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Safety of Roll-on Roll-off vessels

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SAFETY OF ROLL-ON ROLL-OFF VESSELS

by

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The contents of this paper reflect my personal views and are not necessarily endorsed by the World Maritime University.

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ABSTRACT.

The design concept of ro-ro ship has come under considerable criticisms after a series of accidents and subsequent loss of lives.

This thesis studies the design concept of ro-ro which makes it different from traditional, subdivided vessels.

It is felt, that to be able to put ro-ro safety into perspective, particular attention should be given to elements that affect safety of shipping in general.

Casualty statistics are studied, in order to prove if the level of risk of accident is higher for ro-ro than traditional ships. The thesis also hope to show if ro-ros are more likely to capsize after events involving, collision, cargo shift or foundering.

Having identified the various hazards of ro-ro, some changes to the concept are put forward which may improve its safety. Improvement in operation procedures, shore management and training is also suggested.

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CHAPTER I

INTRODUCTION.

The modern roll-on-roll-off ship can trace it's origin back to more than one hundred years when ships were specially designed to carry trains across rivers which were too wide for bridges. It was not until the fifties that the first exclusive ro-ro ships were brought into service and ever since the fleet has been steadily expanding. These vessels are true multipurpose ships which can carry a large variety of cargoes on large open deck. There is no obstruction on the deck and if one were to stand aft, one could see right through the ship up to the collision bulkhead forward but if the bow doors were open one could see right through the ship. The aim of this design is to achieve minimum loss of cubic space and fast and efficient loading/discharging. Basically, ro-ros are intended to provide a prompt and efficient service with a rapid turn-around in port. It is for this reason that the concept has been so popular especially on short sea routes.

Although ro-ros have proved commercially very successful, some concern has been expressed about ro-ro ships from the safety point of view. Accidents to vessels such as Zenobia, Herald Of Free Enterprise and Vinca Gorthon do not help in promoting confidence in the concept. The whole design concept is different from that of traditional ships because of the introduction of elements which make ro-ro ships unique:-

1. Lack of transverse bulkheads,
2. Large cargo access doors,
3. Stability,
4. Low free board,
5. Cargo lashing and storage.

These elements of the concept have been targeted for criticism as far as safety of ro-ros is concerned. The lack of transverse bulkheads on the main deck, has been the main problem area. If any considerable amount of water should flood the deck or cargo should break loose it could lead to loss of stability and capsizing of the vessel.

For all its shortcomings the ro-ro concept is still a viable one but because of the design differences from traditional subdivided cargo ship, the vessel should be operated and handled differently.

It is recognised that the design factor of safety of ro-ros is considerable less than the traditional ship design. However even with this superior design safety factor, there has not been any decrease in the number of casualties involving traditional cargo ship. Therefore when we talk about safety we should not put all our emphasis on the design aspect but look further into shipping operation.

The problem of ro-ro safety is a manifestation of the state of safety of shipping as a whole. For a complete understanding of the ro-ro safety problem we have to identify the factors and actors involved in shipping and then see whether improvement is necessary.

These factors and actors are:-

- Ship design, ship management and operation,
- National administrations, classification societies, shipowners and crew.

CHAPTER II

SHIP SAFETY.

2.1 General.

The whole object of safety is accident prevention -if one can prevent accidents then one decreases the risk of loss of life, damage to the maritime environment and a saving in cost as a consequence of such accident. Shippers also expect their cargo to arrive safely at its' port of destination and should there be no interruption in the line of transport then they also make a saving in cost. In its wider sense maritime safety can be interpreted as a concept that enables the crews of ships to carry cargoes as required in a safe, efficient manner so that the ships, cargo and crew arrive at their destination without incident or harm. Safety and efficiency is thus an intergral part of good management, operation and design. The ship designers and equipment manufacturers have the responsibility of designing a structure that has enough safety margin, robust enough to withstand the force of the marine environment. In operation the structure and equipment should also be capable of withstanding slight misuse by the operator without leading to casualty to either equipment and structure or personnel using it. The term marine safety is all too often only associated with the structure and equipment, the human element, the competence of the personnel is forgotten.

Investigations into the causes of accidents have indicated that as much as 80% of the causes may be traceable to human performance. This shows that the proficiency of ship personnel, either through adequate training and experience is of vital importance in maintaining ship safety. The cycle of marine safety does not stop with the ship designers and the onboard ship operators, it continues with the shore management. The shipowners have the responsibility of ensuring that its ships are built to a required safety standard and, manned by competent and experienced crews. Classification societies and maritime administrations have the responsibility of laying down rules and regulations to regulate shipping and at the same time they have to make sure that the rules and regulations are adhered to.

2.2 National Maritime Administration.

The organisation and procedures of maritime administration are different in various countries reflecting the particular constitutional, political, cultural and other social leaning of each country. The aim however should be the same from country to country and that is to regulate the use of the sea making it as safe as possible, both for the users and the environment. The administrations, in consultation and through the UN International Maritime Organization, should set and implement effective standards. These standards should include regulations for ship construction, training and certification of seafarers and regulations for ship operations. There is not, at the moment, many administrations that put much emphasis on how the ship is managed ashore. With so much of it's field work now being delegated to classification societies the responsibility of the government supervisor for technical safety now more often than not involves random inspection of ships in the home ports. The poor economic conditions in shipping have compelled shipowners to reflag their vessels from the national to open registry flag. The effect of this is that many governments have sought to reduce the size of their administrations and evidence have shown that many of these administrations are modifying their control to meet economic pressures rather than acting to achieve balanced management of safety and risks. The term "to the satisfaction of the administration" found in many of IMO's regulation has had varied interpretation by shipowners through their administration, in an attempt to operate their ships with reduced safety standard in an attempt to lower their operating cost. This is a false economy. The cost of safety can increase the operating cost however the cost of an accident is a lot more. One cannot surely say with total conviction that shipowners do have such power over the administration for there are no arrangements laid down in most countries to challenge the work of the administration. An exception, was the case of Herald Of Free Enterprise accident; because of the loss of lives of so many passengers, public attention and through subsequent investigation showed that there was inconsistency in the administration as well as operator incompetence. A maritime administration should be in a position to guarantee the effective enforcement of treaty standards on ship flying its flag and provide essential navigation service for all ships using its waters. The responsible government should ensure that the administration have the required resource and support to carry out its duties effectively.

2.3 Classification Societies.

Shipping is an industry which is older than a lot of existing industries. Marine Insurance had existed back in Roman times (CATO). General Average is the Oldest Legal principle in the world (the Book of Jonas) and the modern concept of insurance are based largely on marine insurance.

Classification societies have been dealing with ship safety for more than 200 years. It began with the interest of the insurers to make sure that the ship and cargo reached their destination with no accidents. The class societies,insurers were then, not concerned with safety of life at sea since Life Saving Appliçance and Communication was not included in its field of activities. In the last two decades there has been a rapid development in the field of maritime conventions. These conventionsare transformed into laws, regulations and interpretations by National Administration. The administration can authorise class societies to implement some of these laws and regulations. Most administrations delegate some survey functions: Load line, safety construction and marine pollution surveys are often delegated. Safety equipment and safety radio are usually done by officers of the administration. Though the work is delegated to class society the responsibility to guarantee adherence to standards rests with the administrations, and therefore when there is delegation it is important that there are clearly defined roles and obligations of each party. The disclaimer of liability by class society is in the author's opinion inconsistent with national statutory work and should be removed or varied when dealing with such work. There also the bad economic situation of shipping has affected the work.

It has been alleged that the societies have tailored their work to see off competetion and some class societies surveyors have been liberal in the conduct of their duties. However it should be said that international societies have undoubted technical expertise and perform relatively well on behalf of the National Administration.

2.4 Shipowners Obligation.

Shipping being the old industry as it is has developed its own tradition and laws. Modern management procedures was introduced late in shipping in comparison to other industries. The vast majority of ships plying the seas today are owned by single ship company and this doesn't lend itself to modern management procedures let alone safety management, as in most cases these owners will say they are busy trying to make ends meet. There is widespread agreement that ship operators are not affected by pressure of public perception which apply in aviation industry except in rare cases when an accident occurs, as with the Herald of Free Enterprise. Whether there should be the same system of regulation applied to the maritime industry as to the aviation industry - this seems very unlikely, whereby the aircraft industry is made up of a small number of large operators and manufacturers, the maritime industry involves large number of small one ship companies. If this change should happen, it should come about out of the intervention of the state. Self regulation should be the best way to bring safety in merchant shipping. At the moment the industry's support structure is not organised internationally in a manner which readily lends itself to self regulation and audit by administrations.

This situation in fact could change in the near future with the creation by IMO of the World Maritime University where administrators from all over the world are now being trained in various maritime (shipping) fields. The aim of which is to produce a corp of expertise located around the world (mostly in the Third World) which will be able of bringing into full effect, the international conventions concerning the safety of life at sea and the prevention of pollution of the marine environment adopted by National Maritime Administration throughout the world. The intention is good but it remains to be seen if their respective governments will be willing to use these well trained administrators for the intended purpose, when one realises that many of the supposed substandard operators who will be regulated belong to some of those governments.

On the other hand some notable ro-ro sinking since the concept was introduced have been ships, which were supposedly -well-built, owned by responsible operators and flagged under administration of longstanding maritime tradition. This leads us back to the question of whether the shipowners do bring undue pressure on the administration with the aim of reducing safety standard in an attempt to reduce operational cost.

Any proposals aimed at improving operation responsibility need to be realistic and possible to implement in conjuction with existing institution and must recognise the economic reality.

2.5 Importance and Complexity of Safety of Ships.

The dangers, and consequences of an accident in shipping are more emminent today as in previous time. Over the past 25 years there have been quite substantial change in shipping and shipbuilding. There has been a considerable increase in size of ship as well as change in trading pattern. This change is very notable in the ro-ro passenger ferry trade of Northern Europe. These passenger ro-ro ferries can be of length of more than 160m and carry more than 300 passengers. On such ships with the length superstructures towering skywards, the height of the top deck from sea-level could be as much as 25m.

In the former times the consequences of ship casualty will have been a loss of cargo, ship and crew only, except in certain exceptional instances such as the case of Titanic where passengers lost their lives. Today the effect of a casualty is more far reaching. There is the risk today of greater amount of loss of life as well as damage to the marine environment and its ecosystem. Casualty to tankers which are today carrying large amount of crude oil, can pollute the coastal regions, and affect the fisheries and recreational potential of those regions.

The increase in speed of today's larger ships has made manoeuvring them more difficult. This is a danger facing the master of today's passenger ro-ro ferry, who has a tight schedule to keep and who is at most time sailing his vessel across congested channel and in harbours at high speed.

Cargo types have also changed. Many of the cargoes being carried today pose an enormous danger to the ship and environment.

Casualties to ships have been with us ever since shipping has been in existence and unfortunately the various kinds of casualties have not decreased in the years despite technical developments. It doesn't seem likely that there is a decrease in sight.

2.6 Principles of Regulation for Safety.

Marine regulations whether national or international are formulated to cover a group of ships rather than an individual ship. If they were to be of the latter type latter there may be cries of unfair discrimination for certain ship types. The ideal regulation should assist in the creation of a ship that will be able to be operated economically, survive most of the rigours of the sea and allow persons on board to survive in case of any accident. The regulations should as far as possible try to work against the dangers acting against the safe operation of the ships.These dangers can be listed as:-

2.6.1 Collision Avoidance.

The requirements for the avoidance of collisions with other ships or structures in the sea or harbours is a basic one. To achieve this requirements the vessel should have good manoeuverability in all traffic situation and good, reliable navigational equipment.

2.6.2 Ensuring of Buoyancy and Stability.

Wind, waves and current are environmental forces which when acting on a vessel will tend to reduce its stability and buoyancy.

- The ship shall be able to withstand these forces acting against its transverse stability.

- The buoyancy of a ship shall be preserved in all service conditions. For this the watertightness and weathertightness of openings and hatchways shall be ensured.
- It should be ensured that shifting of cargoes does not occur and if it occurs the vessel should have enough reserve buoyancy to stay afloat.
- The ship should be able to suffer a limited amount of damage and still stay afloat.
- The strength of the hull should be of a sufficient high standard to withstand the forces of the environment.

2.6.3 Ensuring of Propulsion and Manoeuvrability.

The functioning of the propulsion plant and steering gear should ensure the above at all times even under conditions of reduced operation. If this should not be available it will lead to drifting of ship in seaway or stranding.

2.6.4 Fire and Explosion Prevention and Fire Fighting.

Extensive means of prevention of the above should be ensured by the regulation and if fire should breakout means have to be provided for fighting it.

2.6.5 Prevention of Pollution of Marine Environment.

The consequence of polluting the marine environment by ships should be recognised when formulating the regulation and means should be provided for reducing chance of occurence.

The above five items deal mostly with the operation of the ship however, if the ship should sustain the accidents and a total loss occurs the crew or passengers should be protected.

2.6.6 Rescue of Persons.

Life saving appliances of sufficient capacity for every person on board are to be provided. These appliances shall be placed in a position where they can easily be transfered from the vessel to the sea and should be undamaged when they reach the sea.

2.6.7 Detection and Rescue of Survivors.

The stepping over of persons from ship to the life saving appliances is not the successful end of the rescue. It is then necessary that the survivors are detected and are taken over by other ships and aircrafts.

The many requirements (SOLAS, MARPOL, LOADLINE, SAR) in international conventions try to achieve the above. In fact a regulation can seldom achieve totally these criteria although it may be partially effective in some areas.

CHAPTER III

SAFETY OF RO-RO VESSELS.

3.1 Introduction.

The design and operation of ro-ro (Roll on-Roll off) vessels have been a source of concern for some years now. Losses of vessels such as Herald Of Free Enterprise and Vinca Gorthon combined to attract public attention. These vessels have special design features which are not found in other ship types. Such as large single open deck, cargo access doors through the shell plating and low freeboard.

In April 1988, the Council of the Royal Institution of Naval Architects took the decision to establish an ad hoc committee to record its opinion on the question of passenger ro-ro ship vulnerability in the event of a serious accident. The fact that only passenger ro-ro ships not cargo was considered here doesn't entail that cargo ro-ro ships are in any way of better design. Both types of vessels have the same design concept and they will both suffer the same consequence should they be involved in an accident, however in the case of passenger ship there would be more loss of life and it's rightly so that people in the industry should pay more attention to the safety of this type of ship first and foremost. As in the case of the airline travel and if the passenger ferry are to be able to compete with them, the ferry operators and everybody involved should be seen by their potential customers as trying to reach a safety level at par with other means of transport. We are not here going to discuss the safety of passenger ro-ro vessel only but cargo vessel safety as well.

The opinion of the Council were as follows:-

a) "Irrespective of statistics, a single accident to this type of vessel can lead to catastrophic loss of life and the risks of such a consequence is too high.

b) In the light of circumstances which now pertain it is considered that current designs of ro-ro passenger ships now in service, despite their full adherence to the law and regulations, are unacceptably vulnerable in that there is a likelihood of rapid capsize under certain conditions, particularly collision. Conventional ships give passengers and crew a reasonable chance of evacuation should such an emergency occur."

The problems affecting the vulnerability of these ships are dangers of flooding large areas of deck close to the waterline, high permeability in some compartments which would allow ingress of large amount of water, dangers of fire in vehicle spaces accomodation and engineroom and difficulty of evacuating passengers in the event of accident. For cargo ro-ro vessels though liable to rapid capsizing in the event of an accident, the problems of evacuating the crew is easier as they are trained professionals for such emergency.

3.2 Ro-Ro Concept.

3.2.1 Historical.

The commercial ro-ro ships can be said to have had their beginning in the thirties, however, the rapid growth of ro-ro fleet occurred in the seventies and continues today. These horizontal loading ships accept their cargo on wheeled vehicles via openings in the bow or stern. Apart from train ferries the first purpose built deep-sea ro-ro ship was the USNS Commet which was built in 1958, for the United States Military Sea Transportation Service, to carry military vehicles across the Atlantic with as quick a turnround as possible. Flexibility and fast port turnrounds are the essential features of ro-ro operation with high cargo handling speeds. In the 1970's there was a high demand for a means to avoid congestion in ports where cargo is handled traditionally using cranes and derricks.

This intense activity in ro-ro growth created problems for designers, shipowners and classification societies.With this increase need for transport of wheeled cargoes a lot of shipowners converted traditional cargo vessels into ro-ro ships. Ships were transferred to trading areas, notable, North Sea and Middle East, which they were not designed for. However some ships were designed to suit the trade, but very little effort were made in the field of research into this new concept. The change in trading pattern were so fast that there were no time to do so and a lot of the old tried and tested methods for building traditional cargo ship were used.

3.2.2 Development.

Ro-ros are multipurpose vessels able to carry any manner of cargoes on huge open deck. The open deck is normally unobstructed from forward to aft only for trunking for passage way leading to engine casing and weather deck. My earliest recollection of ro-ro type ships, was the sort of riverboat one would see in western movies, whereby horse and carriages would be rolled on board such a small draught raft which would then be pulled by certain means across the river. Even when watching such an innocent smooth crossing one was filled with forboding that should there be the slightest movement of the load off the centre of gravity, there was a high risk that the craft would turn over and no doubt that many may have suffered such faith. In the 1920's and 1930's the Americans designed large car carrying ships with a capacity to carry about 700 cars. These vessels were loaded through doors via hoistable ramps built in the docks and they were used in the Great Lakes. In Europe it is the Scandinavians that figure heavily in the development of ro-ro ships. In 1955 Wallenius ordered it's first car carrier. These vessels (Rigoletto and Traviata) could load 300 cars in ro-ro operation plus 700 tons of coal. The first Scandinavian ocean going ro-ro ships was built by Atlantic Container Line.

ATLANTIC CONTAINER LINE.

