Inventiveness in Ship Design

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Introduction

When, at the beginning of this year, in Paris, your esteemed President asked me to present a paper before your Society, I did not realise at once, owing to the advanced hour, the great honour shown to me in inviting me to speak here, before a shipbuilding forum, in the shipbuilding centre of a shipbuilding nation. For this I would like to thank him sincerely and I only hope he was not wrong. Also, I did not perceive then the distinct favour he did me by leaving the choice of subject open to me.

Hence it happens that I am here today and intend to speak to you on a topic which, more or less, followed me, and perhaps many of you, during my professional life: the problematic question of inventiveness in ship design. In other words: can a designer naval architect afford to be an inventor and if so, how far? Shall I infect my students with the virus of inventiveness, which in extreme cases could lead to incurable illness and disaster, or shall I recommend them to design, with small improvements, only that which has existed before, to avoid any risk, at the same time suppressing fantasy and the wish to struggle for competition?

Yes or no, inventiveness in ship design is a fascinating subject. It is a game with many components, requiring born talent, professional knowledge and experience, favourable circumstances, persistence, but also a realistic approach, a feeling for economics, a sales strategy and, last but not least, seriousness.

In the Sixties, being employed by the shipyard Blohm & Voss AG in Hamburg, and in charge of the so-called Scientific Department, one of my tasks was to welcome inventors and to patiently hear their proposals. I remember a gentleman who wrote to the company, asking that £250,000 should first be deposited in his bank account and then he would tell us what his invention was all about. That was not a serious touch and, due to obstinacy, ended with zero results.

There are many people calling themselves inventors. The less scientific and technical the background a man has, the easier he imagines he is a great inventor. How many times was perpetual motion proposed after Carnot? Some inventors are, like roulette players, so convinced of their invention, irrespective of system, that nothing can prevent them from pushing themselves, and, still worse, their families, into ruin, for that one, from the beginning, lost cause! It is a pity that Dostoyevski was not, besides being a gambler, possessed by inventiveness to describe.[1]

Madness or genius, ignorance or knowledge, banality or inspiration; the problem when dealing with inventors is that you have to listen to them. From one thousand proposals, one may be fruitful, and that at the end of the row. The border between genius and madness is a thin one, which should not, of course be crossed, but, on the other hand, passivity is also wrong. One way or another, to think things over is worth while, particularly for young engineers at the beginning of their careers. With the present expansion of maritime technology, particularly in the offshore field, inventiveness can no longer be disregarded.

Definitions

Any analysis, seeking to have even a sheen of a scientific approach, should start with definitions.

What is ship design? It is well known to this audience, but, to avoid any confusion, we shall use for the definition of ship design the most commonly used process, the so-called trial and error method, best represented by a spiral (fig. 1). Starting with some existing ship in mind,

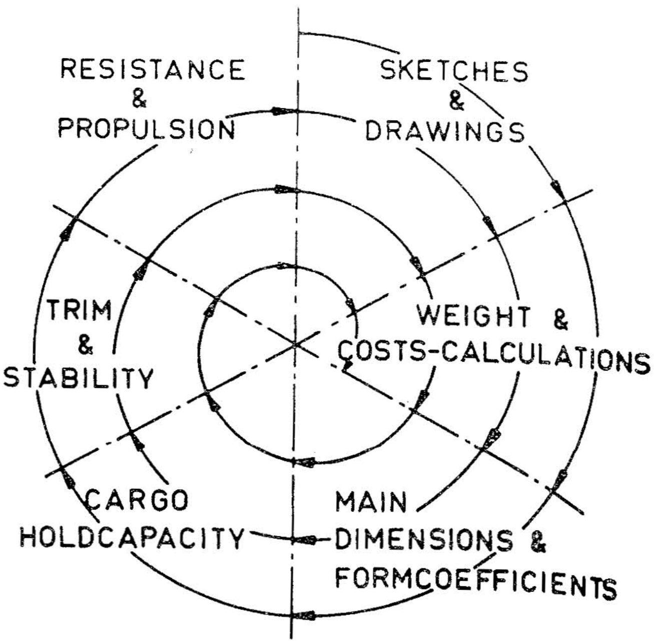


Fig. 1—Design spiral

similar to that required, preferably not too far removed in size and characteristics; a sketch is drawn, some start values are assumed and, step by step, calculations are carried out, until compromise is arrived at between requirements and results, depending on the time available, progress achieved and accuracy required. Calculations are, at the beginning, approximate formulae, later more and more detailed, performed manually or by computer. The spiral in my illustration is turning inward, to represent increase in accuracy, like in shooting, aiming to hit the bull. Some colleagues prefer the spiral turning outward, to demonstrate the increase in the amount of work. Both are true. Of importance is, that the spiral is divided into sectors, representing different kinds of calculations, of weight, of propulsion, etc. The final results depend more or less on these detailed calculations and, directly or indirectly, the building and operating costs of the ship.

