SHIPS THAT GROW

BY

D. K. BROWN, MENG, CENG, FRINA, RCNC
(Consultant Naval Architect and Historian)

ABSTRACT

Reasons are given to explain why growth in the weight and space requirements for a ship are inevitable during design, building and in service. This growth has been allowed for by formal design margins, 'Board' margins and growth margins, but it is never easy to attach suitable values to such margins. Suggestions are made to guide such sizing and some other ways are outlined in which growth can be controlled but proper additions may be accepted.

Introduction

Warships grow in weight during the design stage due to inevitable changes—additions—in requirement, as a result of errors in data supplied on equipments, and in the design process, and they will grow in service due to planned and unplanned additions. Most such additions are inevitable and even desirable to give the versatility and adaptability which history has shown as essential to a warship.

The wise designer has always recognized the need for growth and kept a bit in hand—even Noah must have expected growth in his fertile cargo and design problems in his novel ship. The object of formal margins is to ensure that the ship meets all requirements on completion and can still accept growth without danger but accepting some degradation of performance.

History

In the late 19th century, battleships had a very thick armour belt (up to 20 in) but which often only extended some three feet above the waterline. When the *Trafalgar* completed in 1891 she was 650 tons over weight, floating a foot deeper in the water than designed and considerably reducing the armoured freeboard. Much of the extra weight was due to changes in the requirements during construction such as the change to quick-firing guns.

For the next class, the ROYAL SOVEREIGNS, the new DNC, William White, recommended, and the Board approved, that there should be a margin of 520 tons to allow for such changes, to be used only with the authority of the Board. This margin, the Board margin, has been included in the requirements for most subsequent ships and its omission has been regretted in ships not so blessed. The Board margin has always been a weight margin; space has not been provided for new weapons (or their crews) and margins on services, such as electric power, have been handled less formally. Weight margins are the easiest to define and to explain and though this article will concentrate on weight, the more difficult subjects of space and services will also be mentioned.

Design Margin

Even if requirements do not change, a margin will still be needed to allow for possible errors in the calculation and for the supply of incorrect data from outside the design group. Weights are initially estimated by scaling from the known weights of a similar ship, already in service. Provided that the existing ship is really similar, this approach is very accurate but problems can arise when there is a change of design philosophy such as the replacement of a simple ventilation system by full air-conditioning. There is also evidence that scaling down from a larger ship is less accurate.

At later stages, weight (and the position of the centre of gravity) is assessed in more detail by estimating the weight of every individual component and summing these. The risk then is that whole blocks of items may be forgotten—in the FORD Class seaward defence boat (FIG. 1), there were no estimated weights for machinery seats, uptakes or funnels. Current CASD systems largely eliminate arithmetical errors but do not automatically prevent the input of

