THE EVOLUTION OF THE REGULATORY STABILITY REGIME FOR FISHING VESSELS

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ABSTRACT

The intact stability standards for fishing vessels are considered in their historical development, all fairly recent. Regional differences, that result in the average size of vessels, are considerable together with an extremely poor harmonization of the different regimes of safety. A decisive effort for improvements in the safety levels and in general in the living conditions in the fisheries sector has been undertaken in the frame of the close cooperation established between the IMO, ILO and FAO. In this context, are at an advanced stage of development regulations, mostly of voluntary application, which greatly extend the lower extreme of the interval of ship lengths previously considered by the Torremolinos Convention. With regard to the latter, a major effort is underway to get to the ratification and entry into force internationally as an IMO instrument of the revised Torremolinos Protocol as it results after the Diplomatic Conference held in Capetown in 2012. In this review paper, present situation is critically analyzed also in the light of the contributions given by the research group operating at University of Trieste.

Keywords: fishing vessel; stability; IMO, capsizing; stability criteria

RESUMEN

En este trabajo se consideran las normas de estabilidad sin avería de los buques pesqueros en su desarrollo histórico, todo bastante reciente. Las diferencias regionales, que se traducen en el tamaño medio de los buques, son pesadas y un impulso decisivo para la mejora de la seguridad y de las condiciones generales de vida en el sector de la pesca viene de la estrecha cooperación establecida entre la OMI, la OIT y la FAO. En este contexto, se encuentran en una etapa avanzada de desarrollo normativas, en su mayoría de aplicación voluntaria, que amplían en gran medida los intervalos inferiores de las esloras de aplicación previamente consideradas por el Convenio de Torremolinos. Con respecto a esto último, un importante esfuerzo es en curso para llegar a la ratificación y entrada en vigor a nivel internacional del Torremolinos Protocolo, como revisado después de la Conferencia Diplomática de Ciudad del Cabo, como un instrumento de la OMI. En esta memoria de revisión, la situación actual se analiza críticamente también a la luz de las contribuciones dadas por el grupo de investigación de la Universidad de Trieste.

Palabras clave: buque pesquero; estabilidad; OMI; zozobre; criterios de estabilidad

INTRODUCTION – THE FRAMEWORK

First of all, what is a fishing boat. According to the SOLAS (International Convention for the Safety of Life at Sea) **"***Fishing vessel is a vessel used for catching fish, whales, seals, walrus or other living resources of the sea***".** Apart from considerations based on the modern ecological feeling concerning the capture of whales, seals and walruses (the European Council Directive 97/70 [1] gives the following definition: "*fishing vessel" or "vessel" means any vessel equipped or used commercially for catching fish or other living resources of the sea***),** it should be noted that the fishing boats of various sizes are numerous and contribute with a heavy toll to the mortality at sea. There is no complete agreement on the number of vessels among the various sources because most small boats belonging to developing countries often escape official statistics. These vessels often escape also to any type of security verification [2]. Following Yamada [3], the number of vessels with a length of 24 m and over can still be estimated in about 60,000 units. This number is comparable with that of vessels subject to SOLAS. Going to the total number, instead, it is estimated to be a few million units including undecked vessels [4]. FAO [5] estimates that the global fishing fleet consists, indeed, of some 1.3 million decked and 2.8 million undecked vessels. From this comparison it is easy to understand the extent of the problem as the safety regulations relating to capsizing and sinking until recently almost exclusively concerned fishing vessels of 24 meters in length and over (some extending to 45 m and over). The mortality rate is estimated in approximately 20,000 units per year, in particular for small boats. The Occupational Safety and Health Branch of the ILO [6] estimated that the fishery sector has worldwide an annual mortality of about 80 per 100,000 people, with several million non-fatal accidents each year. During the same period, the mean annual mortality of employed people was estimated to be 14.5 per 100,000 workers, thus classifying the fishing sector among the high-risk occupations. The difference is even more striking if one considers for example the figures of an highly developed country like USA. In the report given in [7], it is reconfirmed that "Commercial fishing is one of the most dangerous occupations in the United States. During 1992–2008, an annual average of 58 reported deaths occurred (128 deaths per 100,000 workers), compared with an average of 5,894 deaths (four per 100,000 workers) among all U.S. workers." . Although the absolute number is low and the rate of fatalities is reported as constantly declining over the years, also due to measures taken by the USCG, it is impressive to note that in the East Coast peaks up to 3÷4 times the average are observed. Of course, there are strong regional differences both in ship size and consequent distribution of safety. For example, following Gudmundsson [5], Asia has the 85% of undecked fishing vessels, the 50% of decked and the 85% of fishermen, against 8.9, 21 and 7.5% of Europe, while the figures of South America are 0.2, 6 and 2.3 respectively.

Given this significant incidence of accidents, the regulatory framework for the fishing vessels, however, is very poor, at least with regard to *mandatory* international regulations (none as per today). Let's start first with the observation that the two main instruments prepared by IMO (the International Maritime Organization is the United Nations agency for maritime safety and the protection of the marine environment):

- the International Convention on Load Lines (ILLC) fixing, inter alia, the minimum freeboard and consequently the reserve of buoyancy;

and

- the International Convention on Safety of Life at Sea (SOLAS), which contains, inter alia, the regulations of subdivision and damage stability;

do not apply to fishing vessels, although the International SOLAS Conference in 1960 recommended to the Contracting Governments to “transmit to the Organization information as to the extent to which they have found it practicable to apply the appropriate provisions of the Convention to fishing vessels, with a view to such information being disseminated to Contracting Governments and the FAO”.

In addition, vessels “solely engaged in fishing” are not required to comply with the IMO Ship Identification Number Scheme (IMO Res. A.600), although several Countries do it. As per 2012 the total number of active fishing vessels of 24 metres in length and over with IMO number just exceeded 15,000 units.

IMPORTANCE OF STABILITY REGULATIONS TO IMPROVE SAFETY IN THE FISHERIES SECTOR

Schematically speaking, the two principal mechanisms leading to ship loss are: sinking, due to insufficient or loss of floatability, and capsizing, due to insufficient or loss of stability. The two concepts were known since ancient times and considered both by Archimedes. The first one is presently regulated through two different instruments: the freeboard (through the relevant International Convention on Load Lines) and the subdivision (through the relevant Convention on Safety of Life at Sea). Elementary rules for freeboard were present to sailors long ago, national regulations appeared after Plimsoll, whereas the international freeboard rules started in 1930. Standards of subdivision were almost contemporary to freeboard at national level, although the first international SOLAS Conference was called only in 1914 after the sinking of Titanic. As we have described elsewhere [8], stability provisions related to survivability after damage have been introduced in SOLAS well after the completion of the factorial subdivision regulation, starting with the 1948 Conference and reaching maturity only with 1990. In turn, the request of intact stability regulations came even later and only after relevant recommendations made during SOLAS Conferences.