The trial and error method is open to any suggestion, it can be applied to total or partial, old or new, concepts. But, because of the complexity of ships and the variety of factors involved in ship design, mostly pragmatic, no reliable calculation method exists, for example, for steelweight. Therefore, a calculation method is usually applied first, to the existing comparison ship, then the results are compared with the reality, and so-called experience coefficients determined, which are further used for corrections in the new design. The more novelties included in a new design, the less sure are the experience coefficients and thus the less reliable are the calculations.

For those who would like to know more about the author's views on ship design, reference is made to literature.[2,3,4] A good impression of the complexity of preliminary ship design can be gained from a recent paper by Watson and Gilfillan, read before the RINA in November 1976.[5]

To sum up, ship design is a creative activity, with the goal of creating an object, a unity, which should perform better than those in competition, otherwise the building order will not be obtained.

At this point we detect an evident link with an invention. Inventing is also a creative activity. Thus far, if not only by chance, then by brainwork, which will play a more dominant part as time goes by, as we shall see. An inventor also tries to produce something better than was available before.

Looking for a proper definition of invention, the most appropriate way, perhaps, ship designer like, is to consider the official requirements for granting a patent to an application. The most recent rules, the "European Patent Convention" of 1973, Part II, Article 52[6] say "European patents shall be granted for any inventions which are susceptible to *industrial application*, which are *new* and which involve an *inventive step*". The first two requirements, the susceptibility to industrial application and the novelty, are more or less determinable. An experienced manager can estimate the industrial applicability and by means of a good research and documentation service, the state of the art can be fixed to check the novelty. Practice shows that it is much more difficult to define the inventive step. It is an abstract definition, which should describe the inventor's brainwork. Fortunately, for many of us, brainwork is one of the few things in life that has yet to be controlled. Unfortunately for patent applicants, it impedes the procedure. The definition of inventiveness depends upon the ability of the defender (the patent agent of the inventor) and upon that of the opponent (the examiner of the patent office), and on the usages of the involved countries. The checking standards in different countries are not equal; there are so-called difficult and easy countries. It is to be hoped that, with the new European Patent Office coming into force in 1978, uniformity will improve.

However, if specialised people, patent engineers and lawyers, having as their life work the checking and defending of patent applications, do not always agree amongst themselves on patentability, we may understand how difficult it is for us here to define correctly what an invention really is.

In an effort to complete the definitions and, perhaps, to find the relationship between ship design and invention, may I suggest we compare the genesis of the two by representing them as in fig. 2. In our computer era, it is 'in' to explain nearly everything by means of flow diagrams. Indeed, it helps us to think clearly. In fig. 2 we can see what is common and what is different. Common is that you must have a motivation to start the work, although the start requirements are unlike. Common, too,

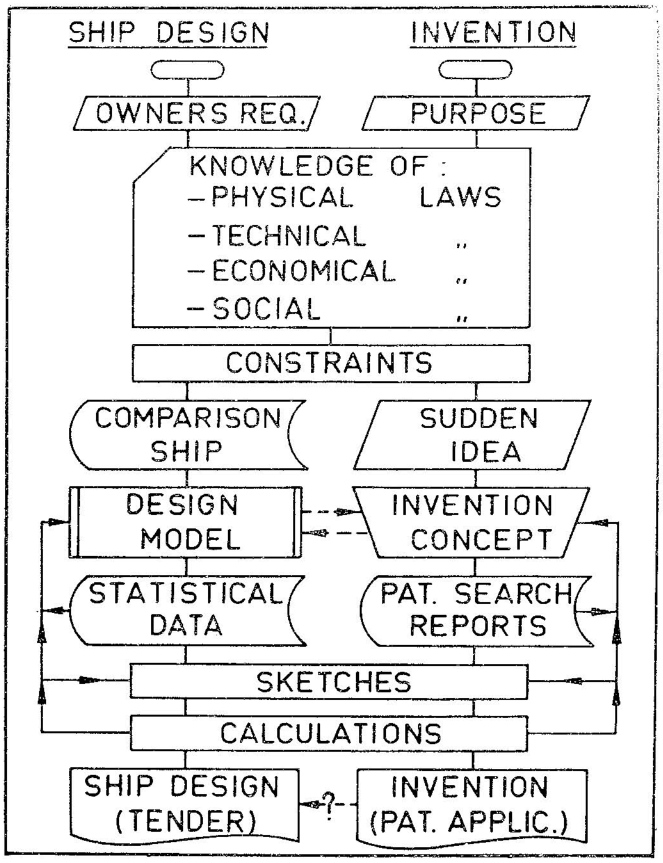


Fig. 2—Comparison between ship design and invention

is that you need a good knowledge of the laws of nature, technical standards, economical and social factors and, above all, that you are prepared to respect them and their constraints. Furthermore, in both cases you need sketches and calculations to check the concepts. Finally, at the end of both activities, you have a written product, with which in some way you try to negotiate a profitable transaction.