These 16,000 dwt vessels combine a stern entry ro-ro capability with a lift on/lift off container capacity. The vessel could carry 569 TEU containers of which 326 are stored on the upper and the lower deck, containers are loaded through four watertight flush fitting hatch covers situated forward. Ro-Ro access to the 44000m^3 of storage

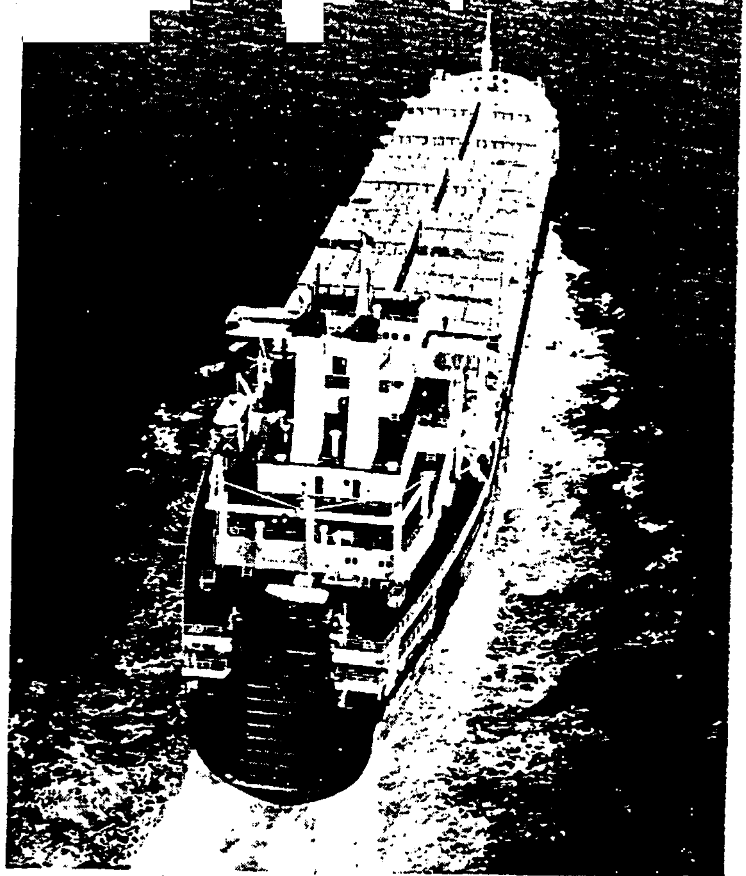


fig 3.1 . *Atlantic Span*

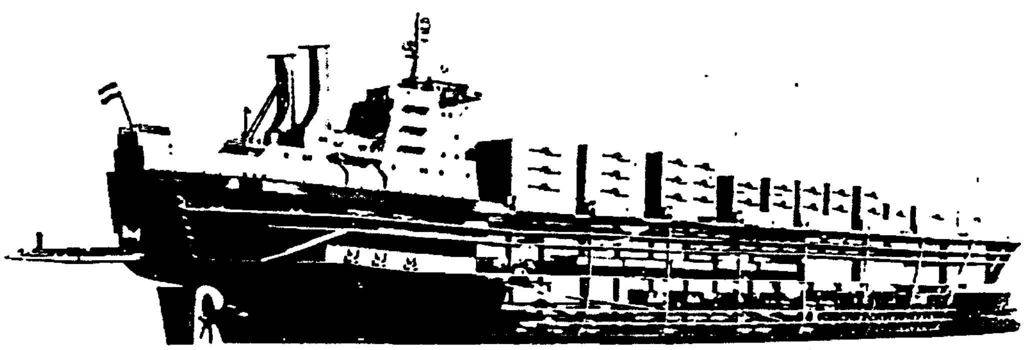


fig 3.2 - Cargo stowing arrangement on the ACL-ships

space is through the stern ramp and within the ship, hydraullically operated fixed ramps lead to various decks.

Rail Ferry.
The Scandinavians have built and operates a substantial number of rail ferries which link Scandinavia with various countries on the European continent.

Short Sea Ferries.
The design aspect of these types of ship are the bow and stern entry doors usually designed to carry cars and trailers on lower vehicle deck with passengers on upper deck. The biggest of these can be as large as 31.000 grt and usually accomodation decks are piled high on a short hull. However one vessel the Norsea has only four decks above the upper vehicle deck, with a length of 169.20m b.p and 25.08m breadth.

3.2.3 Configuration of Ro-Ro Cargo Ship.

A typical mid section of a deep sea ro-ro vessel is shown in the figure (see next page). The below deck space is used for carrying cargoes on trailers, wheeled vehicle and others are wheeled into position by forklifts internal ramps lead from loading deck to other tween deck. One can say that ro-ro ships are shelter deckers, however most of these types of ships are not fitted with transverse bulkheads on these vast open decks. The upper deck which is flush and without hatches except from the forward part are used for carrying containers. Other design may have deck hatches and so possesses the ability to operate as a traditional cargo ship

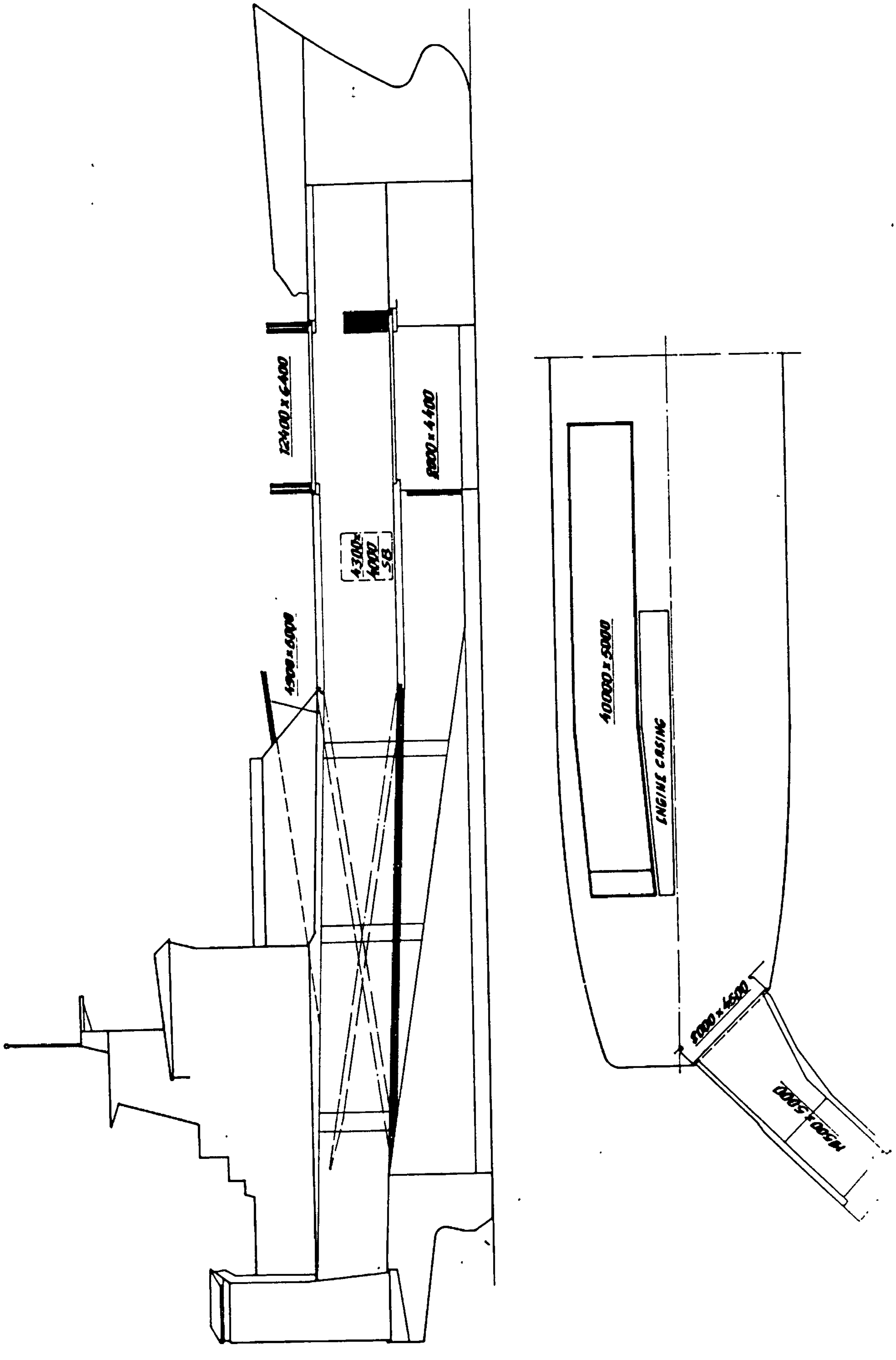


Fig. 3.4

and still possess the ability for carrying rolling stocks. For control of the GM, fuel is usually carried in lower double bottom tanks.

3.2.4 Ferry Design.

A typical crossection of a ferry design is shown in the figure (see next page). The section shows nine different deck levels from the tank top. The calculation for the distribution of masses and vertical centre of gravity is also given.

Recent developments show that the passenger/cargo ferry requires more facilities and space for passsengers plus extra cargo space for trailers. To accomodate for such change the decks have become more parallel and the underwater hull form has become fuller with an increase in block coefficient.

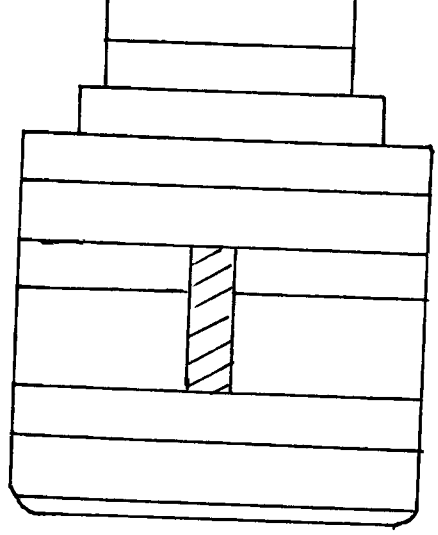


Fig. 3.5 Cross section of Ferry design.

Item	Mass (tonne)	VCG(metre)	VCGm(t-m)
Steel	5212	13.37	69688
Outfit	2600	17.0	44200
Machinery	1100	4.5	4500
Fuel	800	4.2	3260
Lub Oil	50	4.2	420
F. Water	200	4.2	840
Pas & Water	150	18.0	2700
Stores	300	6.0	1800
Life Boats	270	26.0	7020
Cargo (d.4)	200	14.3	2900
Cargo (d.3)	2100	10.5	22050
Margin	114	14	1704
	13096	12.3	161085

VCB = 3.30m
BM = 10.50
GM = 1.50

VCG - Vertical Centre of Gravity
VCB - Vertical Centre of Buoyance
BM - The Metacenter Height from Centre of Buoyance
GM - Metacentric Height.

Table 3.1 Source (OSMAN TURAN MSC THESIS)

CHAPTER IV

RO-RO CASUALTY STATISTICS.

4.1 Casualty Types.

The different types and their definition as per "Lloyds Register Casualty Statistic" are given below.

1. Collision.
Striking another ship, regardless of whether underway, anchored or moored. This category does not include striking underwater wrecks.

2. Grounding.
Vessel touching sea bottom, underwater wrecks etc.

3. Fire and Explosion.
Where the fire and/or explosion is the first incident reported.
Note: It therefore follows that casualties involving fires and/or explosions after collisions, stranding, etc. would be categorised under "collision" stranding. Scavenge fires will be included in fire and explosion.

4. Foundered.
Includes ships which sank as a result of heavy weather, springing of leaks, breaking in two, capsizing etc. and not as a consequence of 1 & 2.

5. Machinery Damage.
Ships lost or damaged as a result of machinery, shaft, rudder, propeller failure.

6. Contact.

Striking an external substance but not another ship or the sea bottom. This includes striking with pier, offshore structure.

7. Missing.

After a reasonable period of time, no news having been received of a ship and its fate being therefore undetermined, the ship is posted as missing at Lloyd's and is included in the missing category.

8. Shift of Cargoes.

All types of casualties involving shift of cargoes, usually not alone.

4.2 Casualty Categories.

The casualty can be divided into 3 categories.

1. all casualties (non serious and serious),
2. serious,
3. total loss.

Serious.

Is a casualty to a ship which result in

a) structural damage which renders the ship unseaworthy, such as penetration of hull underwater, immobilisation of main engines, extensive damage etc.,

b) breakdown necessitating towage or shore assistance,

c) actual total loss.

Non-serious.

Any incident occuring to a propelled seagoing merchant ship of 100 tons gross and above in which the condition of the ship suffers adversely.

Total Loss.

Refers to a merchant ship which as a direct result of being a marine casualty, has ceased to exist, either by virtue of the fact that the ship is irrecoverable or has subsequently been broken up.

Ships which have been declared constructive total losses but which are undergoing or have undergone repairs during the year are not included.

4.3 Casualty Statistics.

This includes all types of ro-ro from January 1970 to 1980.

All casualties	Number
Non-serious-serious	243
Serious	161
Total losses	28

Ship year distribution
All types of Roll-on Roll-off ships, oil tankers and world fleet.

	ship years total
All types Ro-Ro	11154
Oil tanker	38052
World fleet	320088

TOTAL LOSSES

Casualty Types	No	lives lost
Foundered	2	
Collision	7	4+2+4+26
Grounding	1	
Contact	1	
Machinery damage	0	
Fire and Explosion	5	1
Shift of Cargo	4	6
Operational	8	
TOTAL	28	43

Table 4.1
Total losses in the Ro-Ro fleet 1.1. 1965 - 28.2. 1981
Source - Veritas casualty data
LR casualty statistics.

ALL CASUALTIES

Casualty type	%
Collision	28
Machinery damage	18
Grounding	14
Cargo shift and operational	12
Fire and explosion	10
Contact	10
Other	8

Table 4.2
Total losses

Casualty type	%
Shift of cargo and operational	43
Collision	25
Fire and explosion	18
Other	14

Table 4.3
Casualty type distribution (1970-1980)
Source - Veritas casualty data base LR casualty statisics.

The table shows an analysis of the categories of serious, total losses and a breakdown of the number of accident due to casualty type for the year 1965 to 1981. The percentage distribution per casualty type is given. It is seen that for the year of 1965 to 1981 collision was the greatest hazard to ro-ro ships with a total of 7 ships lost with the consequent loss of lives of 36 persons. The appendix 3 gives a summary record of world wide serious ship casualties for the period of 1978 to 1987. It can be seen from the table that approximately 28% of the ro-ro casualties are due to collision, which may collectively be called "errors of navigation". The risk of collision is surprisingly not much higher for ferries or cargo ro-ro ships. A lot of these ships spend a large proportion of their time, in crowded port approaches, and congested shipping lanes. In the case of the car ferries they are also obliged to travel at high speeds even when entering port approaches and in poor visibility in order to keep to their schedules. They are usually fitted with a high amount of modern navigational aids and manned by highly trained crews, however many collisions have occurred due to sheer negligence and complacency or over confidence in certain situation. The report of the investigation into the case of MV European Gateway and MV Speedlink Vanguard states exactly this. "It is our belief that this collision occurred because of a degree of over complacency on the bridge of both vessels in the performance of what may have appeared routine and unexacting navigation."

It is seen from this case that as with all matters of safety, the most important factor is the human element, the calibre of shipboard officers, their training and experience, their standing orders and operational practices.

The second highest risk of hazard are machinery damage (ref submission to IMO by Norway) and grounding. Next Comes casualty due to shift of cargoes and operational errors. The casualty rate due to fire and explosion is 14%.

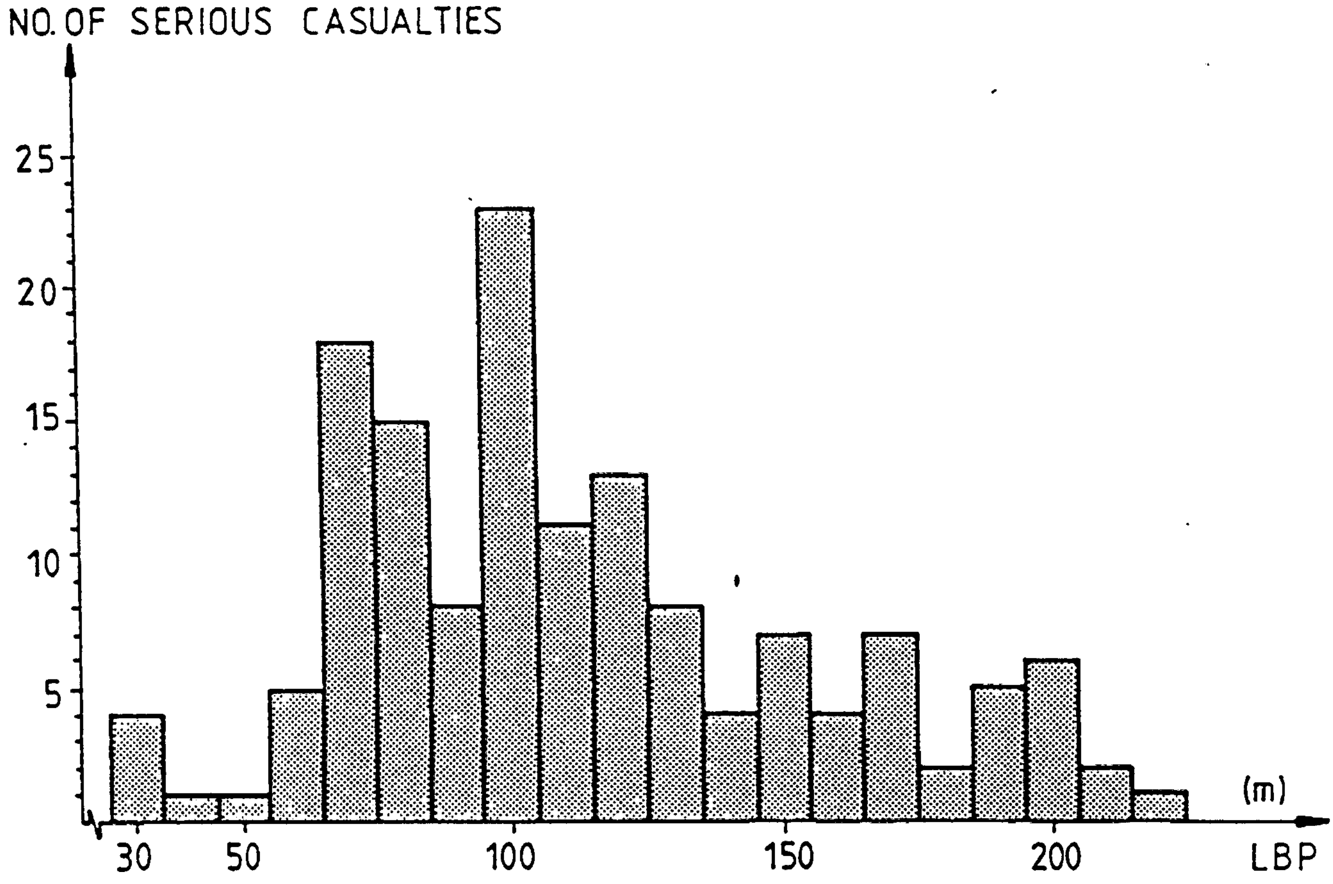
It should be noted here that when the percentage of total losses according to casualty type is computed. It shows that 25% of the ro-ro ships will be a total loss if involved in an accident, 28% due to shift of cargoes and operational errors and 18% due to fire and explosion.

A study carried out by DNV showed that total losses as a result of a collision are much higher for ro-ros than for other ships. Collisions and uncontrolled shift of cargoes account for more than 56% of total losses.

It is also shown that 70% of ro-ro ship declared total losses due to collision involves loss of lives and 60% of those ships is reported to have sunk within ten minutes of the collision. There is also a correlation between total losses and size of ship nearly all total losses involve ships of less than 110 m.

It is felt here that since the passenger ro-ro ship has been so much under scrutiny lately, we should look at this type of ship's casualty statistic in isolation from the rest of ro-ro type. (Appendix II).

55% of all serious casualties fall under the categories of collisions, groundings and contact. The next most frequently occuring casualty is fire with 14% occurrence of which 81% of those started in the


NO. OF SERIOUS CASUALTIES
25
20
15
10
5
30
50
100
150
200
(m)
LBP

engine room. The probable cause will be oil dripping onto hot surfaces from cracked pipes or full drip trays. These are only the reported occurences however the fires that broke out and were promptly extinguished by the deligient crew are not reported. It is right to mention here that the problem of existences of dirty oil in the engine room drip trays and on the surface of equipment is directly due to under manning. The author was able to witness an occassion involving a vessel which was manned by very highly trained, competent and experienced engine room crew, and fitted with the most up to date equipment in the engine room. However because of economic constraint, the vessel was being operated with only two engineers and with no engine room ratings. It was observed on such occassions that those engineers had no time to carry out any cleaning duties. Because of the fact that the manning level was low and the ship was almost at all time entering or leaving ports, these engineers had to be on standby for a large proportion of the time, and when the ship was at sea they were busy mostly with the work that directly affects the operation of the ship, so they could not find time to carry out the cleaning. It was not that the engineers were not aware of the dangers they were putting the passenger, the ship and themselves into. It was just impossible for them to find time.