These two mechanisms are responsible for a great part of death toll at sea. Analysing the 3,212 ship disasters (all ship types) happened in Japan in the period 1973/1977, Takaishi [9] identified 448 cases of flooding and capsizing. One third of this number was relative to fishing vessels with a total of 86 cases of ship capsize. The most relevant phenomena originating capsize were in decreasing order of importance: shipping of water on deck, top-heavy, cargo shift and overloading. In this study Takaishi discovered that for fishing vessels the case of following/quartering waves is almost twice more dangerous than from other ships. Incidentally, this was the starting point for the development of MSC Circular 707 on “Guidance to the Master for Avoiding Dangerous Situations in Following and Quartering Seas” adopted by IMO in 1995 [10] and later on superseded by MSC.1/Circ. 1228 [11].

The first IMCO Resolution (A. 52 of 1963) concerning the stability of fishing vessels revealed that, also due to the interaction with FAO, with which a formal agreement was close (it will be concluded soon as contained in Res. A.103 of 1965, together with the tri-partite with ILO and FAO, contained in Res. A. 116, same year) this subject “should continue with all possible speed”. This decision was stressed again two years later with the objective of “formulating acceptable standards for the intact stability of fishing vessels”, after having “noted with satisfaction” both “the establishment of a Panel of Experts on Stability of Fishing Vessels” and “the close co-operation with FAO”.

The first formulation of international recommended criteria for Intact stability for fishing vessels was indeed adopted in 1968 with IMCO Resolution A.168, for fishing vessels of 24 metres in length and over, developed in parallel to the A.167 for passenger and cargo ships under 100 metres in length. The first left the status of recommendation forty years later with the completion of the International Intact Stability Code in 2008 and its inclusion as mandatory instrument under SOLAS in 2010, while the second one has never gone beyond the level of a recommendation. It is notable to remind that SOLAS Conference in 1960 did not consider the state-of-the-art mature for the adoption of Intact Stability Criteria on the bases of the fact that "The Conference, having considered proposals made by certain Governments to adopt as part of the present Convention Regulations for intact stability, concluded that further study should be given to these proposals and to any other relevant material which may be submitted by interested Governments". In Recommendation 7, the Conference therefore recommended "that the Organization should at a convenient opportunity, initiate studies, on the basis of the information referred to above, of: (a) intact stability of passenger ships, (b) intact stability of cargo ships, (c) intact stability of fishing vessels, and (d) standards of stability information, …". Hence IMCO Resolutions A.167 and A.168.

The successive SOLAS Conference, held in 1974 considered the need of further developments of the intact stability provisions for SOLAS ships, as it is indicated in the Resolution 1, noting that the Res. A.167, as amended by Res. A.206, may not always be appropriate especially in relation to new types of ships of novel design and construction, and that in some cases special provisions may be required in respect of the intact stability of ships of 100 metres in length or more. The Conference "recommends that steps be taken to formulate improved international standards on intact stability of ships taking into account, inter alia, external forces affecting ships in a seaway which may lead to capsizing or to unacceptable angles of heel". After ten years studying and tuning the different proposal, IMO adopted the Weather Criterion as Res. A. 562 in 1985.

Actually, although not very known, different versions of what was later on the Weather Criterion were presented as early as SOLAS'60 by the delegations of URSS and Japan [12]. No definite conclusion was reached in the course of discussions except the generic recommendation previously reported, but it is noteworthy that already in 1977 the first Weather Criterion appeared in an international event organized by IMCO. This was the International Conference on Safety of Fishing Vessels held in Torremolinos in 1977 [13] which led to the homonymous Torremolinos Convention. This Conference was characterised by a very strong impulse to improve safety in the fishing sector and also due to the high level of the participants, resulted in a very complete and thorough set of rules covering the fishing vessels of 24 metres in length and over (with some provisions applicable to vessels of 45 metres in length and over).

This was the first international event explicitly containing Intact Stability Criteria. It was a very complete set of regulations and it remains even today unequalled by other instruments. Unfortunately, this is very likely also the reason why it never entered into force due to the lack of sufficient ratifications. Quoting a private communication by Cleary, however Womack [14] gives a different explanation: "The criteria were not intended to be representative of fishing vessels. It was for all ships. Sometime in the 1960's it became the basis of European Stability criteria for all ships even though it had a very small foundation. Then it was adopted & modified (increased) for fishing vessels in Europe and has been there by default ever since. The principal reason the Torremolinos Convention failed to 'come into force' was that European boats (and rules based on European or their derivative designs) were so different from Japan's fleet of long slender boats that the 24 m length requirement as a single item was not acceptable to Japan. Japan wanted 24m and 150 Gross tons-a double requirement. When this was not accepted by the rest of the nations, Japan's FV fleet instantly became the world's largest fleet by about 20,000 boats. When Japan did not ratify, the Convention was an automatic nonstarter."

At this point, there was a bifurcation in the progress concerning fishing vessels in this range of lengths, with a clear divergence between the results of the scientific and technological research and the activity of the tri-partite International Bodies, IMCO (now IMO)-FAO-ILO. This activity, indeed, clearly turned towards the preparation and adoption of instruments, mostly of diplomatic type, to facilitate the adoption of the Torremolinos Convention. The first of these was a Protocol adopted during the 2nd Torremolinos Conference, called in 1993 [15]. This also underwent the same lack of ratifications as the Convention. From the point of view of the subject of this paper, the Protocol introduced only minor changes to the intact stability provision contained in the Convention. The subsequent history of Torremolinos Protocol involves no technical developments. The reader interested in it can find a notable summary in Ref. [5] covering the period up to 2006, while the subsequent developments will be summarized later on in this paper.