The main sources of inspiration and the sequences are different. At first, the ship designer looks at what exists and chooses as far as possible one or more comparison ships. Then he thinks how his own ship should be designed, and by means of statistical data, using adequate coefficients and assumed input data, he starts the sketches and calculations.

The reverse applies with an invention. With purpose in mind, aware of the laws and constraints involved, out of something not always well defined, sometimes unconsciously in a kind of unrest, or even by chance, a sudden idea is born. The idea leads to a better formulated concept, which, the earlier the better, but always after considerable effort, has to be confronted with what already exists. The checking has to be done by the inventor himself, or with the help of others, in the archives of at least one national patent office. In the majority of the cases "it has all been done before", a hard truth, surprising, mostly, young enthusiastic engineers, but also some older ones. At this point we may underline the difference between inventing and designing. The 'already existing' is, for a correct and objective inventor, a warning signal to stop his efforts or to try something else. For the ship designer such findings give him a safe feeling, the feeling that he is not wrong, and unless he is not too keen on optimising, he can come more quickly to an acceptable design. I dare to say, that the time factor in ship design practice is more critical than the optimal product. To be 'too late' is a state more often achieved than the production of an optimum and having it recognised.

It is, in my opinion, another essential dissimilarity between the two creative activities. To look for and to obtain the data of one or more good comparison ships, is an action depending directly on one's own assiduity, on connections and on available information and documentation. Something which can be willingly achieved or bought. A sudden idea is something else. It is true that it is generated by a conscious or unconscious thought, but it comes alone, at times and places where one would not expect it, in the bathroom under the shower, when shaving, at night when one cannot sleep, in a train or in a plane, etc. etc. The first sketches drawn on the back of a matchbox or a visiting card (if it is not a Japanese one, printed on both sides) are the most decisive and tantalising. The inventor himself, as my colleague Prof. Schneekluth of Aachen says, must be naturally gifted for it. "Inventors are not always the best mathematicians, or people seen as the most intelligent; inventiveness is a talent, such as a musical talent, which often appears independently of other abilities".[7] Furthermore, I would say, inventors are not born or produced when one community or society bitterly needs them, but when destiny or probability laws decide. As in history, talented politicians or generals do not always appear when crises and wars are looming.

A 'hot' aspect of our comparison between ship design and invention is the interaction between the two. In the flow diagram they are represented by interrupted arrows at two points: in the concept phase and in the definitive stage. The interrupted line of the arrows shows its facultative character, the interaction may or may not take place.

In the concept phase, the 'unofficial' one, any combination is possible in both directions. Very often, during the design process, from a need to find a better solution, the sparkle of an invention flashes out. In the opposite direction, a solution which appears at the beginning to be an invention, whether it succeeds independently as such or not, can be totally or partially incorporated into a ship design. I dare to say, the less the chance of it being a real invention, the easier it is to apply it to a ship design. We will see the reasons later. Therefore in our figure the interrupted arrow representing the official use of an invention in a ship design is marked with a question mark, the dot in this lecture is not on an 'i', but on this question mark.

Analysis Method

There are two ways open to us to search for inventive examples under the mosaic or in the labyrinth of the history of shipbuilding and marine engineering, or to use the modern term, marine technology.

We may go through the history of ships from its beginning as known to us, about 5,000 years before Christ, along the River Nile; further we may look at the shipbuilding art of the ancient nations, thereafter at that of the Vikings, and then at the sailing vessels of the Middle Ages, followed by steam and engines, and so up to today's gas-turbined and nuclear propelled ships. We must not forget, by the way, the sketches of Leonardo da Vinci and the names of great men, such as Papin, Watt, Fulton and many other inventors, who through their achievements, marked new epochs in the history of our profession. But then I would write a new book, far above the limitations of a paper, and I wonder if I would succeed, for many wonderful books, on historical designs of ships and marine engines, have already been written.[8,9,10] I do not intend to increase the number of such books, at least not yet. This is a job one usually does after retiring from active professional life. However, throughout history, one can laboriously pick up examples leading to general conclusions of good and bad inventiveness in ship design. For your optical entertainment the photos of the models of two picturesque examples.