4.4 Ro-Ro Safety in Perspective.

It is important to keep the figures in perspective. It can be seen from the figures that risk of ro-ro vessel is comparable to other type of ships. From the period of 1978 - 1987 the loss rate for all types of ships is given below.

Ship types	Losses and casualty per ship year at risk.
Ro-Ro passenger	0.0218
Ro-Ro cargo	0.039
General dry cargo	0.035
Non ro-ro passenger	0.0211
Tankers	0.0177

The point we have to keep in mind is that ro-ro ship is not involved in casualty more often than any other ship type but if it is involved in a casualty the ship is more likely to sink very fast with a high loss of lives, as in the case of the Herald Of Free Enterprise. And one other point is that the ro-ro freight vessels are more at risk than the passenger ro-ros. For example there has only been three ro-ro passenger ferry disaster in the U.K. waters, however the average number of lives lost per accident is 107; an average of 41% of the people on board over this period this is a total of 9 deaths per year, 7 passengers and 2 crew members.

Individual Passenger Risks in U.K. Waters.
There is today 28 million passengers travelling to and from U.K. each year.

Therefore for a typical passenger making one return trip per year, the risk is;

$2 \times 7 \div 28{,}000{,}000 = 5 \times 10^{-7}$ risk per year
i.e. a 1 in 2 million chance of death each year.

Now let us compare this to normal risk of daily lives. It is shown that for a traveller making two crossing a year the risk is very low compared to other hazard.

Cause of death	Risk per year
Smoking	1 in 200
Natural causes (40 yrs)	1 in 850
All accidents	1 in 3300
Accidents at home	1 in 9000
Accidents on the road	1 in 10000
Accidents at work	1 in 44000
Fire	1 in 67000
Homicide	1 in 1000000
Railway	1 in 5000000
Ferry travel (2 crossings/year)	1 in 2000000
Struck by lightning	1 in 10 m

On average the ferry passenger will spend 3.5 hrs on a crossing, that is 7 hours per year. Comparing with other types of transport it can be seen that only train and buses are safer than ferry per hours of time.

Hours spent at sea 3.5 x 28 = 98
Accident rate per hours spent travelling for ferries is:-
7 deaths per year/100m hours spent at sea = 7 deaths/100m hours.

Means of Transport	Deaths per 100 million hours
Motorcycle	660
Aircraft	240
Bicycle	96
Car	57
Ferry	7
Train	5
Bus	3

Here however if we should compare risk per kilometre travel it will be found that travelling by commercial aircraft is less risky than by ferry.

Individual Crew Risk.

Assuming that a crew makes about 400 crossings a year and the total amount of crossings per year for all crew is 5 million.

∴ 400 x 2 deaths per year   5m crossings per year
= 1 in 6000 chance of death per year.

This is an alarmingly high level of risk but when compared to other occupational modes it is seen that many tolerate such high level.

Occupation (Industries)	Risk per year
Clothing	1 in 200000
Vehicles	1 in 7000
Chemical industry	1 in 12000
Ship building	1 in 10000
Construction	1 in 7000
Railway staff	1 in 6000
Ferry crew (accident to vessel)	1 in 6000

CHAPTER V

INTERNATIONAL CONVENTIONS.

5.1 Ro-Ro and Load Line Convention.

The freeboard of a ship is an essential safety feature in providing reserve displacement and in minimising water coming on deck and contributing to the stability of a ship.

The 1966 IMO International Conference on Load Line uses the following criteria as a basis for assessing freeboard.

1. The prevention of entry of water through the exposed parts of a vessel.
2. Probability of deck wetness in relation to bow height.
3. The maintenance of sufficient reserve buoyancy in normal conditions of service.
4. Protection of the crew when moving on deck.
5. Adequate structural strength of the hull.

A notable omission here is that subdivision and stability is not a criterium used when assessing the freeboard, this is undertaken by the SOLAS convention, but many administrations specify that lack of adequate stability will affect the validity of any load line certificate which may have been issued.

According to the conventions cargo ships are divided into two types (Reg. 27).

- Type 'A' are those designed to carry liquid cargoes in bulk with small access openings to the hold.
- Type 'B' ships (roll-on/roll-off ships counting as a type B ships) are usually dry cargo vessel with large openings in the hull for cargo access.

Length for the freeboard for type 'A' ships is lower than that for type 'B' ships as type'A'ships have "high integrity of exposed deck and high degree of safety against flooding, resulting from the low permeability of loaded cargo spaces and the degree of subdivision usually provided".

The process of computing freeboard is as follows one first obtains the tabular freeboard from the table and then carry out the following corrections.

- Increase freeboard for hatch cover corrections if hatches are portable.
- Increase freeboard for ship of length less than 100m with 75% superstructure.
- Increase freeboard for - block coefficient correction, depth correction, Deck line correction.

Decrease freeboard for superstructure and sheer correction. (Reg. 27, 29, 30, 31, 32, 37, 38 and 39).

Freeboard deck is defined "as the upper most complete exposed deck to weather and sea, which has permanent means of openings of all parts thereof, and below which all openings in the sides of the ship are fitted with permanent means of watertight closing".

There is however some relaxation in the rules whereby the owner, subject to approval before hand chose a lower deck as a freeboard deck, provided it is a complete and permanent deck, continuous in the fore and aft direction at least between the machinery space and the peak bulkheads and continuous athwartships. The advantages of designing a lower deck as the freeboard deck are that the part of the hull which extends above the freeboard deck can be treated as a superstructure so far as the application of the conditions of assignment. The benefit to the owner here is that he can have the position of hatchways, doorways and ventilators in position 2 rather than position 1 (Reg. 13).

We should here make some comment on the load line convention as it concerns the ro-ro ship. The conference took the traditional cargo ship as its datum for the regulation and didn't consider the ro-ro ship. A traditional cargo ship usually are of single deck or tween deck with the highest deck above waterline as freeboard deck. This deck was usually well protected from the environment and because of the raised coaming and freeing port, not much water could accumulate on the deck. Cargoes were not carried on the freeboard deck but in well divided holds.

As for the ro-ro ships, were cargoes are rolled onto the freeboard deck, the coamings is completely ommitted. According to Reg. (16) this can be done.

Most ro-ros are of a shelter deck design with the deck above the freeboard deck acting as a superstructure and according to Reg. (12) doors could be fitted in bulkheads at exposed ends of superstructure. These doors are to be gasketed and secured weathertight by means of clamping devices or other equivalent arrangements, permanently attached to the bulkheads and to the doors themselves.

Ro-Ro ships have the need to have the cargo driven and stowed onto several decks. To achieve this those ships are usually fitted with internal access ramps and lifts between the decks which result in an increase in number of openings in the deck. Outer doors to these decks can sometime be below the freeboard deck. Regulation 21 says that cargo ports or similar openings fitted in the sides of a ship below the freeboard deck should be watertight and should not affect the structural integrity of shell. Administration have the authority to permit the fitting of partly immersed cargo ports or similar openings. If this should be done, it is considered that the fitting of a second door of equivalent strength and watertightness should be fitted inside and a leakage detection system should be provided within the compartment between the two doors. In addition, the space should be drained by a scupper pipe led to the bilges with a screw-down valve controlled from a readily accessible position on or above the freeboard deck.

The height of the superstructure of ro-ros has led to particular problems of embarkation for personnel and pilots especially when the ship is in light condition. In such case administration may approve and accept watertight doors in the sides of the ship below the loaded waterline. In this case the internal access to the doors should be from a position above the load waterline and contained within a watertight trunk of scantling equivalent to the hull scantling.

Some examples of problems:-

1. **Versatility design.**

The drawing shows the profile and plan of the standard vession of the 3.000 dwt vessel. (see next page)37

The freeboard deck is shown as D in the drawing. (see next page) The height of the sill of the cargo access door is very close to the freeboard deck.

As the deck is completely open and the access door weathertight without any bulkhead, should any leakage occur it would allow water onto the deck.

This is exactly what happened on a version of this type of ship, where water entered the stern door which leaked due to following seas and the ship capsized.

2. Reduction in freeboard for a ship with effective length of superstructure of 1.0

L = 122m

Tabular freeboard	1729mm
Deduction	1070mm
Freeboard	659mm

A ship with such a low freeboard will be at risk to ingress of water on deck.

5.2 Ro-Ro and SOLAS.

5.2.1 Subdivision and Damaged Stability.

When a Roll on-Roll off ship belongs to the passenger class, it is subjected to very strict legislation which calls for the provision of several watertight bulkheads below the bulkhead deck, on the other hand when the ship belongs to cargo ship class there is no such strict requirement. Under SOLAS a passenger ship is a ship which carries more than twelve passengers and a cargo ship is any ship which is not a passenger ship. (Reg. 11)

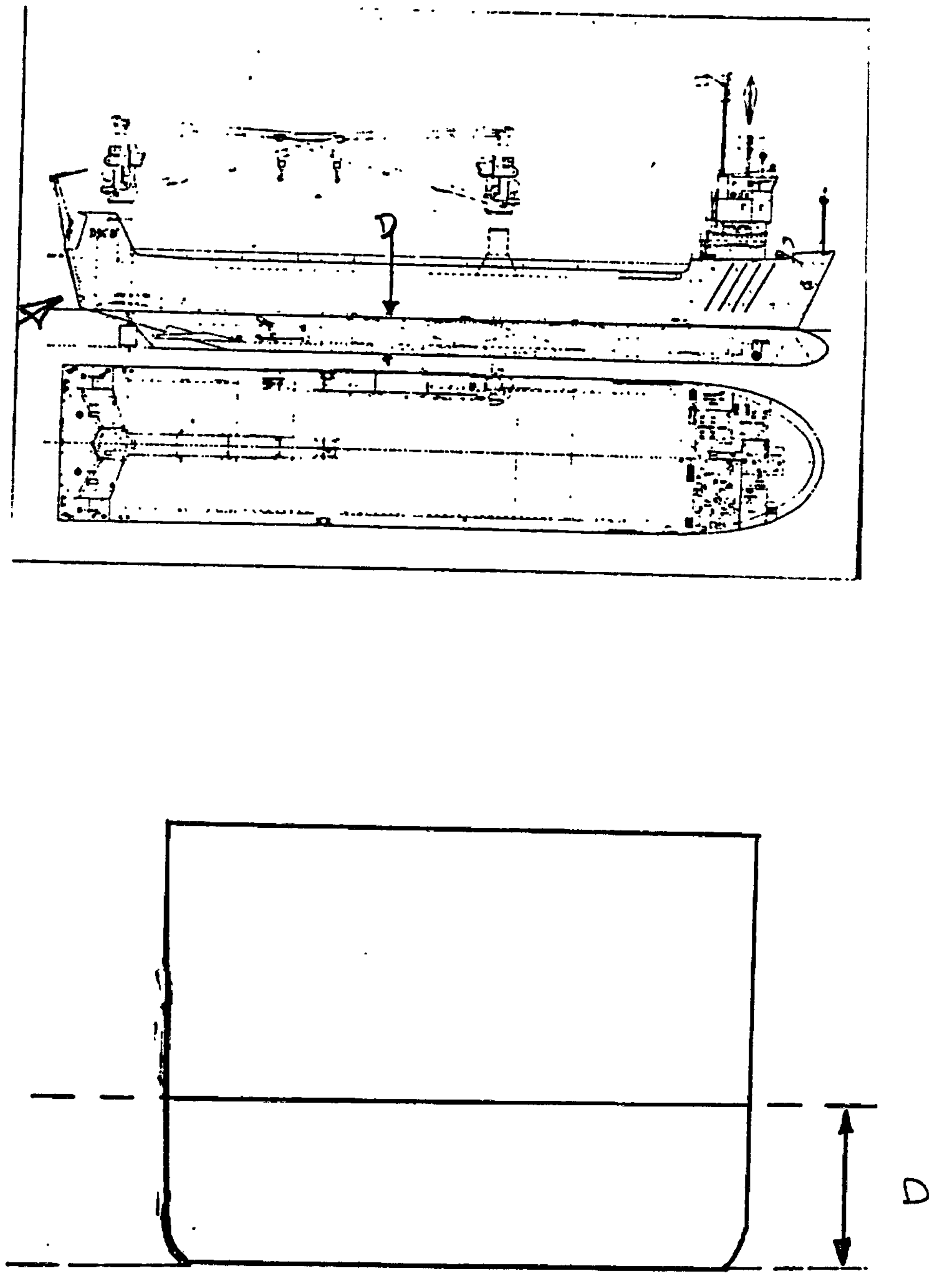


Fig. 5

According to SOLAS a cargo ship is not required to have more than:-

(a) Watertight collision bulkhead up to the freeboard deck which shall be located at a distance of not less than 5 per cent of the length of the ship or 10m from the forward perpendicular, whichever is less. And not more than 8 per cent from FP.
(b) Watertight bulkheads up to freeboard to be fitted for the separation of the passenger or cargo spaces from the machinery spaces.
(c) Watertight bulkheads separating the stern tube from the engine room.

This shows that under SOLAS the mandatory requirement for bulkheads in cargo ship carrying less than 12 passsengers is minimal. On traditional cargo ship due to requirement for strength in the hull, there are always non-mandatory bulkheads between holds. These bulkheads help with restricting of fire within a space and concentrating the use of extinguishers within that space. They also prevent movements of cargoes.

Over long distances should consignment break open, especially where liquids are concerned. Even if such goods are not classified as "dangerous goods" but due to their chemical composition such as in the case of greasy liquid. If it should spread over the deck of a ro-ro ship, this will prevent the crew movement and also reduce the grip between trailer tyres and deck.

In traditional cargo ship these bulkheads will help with the prevention of the spread of flooding in case of breaching of the hull and so reduce the size of the free surface. As mentioned under the load line convention, if a vessel of B-type and over 100m in length possesses a certain amount of subdivision below the freeboard deck this will allow for a reduction in freeboard. Ro-ro vessels don't usually have more bulkheads than required as this would impede the operation and some owners say that this would destroy the ro-ro concept. Ro-ro vessel already have very low freeboard, because of the use of the lower deck as the freeboard deck in the case of shelterdecker and if the ship had 1.0 superstructure the freeboard could be reduced a considerable amount.

The problem with cargo ro-ro vessel is that due to the lack of bulkheading, there is a very great risk of the spread of water through the hull in case of an accident which raises serious stability problems because of free liquid surface effects.

In the case of dry cargo vessels, damage stability regulations have been adopted only when reduced type B freeboard is required. As mentioned before there is up to now no requirement internationally or nationally for a dry cargo vessel to have any degree of subdvision. Since the damage stability calculation is not normally carried out the actual level of safety for ro-ro vessels is not known, and the level of subdivision safety actually in use will vary widely.

To try to tackle some of the problems caused by the lack of subdivision in cargo ro-ro ships, Det Norske Veritas is now working with a new voluntary "Survival Capability Class" (SC) based on a concept of assessing the ship's ability to survive after damage has taken place. This method does not specify the form the internal bulkheading should take, but lay down the end result of buoyancy and stability should damage occur.

i.e the ship's ability to survive after a damage by making use of damage statistics. The concept is the same as that introduced by IMO resolution A 265 which is an alternative to the damage stability requirements in the SOLAS convention 1960. These, resolutions though aimed at passenger ships could be used by other types of ships. Here there is a departure from the watertight subdivision. Whilst the watertight subdivision deals with the lower part of the ship with SC class concept it deals with the whole of the ship and there is no mention that the division should be watertight.

5.2.2 Intact Stability.

Stability of ro-ro ships is to be investigated according to IMO resolution A.206 VII. This lays down the intact stability conditions which should be met by merchant ships, passenger or cargo. The main object of these regulations is to prevent the ship from capsizing when operating in any type of sea conditions and being well operated by a competent crew.

The following are the intact stability conditions required under the British Merchant Shipping Act 1964:-

(a) The area under the GZ curve shall not be less than (i) 0.055 metre-radians up an angle of 30 degrees;

(ii) 0.09 metre-radians up to an angle of either 40 degrees or the angle at which the lower edges of any openings in the hull, superstructures or deck houses being openings which cannot be closed watertight, are immersed if that angle be less;

(iii) 0.03 metre radians between the angles of heel of 30 degrees and 40 degrees or such lesser angles as is referred to in (i).

(b) The righting lever GZ shall be at least 0.20 metres at an angle of heel equal to or greater than 30 degrees.

(c) The maximum righting lever GZ shall not occur at an angle of heel less than 30 degrees.

(d) The initial transverse metacentric height shall not be less than 0.15 metres.

There is mentioned the minimum acceptable GZ but, it is felt that as far as ro-ro ship is concerned there should be also a mention of the maximum GZ. This because the greater a ship's righting moment, the shorter it's rolling period ($TR = 2\pi \frac{k}{KgGM}$), hence the more drastic its acceleration, and this can act on the lashing of the stowed cargo. The designer has to find a compromise between an acceptable GZ curve and not a too high GM value to prevent too strong acceleration in rolling . (Fig. 5.1)

If the vessel should be designed with a high GM, stabilisers can be used to solve the problem of high acceleration.

The master of the vessel should be provided with the

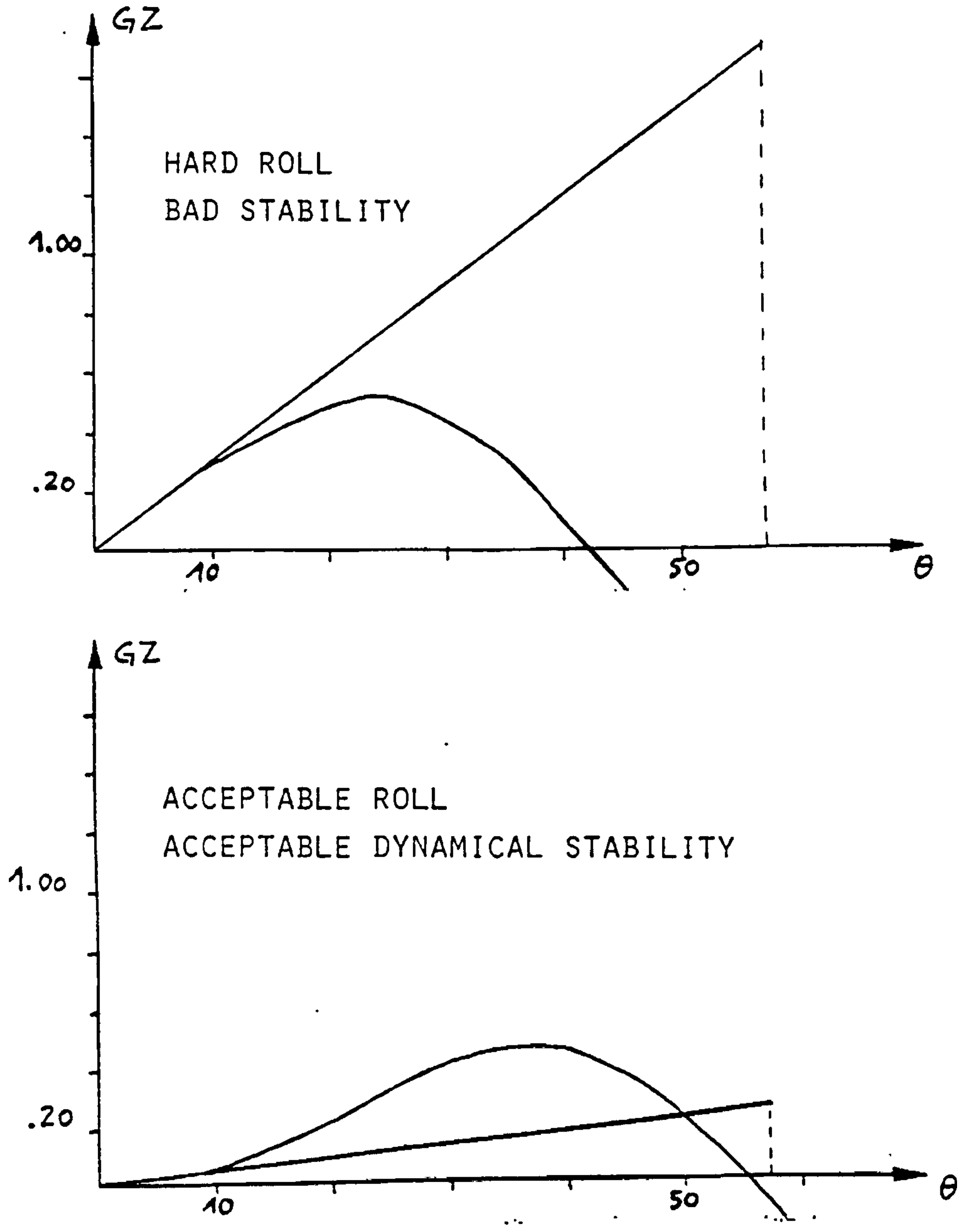


Figure 5.1 - Typical curves of GZ and GM level.

following information to enable him by rapid and simple processe to obtain accurate guidance as to the stability of the ship under varying conditions of service.