Contemporarily, the work of the three Organizations continued towards the development of intact safety instruments, including relevant intact stability provisions, for smaller fishing vessels. Following the adoption of the Torremolinos Protocol of 1993 relating to the Torremolinos International Convention for the Safety of Fishing Vessels, 1977, the Maritime Safety Committee of IMO undertook the review of the FAO/ILO/IMO Code of Safety for Fishermen and Fishing Vessels, Part A and Part B [16]. At the same time, it also decided to review the Voluntary Guidelines for the Design, Construction and Equipment of Small Fishing Vessels [17]. Successively, the Safety Recommendations for Decked Fishing Vessels of Less than 12 meters in Length and Undecked Fishing Vessels were developed [18]. The last two instruments are intended to cover small fishing vessels respectively in the range of lengths 12÷24 metres and 6÷12 metres. The adoption of the terms "voluntary" and recommendations" is to be noted.

The different intact stability criteria outlined above will be introduced and briefly discussed technically together with some alternatives proposed in the course of the years. Particular attention will be given to the present state-of-the-art concerning the fishing vessels of different sizes in comparison with the regulations existing and under development for other ship types and the contributions of the research group operating at University of Trieste in the discussion of the validity/applicability of the proposed criteria.

THE INTACT STABILITY CRITERIA FOR PASSENGER AND CARGO SHIPS

Yet, a study was conducted in 1939 by Rahola [19], which, through a survey of a (limited) number of incidents, quantified the minimum requirements in terms of initial stability, static and dynamic stability at large angles of heeling, that a ship had to possess for not capsizing. The IMCO Res. A.167 is the translation in regulation of this study with some modifications.

Again in 1935 Pierrottet [20] posed the bases for the energy balance that led in the fifties to the formulation of the Japanese criterion [21] which in turn was the basis for the Weather Criterion adopted by IMO in 1985 as Res. A.562.

Both criteria have been modified several times over the years, but until 2010 were not mandatory at international level (were "recommendations"), although they were such in several national rules.
In 2008 the review of the Intact Stability Code was terminated, leading to the adoption of the International Code of Intact Stability, 2008. The new code came into force under the International Convention SOLAS in 2010 and therefore "mandatory" for most of the ships above the 24 m long. For more details on the new code, historical and critical notes, see [22,23].

The Criteria regarding righting lever curve properties (formerly General Criterion of Stability as per IMO Res. A.167)

This Criterion requires that a ship should meet all the following requirements (we assume that the notation is known to the reader):

a) $A(0,30°) \geq 0.055\ m \cdot rad$;

b) $A(0,\phi_1) \geq 0.09\ m \cdot rad$, being $\phi_1 = \min(40°, \phi_f)$ with ϕ_f the angle of downflooding;

c) $A(30,\phi_1) \geq 0.03\ m \cdot rad$;

d) The righting lever $\overline{GZ}$ shall be at least 0.2 m at an angle of heel equal to or greater than 30°;

e) The maximum righting lever shall occur at an angle of heel not less than 25°. If this is not practicable, alternative criteria, based on an equivalent level of safety, may be applied subject to the approval of the Administration. This alternative in the International Intact Stability Code was selected corresponding to the one already existing for Offshore Supply Vessels (and for passenger and cargo ships in several national regulations), i.e. it allows to reduce the angle of maximum down to 15° with an increasing compensation in area;

f) The initial metacentric height GM_0 shall not be less than 0.15 m.

In addition, both the angle of heel on account of crowding of passengers to one side and the angle of heel on account of turning shall not exceed 10°.

This criterion is based on the statistical analysis of a ship specimen. As such, it is difficult to be modified, it doesn't contain any direct relationship between requirements and mechanisms of ship loss and it is typically subject to obsolescence with the advent of new ship sizes or typologies.

The Severe wind and rolling criterion (weather criterion) (formerly IMO Res. A.582)

The ability of a ship to withstand the combined effects of beam wind and rolling shall be demonstrated, with reference to Fig. 1 as follows:

- .1 the ship is subjected to a steady wind pressure acting perpendicular to the ship's centerline which results in a steady wind heeling lever (ℓw_1);
- .2 from the resultant angle of equilibrium (ϕ_0), the ship is assumed to roll owing to wave action to an angle of roll (ϕ_1) to windward. The angle of heel under action of steady wind (ϕ_0) should not exceed 16° or 80% of the angle of deck edge immersion, whichever is less;
- .3 the ship is then subjected to a gust wind pressure which results in a gust wind heeling lever (ℓw_2); and
- .4 under these circumstances, area b shall be equal to or greater than area a, as indicated in Fig.1 below:

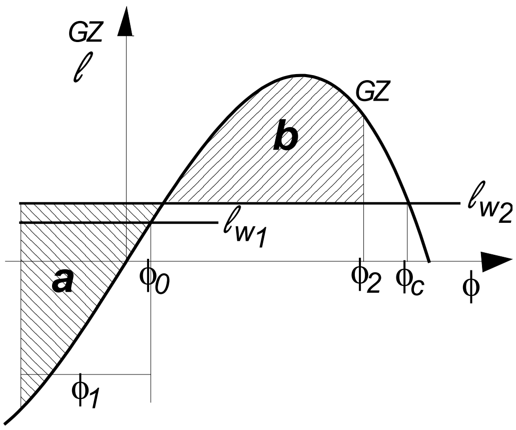

Fig 1. Diagram illustrating the application of the Weather Criterion.

The calculation of the heeling moment of the wind, of the roll angle due to waves, etc., is made following the complete formulation given in the text of the Code [24], to which reference is made.

This criterion is based on a physical approach and as such it contains a direct relationship between requirements and a particular, although important, mechanism of ship loss, i.e. the capsizing in dead ship condition. It contains, however, a number of empirical or adjusted parameters so that it is difficult to be modified, with the advent of new ship typologies. It is in the form of a "goal based rule", the goal being the non-exceeding of the angle ϕ_2 in the prescribed environment. Acknowledging the difficulties in the application to some modern ship typologies and the overestimate of wave heights at large periods of encounter, an alternative procedure on experimental basis was developed and adopted by IMO in 2006, as contained in the MSC.1/Circ.1200 and 1227.