The first one, the turbot-shaped steam yacht *LIVADIA*, built by John Elder & Company on the Clyde in 1880 for the seasick Czar Alexander (fig. 3) by Admiral Popoff, it is said, out of an idea of John Elder. A similar design was built before in Nicolaieff in 1875 as a steady gun platform.[8]

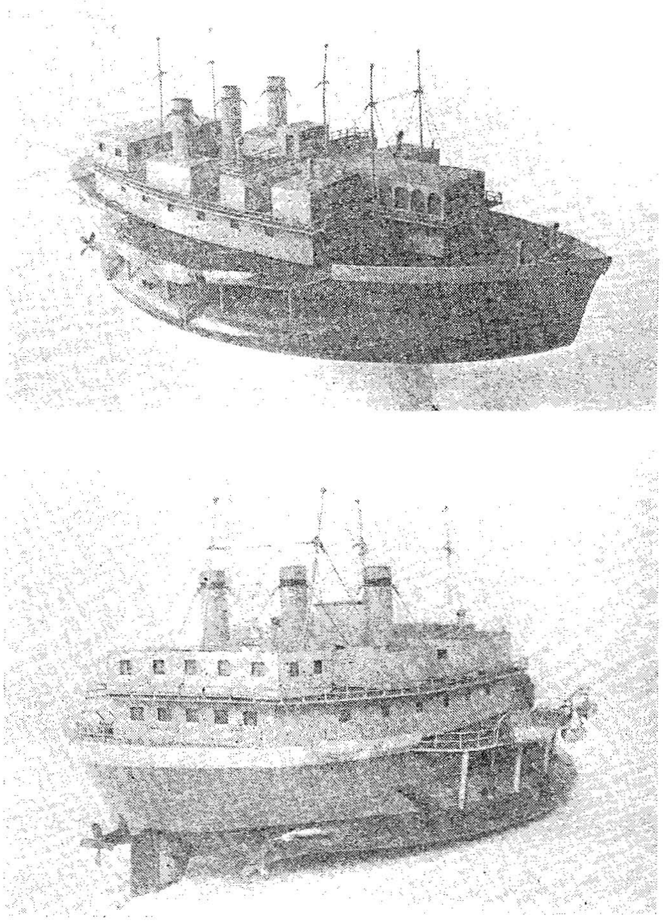


Fig. 3—The LIVADIA

The second example, the Bazin roller boat, designed by the French marine engineer Ernest Bazin in 1897, as a platform above the surface of the water, supported on six upright lenticular wheels immersed to one third and which revolved as the boat, propelled by one screw, moved through the water (fig. 4).[11] The idea was to eliminate the friction resistance of normal vessels and to give to the so called ship a water-tight subdivision.

We could go on for hours. It is also a favourite subject of advertisements with the big oil companies.

The other way to analyse inventiveness in ship design could be to, first, elaborate on the guiding principles and to look, thereafter, for good or bad examples, in the past or the present, to confirm or to reject those tentative principles. In astronomy, both ways were used, to find the laws of celestial mechanics, and the second way, the primordial rational way, is, I would say, the more impressive. We will also choose the second way, not only because it is nicer, but, I must confess, because it is easier going.

One more remark on the analysis method: when choosing examples from the past, you are obliged to take them from books or old transactions. I well remember a slogan hanging on the wall of the students' drawing room in the Aachen Technical University: "Who is lecturing only out

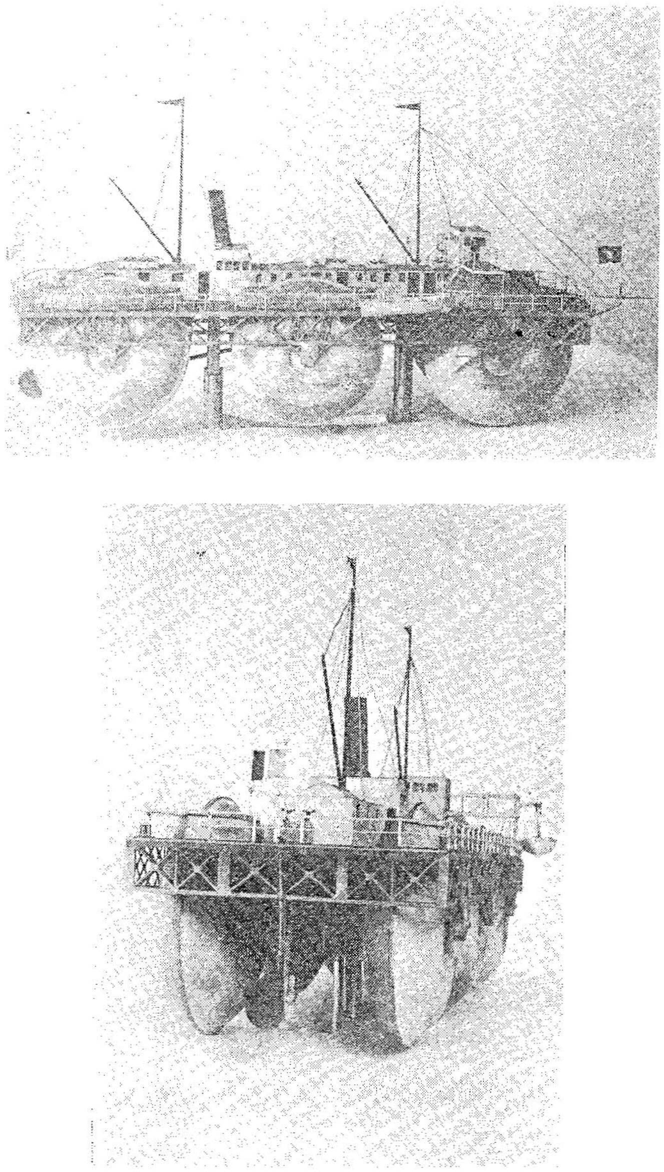


Fig. 4—The ERNST BAZIN

of books has to stay on a book shelf". Drawing from one's own experience, from the present, is 'life', it presents more easily the whole atmosphere to the audience. Of course one's own experience is by nature strongly restricted, and present day examples are incomplete, but who cares to have them really perfect? Nothing is perfect in life. It takes years to accept this. Thus, I prefer the present.