1. The ship's name, official number, port of registry, gross and register tonnages, principal dimensions, displacement, deadweight and draught to summer loadline.
2. A profile view and a plan view of the ship drawn to scale showing with their names all compartments, tanks, storerooms and crew and passenger accomodation spaces, and also showing the middle length position.
3. The capacity and the centre of gravity (longitudinally and vertically) of every compartment available for the carriage of cargo, fuel, stores, feed water, domestic water and ballast water.

In the case of vehicle ferry, the vertical centre of gravity of compartments for the carriage of vehicles shall be based on the estimated centres of gravity of the vehicles and not on the volumetric centres of the compartments.

4. The estimated total weight of:-
   (a) passengers and their effects and
   (b) crew and their effects and the centre of gravity (longitudinally and vertically) of each such total weight.
5. The estimated weight and the disposition and centre of gravity of the maximum amount of deck cargo which the ship may be expected to carry.
6. A diagram or scale showing the load line mark and load lines with particulars of the corresponding freeboards, and also showing displacement, metric

tons per centimetre immersion, deadweight and corresponding in each case a range of mean draughts extending between the waterline representing the deepest load line and waterline of the ship in light condition.

7. Hydrostatic particulars of the ship should include
   (i) extreme displacement in salt water at stated density,
   (ii) moment to change trim,
   (iii) transverse metacentric height,
   (iv) longitudinal metacentric height,
   (v) vertical centre of buoyancy,
   (vi) longitudinal centre of floatation,
   (vii) longitudinal centre of buoyancy.

8. Tables and curves showing the effect on stability of free surface in each tank in the ship in which liquids may be carried, including an example to show how the metacentric height is to be corrected. In the case of tanks containing liquids which may be consumed, discharged or transferred to and from other compartments whilst the ship is at sea, including antirolling tanks and/or healing tanks, the maximum free surface moments which may be developed should be given.

9. A diagram showing cross curves of stability indicating the height of the assumed axis from which the righting levers are measured and the trim which has been assumed. Where the buoyancy of a superstructure is to be taken into account in the calculation of stability information to be supplied in the case of a vehicle ferry having bow doors, ship's side doors or stern doors, there shall be included in the stability information a specific statement that such doors must be secured weather-tight before the ship proceeds to sea and that the cross curve of stability are based upon the assumption that such doors have been secured.

10. Maximum permissible draught at forward perpendicular necessary for bow height and the freeboard at stern respectively.
11. Pre calculated tables and/or diagram from which the master can determine if the stability of the ship is acceptable for a given loading condition under the governing stability criteria.
12. Conditions of loading appropriate to the operation of the ship should be included showing the practical limits of service for which the ship is intended and to demonstrate the stability characteristics in relation to the specified stability criteria. The conditions of loading are:-
    (i) Light Condition,
    (ii) Ballast Condition,
    (iii) Departure and Arrival.

Training Stability.

Attention has to be brought into training of seafarers to understand the importance they should attach to rolling period. Most navigators try to load cargo as low as possible, and to refuse to load anything high up in order to obtain a substantial stability mode without paying much attention to the reduction in rolling period.

The stability standard of ships was established a long time before introduction of the roll on-roll off concept with it's large open deck and it is very doubtful if a SOLAS convention held to-day would arrive at the same conclusion. It is recognised by everyone that these ships have a lack of residual stability in damage conditions however despite the relevance of a requirements to improve, it has so far proved impossible to obtain international agreement on enhancement of the standard. The passenger ro-ro vessels have by the existing criteria, some resistance against flooding and a certain level of survival capability in case of damage. On the other hand cargo ro-ro may be designed with little safety margin in case of damage.

5.2.3 Structural Fire Protection.

Fire and explosion is one of the main causes of total losses of vessels. Some of the worst ferry accidents have been due to fire, such as the loss of the Tampomas II with 580 lives in the Jave Sea in 1981.

One of the most effective ways of protecting a ship against fire is to divide it by means of fire resistant bulkheads.

So the purpose of SOLAS regulations vis a vis fire is to provide the ship with means of fire protection, fire detection and fire extinction. The basic principles involved:-

(i) division of ship into main vertical zones by thermal and structural boundaries,

(ii) separation of accomodation spaces from remainder of the ship by thermal and structural boundaries,

(iii) restricted use of combustible materials,

(iv) detection of any fire in the zone of origin,

(v) containment and extinction of any fire in the space of origin,

(vi) protection of means of escape or access for fire fighting,

(vii) ready availability of fire-extinguishing appliances,

(viii) reduction of possibility of ignition of flammable cargo vapour.

Ships carrying more than 36 passengers, the hull superstructure and deckhouses are to be divided into main vertical zones by 'A' class division at intervals of not more than 40m. 'A'class divisions are those formed by bulkheads and decks which shall be capable of preventing the passage of smoke and flame to another division of up to an hour. In ro-ro type ship the horizontal zone concept has been introduced because of their garage spaces (i.e. enclosed spaces above or below the bulkhead deck intended for the carriage of motor vehicles with fuel in their tanks for their own propulsion, into and from which such vehicles can be driven and to which passengers have access). These ships operate in conditions which enable them to apply a special set of regulations exempting their garage space to be fitted with main fire bulkheads at every 40m, provided equivalent means for controlling and limiting a fire, shall be substituted and specifically approved by the administration.

Protection of Special Category Spaces. (Reg. 37)

The principle of this regulation is that in cases of vessels such as ro-ro ships the use of vertical zone bulkheads would defeat the purpose for which the ship is intended, horizontal zoning provided should give equivalent protection. The horizontal zone concept can be applied to spaces on more than one deck provided that the total overall clear height for vehicles does not exceed 10m.

Structural protection - the boundary bulkheads of the cargo space shall have fire integrity which satify minimum requirement laid down i.e. prevent

(i) the risk of fire in the space and the danger of its spreading to adjacent spaces,

(ii) the risk of fire in adjacent spaces and the danger of its spreading to the cargo space,

(iii) the importance of the space in terms of safety of the ship. In this contextthe fire insulation shall be of A0 or A60 category.

Indicators are also to be fitted on the navigation deck which would inform the officers wherever the firedoors leading to these spaces are opened.

Fixed Fire Extinguishing System.

If horizontal zoning is used the space should also be fitted with efficient fixed fire extinguishing system, including sprinklers. The regulation ask for an approved fixed pressure water spraying system for manual operation which shall protect all parts of any deck and vehicle platform in such space, however administration are allowed to approve other equivalent means. In practice this may sometime amount to the use of curtains of water which are only fully effective if they are not interrupted by part of the cargo. The distribution valves, of the system should be situated in an easily accessible position adjacent to, but outside the space to be protected whcih will not be readily cut off by a fire within the space. Direct access to the distribution valves from the vehicle deck space from outside the space should be provided. The system should be supplied by an additional pump which is none of the fire pumps and the suction to these pumps shall be at a distance B/5 from ship's side.

5.2.4 Patrols and Detection.

A continuous fire watch is required to be maintained at all time during voyage on the special category space but if this is not done the space should be provided with a fixed fire detection and fire alarm system of an approved type. With regard to the fire detection system if a ship should use smoke detectors, there does occur sometime difficulty of picking the smoke this entails a substantial loss of power in conducting the smoke from the spaces to the detection point which contain the photoelectric cells. When this happens the detector does not function as efficiently as might be desired and this problem is more acute when the space is being ventilated,and therefore there might be a delay in response by the detection to a fire breaking out. It is very important that before the detectors are placed in position, a full-scale test is carried out to make sure the positioning is effective.

The ionized type of detectors seems to work more effectively than the smoke type in this situation.

Fire extinguishing equipment should be provided in addition to those of the main fire system, which is a system of water hoses;

- a fixed inert gas extinguishing system, if the space can be sealed off,
- one portable foam applicator,at least three water fog applicators,

- as many portable fire extinguishers of an approved type as the administration may deem sufficient.

Here there may be a problem in using the appliances. Because of crowding of the cargo spaces it is very often not very accessible making it very difficult to use the extinguishers and to place the hoses in the right position. One other danger is that if the crew had not been informed of the type of cargo being carried and had used the wrong type of extinguishing medium, instead of putting out the fire one could make the situation worse. For this reason the crew should be well trained in fire fighting methods and they should be informed of any special cargo being carried on board. The regulations on the carriage of dangerous goods by sea is thus imperative on board ships.

Ro-ro spaces which are fitted with fixed water spraying system should be fitted with drainage and/or pumping arrangements which could be capable of preventing the build up of free surfaces. According to IMO resolution A 123 (V) if it is not possible to remove the water on the cargo deck the adverse effect upon stability of the added weight and free surface of water shall be taken into account when approving the stability information.

5.2.5 Ventilation System.

The requirement here is that, for a vessel carrying or likely to carry in its cargo spaces vehicles with fuel in their tanks, these spaces should be thoroughly and permanently ventilated to prevent formation of combustible explosive vapour. For a vessel carrying more than 36 passengers the ventilation system should be able to give 10 air changes per hour and 6 air changes per hour for ship carrying not more than 36 passengers. It is required that, whenever the vehicles are on board the system should be run continuously if practicable. During loading and unloading this could be increased, according to the administration's wish.

Ventilation ducts serving ro-ro cargo spaces that can be completely sealed off should be separated for each space and the system should be controlled from a position outside such spaces.

On several ro-ro ships it had been necessary sometime for them to go to sea with the bow doors open so that they could clear their deck of exhaust fumes. This shows that these vessels do not posses an efficient means of ventilation. It can be noted here that many ships have only manual switch on each ventilator duct or cowl. The result is that crew members are forced to go on deck to shut the ventilator ducts in the event of fire. It would be safer if these ships were fitted with ventilator ducts that could be closed from a central position, automatically by remote control.

5.2.6 Means of Escape.

SOLAS states "in all ro-ro cargo spaces where the crew is normally employed the number and locations of escape routes to the open deck shall be to the satisfaction of the administration but shall in no case be less than two and shall be widely separated".

Here the author feels that it doesn't take into consideration that in cargo spaces of ro-ro vessels it is normally crowded and full of lashing, criss-crossing the deck. Taking this into consideration it is not easy for anybody to move about in complete black out. To improve this situation it is felt that provisions should be made for passage to be made in the middle of the space and provided with luminous signs. These passages should be kept clear at all time.

5.2.7 Stairways and Ladders.

These are to be built of steel and to be placed within an enclosure formed of 'A' class divisions, with positive means of closures. These stairways and ladders shall be arranged so that they provide ready means of escape to the lifeboat and liferaft embarkation deck from all passengers and crew spaces and from spaces in which the crew is normally employed, other than machinery spaces.

5.2.8 Proposed SOLAS Amendments in the Aftermath of Herald Of Free Enterprise Accident.

In the aftermath of the above accident the United Kingdom government have proposed to the Maritime Safety Committee, the following Amendments to SOLAS 74:-

1. Proposed regulation 8-1-1 dealing with KGF envelope curve. It has been suggested that since ro-ro passenger ferries often operate in condition of loading other than those presented in stability booklet, additional information should be provided to enable the master to readily ascertain whether any particualr condition of loading meets all prescribed stability requirements.

2. Proposed regulation 8-1 2-1 provision of draught gauges or indicators.

3. Proposed regulation 8-1 2-2. Improving means of calculating "condition of loading".

4. Proposed regulation 20-1 deals with the requirement to ensure that the bow and stern loading doors serving the main vehicle spaces on ro-ro passenger ferries are effectively closed before the ship leaves the berth.

5. Proposed regulation 22-1 deals with lightship weight and re-inclining.

6. Proposed regulations 28-1 and 28-2 deals with escape and emergency lockers.

7. Proposed new Chapter II-3 dealing with Operational procedures and management ashore.

CHAPTER VI

IMPROVING RO-RO SAFETY.

6.1 General.

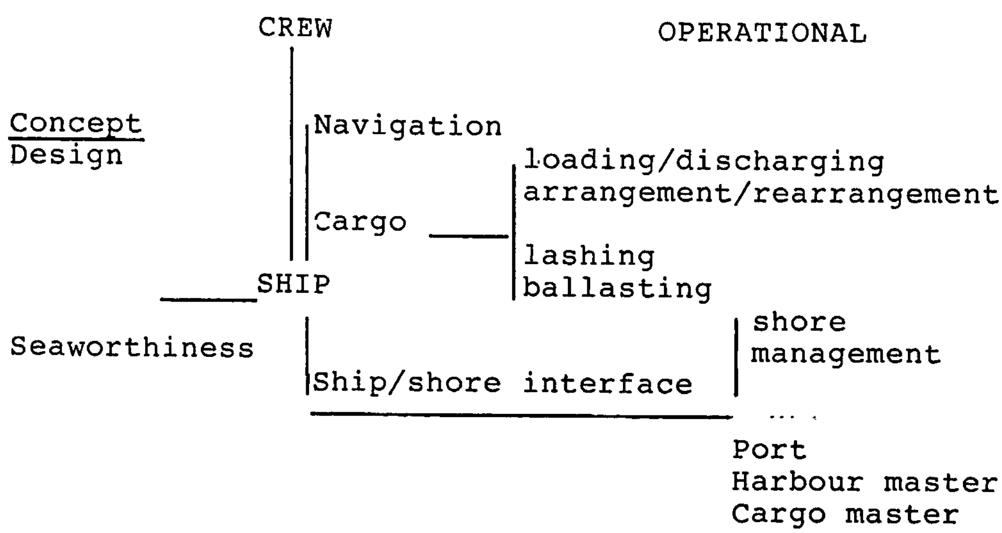
Various changes to the ro-ro concept have been suggested, each of which would improve its safety in some respect, though not all provide such a clear improvement to safety as at first appearance several problems may still bar the way to better ro-ro safety standards. One is that all improvement involves some economic cost.

As has been seen before, the ro-ro concept with it's large open deck and high superstructure is a ship type that if involved in an accident and water flooded the decks, it would capsize more often than it would not. On the other hand it was shown that ro-ro ship are not a higher risk vessel when it is compared with other design.

When we start calling for design change to the concept we should make sure that the safety criteria we introduced does not destroy the concept completely.

The shelter deck design has always been a ship which is difficult to handle and keep afloat because of its special design. Everytime that type of vessel was pierced it would sink. With this in mind we should design one that would sink slowly and not overturn quickly. With the traditional shelter decker, that was possible with its many cargo subdivisions.

The ro-ro ship is an evolution of the traditional cargo ship but when the cargo hold subdivisions were removed to create this new concept, nothing was added to the new type to replace them as far as safety is concerned. There is no way that a totally safe ship can be designed. Every engineering structure has a limit to safety and where it concerns ships the safety limit is reduced because of the hostile environment in which it has to operate. The airline industry people realise the limitation of their aircraft and the consequence of an accident and so they at all time try to reduce the risk of an accident happening. The whole concept of ro-ro transport should be seen and tackled not the ship design in isolation we should bear in mind the training of the officers and crew in improving safety consciousness, operational competence and practice. For total safety we should look into the following as a whole.



6.2 Some Design Improvement.

It has long been recognised that ingress of water on the main vehicle deck is a source of danger. The ship is designed to have a low sill height at the access doors for easier loading.

The danger here is that through bad operational practice water could flood the vehicle deck either through heeling when loading in part or through bow water coming over the sill if the bow doors are left open. The best known accident was the Herald Of Free Enterprise in which the bow wave and low down trim combined to bring the bow door under water. The Santa Margarita Dos capsized in port in Venezuela in 1978 due to heeling while loading vehicles and a ro-ro vessel squatted enough while entering port in Melbourne to bring water on the vehicle deck. The main causes of vehicle deck flooding are:-

1. Open access doors,
2. Side collision damage which can cause assymetric flooding,
3. Weather damage causing cargo shift,
4. Cargo shifting damage due to heel in turn and faulty ballasting operation,
5. Berthing damage/overloading.
6. Leaking access doors.

6.2.1 Transverse Subdivision bulkhead on Vehicle.

Portable transverse subdivision bulkheads or fixed bulkheads with large doors have been suggested for the vehicle deck as means of preventing flooding and to reduce the free surface in case of flooding. These are already in use on some large ro-ro ships. When closed these will turn the ro-ro into a conventional subdivided cargo ship and increase the ability to survive flooding.

Down Flooding.

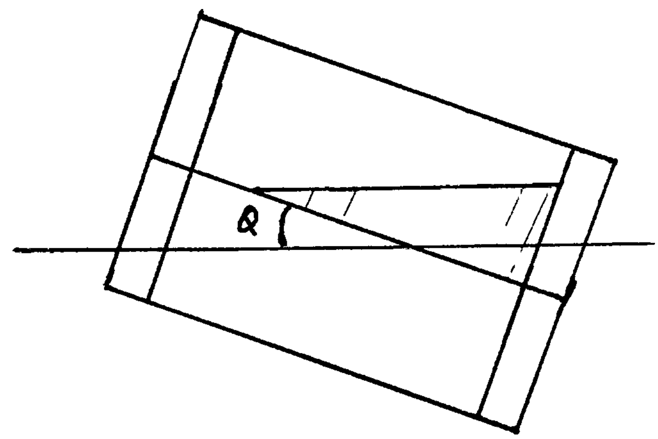
This theory suggests that vehicle deck which many suffer immersion from whatever source, should be non-watertight. Furthermore such decks should be designed to allow both water and air to pass freely through them. This theory is based on the fact that at up to a certain depth of water on the vehicle deck the maximum heel angle remains within reasonable limits without cargo shift and the ship can return to stable upright condition. It may be advantageous to deliberately drain floodwater from the vehicle deck to empty tanks beneath. This would lower the centre of gravity (KG) although it would also increase the draught and temporarily increase the free-surface effect. How this should be accomplished in practice without spreading the flooding to compartments below the vehicle deck is not yet clear. The drainage system must be capable of allowing very large quantities of water to drain directly into lower cargo spaces without access to machinery or other critical spaces, which must be effectively sealed from the cargo spaces at all times.

