the EuRoPax 3000.

The DESSO ROPAX will – as shown in the WP5 report – survive all 3-compartment and MCA damages and she will not capsize after damages more extensive than that.

The new rules contain deterministic requirements that, in some cases, might be contradictory to the recommendations of WP4 and WP7.

8.2 Fire

The DESSO ROPAX Ship is designed according to the upcoming rules as described in the WP7 and which are considered in line with the principles suggested for DESSO.
9 Cost / Benefit Aspects

9.1 Costs

The Generic EuRoPax 3000, fulfils the SOLAS as well as the MCA rules for damaged stability and also, with some modifications, the upcoming SOLAS probabilistic damaged stability rules. The EuRoPax 3000 and the DESSO ROPAX has identical cargo capacity and cargo area layout and the same passenger capacity although with a slightly different layout.

The costs for adopting the "above the rules" safety features of the DESSO ROPAX ship, compared with those of the Generic EuRoPax 3000 can be described under four major headlines:
- Enhanced floatability and "sinking upright".
- Enhanced redundancy.
- Enhanced fire safety and fire fighting
- Life saving appliances

Enhanced floatability and "sinking upright"
These features are achieved by adopting wide and fully enclosed side casings. The additional steel needed for this is estimated to about 600 tons. The light weight of the EuRoPax 3000 is estimated to about 10,200 tons out of which construction steel is about 7,500 tons. In this context, the added 600 tons is about 8% increase of the construction steel and probably less than 2% of the ship's total cost.

Enhanced redundancy
A four engine arrangement is assumed already in the Generic ship and the added cost to separate the engine compartments longitudinally is considered marginal. Considerable costs is however caused by the required doubling of the needed auxiliary systems like fuel, lub oil, cooling water etc as well as doublings of the systems for operation and electrical power including structural protection thereof. Without doing detail studies of different ambition levels any estimate will be very approximate. Low ambitions in this respect give low costs - high ambitions give high costs. For the highest ambition levels a cost increase of 15 to 20% of the engine and system costs might be expected. As the total engine and system costs for a ship of this type might be some 25% of the total costs for the ship, an increase of 4 to 5% of the ship's total cost might be expected to achieve a full DESSO Redundancy.

Enhanced fire safety and fire fighting
For the DESSO ROPAX ship this means a totally water based fire fighting system with increased capacity, increased fire insulation/separation, increased number of sensors and additional ventilation arrangement (smoke evacuation). Redundancy for power and water supply in a part of the enhanced fire safety concept. Cost wise these added qualities may amount to less than 1% of the ships costs considering savings for the CO2 system and belonging arrangements.

Life saving appliances.
The DESSO concept calls for a multifunctional life saving arrangement based on inflatable rafts. The arrangement is chosen and developed according to the advises from the expert panel (WP 3) who clearly favoured rafts compared with conventional lifeboats. The upcoming rules goes the opposite way and penalise substantially any system not based on a 100% lifeboat capacity application. Cost wise the DESSO arrangement is equal or less expensive than a full lifeboat arrangement.

9.2 Benefits

General
Safety features above the valid rules or those in the near future upcoming ones, gives in general little - if any - benefit or reward in the eyes of the authorities and the insurance companies.
Possible benefits may be gained within areas like "Image for the Company", for making compulsory safety rules more rational to perform or to limit identified high risks in the actual commercial service.

**Redundancy**
Enhanced propulsive redundancy may lead to a possible saving in case of a future avoidance of a salvage bill or avoidance of a total loss.
In the first case a cost/benefit analysis will most likely be discouraging.
In the last case the insurance companies may give a marginal premium reduction but most likely not.

If combined with the feature "different power needed for summer/winter schedules" an enhanced redundancy can be achieved at marginal costs.

**Fire safety**
Enhanced fire fighting (and cooling for better insulation) created by means of an all purpose high pressure water system may appear beneficial due to simplicity in maintenance compared with various combined systems.