Rational or not, present or past, perhaps we will compromise. If we examine here certain inventions, no advertising benefit, for persons or companies, is behind our examination. We deal only with examples and I realise that I may have been unjust not to mention other, perhaps better, cases. They lie in the many coloured subject of inventiveness in ship design and in the deficiencies of the human being.

Tentative Principles

For several years I have attempted to formulate, on behalf of my students, from own experience and from my observation of contemporary professional developments, some principles of inventiveness in ship design. In the beginning it appeared nearly impossible to find rules and regulations for good inventions. Who has the right to do so? But thinking more about it, one feels that there must, at least, exist some guidelines for it, as for any other activity oriented to reach a target. With time, the feeling became a conviction, independent of the success quotient of my own experience. Thus, the challenge of this paper is welcome, but risky. Welcome, to put order in thoughts and intuitive feelings, risky, because nobody has the capability of Moses.

When Professor Schneekluth of Aachen, of whose inventiveness, from many friendly and cooperative talks during the past years, I am sincerely aware, heard of my commitment here, he promised to send me his opinions on inventiveness in ship design. To my great pleasure his essay was also written in the form of principles for young naval architects.(7)

It is a duty, and second nature, of a designer to look for similarity in existing literature. When searching through literature connected with the present subject, going from one reference to another, I fell on a comparable paper, a presidential address, given in 1937 in Cardiff, by Professor Frederic Bacon to the South Wales Institute of Engineers.(12) To my surprise and reassurance, Bacon tried, then, to set up some principles on behalf of youth. It was a confirmation of my intention and the result is an amalgam. Bacon based his attempt on the past, mainly on two illustrious cases, Brunel and Parsons, while I have promised to remain in the present.

After all that let us begin with a tentative setting out of principles for inventiveness in ship design. The sequence is not related to priorities. Some of the principles may be applicable for other branches of engineering, too, but cobbler, stick to your last!

An innovation should come out at the right moment

That is one of the most obvious rules. It really does not need further explanation. The problem is that inventors do not always know when the right moment has arrived! The right moment may be determined by technological or economical circumstance. For example the bulbous bow, known a very long time ago, has only been intensively applied in the last two decades, due to increased speeds of modern merchant ships or the use of extreme high block coefficients. The same applies to the stern bulb, the importance of which was recognised by Hogner and Kempf in the Thirties. This came to fruition only in the last decade, too, thanks to the efforts of Nitzki at AG Weser, because of the necessity for a uniform wake in front of heavily loaded propellers and because of afterships with excessive block coefficients.(13,14) Nowadays the need to limit unavoidable cavitation and of vibration generation prevail over the upper efficiency percentages strived for. Consequently several patents for alternative or improved stern bulb forms appeared.(15,16)

The classic example of inventiveness, far ahead of technological development, is the *GREAT EASTERN* story, which can be found in every book or paper on the history of ships. It is impressive and astonishing indeed, how right Isambard Kingdom Brunel was 126 years ago, in applying the 'economy of scale' to his creation. This idea is fully accepted today, in thousands of VLCC and bulkcarriers. Unfortunately, at the time the means to handle the *GREAT EASTERN*, from launching to propulsion, were not available with the reliability required for such an investment. The launching alone was sufficient to produce the bankruptcy of the company and to start a series of financial miseries. But you know all about that better than I. I should not carry 'coals to Newcastle', as my dictionary says in place of 'owls to Athens'.

Shall we consider a recent proposal, published in 1976, by a well known Danish shipyard.(17,18) A "Panamax" bulkcarrier, fitted with a slow running main diesel engine of 127 rpm, combined with a reduction gear to obtain 50 rpm at the propeller, while increasing the diameter from 6,35 to 9 m (Fig. 5). On behalf of it, a ducted stern has been adapted with protruding fins (fig. 6a, b). The reduction gear and the aftership form are unusual for this kind of ship and additional building costs are involved.