6.2.2 The Free Surface Effect on Vehicle Deck.

The effect of having a large amount of water on a ro-ro vehicle deck which has no subdivision is the same as having a large pendulum hanging from the top of the ship and its centre of mass will be that of the mass of water on the deck. This will produce a rise in the ship's virtual centre of gravit and thus reduce the GM value.

For a ship of the following breath 20m, initial GM = 2.167m and with a 2.7m layer of water on deck; the virtual loss of GM is 2.731m.

Therefore, even with the substantial GM of 2.167m and heel of 28.40 such a vessel will immediately heel until stability is regained. With lower initial GM, the heel is rapid even with as much as 0.5m of water on the car deck. (see drawing p. 59).



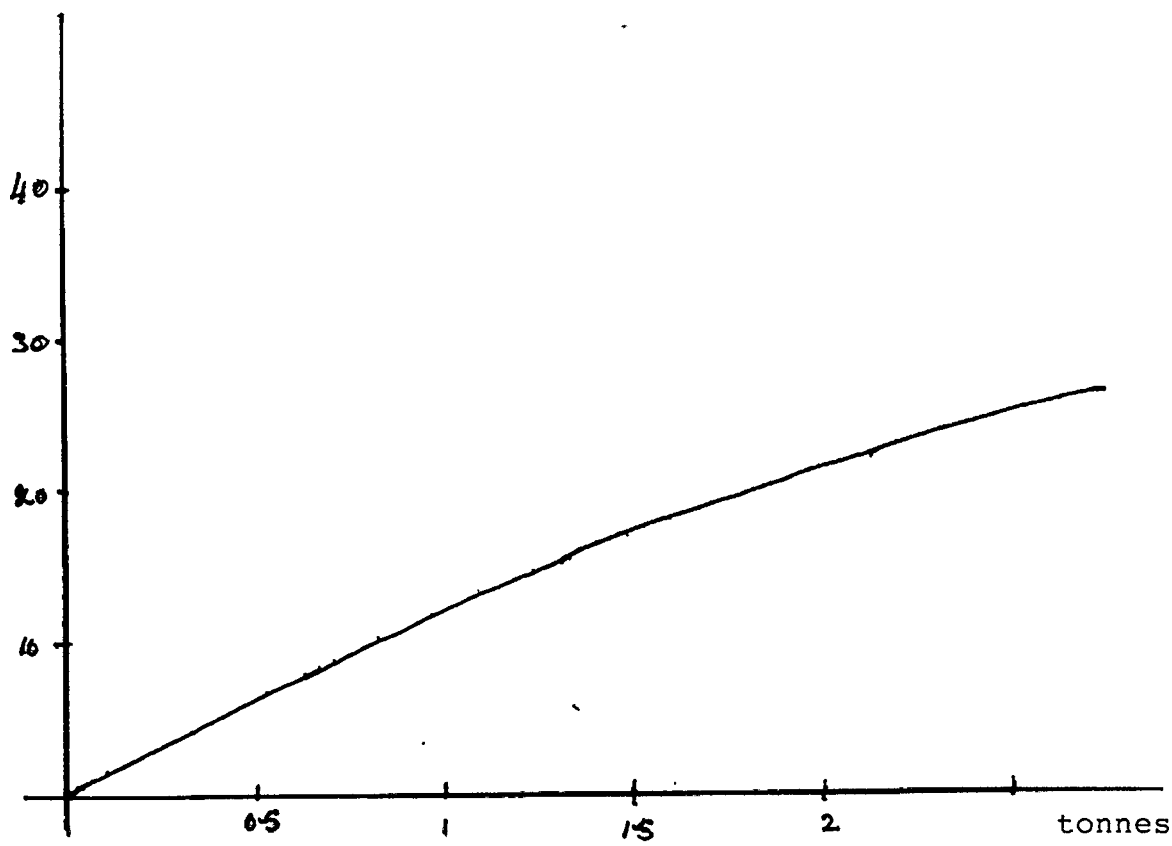


Fig. 6.1 Effect of free water depth on car deck

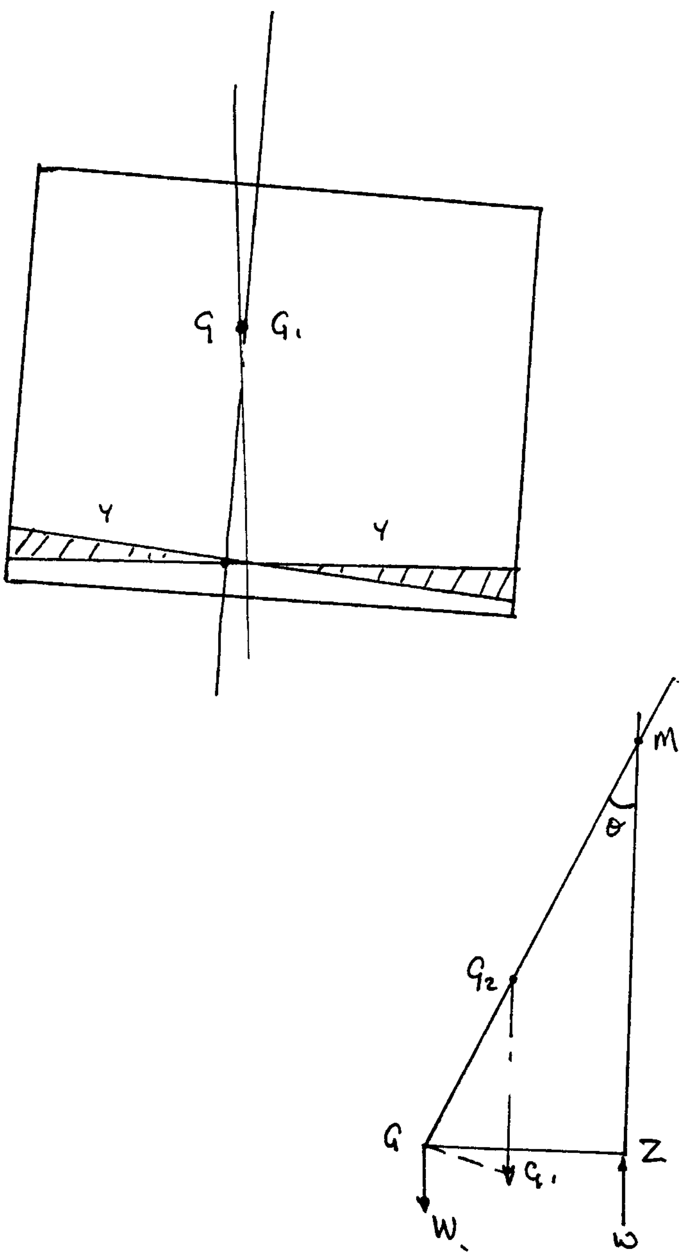


FIG 6.2 (MUCKLE)

From figure 6.2

Volume of wedge = $\int_0^L \frac{1}{2} y^2 \theta \, dx$ L = ship Length

Momement of volume = $\int_0^L \frac{1}{2} y^2 \theta \, dx \cdot \frac{4}{3} y$

if wedge is treated as Δ
moment of volume = $\theta \int_0^L \frac{2}{3} y^3 \, dx = \theta I$

Where I is moment of Inertia of the free surface
moment of mass moved = $\rho_L \theta I$ ρ_L = density of Liquid

If the shift in centre of gravity = $GG_1 = \frac{\rho_L \theta I}{W} = \frac{\rho_L \theta I}{\rho_w g V}$ ρ_w = density of water

The righting arm GZ is reduced by an amount GG1.
Righting moment = $W(GG_1 \cos\theta)$
since for small angle of heel GZ = $GM \sin\theta$

Hence shifting of G to G1 is equivalent as raising G to GZ so that GG1 = $GG_2 \tan\theta$
and righting moment = $W(GM\sin\theta - GG_2 \cos\theta \tan\theta)$
= $W(GM - GG_2)\sin\theta$

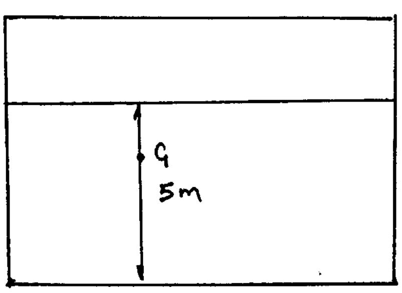
The effect therefore of the moment of liquid is equivalent to a rise of GG2 and so a decrease in GM

$$GG_2 = \frac{\rho_L}{\rho_w} \times \frac{I}{V}$$

I without centre division = $\frac{1}{12} LB^3$

I with centre division = $\frac{1}{48} LB^3$

e.g. A car ferry of the following particulars is flooded to 0.05m.



Δ = 2800 tons
KG = 4.0 m
KM = 4.7 m
L = 40 m
B = 10m

Weight of water on car deck = 40x10x0.05x1.025 = 20.5 tons.

New KG^1

$$KG^1 = \frac{\Delta \times 4.0m \times W \times 5.025m}{\Delta + W} = 4.007m$$

loss of GM due to free surface effect

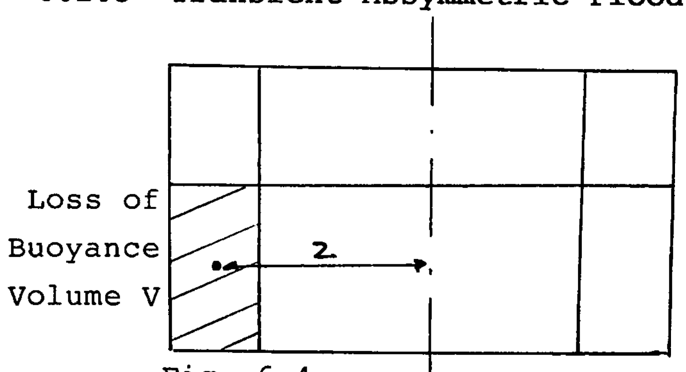
$$I = \frac{1}{12} 40x10^3 = 3333m^4$$

$$\text{loss of GM} = \frac{1.025 \times I}{\Delta + w} = 1.21m$$

$\therefore$ G''M = G'M - loss of G'M = km - KG- 1.21

= - 0.517m Negative GM

6.2.3 Transient Assymmetric Flooding.



Longitudinal bulkhead at B/5

Fig. 6.4

If a vessel is designed as above with the longitudinal bulkheads at position B/5 from ship's side as per SOLAS 74 regulation and should that vessel happen to lose buoyancy in the compartment shown, only that compartment will be affected if the damage doesn't go beyond B/5.(However IMO have shown that 45% of side shell damage are beyond B/5).

Under these circumstances water enters on one side of the ship only and an angle of heel will develop.

Let's take the above diagram.

The added mass of water = $\rho g V$

heeling moment = $\rho g V z$

∴ The ship will heel until a righting moment of this magnitude is produced.

It is important to limit this type of flooding and therefore crossflooding arrangement should be provided whereby flooded water can be transfered via pipes to tanks on opposite side of the ships. The investigation into the sinking of the ro-ro Ferry European Gateway showed that after being hit in her side by the bulbous bow of the Speedink Vanguard a mass of water entered by the bulbhole which represented a wave front moving into the engine room. The mass of water entering the starboard side in the initial moments after the collision could not adopt a symmetrical posture instantaneously. For a period there was a wedge of water with a greater weight of water on the starboard side than the port side. This displaced the centre of gravity of the vessel and caused it to list to starboard. This caused the bulkhead deck to dip well below the waterline, reducing the moment of Inertia at which point capsize was inevitable.

The reason that so much water was able to enter the engine room was because the machinery space watertight doors were left open. If SOLAS operatings regulation had been observed these doors should have been closed during navigation.

Longitudinal subdvision and crossflooding:

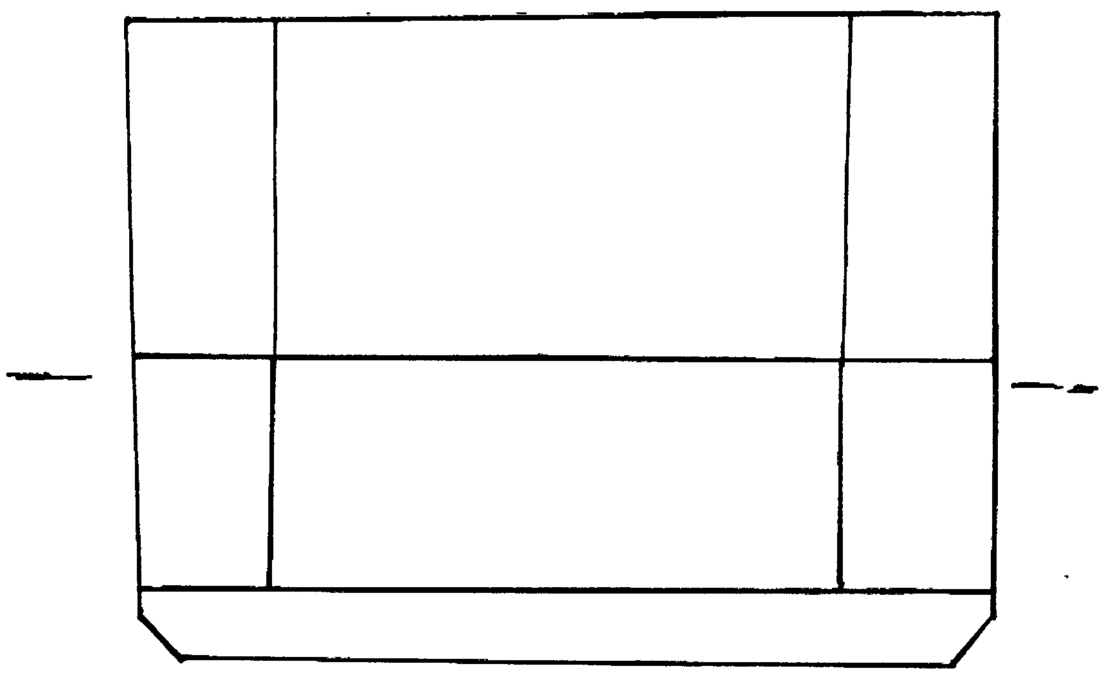


Fig. 6.5 Showing Longitudinal subdivision (wing tanks) at B/5

The double skin construction seems to have the following merits.

1. Increase reserve buoyancy of the vessel.
2. Reduce the risk of vehicle deck flooding due to side damage.
3. Reduce free surface effect if deck should be flooded.
4. Side compartments may be used for vehicles, bunkers or ballast.
5. The smooth side walls make cargo handling easier.

A danger with the wing tanks is that if one side is flooded they may cause a heel which may bring the sill of vehicle deck below the waterline. To prevent this these tanks should be subdivided transversely and so reducing theirlength.

Cross flooding arrangement to be fitted, which help to prevent assymetric flooding. For full effectiveness the arrangement should be automatic with a rapid cross flow. As required by IMO and by recommendations of Resolution A.266 (VIII) the "time to equalization", for ro-ro passenger ships is limited to 15 minutes.

6.2.4 Permanent Buoyancy in Wing Tanks.

It is suggested that in order to reduce immersion and heeling of a vessel by masses of water entering, the permeability of the flooded compartment should be reduced. Permanent buoyancy could be applied in the void wing spaces by stowage of polythene drums or balls. By proper stowage it is claimed that the permeability of the compartments can be reduced to 50-60%.

6.2.5 Increased Freeboard.

Increasing the freeboard to the main vehicle decks, will raise the height of the deck sill, and will augment the safety level of the ship, as it would reduce the risk of flooding such decks and the "progressive flooding of intact spaces which could lead to capsize".

Increasing the freeboard of cargo ro-ros will result in a loss of deadweight and have a commercial consequence on the operational viability of the vessel. It may happen that in future design operators may increase the freeboard but at the same time increase the depth to maintain the same deadweight, the consequence of which is a rise in the overall centre of gravity in the intact condition and even reduced residual stability in the damage condition.

6.2.6 Draught Gauge System.

In the aftermath of the sinking of the ro-ro passenger vessel the Herald Of Free Enterprise, the U.K. government has made a proposition to IMO that this type of ferries should be fitted with draught gauges or indicators of mechanical, pneumatic, electrical or hydrostatic type to read draught, forward and two points amidships.

6.3 Operational Safety.

It has already been mentioned that operation and design are interlinked and cannot really be divorced from each other in any consideration of safety. The way a ro-ro vessel behaves, and is handled as well as the way in which it is managed, is of importance in any study of safety. The ship should be designed with a large enough factor of safety, so that it can withstand the forces of the environment and any slight abnormality in operation. The shore management should keep contact with what is happening on board and should constantly provide information for proper operation. The crew should be made aware of the limitation of the vessel. If there is a better understanding of the operational capability of the vessel, proper understood procedures could be devised to operate the ship safety.

Top management ashore should pay attention to the following (UK)

(a) Clear and concise orders.
(b) Strict discipline.
(c) Attention at all times to all matters affecting the safety of the ship and those on board. There must be no "cutting of corner."
(d) The maintenance of proper channels of communication between ship and shore for the receipt and dissemination of information.
(e) A clear and firm management and command structure.

We should mention here that the inspection of operating procedures on board ship is not high on the list of IMO requirements. Most administrations place the onus of responsibility for the safe operation of the ship on the master. Responsibility is also placed upon owners and operators of ships and the more responsible among them issue various standing orders from time to time.

6.3.1 Loading and Unloading.

Turn around time for Roll-on Roll-off ships is very short, it may be as low as 60 minutes but rarely more than 24 hours, for loading and unloading, on occassions both operations being carried out simultaneously. With such a quick operation it is very difficult for the masters and officers to have time to prepare their loading plans and to make their trim and stability calculations in advance. In pure ro-ro companies loading process and stability calculation have been transfered to shore terminals. However the author is not sure that small ro-ro companies possess the will or means to undertake such a system. Some of these even carry out stability calculation when the ship has left the berth.

The Barber Blue Sea Experience.

Because of the tight schedule and very fast turnaround, the company has centralized the decision making for the loading and discharging of the ships. The whole loading/discharging process is preplanned and decided before the vessel even get alongside. The 'Central Planner' works in conjunction with a coordinator from each local agents and he has the responsibility for:-

(a) cargo bookings,
(b) local cargo carrying equipment,
(c) cargo readiness/unitizing,
(d) operation/stevedoring/costs.

In each port there is a Cargo Superintendent who works out the details. The following table shows how the job is split between, Head Office, Vessel Operator, Agents and Terminal/Stevedore. (see next page)

TABLE 6.1

SUPERCARRIER OPERATION - RESPONSIBILITIES

BBS	- SPACE ALLOCATION, CONTROL. - CARGO EQUIPMENT - PROCUREMENT AND POSITIONING. - LOAD/DISCH - PLANNING AND COMPLETE FOLLOW UP. - STABILITY CALCULATIONS. - BUNKERING. - CARGO PLANS. - OVERALL COORDINATION.
VESSELS	- SHIPS HANDLING EQUIPMENT - MAINTENANCE AND SERVICE. - BALLASTING/TRIM. - OPERATIONG OF RAMPS, COVERS, DOORS, ETC. - CARGO SECURING. - MONITORING/SERVICE OF REEFER CONTAINERS (WHEN ONBOARD).
AGENTS	- CARGO ACCEPTANCE, DEADLINES AND READINESS. - LOCAL EQUIPMENT - TRACKING/COORDINATION. - DOCUMENTATION, REPORTING. - HUSBANDING FUNCTIONS.
TERMINAL/ STEVEDORE	- CARGO PREPARING/PRESTAGING. - DOCK PLAN OF CARGO. - CARGO PLANS LOCAL LOADING. - SEQUENCE LISTS (IN COOPERATION WITH CS). - PROCUREMENT OF SHORE HANDLING EQUIPMENT. - DRIVERS, LABOUR.