**Damage survival**
To widen and close the side casings offers possibilities for attractive arrangements.
Examples of such possibilities are:
- More flexibility to arrange the passenger accommodations including assembly stations and abandon ship arrangement.
- Wide side casings can be utilised for allocation of
  - Boilers and silencers which otherwise would either been high located or disturbed the accommodation layout.
  - Mob and FRB boats get positions for a better and safer launching arrangements
  - Lower arrangement of ventilation and air treatment units for facilitating of smoke evacuation systems.
  - Easy arrangements for access and emergency routes.
10 Conclusions

The DESSO Project demonstrates that it is possible to design a ship that has a very high survival capacity after a damage and that if she sinks, does it without capsizing.

The Project demonstrates that this is possible to achieve without limiting any carrying capacity or commercial quality.

The additional costs for satisfying the DESSO requirements are possible to keep modest.

The upcoming rules, as described in the MSC 80/3/4 Chapter II-1, are principally of probabilistic nature with complementary deterministic detail regulations.
The deterministic requirements might, in some cases, be contradictory to the recommendations of WP4 and WP7.
Examples: Penalties for life rafts only. Remote closing of cargo access equipment not allowed.

The EuRoPax 3000 and the DESSO ROPAX, may both satisfy the required probabilistic index but will, as demonstrated, behave completely differently in case of a damage.
This must be considered a risk by itself.
EuRoPax 3000, the Generic RoPax Design

A ro/ro or ro/pax ship has, almost without exception, conceptually a considerable possible spare buoyancy in the covered above freeboard deck volumes. It has also - conceptually - a high degree of freedom to arrange the spatial relations of the volumes in order to achieve a good floatability in case of a damage on the watertight integrity.

The Generic RoPax Design - EuRoPax 3000 - fulfilling all present rules (March –06), constitutes the basis for the further safety engineering work within the DESSO Project.

The ship has a capacity of 1,500 passengers (1,000 beds) and 3,400 lane meters for trailers, a capacity rather typical for many European Short Sea Routes.

The design is truly generic as a wide range of cargo access modes, capacities and passenger facilities can be adopted without changing the basic safety principles in the design.

These qualities are maintained for the DESSO ROPAX ship.

Safety features

The EuRoPax 3000 is high performing for a wide range of damage cases when it comes to “upright and afloat” properties.

The spatial arrangements below the freeboard deck of the EuRoPax 3000 has the engine compartments located outside of the B/5 longitudinal bulkheads.

With this is achieved:
- Simple solutions for fulfillment of the today rules for floatability after a damage.
- Uncomplicated arrangement for symmetrical flooding for increased safety in case of a damage.
- Symmetrical flooding means small heeling angles which is a requirement for safe evacuation.
- A very good utilisation of the lower hold including the qualities of straight lanes and straight access.

The EuRoPax 3000 is also provided with closed side casings from the freeboard deck and up to the passenger accommodation. This does not receive any bonus from the present rule point of view but does give a certain safety in case of a rip-up and minor structural damages.

Commercial features

Cargo areas are designed with straight lanes and with possibilities to arrange straight entrances to the lanes. With such an arrangement the following is achieved:
- Fast and safe cargo handling.
- Possibilities for automatic or semi-automatic securing of the cargo.
- Acceptance of pillars on the decks which in turn gives a lighter deck structure and also form an efficient mitigate in case of a solid cargo shift.

The "outside B/5" arrangement of the engine rooms facilitates a very good utilisation of the lower hold.

The EuRoPax 3000 concept has flexibility to arrange for the major ways to handle rolling cargo and to arrange for the passengers:
- In/out on one or more levels.
- Through driving on one or more levels (including the lower hold).
- Combination thereof including turn driving.
- Pax areas have full flexibility to be adopted to the trade requirements.

### Particulars

<table>
<thead>
<tr>
<th>Particulars</th>
<th>EuRoPax 3000</th>
<th>DESSO ROPAX</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Dimensions</strong></td>
<td></td>
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</tr>
<tr>
<td>LOA</td>
<td>185.5 m</td>
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<td>LBP</td>
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<td>Depth to dk 1</td>
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<td>85% MCR</td>
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