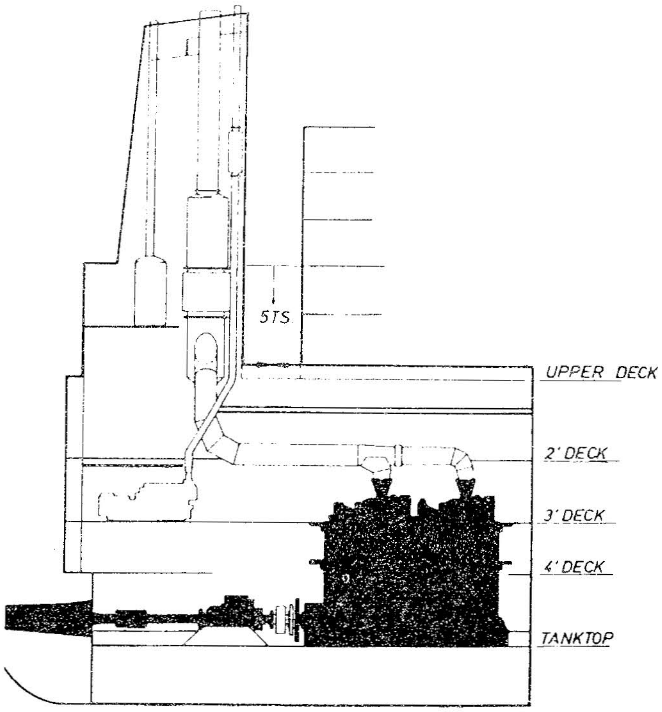


Fig. 5—Slow diesel engine with reduction gear in a B&W Panamax *bulkcarrier*

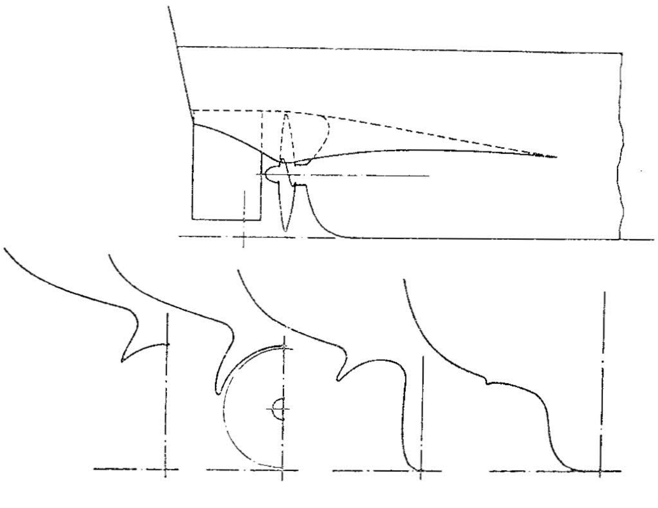


Fig. 6a—Frames in aftership of the B&W Panamax *bulkcarrier*

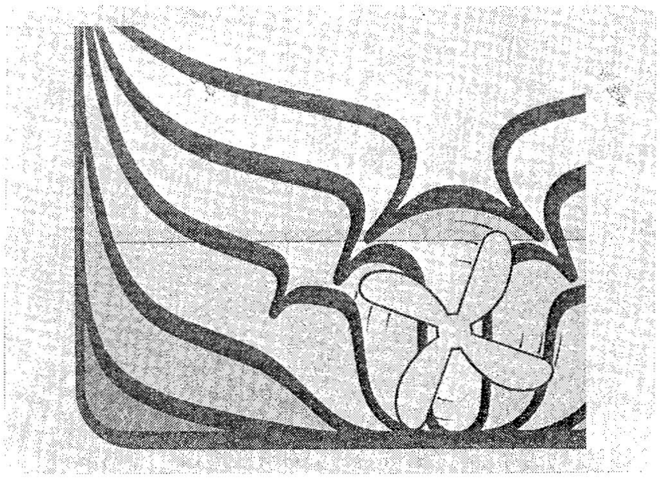


Fig. 6b—Frames in aftership of the B&W Panamax *bulkcarrier*

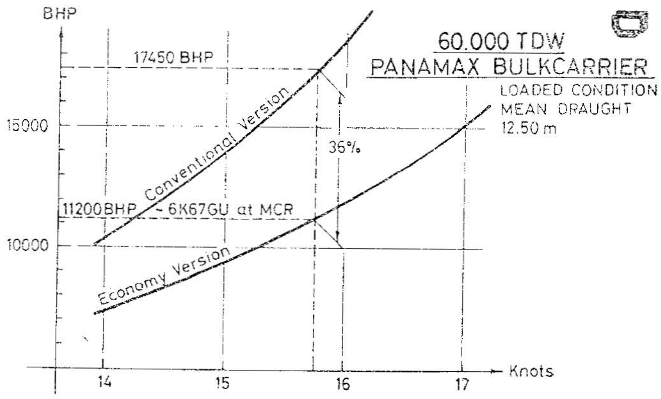


Fig. 7—Power versus speed of conventional and B&W Panamax *bulkcarrier*

But higher propulsive efficiency and consequent fuel cost reductions of, at least, 30 per cent, inclusive of a bulbous bow contribution, are claimed by the inventors (Fig. 7). The idea is quite correct from a naval architect's point of view. For the shipowners, the proposal maintains the reliable slow diesel engine, preferred by many in that trade. The use of a reduction gear and an unusual aftership may perhaps be a matter for reflection by others. One factor, related to the recent bad shipping market and present shipbuilding crisis, remains unfavourable: the extra building costs, even if it is claimed to recover them, through higher efficiency, in short time. The low prices at which new or second-hand bulkcarriers are being offered, whereby a second-hand ship is a better proposition than a new one,[19] are an undeserved handicap for any invention requiring extra investment.