TABLE 6.2

SUPERCARRIER - SHORE OPERATING PERSONNEL - RESPONSIBILITIES

CENTRAL PLANNER (CP)	-	Coordination of all regional bookings.
	-	Acceptance of unusual cargo.
	-	Equipment prepositioning.
	-	Overall responsibility for stowage planning, stability.
	-	Bunkering in cooperation with Oslo.
CARGO SUPER-INTENDENT - (CS)	-	Detailed preplanning of vessels.
	-	Follow up on unitizing/prestaging.
	-	Sequence lists, ordering of labour and euipment in cooperation with agents port representative/terminal/stevedore.
	-	Load/Disch - Full follow up in all ports.
	-	Cargo plans, stability.
AGENT'S PORT REPRESENTATIVE	-	To be responsible for and to keep CP and CS routinely informed about following: - Cargo bookings/readiness. - Unitizing/prestaging. - Local equipment situation. - Equipment/labour/berth situation.

Preplanning and the final coordination with the agents' port representatives in regard to cargo readiness.

As can be seen the terminal managers (Central Planner and Cargo Superintendent) have taken over the responsibility of cargo planning from the masters and ship's officers. The master of the ro-ro ship, thus finds himself compelled to take over the ship as loaded by the terminal. This in itself is not particularly bad. However we should realise that in this, situation the master has no control on loading while in law the responsibility for proper loading and stowage is his.

The author feels that if this system is to be used there need to be a good deal of exchange of information between ship and terminal, prior to loading. Particulars of loading, nature, weight and type of cargo should be transmitted to the ship, well in advance. The condition of the ship (trim, ballast etc..) should be transmitted to the terminal as well. In addition, there should be a meeting on board the ship between the terminal and ship personnel, prior to start of loading.

6.3.2 Cargo Stowage and Lashing.

Shifting of cargo within the unit (containers, trailers..) and shifting of the unit itself is one major cause of accident in ro-ro operation. As explained previously fifty six percent of the total losses can be attributed to cargo shifting and operation errors. It is for this reason that in 1981 the IMO Sub-Committee on containers and cargoes initiated work on guidelines for securing cargo units on board ro-ro ships. The

Sub-Committee felt that governments should encourage ship owners to put on board their ships a manual "appropriate to the characteristics of the ship and it's intended service, in particular the ship's main dimensions its hydrostatic properties, the weather and sea conditions which may be expected in the ship's trading area and also cargo composition." The Sub-Committee pointed out that cargo intended for sea transport should be presented for shipment in a marine mode that is there should be enough securing points on the unit and also the cargo inside the unit should be well stowed.

Among the difficulties which cargo stowage presents to the ro-ro operators are the following:-

Packing of Cargo in Containers and Vehicles.

For security and custom reasons cargoes within the containers are secured and sealed at the point of loading and are not reopened until they reached their destination.

The people who do these packing have good expertise on packing for the road transport mode,but very often are nòt aware of the forces of marine environment, (wind, wave causing rolling, pitching and heeling motions) which will be encountered on board a ship.

It is imperative that people doing these packing should be educated and made aware of the consequence of badly packed units on ro-ro ships. Guidelines should be develop, in conjunction with road transport organisation, shippers etc.. which will advice on how to pack a unit for ro-ro international voyage. Some countries have already provisions in their regulation for proper securing of cargo on or within unit. However in a spot check it was found by Sweden, that out of 535 loaded vehicles leaving Swedish ro-ro terminals, only 300 conformed with the Swedish regulations concerning cargo securing on road vehicles. An alternative is that stowage firms could be licensed for ro-ro operation.

Stowage of Cargo on Deck.

It is the author's opinion that ship owners apply two lines of thoughts where it concerns securing of cargo on ro-ro deck. Some ship owners lash the cargoes at all time, others will only lash if there is a chance of encountering bad weather on the way and if the ship should, do so the vessel would be rerouted. However except for very short international voyages cargo should be secured on ro-ro deck.

The ship and vehicles should be provided with enough securing points which are well positioned, and suitable for all types of cargoes.

There is also a difficulty from the way the security operation is conducted and verified. This special job is generally done by teams of dockers, although sometimes it is left to the crew. But most of the time the crew are too busy doing other jobs to be able to supervise the dockers and once the ship is at sea the crew on duty will have to make fast lashing. This is not so easy because of the lack of space between the units and in bad weather this can't be done without danger to the crew. In the case of the Barber Blue Sea it is seen from the table that cargo securing is left totally to the crew. This is a more acceptable way to do since the crew are more aware of the consequence of badly secured cargo unit. With a tendency by ship owners to reduce manning level, let's hope that the crew has enough time to carry out proper securing before the vessel put to sea.

With all precautions taken, we still cannot consider that cargo securing is 100% efficient. It should be recommended on ro-ro ships that the doors in the hull be protected against accidental shocks caused by moving trailers.

The lack of transverse bulkhead in a ro-ro ship means that should a trailer topple over as a result of defective lashing, nearby units can be dislodged and a domino effect occurs with a subsequent loss of stability to the vessel.

6.3.3 Organizational Aspects Ro-Ro Operation.

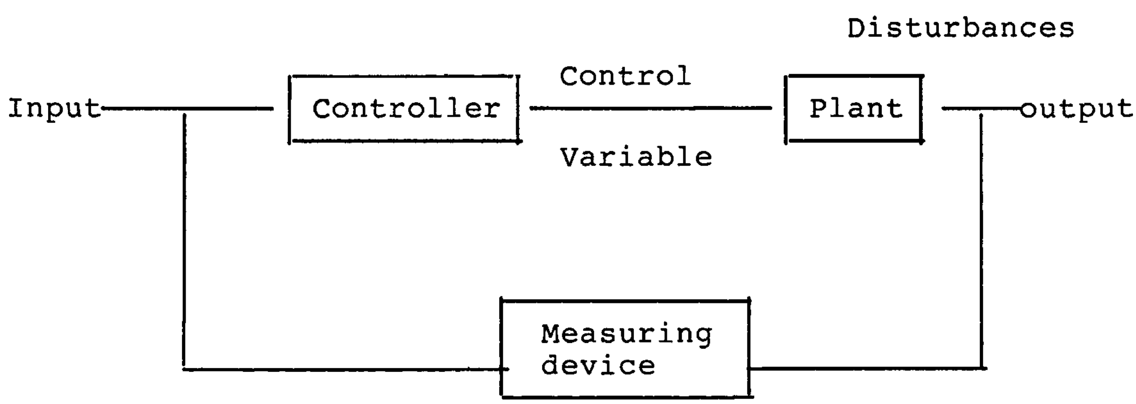
As mentioned previously safety and efficiency are intergral to good management. A company, if it wants to develop a good reputation among shippers, should be in a position to make sure that it's ship is always available when required. Should a company develop a reputation of unreliability due to constant breakdown or, even one disastrous accident (Titanic), could doom a company to extinction. As the saying goes "if you think that safety is expensive, try having an accident".

To increase the efficiency and safety of the ship the risk of accident has to be minimized and this can be done by proper management.

The ship manager should be aware that, for complete management, he is dealing not only with the hardware (ship and/equipment) but the software (people) should be taken into consideration. He has to understand that organization is made up of people and each person in the organization has different objectives. These objectives could be work satisfaction, money or power.

Management Principles.

Management must keep an organization under control so that it will do the things it is supposed to do.



If we take a closed loop feedback system the output influence the controller. The input is the desired or command value, of the output which the controller is trying to achieve. By comparing the output to input the error in the control loop can be computed. This error is a direct measure of the performance of the control system in achieving the commanded output. The error signal is fed back to the controller to bring the output to the required value.

A control system has the basic task of keeping the controlled variable within a specific limit. For example the task of a quatermaster is to keep the ship on a predetermined course. By applying command to the steering he should be able to reduce the error. The whole safety aspect of ships can be modelled on a closed loop feedback system.

Management should:-

1. Determine the goals of the organizaiton (define policy on safety, operational practice) and planning.
2. Organizing.
   (determine and organise what activities are required to accomplish the goals and provide the organization with personnel of right skills knowledge and experience).
3. Commanding.
   Influence people to change their behaviour.
4. Coordinating.
   Provide effective communication and information.
5. Controlling.
   Measure the results of activities and compare predermined objectives, and take proper action if deviation should exist.

Operating Procedures and Manuals.

There has always been manuals on board ships one would say and why should there be a need for anymore. If one were to study the manuals existing on ships now, one would find that they are just individuals books describing the operation of separate item or equipment and not a complete intergrated procedural document. What is required is that those data from maker's manuals have to be transcribed into an operationable one.

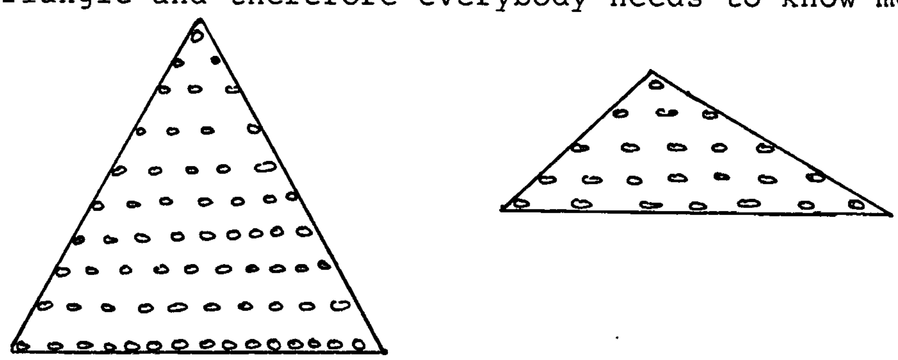
The need for a manual must be considered a must today because of:-

- Prior to the sixties, ships and equipment design did not change much. But now due to various aspects of transportation, basically due to economic, the design of ship's and their equipment are constantly changing and to keep abreast with the changes the crew of today is required to read a bit more than its predecessor.

- In the old days a seafarer could expect to spend a long time on a ship and get to know it very well. Whilst today a seafarer spend more time ashore and is constantly moving from ship to ship.

- Traditional education system can't keep pace with these change (One suggestion for this problem is that a modern crew member could be trained to a basic degree level in Marine Technology (Engineering, Navigation Management and Operation) then he should attend college and be certificated for the type of ship he wish to work on e.g. ro-ro certificated.

- The decrease in manning level has meant that the triangle of authority is getting smaller. The old hierarchal system is being replaced by a shallower triangle and therefore everybody needs to know more.



It has been suggested that manuals describing operating procedures has to be developed and placed on the ship if this doesn't exist yet. The manuals should be developed by the Head Office in conjunction with experienced seafarers and should be placed on board ships in the Head Office, in port and linked to the administration.

They should cover:-
General information about each individual ship,
Cargo handling procedure,
Safety,
Emergency operation,
Master's information.

6.3.4 Human Factor.

Maritime technology change is going on at a fast pace. Whereas in the old days a seafarer could expect to work with the same instrument throughout his working life, this is no longer the case today. Technology is moving rapidly and ships are being equiped with the most advanced navigational aids available. Bridges are now being turned into operational centres, with all the necessary controls for the running of the ship being located there. The equipment for all ship's functions are more and more being centralised. Equipment for propulsion control are being transfered from engine room to the bridge. This centralised system has led to a reduction in manning. However one may ask, are the system of education used for training officers/crew of bygone days adequate as a sound tool for the operation of today's ships.

The bridge operator is now being asked not only to act as a navigation officer but he has also to monitor all activities going on in the ship e.g. navigation, engine monitoring and cargo space monitoring. At one time there may have been two men on the bridge, one acting as 'Look out' whilst the other was responsible for the navigation and equipment monitoring. Today we can expect to find, even on very dense traffic regions, that the bridge of many large and fast ships are being manned by a single person, who may or may not understand the instrument and may wrongly interpret what he sees on the screen.

It has been shown that risk to accident due to ship design and equipment defect is smaller than that due to human error. Therefore for a total safety the operational and human error must be minimised. The magnitude of risk of accident depends to a large extent on the consciousness and professional skills of the operators. There is a need for the operator to be able to detect signal of hazard in the system and then have enough knowledge, experience and confidence to take corrective actions. Whilst previously the eyes,ears and noses were used for this purpose this is now turn over to sensors, minic lights and VDU. Decision to take action depends on the ability to understand the total system. The less the understanding the higher the risk for human errors.

6.3.5 Training.

In marine fields due to many different reasons, the onboard technology moves a lot faster than the education system of the crew. One may have studied the working of a Scotch Boiler at college and understood it perfectly however with the scarcity of such equipment on ships it would have been better and more useful to the student to have studied control engineering.

Shipmasters and officers are now in control of lots of lives and multimillion dollars investment. They have been recognised as professional on the same par as doctors, lawyers and like any other professional they need sound academic background.

Shipmasters of most countries are normally highly experienced before being appointed in command. They may have started out as deckhand and worked their way up and inbetween spent some time in college. The Shipmaster is thus mainly a practical man, an operator. On board, however he is being asked to be a manager. Why should the route to management on board ship be different than ashore. The industry should not be merely training operators but highly trained professionals with a broader base of learning.

Simulator Training.

On many occassions lack of knowledge of equipment can lead to prejudice and fear and to some extent misuse, on board ships this is very common. Very often ship's officers have no understanding of what he is working with and by trial and error and may be by switching off certain devices he has managed to get the ship going. The ship which was designed to work unmanned is now still working unmanned but equipment vital for such mode is un operational.

An example of where lack of understanding of control system could have been dangerous. A fully automated gas tanker was crossing a very busy channel when its engine cut out, for some reason, but not one of the senior engineers on board, could restart the engine, because they didn't realise that the system had to be re set. But luckily for them there was a cadet on board who had experienced such a breakdown previously.

To alleviate such misunderstanding simulators could be used in maritime college for training and retraining of ship's officers.

Simulators have been an intergral part of training for aviations for sometime, whilst merchant marine training has been based on classroom and "on the job" training. Over the years computer technology and modelling have improved and it is now possible for a simulator to reproduce various characteristics of ship operation.

CONCLUSION.

The modern Ro-Ro ship is an evolution of the traditional, subdivided, general cargo ship. The development was carried out through a series of modification to the cargo ship design. The rapid growth in this type of vessel both in numbers and sizes did not leave much time for research to be undertaken. However since the seventies, I.M.O.has initiated, through the Maritime Safety Committee, some studies into safety and survivability.

The evolution of the ro-ro ship is comparable to that of tankers in the fifties. The same situation existed then, and it was only after a series of accidents on these vessels that regulations were formulated, aim especially at tankers. The obvious thing to do now, if the safety of ro-ro ship is to be improved, is to formulate a special set of regulations, tailor made for them, bearing in mind it's economic and operational aspects. The regulations should facilitate the operation, not hinder. They should cover the items which are problematic with ro-ros,and should be introduced after research has been carried out.

The most serious threat to the safety of ro-ro ship is from the vessel flooding, heeling and capsizing. The capsizing is very rapid if the watertight intergrity of the vehicle deck is breached. There is a need for a suitable method for the design of improved subdivision arrangement. The deterministic method, which has been used to calculate subdivision seems lacking where it concerns ro-ro ship, as it had not taken into account the change which had occured in this ship type. The method is based on the traditional subdivided cargo ship.

The probalistic method which take into account the recorded damage statistics, has been suggested as an alternative. (appendix 4) It is believed that this method will give an improvement in the level of safety for dry cargo ships including ro-ros.

We have seen that the ro-ro ship is not likely to be involved in accidents more often than general cargo ships, however when it is involved in an accident it is more likely to sink. Therefore we may conclude that the safety problem is not unique to this type of ships but an enigma that exists in shipping industry. The whole aspect of shipping should be looked into. The following institutions should look into their working method and see what improvements can be achieved.

(a) National Administrations,
(b) Classification Societies,
(c) Shipowners.

Generally many accidents occur because of human errors. The repetitive nature of the work must promote boredom and complacency. The training institutions should look into improvement of training which will be suitable for seafarers manning today's vessels.

There is a need for a better control of human factors (better human-machine interfaces, more training and improved personnel management). There is also a belief, supported by facts that up to now we have not succeded in applying human factor principles sufficiently. A more scientific approach is required. Knowledge from engineering, system analysis, anthropology, psychology and physiology has to be collected to define the basic characteristics of shipborne operators. Research should then be undertaken to try and solve the problem of ship operation. The information obtained can be used for improving operation tasks and training.

Another ro-ro problem identified is cargo lashing. In Lift on Lift off ships, the cargo is closely packed together in subdivided holds. In ro-ro stowage, it is more difficult to stow the cargoes lightly, and very often a variety of cargoes is being carried on or in a variety of units (trailers, MAFI..) The lack of transverse bulkheads on the vehicle deck make it dangerous should cargo break loose. A domino effect may occur and this leads to listing and subsequent reduction in stability and sometimes unprotected access doors may be damage by the moving cargoes. Cargo lashing should be undertaken by competent personnel and vessels should not leave the berth without cargoes being securely lashed. Road transport operators should be educated to accept their responsibilities with regard to the proper stowage and packing of their vehicles, suitable for the marine mode.

In conclusion the author would say that the ro-ro design lacks safety margin and thus research should be done to improve the safety. There is also a need for improvement in operational procedures.