Present developments (Second generation intact stability criteria)

In the terminology adopted at IMO [25]:

- *criterion* is a procedure, an algorithm or a formula used for judgement on likelihood of failure;
- *standard* is a boundary separating acceptable and unacceptable likelihood of failure; and
- *rule* (or *regulation*) is a specification of a relationship between a standard and a value produced by a criterion.
- *Intact stability failure* is a state of inability of a ship to remain within design limits of roll (heel, list) angle and combination of rigid body accelerations;
- Two types of intact stability failures are distinguished:
    1. *Total stability failure, or capsizing*, results in total loss of a ship's operability with likely loss of lives. Capsizing could be formally defined as a transition from a stable nearly upright equilibrium that is considered safe, or from oscillatory motions near such equilibrium, to another stable equilibrium that is intrinsically unsafe (or could be considered unacceptable from a practical point of view).
    2. *Partial stability failure* is an event that includes the occurrence of very large roll (heel, list) angles and/or excessive rigid body accelerations, which will not result in loss of the ship, but which would impair normal operation of the ship and could be dangerous to crew, passengers, cargo or ship equipment. Two subtypes of partial stability failure are intended to be included in the development:

Although the term stability strictly applies only to the condition for the initial stability of the upright position, it has become customary that this term indicates the set of regulations that guarantee the safety of the ship from capsizing. As such, they actually include a set of rules that would ensure a sufficient limitation of the maximum angle of heeling to be reached in the different cargo/environmental conditions.

In this frame, the so-called Second Generation Intact Stability Criteria is under development at IMO. These criteria are to large extent mechanism-specific so that they are based on physics and address the following stability failures:

- Stability failures under dead ship conditions;
- Stability failures in following seas associated with matters related to stability variation in waves, in particular reduced righting levers of a ship situated on a wave crest;
- Stability failures caused by parametric resonance, including consideration of matters related to large accelerations and loads on cargo and stability variation in waves;
- Stability failures caused by broaching including consideration of matters related to manoeuvrability and course keeping ability as they affect stability; and
- Problems related to excessive accelerations.

In the work undertaken at IMO it was considered more appropriate to adopt a multi-tier approach, based on 1st and 2nd level vulnerability check eventually followed by a direct assessment, for each failure mode, to avoid excessive application of the third level, i.e. straightforward application of direct assessment, in view of its likely high complexity and consume of time. Operational Guidance/Operational Limitations can be developed for ships not passing the third level or for which it is unpractical to go to this level.

THE INTACT STABILITY REGULATIONS FOR FISHING VESSELS IN RELATION TO THEIR SIZE

Provisions presently included in the International Code on Intact Stability, 2008

The provisions contained in the International Code on Intact Stability 2008 refer to ships of 24 metres in length and over. The intact stability criteria for fishing vessels currently contained in the Code refer to the Torremolinos Protocol merged with IMO Res. A.207 introducing in 1971 “recommendations for an Interim Simplified Criterion for Decked Fishing Vessels under 30 meters in length”. It is important to remember that the Protocol restricts the binding force of regulations to vessels with a length of 45 m and more, while the ability to make the implementation of the safety regulations to vessels with a length between 24 and 45 m is assigned to agreements region. In this sense, for example, has moved the European Union which, with the Directive 97/70/EC of 11 December 1997, adopted an harmonized system of safety for vessels with a length of 24 m and more [1]. This Directive has been amended by 2002/35/EC of 25 April 2002 that extended to vessels of lengths in the range 24÷45 certain regulations previously limited to vessels with a length of 45 m and more.

The differences between the Torremolinos Protocol and the Code for cargo and passenger ships are mainly related to:

- the standard e) of the Criteria regarding righting lever curve properties fixing minimum angle for the maximum righting lever. This remains fixed to the old rule, stating “the maximum righting arm should occur at an angle of heel preferably exceeding 30° but not less than 25°", and no reduction with compensation in area is possible;

- the standard f) of the Criteria regarding righting lever curve properties fixing the minimum metacentric height "which, for fishing vessels, should not be less than 0.35 m for single-deck vessels. In vessels with complete superstructure or vessels of 70 m in length and over the metacentric height may be reduced to the satisfaction of the Administration but in no case should be less than 0.15 m." in partial modification of A.168;

- the Weather Criterion mainly concerning the table of values of wind pressure, to be used for the determination of the arms ℓw_1 and ℓw_2, which can be reduced in relation to the modest elevation of these vessels on the waterline. No alternative assessment on experimental basis is allowed, in spite of the generally high values of B/T and of the fact that the basic formulas have been developed and tunes for other ship typologies. Concerning the applicability of the Weather Criterion, this was undefined in Torremolinos Convention (1973), a lower limit of 45 metres for fishing vessels was indicated in Res. A.562 (Recommendation on a Severe wind and rolling criterion (weather criterion)… "which is also recommended for fishing vessels of 45 metres in length and over in unrestricted service", 1985) and in the subsequent Res. A.749 (Code on Intact Stability for All Types of Ships Covered by IMO Instruments, 1993), whereas the Res. A.685 (Weather Criterion for Fishing Vessels of 24 metres in length and over, 1991) recommended its application from 24 metres, so creating a possible conflict. Torremolinos Protocol adopted Res. A.685, so extending the application of Weather Criterion to fishing vessels down to 24 metres.

- no provision is included concerning accumulation of crew on side or heeling in turning. Furthermore, the calculation methodology for the correction of initial metacentric height and righting levers due to the effect of liquids with free surface present on board is still based on the table of factor "k" in Torremolinos Protocol, whereas the methodology included in the Code has been completely restructured (for cargo, passenger vessels and also for the other ship typologies included in part B of the Code), so creating again a possible conflict.

Recommendation for an interim simplified stability criterion for decked fishing vessels under 30 m in length

This was developed as early as 1971 as IMO Res. A.207 to take into account the great variety of typologies of fishing vessels and the fact that for a great majority of vessels in this range design drawings and stability information is hardly available. It is presently included in Part B of the Code (non-mandatory) and went never out of the position as "interim". A series of "warnings" concerning its application, indeed, are included in the text of this regulation. Later on it was incorporated in the voluntary guidelines for small fishing vessels.

Provisions for fishing vessels between 12 and 24 metres in length

Currently IMO, ILO and FAO together are conducting a concentric attack to the problem of safety of vessels based on the revision of existing provisions and development of new ones for fishing vessels of length smaller than 24 metres.