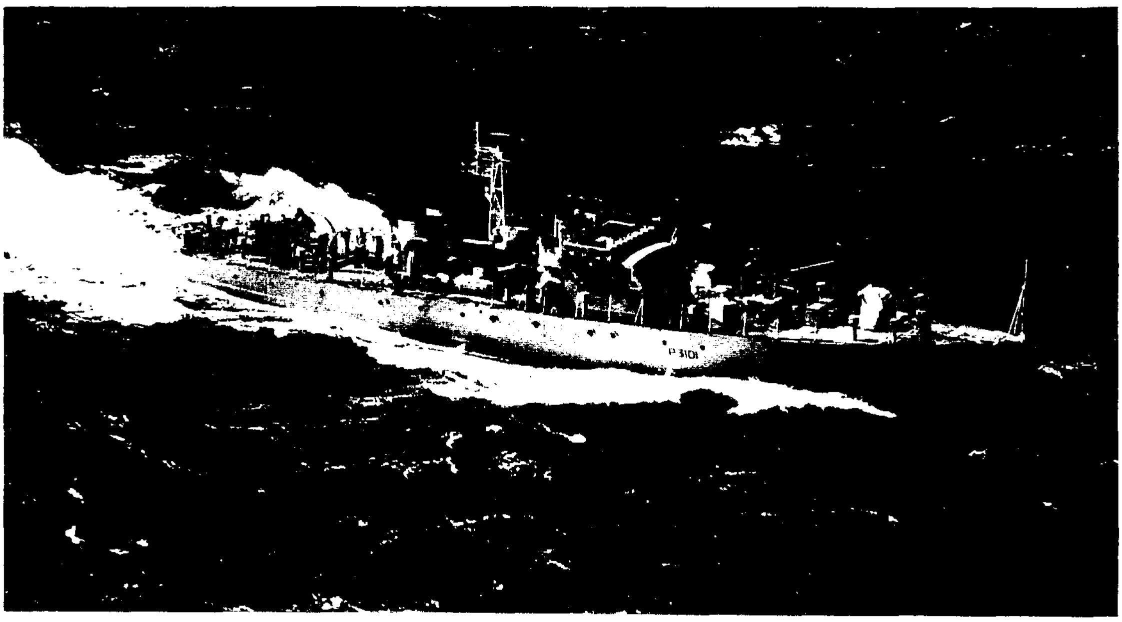

FIG. 1—HMS 'SHALFORD', A SEAWARD DEFENCE BOAT, COMPLETED VERY MUCH OVER WEIGHT DUE TO OMISSIONS IN THE WEIGHT ESTIMATES

wrong or incomplete data. Such systems, used critically, do help in making comparisons with existing ships and hence in picking up errors.

Data supplied from outside the design team, by bodies less concerned with the ship as a whole, may have much larger errors which may be a simple underestimate of the final size or there may be a lack of understanding with the ship designers of what is included in the estimate. The ship designer should examine the track record of similar equipments and of the contractor in past work and remember that the more novelty there is, the greater is the likely error. As a result of such an examination, the design weight of the 965 aerial for the TRIBAL Class (FIG. 2) was taken as 2½ times that given by the radar designer—an estimate which proved correct on delivery of the first set.

It is worth noting that competitive tendering on price for individual equipments will often lead to large and heavy items being selected.

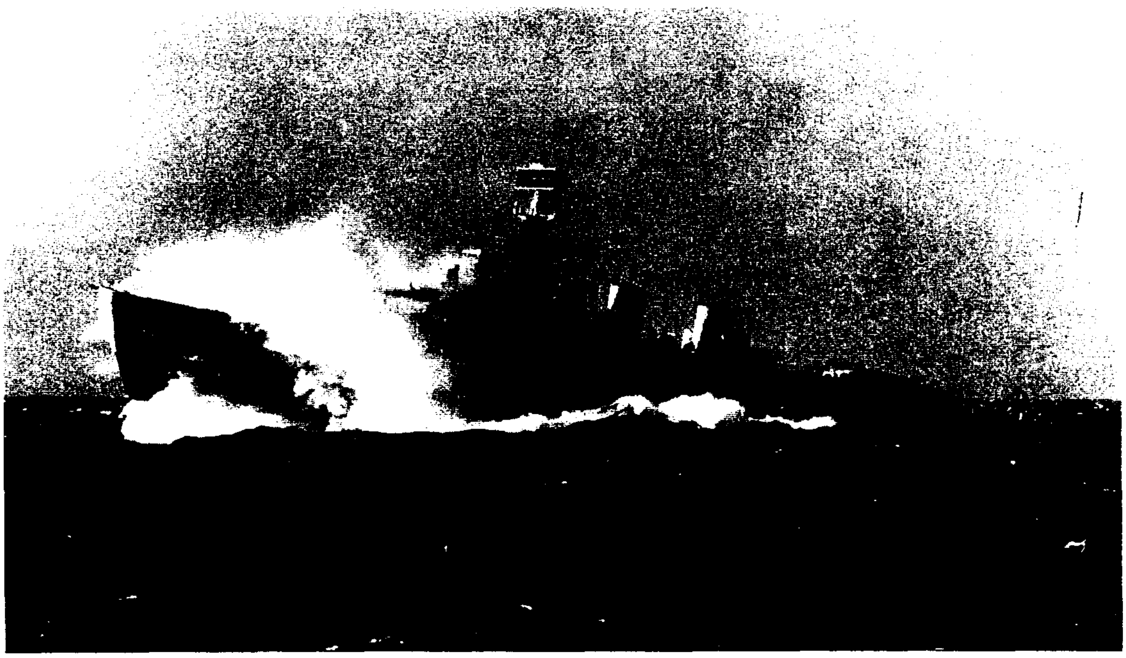

FIG. 2—A 'TRIBAL' CLASS FRIGATE IN HEAVY SEAS. THEY WERE DESIGNED WITH ADEQUATE WEIGHT MARGINS AND COMPLETED TO THE DESIGN DISPLACEMENT