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Serious Casualties to Dry Cargo Ships above 500 GRT
Jan. 1978 — Oct. 1983

	1978	1979	1980	1981	1982	1983	Total Number
Number of Dry Cargo Ships at Risk	21.270	21.572	21.741	21.715	21.86 1	17.519	
Number of Total Losses	241	236	169	179	174	99	1098
%	1,1	1,1	0,8	0,8	0,8		
Number of Serious Casualties incl. Tot. L.	576	863	912	801	767	620	4539
%	2,71	4,00	4,19	3,69	3,51		
Number of Lives lost	336	458	563	932	218	216	2723

	Collision	Contact	Fire/ Explosion	Foundered	Hull/ Machinery Damage	Miscell- aneous	Missing	Wrecked/ Stranded	Total
Number of Total Losses	103	25	232	332	34	3	19	350	1098
Percentage Distribution	10	2	21	31	3	< 1	< 1	33	100
Percentage Distribution of 4 539 Serious Casualties	19	6	15	8	24	< 1	< 1	28	100
Number of Lives lost	374	29	626	1040	34	0	469	151	2723
Percentage Distribution	14	1	23	38	1	0	17	6	100

Data extracted from
LR-Report 84/37

Nr.Fd 187/09/84 Rg.Nr. I/12/6

Appendix B

SERIOUS SHIP CASUALTIES [1978 - 1987] WORLD WIDE ANALYSIS BY SHIP TYPE AND TONNAGE [OVER 500 GRT]

RO/RO PASSENGER SHIPS [SHIP YEARS AT RISK 9998.75]

DWTs	TOTAL SHIP LOSSES AND SERIOUS CASUALTIES [NUMBER OF INCIDENTS]										
	COLLISION	CONTACT	FIRE EXPLOSION	FOUNDERED	HULL/ MACHINERY DAMAGE	MISSING	WRECKED/ STRANDED	MISC	TOTALS	TOTALS ALL TONNAGE RANGES	LOSSES AND CASUALTIES PER SHIP YEAR AT RISK
LESS THAN 1600	27	17	24	3	18	0	31	1	121		
1600 - 3999	16	8	19	3	14	0	2	1	83		
4000 - 9999	3	0	1	0	1	0	4	0	9	218	.0219
10000 - 19999	0	1	1	1	0	0	0	1	4		
OVER 20000	1	0	0	0	0	0	0	0	1		

RO/RO CARGO SHIPS [SHIPS YEARS AT RISK 8316.25]

DWTs	TOTAL SHIP LOSSES AND SERIOUS CASUALTIES [NUMBER OF INCIDENTS]										
	COLLISION	CONTACT	FIRE EXPLOSION	FOUNDERED	HULL/ MACHINERY DAMAGE	MISSING	WRECKED/ STRANDED	MISC	TOTALS	TOTALS ALL TONNAGE RANGES	LOSSES AND CASUALTIES PER SHIP YEAR AT RISK
LESS THAN 1600	7	1	1	2	5	0	5	1	22		
1600 - 3999	21	9	14	9	38	0	15	4	110		
4000 - 9999	26	5	15	3	44	0	20	1	114	324	.039
10000 - 19999	7	6	8	1	18	0	13	0	53		
OVER 20000	6	3	2	0	9	0	5	0	25		

GENERAL CARGO SHIPS [SHIP YEARS AT RISK 129411.25]

DWTs	TOTAL SHIP LOSSES AND SERIOUS CASUALTIES [NUMBER OF INCIDENTS]										
	COLLISION	CONTACT	FIRE EXPLOSION	FOUNDERED	HULL/ MACHINERY DAMAGE	MISSING	WRECKED/ STRANDED	MISC	TOTALS	TOTALS ALL TONNAGE RANGES	LOSSES AND CASUALTIES PER SHIP YEAR AT RISK
LESS THAN 1600	61	17	55	89	128	1	145	3	499		
1600 - 3999	171	63	137	159	294	8	289	7	1128		
4000 - 9999	247	71	176	182	399	11	376	12	1474	4509	.035
10000 - 19999	303	84	232	41	324	4	305	7	1300		
OVER 20000	24	8	20	7	21	0	28	0	108		

NON RO/RO PASSENGER VESSELS [SHIP YEARS AT RISK 8480.00]

DWTs	TOTAL SHIP LOSSES AND SERIOUS CASUALTIES [NUMBER OF INCIDENTS]										
	COLLISION	CONTACT	FIRE EXPLOSION	FOUNDERED	HULL/ MACHINERY DAMAGE	MISSING	WRECKED/ STRANDED	MISC	TOTALS	TOTALS ALL TONNAGE RANGES	LOSSES AND CASUALTIES PER SHIP YEAR AT RISK
LESS THAN 1600	8	9	26	7	0	0	31	0	81		
1600 - 3999	2	5	9	3	1	0	12	1	33		
4000 - 9999	9	3	8	3	4	0	17	0	44	179	.0211
10000 - 19999	1	1	5	0	2	0	2	0	11		
OVER 20000	4	1	0	1	0	0	4	0	10		

TANKERS [SHIP YEARS AT RISK 48793.75]

DWTs	TOTAL SHIP LOSSES AND SERIOUS CASUALTIES [NUMBER OF INCIDENTS]										
	COLLISION	CONTACT	FIRE EXPLOSION	FOUNDERED	HULL/ MACHINERY DAMAGE	MISSING	WRECKED/ STRANDED	MISC	TOTALS	TOTALS ALL TONNAGE RANGES	LOSSES AND CASUALTIES PER SHIP YEAR AT RISK
LESS THAN 1600	5	3	14	2	13	0	14	0	51		
1600 - 3999	21	9	26	12	30	0	20	1	119		
4000 - 9999	12	6	21	1	25	0	18	0	83	862	.0177
10000 - 19999	9	2	17	0	15	0	11	0	54		
OVER 20000	54	41	135	8	209	0	106	2	555		

DECEMBER 1987 DRMB

Appendix C

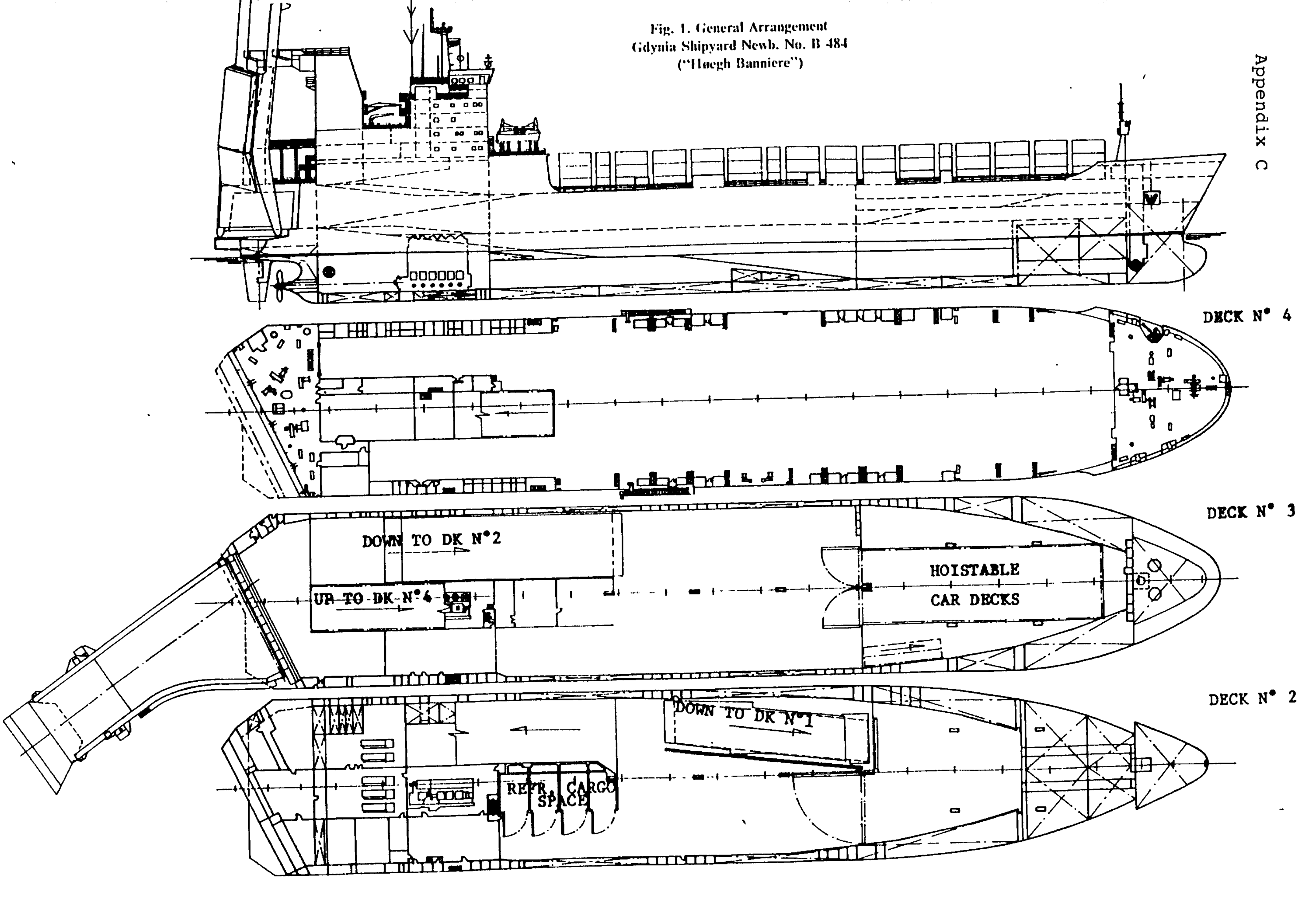

Fig. 1. General Arrangement
Gdynia Shipyard Newb. No. B 484
("Høegh Banniere")

Appendix D

SUBDIVISION STANDARD

In the following an investigation of subdivision standard according to IMO draft regulations (ref. IMO SLF 32/21 annex 2) is presented.

The investigation is to a large extent based on previously carried out calculations which means that some of the calculation preconditions deviate from the IMO preconditions.
(On a case by case basis deviations have been evaluated)

Nevertheless, the findings can be considered to represent today's subdivision standard calculated according to outlined IMO regulations.

Calculation of attained subdivision index A is based on:

- Damage stability booklet, DWG no. AC-B007 of 1st Dec 1986 (issued 890930/stamp)

Deviations between these calculations and the preconditions of the IMO draft regulations are:

Permeability in cargo holds are assumed to be 0.6 instead of 0.7 as in the IMO draft. This difference could influence the value of A (for damage cases with residual stability resulting in Si = 0.99, approximately or margin line close to water line).

Initial intact conditions being presented in the damage stability booklet are full load and ballast condition. In the IMO draft, full load condition and partial load condition should be calculated. Experience show that the full load condition is the severe condition, in general.

Consequently, the part load condition cases is assumed to have similar residual stability characteristics as the final condition cases.

In fig. 1 below the vessels subdivision arrangement is shown.
As can be seen in figure 1, twelve (12) fictitous damage zones (compartments) limited by bulkheads bounding either inboard or wing compartments have been used when calculating index A.

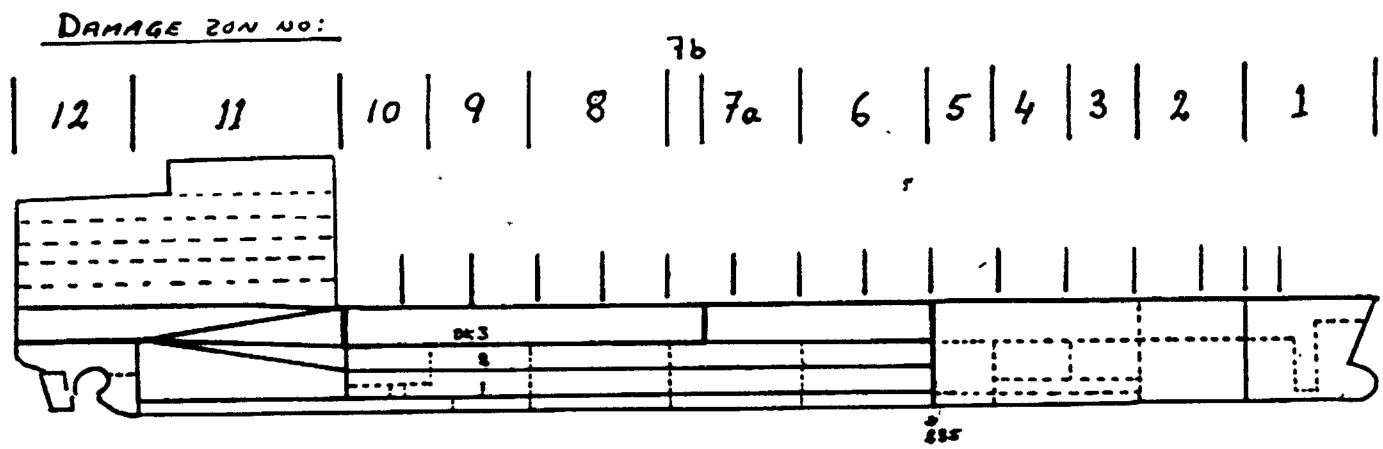

Fig. 1

In the above referred damage stability booklet only 8 different damage cases are presented of all cases (at least 24) being possible.
But, the damage cases in the damage stability booklet are conservative as they generally include "two compartment" (2 damage zones) damages. Based on the results of these damage cases assumptions on for example "one compartment" damages have been made.

CALCULATION RESULTS

The following ship particulars have been used:

Subdivision length	Ls	=	290.5 m
Breadth	B	=	32.26 m
"Required" subdivision index	R	=	0.662

RESULTS

Attained subdivision index:

$A = 0.5\ A_F + 0.5\ A_P = 0.5 \times 0{,}6934 + 0.5 \times 0.832 = 0.7627$
(to be compared with outlined R = 0.662)

Detailed calculation results are shown in the table below.
Please note that damages in the following zones result in S = 0 (for ro-ro space if vertical damage extend above deck no 3): (see figure 1).

Engine room (P), zone 11
Container/ro-ro hold flooded simultaneously, zone 5 + 6
Container hold plus forward of collision bulkhead, zone 1 + 2
Damage to "new" bulkhead of main dk, zone 7a + 7b

CALCULATION OF SUBDIVISION INDEX A

L 290.5
B 32.26 A= 0.6934 (FULL LOAD)
Lamda-max 0.1652

FULL LOAD CONDITION

"1 - COMPARTMENT DAMAGE"

COMP.	X1	X2	s	v	r	Pi	Ai	e	lamda	y	a	F	p	q
1	263.13	290.5	1.000	1.00	1.00	0.0826	0.0826	0.9528	0.0942	0.5701	1.2	0.9434	0.0435	0.0005
2	241.34	263.13	1.000	1.00	1.00	0.0346	0.0347	0.8682	0.0750	0.454	1.2	------	0.0289	0.0003
3	227.34	241.34	1.000	1.00	1.00	0.0152	0.0152	0.8066	0.0481	0.2915	1.2	------	0.0126	0.0000
4	213.35	227.34	1.000	1.00	1.00	0.0152	0.0152	0.7585	0.0481	0.2915	1.2	------	0.0126	0.0000
5	199.36	213.35	1.000	1.00	1.00	0.0152	0.0152	0.7103	0.0481	0.2915	1.2	------	0.0126	0.0000
6	172.78	199.36	1.000	1.00	1.00	0.0495	0.0496	0.6405	0.0915	0.5538	1.2	------	0.0413	0.0005
7a	143.64	172.78	1.000	1.00	1.00	0.0582	0.0583	0.5446	0.1002	0.6069	1.2	------	0.0485	0.0006
7b	130.26	143.64	1.000	1.00	1.00	0.0134	0.0134	0.4714	0.0460	0.2787	1.1543	------	0.0116	0.0000
8	102.28	130.26	1.000	1.00	1.00	0.0470	0.0471	0.4002	0.0963	0.583	1.0403	------	0.0452	0.0006
9	83.74	102.28	1.000	1.00	1.00	0.0195	0.0196	0.3201	0.0638	0.3862	0.9122	------	0.0214	0.0001
10	63.4	83.74	1.000	1.00	1.00	0.0205	0.0205	0.2532	0.0700	0.4237	0.8052	------	0.0254	0.0002
11	22.6	63.4	1.000	0.16	1.00	0.0544	0.0086	0.1480	0.1404	0.85	0.6368	------	0.0855	0.0017
12	0	22.6	1.000	1.00	1.00	0.0242	0.0242	0.0388	0.0777	0.4708	0.4622	0.0167	0.0308	0.0003
14	-	-	1.000	1.00	1.00	3E-17	0.0000	0	0	0	0.4	3E-17	0	0
15	-	-	1.000	1.00	1.00	3E-17	0.0000	0	0	0	0.4	3E-17	0	0

SUM: 0.4042

"2 - COMPARTMENT DAMAGE"

COMP.	X1	X2	s	v	r	Pii	Ai	e	lamda	y	a	F	p	q
1 + 2	241.34	290.5	0.000	1.00	1.00	0.1700	0.0000	0.9153	0.1692	1.0241	1.2	0.8984	0.1141	0.0029
2 + 3	227.34	263.13	1.000	1.00	1.00	0.0828	0.0329	0.8441	0.1231	0.7455	1.2	------	0.0690	0.0012
3 + 4	213.35	241.34	1.000	1.00	1.00	0.0542	0.0239	0.7826	0.0963	0.583	1.2	------	0.0452	0.0006
4 + 5	199.36	227.34	1.000	1.00	1.00	0.0542	0.0239	0.7344	0.0963	0.583	1.2	------	0.0452	0.0006
5 + 6	172.78	213.35	0.000	1.00	1.00	0.1017	0.0000	0.6646	0.1396	0.8453	1.2	------	0.0848	0.0017
6 + 7a	143.64	199.36	1.000	1.00	1.00	0.1640	0.0562	0.5903	0.1918	1.1607	1.2	------	0.1367	0.0040
7a + 7b	130.26	172.78	1.000	0.16	1.00	0.1088	0.0058	0.5215	0.1463	0.8857	1.2	------	0.0913	0.0019
7b + 8	102.28	143.64	1.000	1.00	1.00	0.0942	0.0337	0.4232	0.1423	0.8617	1.0772	------	0.0874	0.0018
8 + 9	83.74	130.26	1.000	1.00	1.00	0.1039	0.0373	0.3683	0.1601	0.9692	0.9893	------	0.1050	0.0025
9 + 10	63.4	102.28	1.000	1.00	1.00	0.0677	0.0277	0.2851	0.1338	0.81	0.8562	------	0.0791	0.0015
10 + 11	22.6	83.74	1.000	0.24	1.00	0.1076	0.0078	0.1830	0.2104	1.2737	0.6928	------	0.1553	0.0051
11 + 12	0	63.4	1.000	0.24	1.00	0.1056	0.0064	0.1091	0.2182	1.3208	0.5745	0.0531	0.1631	0.0056

SUM: 0.2555

"3 - COMPARTMENT DAMAGE"

COMP.	X1	X2	s	v	r	Piii	Ai	e	lamda	y	a	F	p	q
1+2+3	----	----	0.000	1.000	1.000	3E-17	0.0000	0	0	0	0.4	3E-17	0	0
2+3+4	213.35	263.13	0.000	1.000	1.000	0.1395	0.0000	0.8201	0.1713	1.037	1.2	------	0.1162	0.0030
3+4+5	199.36	241.34	1.000	1.000	1.000	0.1074	0.0141	0.7585	0.1444	0.8745	1.2	------	0.0895	0.0019
4+5+6	----	----	0.000	1.000	1.000	3E-17	0.0000	0	0	0	0.4	3E-17	0	0
5+6+7a	----	----	0.000	1.000	1.000	3E-17	0.0000	0	0	0	0.4	3E-17	0	0
6+7a+7b	130.26	199.36	1.000	0.157	1.000	0.2185	0.0006	0.5673	0.2378	1.4395	1.2	------	0.1827	0.0069
7a+7b+8	102.28	172.78	1.000	0.157	1.000	0.2132	0.0037	0.4734	0.2426	1.4687	1.1574	------	0.1876	0.0073
7b+8+9	83.74	143.64	1.000	1.000	1.000	0.1550	0.0040	0.3913	0.2062	1.2480	1.0261	------	0.1511	0.0048
8+9+10	63.4	130.26	1.000	1.000	1.000	0.1634	0.0113	0.3333	0.2301	1.393	0.9333	------	0.1750	0.0064
9+10+11	22.6	102.28	0.000	1.000	1.000	0.1630	0.0000	0.2149	0.2742	1.66	0.7439	------	0.2192	0.0099
10+11+12	0	83.74	1.000	0.238	1.000	0.1589	0.0000	0.1441	0.2882	1.7445	0.6306	0.0742	0.2331	0.0111

SUM: 0.0337

CALCULATION OF SUBDIVISION INDEX A

L 290.5
B 32.26 A= 0.8320 (PART LOAD)
Lamda-max 0.1652

PART LOAD CONDITION

"1 - COMPARTMENT DAMAGE"