It has been in particular completed the revision of the "Voluntary Guidelines for the Design, Construction and Equipment of Small Fishing Vessels" [17]. The purpose of these guidelines is to provide information on the design, construction, and equipment of small fishing vessels with a view to promoting the safety of the vessel and safety and health of the crew. They are not intended as a substitute for national laws and regulations but may serve as a guide to those concerned with framing such national laws and regulations. The Guidelines apply to vessels with lengths in the range 12 ÷ 24 m. In Chapter 2 it extends the application of the general criterion of stability to vessels under 24 meters in length. Wherever practicable, guidance should be provided for an approximate determination of the vessel's stability by means of the rolling period test including values of rolling coefficients particular to the vessel. The main difference with respect to A.168, consists in the standard d), for which there is an attenuation: "the righting lever GZ should be at least 200 mm at an angle of heel equal to or greater than 30°. The righting lever GZ may be reduced to the satisfaction of the competent authority but in no case by more than $2 \cdot (24 - L)\%$". For vessels intended for operation in areas where exceptionally adverse weather condition may be experienced, special attention should be given to the capability to withstand the capsizing effects of breaking waves. In order to demonstrate ability to withstand such effects, the competent authority should give consideration to the benefits of enclosed deck erections which may provide an improved range of positive stability to larger angels of heel with openings assumed closed weathertight. A positive range of stability up to an angle of 80° may be used as a criterion. Alternatively, the Severe wind and rolling criterion (weather criterion) for fishing vessels may be used. An early formulation of these Guidelines was completed in 1979, but it was recognized that its stability criteria proposed, in particular, required further study before a definitive formulation.

Provisions for fishing vessels of less than 12 metres in length

Furthermore, also the "Revised FAO / ILO / IMO Code of Safety for Fishermen and Fishing Vessels, 2005" [20], divided into Part A dedicated to masters and crews and Part B dedicated to builders and owners of fishing vessels was completed. The first version of Part A was approved in 1968 and subsequently amended. Part B was prepared in 1975 and then subject to revision as required under the Torremolinos Convention of 1977. This is a very comprehensive text, which covers in detail all aspects of safety for vessels above and below 12 m. Part A includes a description of the method to determine the metacentric height from the rolling period and the information to the master referred to MSC Circ.707 [10]. Part B contains the general criterion of stability for vessels and also provides the capability to survive the combined action of wind and sea;

- Development of the "Safety Recommendations for Decked Fishing Vessels of Less than 12 m in Length and Undecked Fishing Vessels" [21]. In this regulation the fishing vessels are divided in four design categories. The categories indicate sea and wind conditions for which a vessel is assessed by this standard to be suitable, provided the vessel is correctly operated and at a speed appropriate to the prevailing sea state.
- Design category A concerns the vessels considered suitable to operate in seas with significant wave heights above 4 m and wind speeds in excess of Beaufort Force 8 (19 m/s), but excluding abnormal conditions, e.g., hurricanes;
- Design category B concerns the category of vessels considered suitable to operate in seas with significant wave heights up to 4 m and winds of Beaufort Force 8 (19 m/s) or less.;
- Design category C concerns the vessels considered suitable to operate in seas with significant wave heights up to 2 m and a typical steady wind force of Beaufort Force 6 (12 m/s) or less.;
- Design category D concerns the vessels considered suitable to operate in seas with significant wave heights up to and including 0.30 m with occasional waves of 0.5 m height, for example from passing vessels, and a typical steady wind force of Beaufort Force 4 (7 m/s) or less.

The stability criteria are different for the different categories and depending on whether it is a decked vessel or not. For decked vessels of all categories the stability standards are the same reported in Ref. [17]. Several alternatives are introduced for decked vessels and for undecked ones.

Different *speeds* in different times

As we have seen, at the beginning of IM(C)O existence, the safety of fishing vessels and in particular its part related to ship stability were considered items of high priority ("with all possible speed"). While the problems connected with damage and flooding were practically discarded in the frame of SOLAS'60, the attention to intact stability of fishing vessels was present in IMO Resolutions well before the intact stability of other ship types, passenger ships included.

This process culminated in the formulation of the Torremolinos Convention in 1977 for fishing vessels of 24 metres in length or over. The intact stability provisions included in this Convention were by far in advance with respect to the corresponding developments relating to cargo and passenger ships. It contained, in particular:

- a Weather Criterion in the same format later (8 years) adopted in IMO Res. A.562 for cargo and passenger ships. It was complete in the formulation lacking, however, the values to be adopted for the environmental actions (the compliance should be "to the satisfaction of the Administration"…), which were established only with reference to Res. A.562 in Res. A.685 in 1991 (as we have seen, with some discount in wind pressure);
- a Criterion for Water on Deck, that we have seen to represent the major cause of capsizing. Also this criterion was complete in the (simplified) formulation lacking, however, of general indications on the factor K essential for the calculation of the heeling moment due to the accumulated water (here again the compliance should be "to the satisfaction of the Administration"…). The corresponding criterion for cargo and passenger ships was never formulated. In addition, this Criterion is simply omitted in the International Intact Stability Code 2008.

The process of development underwent a sharp reduction of speed due to the difficulties encountered in the ratification process (it is impressive to consider this after having seen the signatures of the representatives of 45 Countries at the beginning of the Final Act of the Conference). A long work was undertaken to change the structure of the Convention to make it more appealing for ratification. This process culminated in the 2nd Torremolinos Conference presenting the Protocol. Just to consider again the two Criteria described above, it is noteworthy that for the relevant explanations and figures the reader is simply invited to go back to the original text of the Convention and to Res. A.685…

After the new lack of ratification, all the energy previously spent in development of Criteria was devoted in development of instruments to ease ratification or in developing/updating instrument to improve safety of smaller vessels. Contemporarily, a complete revision of the Intact Stability provisions for cargo and passenger ships was started, its present objective, being the development of the Second Generation Intact Stability Criteria mentioned in previous Section. Several changes have been introduced in the Intact Stability provisions for cargo and passenger ships, including, but not limited to:

- the adoption of an alternative assessment to the Weather Criterion on experimental bases as contained in the MSC.1/Circ. 1200 and 1227;
- the adoption of an alternative to the criterion for the angle of maximum GZ in the General Criterion of Stability, as contained in the explanatory notes to International Intact Stability Code 2008.

None of these was translated in stability instruments for fishing vessels. The situation in this field, thus, continues to have the same picture it had in 1993.