Changes in Requirement and the Board Margin

A warship is large and complex and there is no prototype on which to sort out problems. The threat can change rapidly and it is impossible for the wisest of staff officers to write a requirement that will be 100% complete and valid when the ship completes, let alone at the end of her long life. A 'Board Margin' of some sort to allow for some additions would seem essential, though in the recent past finance officers and Ministers have sometimes decided to economize by omitting such a margin. The designer cannot insist but it is his duty to point out the problems caused by such an omission. A high level decision that a ship should be designed 'without margins' must be read as applying to the Board Margin and growth margin and not to the design margin which is there to ensure that the ship completes in accordance with the approved requirement. A strictly enforced cash limit, as in the Type 23, does much to discourage excessive weight growth.

Differing interpretations of requirements can also lead to weight growth. Most classes of post-war frigates have completed some 500 tons above the figure quoted at Staff Target stage due to decisions to include features not mentioned in formal requirements, such as wood decks, stabilizers, air-conditioning, etc. A requirement that Whiz-Bang Mk.II is to be accepted 'for but not with' differs from a margin and can be treated as part of the design load though, if the Mark II does not exist, a generous design margin may be appropriate.

Growth in Service

There will be required additions in service such as counters to new threats but there will also be unapproved growth. This will include paint—on modernization after ten years, LEANDERs were found with up to 80 coats, adding 45 tons to the displacement—'come in handy' stores, and DIY improvements to living spaces. A decision to adopt austere standards or a limitation on stores can be counter-productive if the crew is allowed to add items after completion.

Growth in weight will always reduce freeboard and increase the immersed volume, it will usually raise the centre of gravity (G) and, for many hull forms, the metacentre (M) will fall. The probable consequences will be a loss of initial stability (metacentric height) due to the rise in G and the fall of M and a further loss of righting moment at large angles due to loss of freeboard. These effects will be most severe after flooding when the loss of freeboard may increase the risk of the flood water spreading to other spaces.

Seakeeping will deteriorate, mainly due to loss of freeboard, and the bending moment may increase, depending on where the weight is added. The increased immersion will reduce speed and endurance and may require the design of a new propeller to retain noise performance.

The first step is to limit growth but some is inevitable. Growth will need space and a ship that is cramped will grow less in weight than one which is spacious. This should not be taken as an argument in favour of cramped designs but is something which the designer must bear in mind.

A margin for growth (on both weight and stability) should be such that a 'reasonable' amount can be accepted with no reduction in safety standards and with only a small reduction in performance.

Growth is estimated at ½% per year for ten years on the assumption that the ship will be stripped out at half life, something which no longer happens. Long life ships must have some form of weight reduction at intervals or much larger margins will be needed.

Space Margins

Up till the end of World War II there was little problem. New electronic cabinets could be built into a mess deck and the extra ratings needed squeezed into the reduced space remaining. Hammocks obey the Gas Law, PV = constant (through with associated rise in temperature). Such compression is no longer possible in modern messes.

In most cases the space needed for a new equipment has positional requirements, both absolute (on 2 deck) and relative (adjacent to the operations room), and will often have limitations on shape. The original Type 42 had a space margin in the form of wide passageways but the extra space was too narrow and distributed to be of value.

A space marked 'Margin' on an early drawing will soon be usurped and designers often seek to conceal space margins. The US designers of SPRUANCE succeeded in retaining the many recreation spaces of that class, marked 'reserved for future equipment' which made it possible to fit the extra equipment of KIDD and TICONDEROGA. The TRIBALS had a margin marked 'Marines' mess' until First Sea Lord inspected the drawings and said 'I didn't know these ships carried marines, what a good idea'! Some possible approaches to the provision of extra space are discussed later.