From the first principle of actuality of an invention we may derive another, as Professor Bacon said:

"Not all inventions which have failed should be forgotten, some of them deserve reconsideration periodically".[12]

Indeed, changed circumstances, new knowledge, better material, advanced technologies and different customers requirements can transform totally the picture in favour of an invention. Improvements can be added to the initial thought or can extend it.

Classic examples are the passive stabilisation tanks. They were fitted for the first time on board the *INFLEXIBLE* as reported by P. Watts before the RINA in 1883[20] as a method to reduce the rolling of the ship at sea. The same main principle, improved and properly designed, was industrially applied by Frahm in 1911.[21] The Frahm system fell into disuse for a long time, perhaps, as Goodrich presumes,[22] due to the inefficient steam engines and boilers of the day, requiring large quantities of coal, which restricted space for it. Stability losses may be another reason. However, passive stabilisation tanks of changed design have enjoyed popularity again since the mid-Sixties under the name of Flume tanks which became a large commercial success.

If we pursue our logic, we arrive to a point where we recognise that:

Most successful inventions do not suddenly appear on the market, they are the result of step by step application of inventiveness in ship design.

I read that Parsons, the father of the steam turbine in ship propulsion, said: ". . . an invention is the work of many individuals, each adding something to the work of his predecessors, each one suggesting something to overcome some difficulty, trying many things, testing them when possible, rejecting the failures, retaining the best, and by a process of gradual selection arriving at the most perfect method of accomplishing the end in view. . .".[12]

Today, we can take as an example the nuclear propulsion of ships, even though it is not yet commercially successful. It is the result of a long, step by step, effort by many scientists and engineers to discover and to put atomic energy at the disposal of, or perhaps against, mankind.

If substantial inventions and new developments in ship design occur step by step, one can ask why? The first easier answer is the complexity of modern techniques, in ships and their installations. In a ship the work of many branches of engineering is represented. To name only the principal groups, steel construction, mechanical engineering of all kinds and electronic techniques to the most sophisticated degree. Too much knowledge, time and work for one man alone. Specialisation imposes itself on the scene, ships and offshore constructions are team products. But it is my opinion that the major reason is, briefly:

Shipowners do not like inventions!

In its simplified form that is a dangerous statement. A sympathiser of inventiveness in ship design could be inclined to accuse shipowners of conservatism. They are indeed conservatives, but they are not to be blamed for it! The shipowners' daily task is a risky business, in which large capital is engaged. The risks are of two kinds: natural-physical and economical. In the natural-physical field I understand the sea as a not too friendly environment. Formerly a major enemy it is today, due to technical progress still dangerous but less so. But striving for progress requires intricate installations, high quality crew and specialised maintenance and repairs. The second type of risk, the economic adventure, lies in the large and sudden fluctuations of the shipping market, often unforeseen. Worse, these fluctuations are worldwide, where political or geophysical influences are far beyond the power of most capable men or companies to control.

Confronted with enough unavoidable risks, shipowners are entitled to refuse any voluntary risks, unless the benefit is so extraordinary as to justify them. Consequently the amount of novelty in a ship design should be restricted to a minimum. I would like to formulate the consequence of this principle in this way:

Do not include in a ship design more than one major invention at a time.

When more novelties are available, then please, step by step, one after the other, after successfully individual proof and long service.

In this respect an example from my own experience, 'a meal out of my kitchen'. About ten years ago, when the run for Liberty-ship replacements started, the shipyard Blohm & Voss of Hamburg developed an interesting proposal, called the Pioneer-ship. For detailed information see the references.[23,24,25] That ship design included a series of novelties, based on three major patents,[26,27,28] as follows:

A flat sided hull form, the shell consisting exclusively of flat plates, to save costs and to speed production, and that in two alternatives: for a slower fuller ship called *BASIC PIONEER* (for speeds between 15 and 17 knots) and a faster slender ship named *CONTAINER PIONEER* (for speeds in the range of 19–21 knots) (figs. 8a, b, c).

A hull construction, built up from a number of 'interchangeable' sections, for example similar sections for top deck and double bottom and a modular system offering, from the outset, the possibility of lengthening the ship for four different deadweight values (fig. 9). Furthermore, there was a modular system for the engineroom, whereby one or two medium speed diesels of varying output, in reversed position, could be arranged, but it was not possible to choose a slow running motor (fig. 10).