FURTHER STUDIES ON FISHING VESSELS STABILITY OR OF INTEREST TO IT

From the mid-seventies, a huge amount of work was done to develop more rational intact stability criteria. Almost contemporary to the adoption of the Weather Criterion, in 1986 the results of the large British Project SAFESHIP were presented, including several innovative approaches, following thorough investigations on fishing vessel losses, with particular attention to small units, by Morrall & McNaughton [26]. Among these, particularly relevant to our subjects are the Energy-Balance in waves developed at Strathclyde University [27] and the method based on the analysis of stability of the system of anti-symmetric motions of sway, yaw and roll, introduced by Brunel University [28] to explain the phenomenon of Broaching.

Almost contemporarily, several studies considered the effect of trapped water on deck on capsizing. Of particular interest in this frame, the results of the Norwegian Research Project Stability and Safety for Vessels in Rough Weather [29] and the studies of Sevastianov on the volume of the well on deck of fishing vessels [30]. Grochowalski extended the studies of water-on-deck to the important phenomenon of deck-in-water. Starting from the consideration that the hydrodynamics of the trapped water is different in the two cases, he made extensive testing on scale models to identify the nature of forces and moments acting in these extreme conditions [31].

It is noteworthy to consider that, although several of these approaches have been submitted to IMO, none of them was later on taken into consideration for the development of Second Generation Intact Stability Criteria. The relevance of these new proposals for the case of fishing vessels will be shortly discussed at the end of this section.

Development of a novel Energy-Balance Method

This method consists in a generalization of the classical Weather Criterion (at the time just adopted, but already developed in its main characteristics in 1977 [13]) by taking into account the effect of a longitudinal wave on the transverse stability during the so-called ultimate half roll [27]. Fig. 2 clarifies the application of this methodology, which is based on the consideration of the minimum righting arm in the butterfly diagram and on the evaluation of the net area $b-a$ and the percentage of time this is positive. Actually, instead of time, the different positions of the wave crest along the ship are considered. No indication of the standard in terms of percentage were given in the study, leaving them to be identified through a thorough calibration of the method and its comparison with the two existing intact stability criteria. To clarify this point, a parametric analysis was undertaken on a family of fishing vessels based on the well-known BSRA series of hulls. The results are shown in Fig. 3a and Fig. 3b [32].

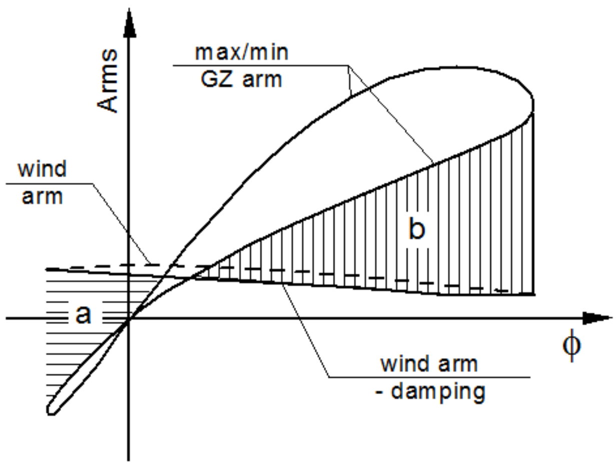

Fig 2. Diagram illustrating the application of the Energy Balance method.

It appears that the two existing criteria (General, here called *Statistical* for its origins [19] and Weather) give comparable results and they correspond to the application of the Energy-Balance method with a 20-30% net area positive. Comparing, however, as a function of the Kempf's non-dimensional roll period $T_K = T_{Roll} \cdot \sqrt{g/B}$, it appears that the requirement of 100% net area positive leads to vessels to stiff in roll, with high accelerations, so decreasing the crew operability and increasing and increasing the probability of man-overboard, that has been seen so much contributing to fatalities [7].

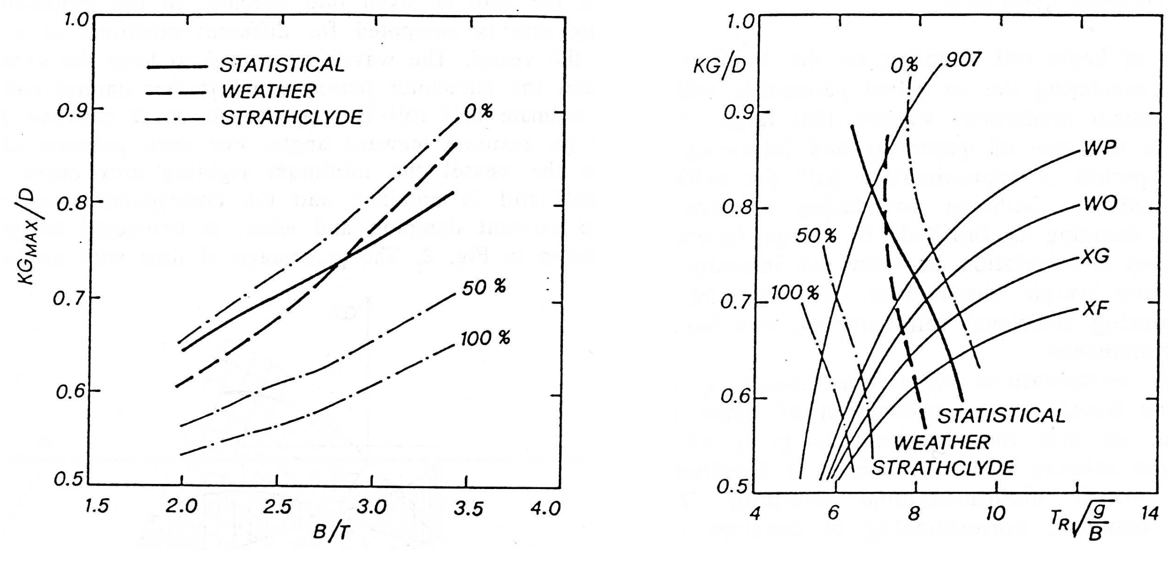

Fig 3a (left). Limiting value of height of center of gravity normalized to depth as a function of the ratio beam over draft for the two IMO criteria in comparison with the requirement of Energy-Balance method reported for different values of the percentage of area positive [32]. – Fig. 3b (right). Limiting value of height of center of gravity normalized to depth as a function of the Kempf's non-dimensional roll period [33] for the two IMO criteria in comparison with the requirement of Energy-Balance method reported for different values of the percentage of area positive for a specimen of BSRA hulls.