Services

Much of the cost of a 'service' lies in the *number* of prime movers, generators, pumps, etc. and in the *number* of bulkhead penetrations. A big pump may cost little more than a smaller one if both are stock items whilst the installation costs of a bigger pipe or cable will not be much greater. One can afford to be generous in supplying main services though there may still be difficulties in ensuring that the outlet is in the right place.

The Object of margins

It is suggested that there are two basic aims:

(*a*) *On completion* the ship shall carry all the required equipments at the required speed and endurance whilst meeting current safety standards (stability, strength, etc.) and complying with hability standards.

(*b*) *In service*, even in the last years, it shall meet fully the safety standards to which it was designed and, as far as is possible, any later standards; and similarly with habitability standards. Significant weight increases will necessarily lead to reduction of speed, endurance and seakeeping but these should be minimized.

Sizing the Margin

If a ship is to be effective over a long life, margins must be adequate but the provision of margins is expensive and over-large margins may encourage the designer or staff to be profligate—'Thicken it up a bit, we've plenty in hand.' or 'Another Whiz Bang would be useful'. Big space margins will certainly encourage weight growth.

If, as in SPRUANCE, large margins are incorporated so that a Batch II or III (KIDD, TICONDEROGA) can be created on the same hull, care will be needed that the later batches do retain an essential margin for over-weight equipment and in-service growth. Small changes to the structure and subdivision of the original design have left the TICONDEROGA with a small but just adequate margin on completion.

Care is needed that margins are not added to margins. For example, if the power is enough to give the design speed with weight growth, there is no need for a margin on power. Rounding up sub-groups, then adding a margin to each group before a further margin is added to the total can easily be carried too far.

The Way Ahead—a personal view

It seems almost certain that smaller defence budgets will mean that the service life of ships will be extended. There may be sound economic arguments for short-life, throw-away ships, but such arguments are unlikely to carry political conviction. In an unstable world, the threat will change several times during an extended life and the equipment fitted must change too. Inevitably, such changes will mainly be additions.

Changes in requirements, allowed for in the current Board margin, will be controlled by strict cash limits but such limits must also have a margin. Central approval should include x% on cost to allow for changes, subject, of course, to strict control. Weight margins to accept these changes with acceptable strength and stability will then be provided. The increasing accuracy of fatigue life calculations suggests that a margin on fatigue life is needed to replace the earlier, generous factor of ignorance.

In the 'Cellularity' style of design, it was envisaged that there should be 'soft areas' to allow for expansion adjacent to electronic compartments where demand in service is most likely to occur. These soft areas would be offices, stores and (possibly) mess decks which could be re-sited. The most feasible place to re-site is the upper deck and hence the philosophy of soft areas was associated with very small superstructures so that there was space for bolt-on weapons and for deck-houses to accommodate spaces displaced from below.

Even if the full style of Cellularity are not accepted, the concept of soft areas and small superstructures remains valid. Additional weight has least effect on bending moment and hence on stresses if added at about one-quarter length from bow and stern and hence open space for additions should be provided at these points. EW equipment will probably need an aerial on the mast and there should be space for a containerized office close by.

The fall in the height of the metacentre can be reduced or even eliminated by flared hull sides which can reduce the loss of stability associated with weight growth. The loss of speed can be minimized, not eliminated, by a new propeller and by a variable incidence transom flap.

A more fundamental approach to growth is to design the ship so that it can be cut in half and a new, parallel body inserted. Such a step can be contemplated either to ease the creation of a bigger Batch II or, with more difficulty, in modernizing an existing ship. In the latter case, the new section can be pre-outfitted, reducing refit time. Proper application of zoning will reduce the number of through services though the remaining runs will still present problems in lengthening the ship. The geometry of an insert is not as easy as it may sound, all the hull lines must be parallel and decks parallel to the keel but it is probably the only way of making major changes at moderate cost.

Margins are expensive and hence an emotional subject. Politicians, finance officers and staff officers think that ships should not grow but the naval architect knows that it will and keeps a little something up his sleeve. Margins must be spelt out very clearly in a design contract and solutions with inadequate margins rejected.

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