COMP.	X1	X2	s	v	r	Pi	Ai	e	lamda	y	a	F	p	q
1	263.13	290.5	1.000	1.00	1.00	0.0826	0.0826	0.9528	0.0942	0.5701	1.2	0.9434	0.0435	0.0005
2	241.34	263.13	1.000	1.00	1.00	0.0346	0.0347	0.8682	0.0750	0.454	1.2	------	0.0289	0.0003
3	227.34	241.34	1.000	1.00	1.00	0.0152	0.0152	0.8066	0.0481	0.2915	1.2	------	0.0126	0.0000
4	213.35	227.34	1.000	1.00	1.00	0.0152	0.0152	0.7585	0.0481	0.2915	1.2	------	0.0126	0.0000
5	199.36	213.35	1.000	1.00	1.00	0.0152	0.0152	0.7103	0.0481	0.2915	1.2	------	0.0126	0.0000
6	172.78	199.36	1.000	1.00	1.00	0.0495	0.0496	0.6405	0.0915	0.5538	1.2	------	0.0413	0.0005
7a	143.64	172.78	1.000	1.00	1.00	0.0582	0.0583	0.5446	0.1002	0.6069	1.2	------	0.0485	0.0006
7b	130.26	143.64	1.000	1.00	1.00	0.0134	0.0134	0.4714	0.0460	0.2787	1.1543	------	0.0116	0.0000
8	102.28	130.26	1.000	1.00	1.00	0.0470	0.0471	0.4002	0.0963	0.583	1.0403	------	0.0452	0.0006
9	83.74	102.28	1.000	1.00	1.00	0.0195	0.0196	0.3201	0.0638	0.3862	0.9122	------	0.0214	0.0001
10	63.4	83.74	1.000	1.00	1.00	0.0205	0.0205	0.2532	0.0700	0.4237	0.8052	------	0.0254	0.0002
11	22.6	63.4	1.000	1.00	1.00	0.0544	0.0545	0.1480	0.1404	0.85	0.6368	------	0.0855	0.0017
12	0	22.6	1.000	1.00	1.00	0.0242	0.0242	0.0388	0.0777	0.4708	0.4622	0.0167	0.0308	0.0003
14	-	-	1.000	1.00	1.00	3E-17	0.0000	0	0	0	0.4	3E-17	0	0
15	-	-	1.000	1.00	1.00	3E-17	0.0000	0	0	0	0.4	3E-17	0	0

SUM: 0.4501

"2 - COMPARTMENT DAMAGE"

COMP.	X1	X2	s	v	r	Pii	Ai	e	lamda	y	a	F	p	q
1 + 2	241.34	290.5	0.000	1.00	1.00	0.1700	0.0000	0.9153	0.1692	1.0241	1.2	0.8984	0.1141	0.0029
2 + 3	227.34	263.13	1.000	1.00	1.00	0.0828	0.0329	0.8441	0.1231	0.7455	1.2	------	0.0690	0.0012
3 + 4	213.35	241.34	1.000	1.00	1.00	0.0542	0.0239	0.7826	0.0963	0.583	1.2	------	0.0452	0.0006
4 + 5	199.36	227.34	1.000	1.00	1.00	0.0542	0.0239	0.7344	0.0963	0.583	1.2	------	0.0452	0.0006
5 + 6	172.78	213.35	0.000	1.00	1.00	0.1017	0.0000	0.6646	0.1396	0.8453	1.2	------	0.0848	0.0017
6 + 7a	143.64	199.36	1.000	1.00	1.00	0.1640	0.0562	0.5903	0.1918	1.1607	1.2	------	0.1367	0.0040
7a + 7b	130.26	172.78	1.000	1.00	1.00	0.1088	0.0372	0.5215	0.1463	0.8857	1.2	------	0.0913	0.0019
7b + 8	102.28	143.64	1.000	1.00	1.00	0.0942	0.0337	0.4232	0.1423	0.8617	1.0772	------	0.0874	0.0018
8 + 9	83.74	130.26	1.000	1.00	1.00	0.1039	0.0373	0.3683	0.1601	0.9692	0.9893	------	0.1050	0.0025
9 + 10	63.4	102.28	1.000	1.00	1.00	0.0677	0.0277	0.2851	0.1338	0.81	0.8562	------	0.0791	0.0015
10 + 11	22.6	83.74	1.000	0.24	1.00	0.1076	0.0078	0.1830	0.2104	1.2737	0.6928	------	0.1553	0.0051
11 + 12	0	63.4	1.000	1.00	1.00	0.1056	0.0270	0.1091	0.2182	1.3208	0.5745	0.0531	0.1631	0.0056

SUM: 0.3073

"3 - COMPARTMENT DAMAGE"

COMP.	X1	X2	s	v	r	Piii	Ai	e	lamda	y	a	F	p	q
1+2+3	----	----	0.000	1.000	1.000	3E-17	0.0000	0	0	0	0.4	3E-17	0	0
2+3+4	213.35	263.13	1.000	1.000	1.000	0.1395	0.0176	0.8201	0.1713	1.037	1.2	------	0.1162	0.0030
3+4+5	199.36	241.34	1.000	1.000	1.000	0.1074	0.0141	0.7585	0.1444	0.8745	1.2	------	0.0895	0.0019
4+5+6	----	----	0.000	1.000	1.000	3E-17	0.0000	0	0	0	0.4	3E-17	0	0
5+6+7a	----	----	0.000	1.000	1.000	3E-17	0.0000	0	0	0	0.4	3E-17	0	0
6+7a+7b	130.26	199.36	1.000	1.000	1.000	0.2185	0.0039	0.5673	0.2378	1.4395	1.2	------	0.1827	0.0069
7a+7b+8	102.28	172.78	1.000	1.000	1.000	0.2132	0.0236	0.4734	0.2426	1.4687	1.1574	------	0.1876	0.0073
7b+8+9	83.74	143.64	1.000	1.000	1.000	0.1550	0.0040	0.3913	0.2062	1.2480	1.0261	------	0.1511	0.0048
8+9+10	63.4	130.26	1.000	1.000	1.000	0.1634	0.0113	0.3333	0.2301	1.393	0.9333	------	0.1750	0.0064
9+10+11	22.6	102.28	0.000	1.000	1.000	0.1630	0.0000	0.2149	0.2742	1.66	0.7439	------	0.2192	0.0099
10+11+12	0	83.74	1.000	0.238	1.000	0.1589	0.0000	0.1441	0.2852	1.7445	0.6306	0.0742	0.2331	0.0111

SUM: 0.0745

DAMAGE IN ZONE 1

Estimated volume being flooded:
(FP-tank + Deep tk) x 1.1 = 1692 m^3

Weight	:	1735 tonnes 8 fr LCF: 130 m
Trim moment	:	225,550 ton x m
MTC	:	1760 ton x m/cm trim
TPC	:	85 ton/cm immersion
Mean draught	:	11.55 + 0.2 = 11.75 m
Trim	:	+128 cm (+ = forward, − = aft trim)
Draught forward	:	~ 12.5 m

The conclusion is that no problems with immersion of margine line will appear.

s = 1.0 (all conditions)

DAMAGE IN ZONE 2 AND 3

Flooded compartments:
- Container hold
- No. 1 upp WG TK
- No. 1 lwr WG TK
- No. 2 upp WG TK
- No. 2 lwr WG TK

Ref. to damage case no 1 in the Damage Stability Booklet.
This is a "2-comp." damage.

Resulting damage case particulars: (Permeability = 0.6)

Draught at L/2	:	12.2 m
Trim	:	5.2 m
Heel	:	18.68 degr.
TPC	:	74 tons/cm immersion
Flooded volume	:	(91400 - 80400)/1.025 = 11.000/1.025 = 10.730 m^3

M.L.-point	Distance water - m.L.
10	1.75
13	0.62
16	-0.33
18	1.34

MTC: ((89731 - 84549) x 75) / (426-166)= 1495 ton x m/cm

Consequence of permeability = 0.7

Wingtank volume: (1193,9 + 1238.0 + 0.9 (1182.6 + 1439.6)) x 0.95 = 4550 m^3

(upper w.tk not full)

Container hold volume: 10.730 - 4550 = 6180 m^3

Flooded volume would be; $4550 + \frac{7}{6} \times 6180 = 11760\ m^3$

that is additional weight of 1056 tons which means

Mean draught:	12.2 + (825/74)/100 = 12.2 + 0.14= 12.4 m
Trim:	5.2 + (825 x 75/1495)/100= 5.2 + 0.53 = 5.7 m
Heel:	18.68 x 7/6 = 21.8 degrees
GZ max:	0.25 x 6/7 = 0.21 m
Draught at FP:	15.2 m

Margine line additionally immersed 15.2 - 14.8 = 0.4 m forward gives the following points below waterline.

Margin point	Distance to w.l.
14	0.03
15	- 0.3
16	- 0.7
17	- 0.5
18	1.4

As the margin line represent the deck corner possible flooding point has been checked.

Only M.L-point 17 is outside (forward) the flooded volume and could result in additional flooding.
But, the water line would only "come in over the deck-side" approximately 1.5 m and in that region no flooding point/risk exist.

Conclusion		
	- Margin line,	OK
	- Residual stab,	OK
	- Heel $\leqslant$25	OK

DAMAGE (ZONE)	S-FACTOR
2	1.0
3	1.0
2 + 3	1.0

both full and part load condition

DAMAGE IN ZONE 4 AND 5

Ref. damage case no 2 in Damage Stability Booklet.

This is a "2-comp" damage

Damage case particulars:

Draught at L/2:	12.12 m
Trim :	4.1 m
Heel :	17.25 degr.

Flooded volume:	(89900 - 80400)/1.025 = 9270 m^3
Wingtank volume:	(1439 + 758 496)x 0.9 x 0.95 = 2300 m^3
Flooded cont. volume:	9270 - 2300 = 6970

Comparing the margin line distance to W.L for this case and the result of permeability 0.7 as evaluated for damage of zone 2 and 3 gives the conclusion that no flooding or immersion of margin line will occur.

Conclusion:	- Margin line	OK
	- Residual stab.	OK
	- Heel < 25	OK

DAMAGE (ZONE)	S-FACTOR
4	1.0
5	1.0
4 + 5	1.0
3 + 4	1.0

DAMAGE IN ZONE 3, 4 AND 5

Including zone 3 in the damage of zone 4 and 5 would mean additional flooding of No. 2 LWR WG TK (619 m^3).
Consequence of this is:

Displacement: 89900 + 619 x 1.025 = 90600 tonnes
Draught at L/2: 12.116 + (700/75 x 0.01 = 12.116 + 0.09 = 12.2 m

Compare damage case 1, zone 2 and 3.
Displacement: 91400
Volume of wing tanks (below "dk 3") open to the sea:
Damage zone 3,4 and 5: 758 + 496 + 619 = 1873 m^3
Damage zone 2 and 3 : 1193 + 619 = 1812 m^3

Heeling moment to be added to damage in zone 4 and 5 (case 2) due to flooding of No 2 LWR WG TK:
M_H = 619 x 1.025 x 0.95 x 10.69 = 6445 (t x m)

From the GZ-curve of damage case no 2 it is found that resulting heeling after adding zone 3 to damage of zone 4 and 5 is:

GZ = 6445/90600 = 0.07 m ⇒ <u>Heel = 20.5 degrees</u> (case 2 $\phi = 17.3°$)

<u>Conclusion</u>:
Damage in zone 3, 4 and 5 i.e. adding no. 2 LWR WG TK (619 m^3) to damage case 2 (zone 4 and 5) would result in a damage case no more severe than case no 1 (zone 2 and 3)

DAMAGE ZONE	S-FACTOR	COMMENT
3 + 4 + 5	1.0	Full and part load cond.
2 + 3 + 4	0	M.L. probably immersed Full load.
2 + 3 + 4	1.0	Part load condition

DAMAGE IN ZONE 6 AND 7a (CASE NO 3)

FINAL CONDITION PARTICULARS:

Draught at L/S	:	14.7 m
Trim	:	- 0.18 m
Heel	:	8.22 degrees

Flooded volume

- Wing tanks	:	(1101+632) x 0.95 = 16.46 m^3
- Cargo holds	:	(109080-80386)/1.025 - 1646 = 26350 m^3
TPC	:	87 tonnes/cm

Calculating heel due to filling of wingtanks only would give by added weight method and initial loading condition (displ: 80 386)

GZ x Displ = 1640 x 1.025 x 14.9 gives
GZ = 0.32 m → Heel equilization = 16 degrees
if flooding of wingtanks only.

Consequence of permeability 0.7

"Additional weight"	:	4500 tonnes
Draught at L/2	:	14.7 + 0.5 = 15.2 m

Distance between W.L - margin line is at all points > 2.9 m → no problem.

Conclusion:
- Heel, OK
- Residual stab., OK
- M.L., OK

DAMAGE (ZONE)	S-FACTOR	COMMENTS
6	1.0	Full and part load condition
7a	1.0	
6 + 7a	1.0	

DAMAGE IN ZONE 7b AND 8 (CASE NO 4)

FINAL CONDITION PARTICULARS:

Draught at L/2	:	14.7	m
Trim	:	-1.5	m
Heel	:	10.7	degrees

Flooded value:

- Wing tanks : $(1101 + 659) \times 0.95 = 1672\ m^3$
- Cargo holds : $(110800-80386)/1.025 - 1672 = 28000\ m^3$

"Additional weight" if permeability = 0.7

$(7/6 \times 28000 - 28000) \times 1.025 = 4800$ tonnes

Compare results from evaluation of damage in zone 6 and 7a.

CONCLUSION:

	DAMAGE (ZONE)	S-FACTOR
Both full and part load condition	7b	1.0
	8	1.0
	7b + 8	1.0

Damage in ZONE 7a and 7b.

Compare Damage Stability Booklet p. 64-65

Full load condition - M.L. not ok => s=0

Partload condition assumed s=1

DAMAGE IN ZONE 8 AND 9 (CASE NO 5)

As the initial loading condition and cargo hold volume flooded is the same as in the previous cases (zone 7b, 8, etc) being evaluated and margin line is more than 3.5 m above final waterline, the following conclusion is made: (both full and part load condition):

DAMAGE (ZONE)	S-FACTOR
8	1.0
9	1.0
8 + 9	1.0

DAMAGE IN ZONE 9 AND 10 (CASE NO 6)

Evaluation - compare cases above.

CONCLUSION: (Both full and part load condition)

DAMAGE (ZONE)	S-FACTOR
9	1.0
10	1.0
9 + 10	1.0

DAMAGE IN ZONE 7B, 8 AND 9 OR 8, 9 AND 10

By using the resulting GZ-curves from the two-compartment damage cases (No 4, 5 and 6) together with "added" heeling moment due to additional flooding of wing-tank gives a check on heeling angle.

If heeling angle is OK the additional weight of wingtank being flooded will not create any problems with regard to residual stability or margin line.

Zone 7b, 8, 9

Additional heeling moment: 608 x 1.025 x 14.52 = 9050 t x m

(No 6 WG Tk and case 4)

GZ = 9050/110800 = 0.08 m → Heel ~ 13 degrees

or

Heeling moment:

(No 5N WG Tk and case 5): 1101 x 1.025 x 14.96 = 16883

GZ = 16883/110220 = 0.15 → Heel ~ 12.5 degrees

Zone 8, 9 and 10

Additional heeling moment: (No 7 DO WG Tk and case 5)

MH = 283 x 1.025 x 15.03 = 4360 t x m

GZ = 4360/110220 = 0.04 → Heel ~ 9.5 degrees

or

Additional heeling moment (No. 5 WG Tk and case 6)

MH = 659 x 1.025 x 14.96 = 10.105 t x m

GZ = 10.105/109800 = 0.09 → Heel ~ 9.0 degrees

Conclusion "3-comp" damage:

- Residual stability, OK
- Margin line, OK
- Heel, OK
- Valid for both full and part load condition

DAMAGE (ZONE)	S-FACTOR
7b + 8 + 9	1.0
8 + 9 + 10	1.0

Damage in zone 7b, 8, 9 and 10

Additional heeling moment (No 5N WG Tk + No 7 WG Tk and case no 5).

MH = 1101 x 1.025 x 14.96 + 283 x 1.025 x 15.03 = 21243 t x m

GZ = 21243/111000 = 0.2 m → Heel ~ 15 degrees

Resulting lowering of margin line will be approximately 2 m but no risk for immersion of flooding points.

CONCLUSION: S = 1.0

DAMAGE IN ZONE 11 (CASE 7 AND 8)

Damage in zone 11 (P) will result in flooding of ro-ro space dk 3 Fr. 44-115 and below dk 3 Fr 115-235 plus engine room (case 8).

Damage (S) will result in flooding of engine room plus ro-ro space dk 3 Fr 44-115 (case 7).

Case 7 → S = 1.0
Case 8 → S = 1.0 (Assumed for full load condition)
S = 1.0 Part load condition

COMMENTS:
ML points 4, 2 and 1 are immersed in case 8 (flooding below dk 3 ro-ro space, P.S-damage). The immersion is less than 0.4 m. Change of permeability (from 0.6 to 0.7) would result in approximately the following trim increase:

$$7/6\ (11.7 - 8.7) - 3.0\ \text{m} = 0.5\ \text{m}$$

Consequently M.L points 1-4 would be immersed about 1.0 m.

Although no clear description of the engine room compartment is given in the Damage Stability Booklet immersion of the flooding points is considered to give no consequence or could be taken care of design wise
Possible additional flooded volumes would be steering gear room, minor stores at dk 2 level etc.

Combined damage ro-ro/container space
Damage zone 7a, 7b and 8:
In full load condition S = 0
In part load condition S = 1.0

SUMMARY OF EVALUATION

COMPARTMENT	LOADING CONDITION FULL S	LOADING CONDITION PART S	
1	1.0	1.0	
2	1.0	1.0	
3	1.0	1.0	
4	1.0	1.0	
5	1.0	1.0	1-COMP
6	1.0	1.0	
7a	1.0	1.0	
7b	1.0	1.0	
8	1.0	1.0	
9	1.0	1.0	
10	1.0	1.0	
11	0*	1.0	
12	1.0	1.0	
1 + 2	0	0	
2 + 3	1.0	1.0	
3 + 4	1.0	1.0	
4 + 5	1.0	1.0	
5 + 6	0	0	2-COMP
6 + 7a	1.0	1.0	
7a + 7b	0*	1.0	
7b + 8	1.0	1.0	
8 + 9	1.0	1.0	
9 + 10	1.0	1.0	
10 + 11	0*	0*	
11 + 12	0*	1.0	
2 + 3 + 4	0	1.0	
3 + 4 + 5	1.0	1.0	
6 + 7a + 7b	0*	1.0	
7a + 7b + 8	0*	1.0	3-COMP
7b + 8 + 9	1.0	1.0	
8 + 9 + 10	1.0	1.0	
9 + 10 + 11	0*	0*	
10 + 11 + 12	0*	0*	

* Effect of limiting damage vertical extent to be evaluated.

LIMITING VERTICAL EXTENT OF DAMAGE

As some of the damage cases resulted in S = 0 if unrestricted vertical damage extent is assumed a limitation to the w.t. deck 3 is considered below.

The watertight deck no. 3 is positioned 12.7 m above BL (in engine room 13.5 m).

Full load draught: 11.6 m

$$v_1 = \frac{12.7 - 11.6}{7} = 0.1571 \quad \text{in cargo area}$$

$$v_1 = \frac{13.5 - 11.6}{7} = 0.2375 \quad \text{in engine room area}$$

Limiting vertical extent of damage below deck 3 level will result in S = 1.0 for the following cases:

Damage zone	11	full load
	7a + 7b	full load
	10 + 11	full and part load
	11 + 12	full load
	6 + 7a + 7b	full load
	7a + 7b + 8	full load
	10 + 11 + 12	full and part load