Studies connected with the phenomena of Water-on-Deck

Although with some ambiguity, a provision concerning water on deck is present in fishing vessel criteria since 1977 [13]. More recently, the results of the experiments done by several researchers were used by Dahle et al. [29] to obtain the height of a "critical" wave H_c, i.e. a steep wave capsizing the vessel, as a function of the "potential energy" E:

$$E = \Delta \int_0^{\phi_v} \overline{GZ}(\phi) d\phi \qquad t_f \cdot m \cdot \deg \tag{1}$$

connected with the classical dynamical stability up to the vanishing static stability angle ϕ_v or to the angle of progressive flooding ϕ_f. This led to the diagram reported in Fig. 4a where the critical wave for ships with bulwark and for ships with rail are indicated. Starting from this result, the statistical distribution of steep waves height can be used to evaluate the risk of capsizing of the vessel.

The following conclusions were reached during the study: a) the area below the $\overline{GZ}$ curve is important, and may be provided by enclosed superstructures, by low $\overline{KG}$ or both; b) for large angle of vanishing static stability and reasonable Δ and $\overline{\mathrm{GZ}}$ values, capsize is very unlikely; c) models with positive $\overline{GZ}$ values extending beyond 90 degrees never capsized in waves up to 10 m height.

A very important feature is in any case represented by the capacity of the deck well to trap water. A diagram and a regression curve was developed by Sevastianov [30] on a large specimen of fishing vessels (Fig. 4b).

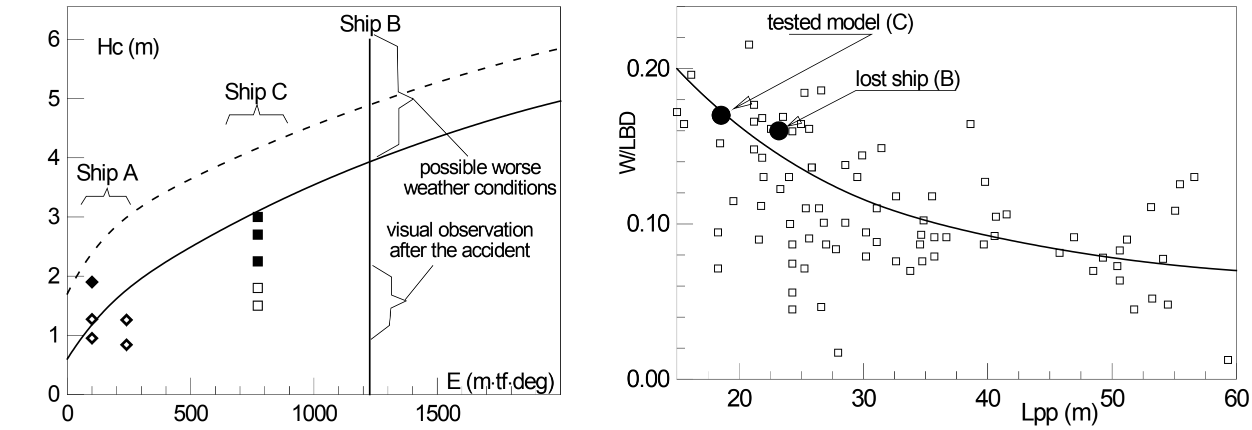

Fig 4a(left). Critical wave height for capsizing in beam steep and high waves [29]. Solid line refers to fishing vessels with bulwark, while dashed one to fishing vessels with rail. The points represent the results of the experiments conducted at the University of Trieste. Points ■ and ♦ represent tests with capsize, while ◇ and □ represent tests with water on deck but not capsize. The vertical line represents the E value of the ship C in the loading conditions at the time of capsize. - Fig. 4b(right). Relative deck wells volume for fishing vessels [30].

Several experiments have been conducted in the towing tank of the University of Trieste on two scale models, A and C, to try to identify the reason of two capsizing observed [34, 35] in small fishing vessels ($L_{pp} < 24\ m$), A and B. The results, shown in Fig. 4a, are in reasonable agreement with the capsizing threshold. In Fig. 4b the size of the well present on deck of the capsized vessel B and of the tested model C are compared with the diagram developed by Sevastianov [30] revealing that the capsized vessel had a quite large well with respect to the overall dimensions.

Studies connected with the coupling among the anti-symmetric motions

Following the approach proposed by Bishop et al. [28], the same BSRA series of fishing vessels previously considered was used to study [36] the effect of trim on the stability of the coupled set of anti-symmetric motions sway, yaw and roll. Typically, the set of the first two motions, sway and yaw, is considered in connection with straight-course stability, while the roll motion is considered in stability. Here the coupling between the three motions is considered to investigate the possibility of directional stability coupled with roll motion as a dangerous situation possibly leading to capsizing as a consequence of broaching.

$$
\begin{aligned}
&m(\dot{v}+Vr)=mg\phi+Y_{\dot{v}}\dot{v}+Y_{v}v+Y_{\dot{p}}\dot{p}+Y_{\phi}\phi+Y_{\dot{r}}\dot{r}+Y_{r}r\\
&I_{xx}\dot{p}-I_{xz}\dot{r}=K_{\dot{v}}\dot{v}+K_{v}v+K_{\dot{p}}\dot{p}+K_{p}p+K_{\dot{r}}\dot{r}+K_{r}r-\rho g\nabla\overline{GM}\phi\\
&I_{zz}\dot{r}-I_{xz}\dot{p}=N_{\dot{v}}\dot{v}+N_{v}v+N_{\dot{p}}\dot{p}+N_{p}p+N_{\dot{r}}\dot{r}+N_{r}r
\end{aligned}
\qquad (2)
$$

To check the resistance of this system to a perturbation, the following solution was considered to represent initial conditions:

$$v(t)=v_0e^{\lambda t},r(t)=r_0e^{\lambda t},\phi(t)=\phi_0e^{\lambda t},p(t)=\lambda\phi_0e^{\lambda t},\quad \lambda=\mu+i\omega \qquad (3)$$

Substituting Eqns (3) in System (2) and imposing the vanishing of the determinant of the algebraic system of equations in v_0, r_0, ϕ_0, the characteristic equation is obtained in the unknown λ. The solutions of this equation are the eigenvalues of the system and the condition for stability is that all eigenvalues have negative real part. The eigenvalues are reported in Fig. 5 for two different ship hulls at high speed, in marginal stability conditions in relation to the general intact stability criterion, as a function of the parameter $\gamma=\Delta T/T_m$ representing trim (negative by the bow).

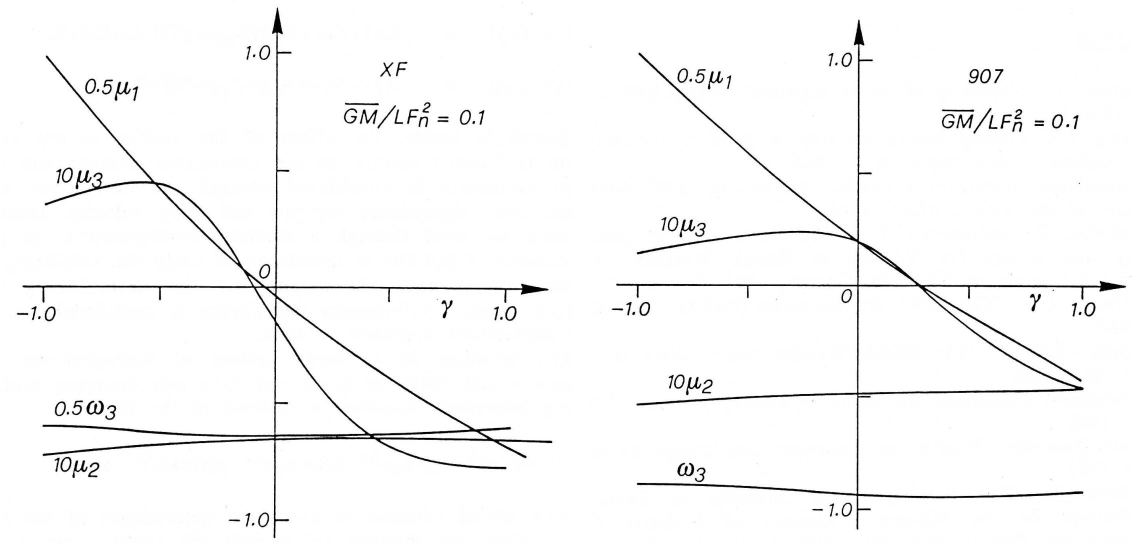

Fig 5. Variations of the eigenvalues of the characteristic equation corresponding to the system of differential equations of anti-symmetric motions as a function of trim for two hulls of BSRA series. Model XF (left) with B/T=1.907 and 907 (right) with B/T=3.437 [36].

The results for model XF indicate that $\lambda_2=\mu_2$ is real and negative, $\lambda_1=\mu_1$ is positive for $\gamma<0$ and contemporarily the other two $\lambda_{3,4}=\mu_3\pm i\omega_3$ are complex with positive real part in almost the same range of γ values. The results for model 907 are similar but the range of γ values where λ_1 is positive and contemporarily the other two $\lambda_{3,4}$ are complex with positive real part includes a part of the $\gamma>0$ domain. The characteristics of the motion can be identified by the analysis of the eigenvectors as a function of trim. It appears that there can be an instability with oscillatory roll and coupled yaw and sway. It is noteworthy that the vessel 907, in spite of having a greater form transversal stability due to the larger value of B/T, has a more extended range of coupled yaw/roll instability. This indicates that the two modes of stability failure, capsizing due to loss of stability and capsizing as a consequence of broaching are different. Current approaches to the development of Second Generation Intact Stability Criteria, in fact, consider them separately.

Studies connected with the development of Second Generation Intact Stability Criteria

As we have seen, the development of the second generation intact stability criteria is based on the separate consideration of five different dangerous phenomena, each one very relevant to fishing vessels safety. Although the main aim of the IMO in this moment is the application to passenger and cargo ships (SOLAS Ships), several studies have concerned the application of the proposed methodologies to fishing vessels.

The relative importance of the beam (dead ship) and longitudinal waves situations for a fishing vessel (model B above mentioned) has been studied in [37] taking into account its peculiarities with respect to conventional ship types, i.e: low length, high beam/draft ratio, low roll period, large well on deck, speed not so far from that of a wave of same length, low height of superstructure, etc. First of all, the dynamic stability in beam waves has been analysed by considering the generalisation of the current weather criterion to include the real environmental action through proper statistics. As a result, a capsize index is evaluated as a function of environmental parameters and the effect of increasing static stability is discussed versus the effects of wind and waves. Second, the phenomena in longitudinal waves are considered through numerical and analytical modelling. Both parametric rolling in head and/or following waves, as appropriate to the typology/loading condition, and loss of stability in waves are considered. For the fishing vessel under analysis the harmonic resonance in beam sea has been found to be the most dangerous condition, especially in the case of low metacentric height. The effect of bilge keels has been assessed in order to understand their effectiveness in reducing the roll peak in regular sea and the capsize index in irregular sea. On the contrary, the effect of wind gustiness is found to be negligible in comparison with the effect of waves, due to the long typical periods of gusts when compared to the relatively short roll period.

The possibility of the onset of parametric roll has been found in regular sea for the "design regular wave" used in the analysis. In that case the fitting of bilge keels, to a large extent, mitigates the parametric roll amplitude. On the other hand, parametric roll in realistic irregular waves seems not realistic due to the small variations of metacentre position compared to the mean metacentric height.

CONCLUSIONS

In this short presentation the intact stability standards for vessels have been taken into account in their historical development, all fairly recent. It was seen that the regional differences that result in large variations in the average size and typologies of vessels, are heavy and that a final push for improvements in the safety and general living conditions in the fisheries sector can be found in the close cooperation established between IMO, ILO and FAO.

Nevertheless, the implementation of the first international instrument for safety of fishing vessels, i.e. the Torremolinos Protocol, still encounters heavy difficulties. A Diplomatic Conference, recently held in Capetown, produced a revised text of the Protocol [38, 39]. The application is limited to vessels operating in the *high seas*, i.e. the waters beyond the territorial sea or exclusive economic zone (or the equivalent) of any nation and a new methodology for *counting* the fishing vessels subject to the different Administrations is being developed. In this context, some type of *equivalence* between length and displacement has also being considered. The revised Protocol shall enter into force 12 months after the date on which not less than 22 states the aggregate number of whose fishing vessels of 24 m in length and over operating on the high seas is not less than 3,600 have expressed their consent to be bound by it. Fifty-four States signed the Final Act of the Conference. Let's hope that this time…

On the other hand, due to the difficulties encountered since the very beginning, in 1977, the Torremolinos Protocol and the other instruments developed on its basis were not opened to the important scientific developments, with particular regards to ship stability, seen in the subsequent years.

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