A prefabricated accommodation system, M1000. As the name implies, a cagelike steel framework for cabin

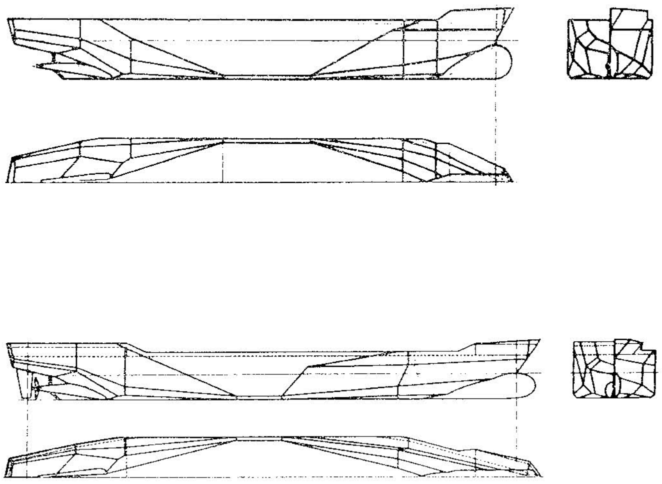
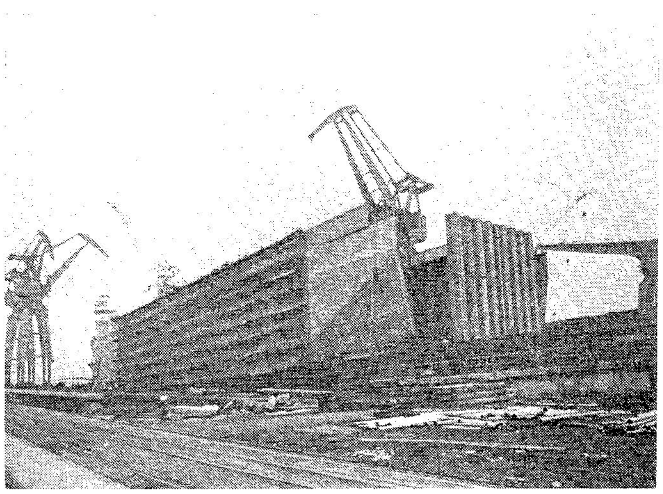


Fig. 8a—Flat sided hull of B& V Pioneer *design*



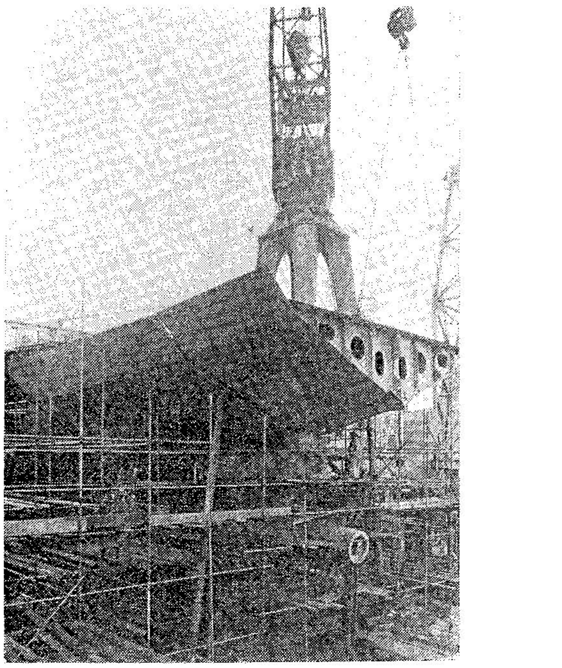


Fig. 8b—Flat sided hull of B&V Pioneer *design*

structures (fig. 11), in standard parts, or multiples, in metre measurements; the same applied to the furniture. Well thought out connection details and fire proof panels ensured quick assembly.

The first novelty, the flat sided hull, designed to eliminate all curves, and bending work, was probably unusual enough to frighten many shipowners (fig. 12), in spite of the fact that it was a hydrodynamic success. Through

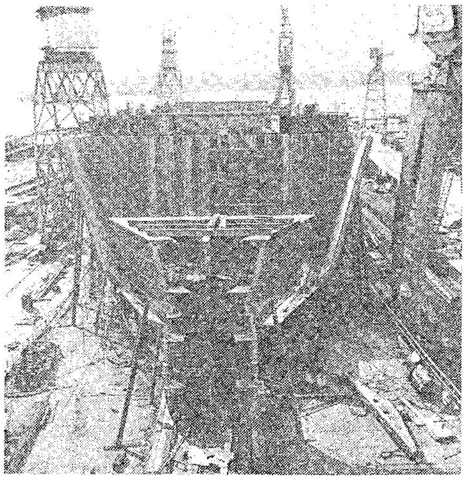


Fig. 8c—Flat sided hull of B&V Pioneer *design*

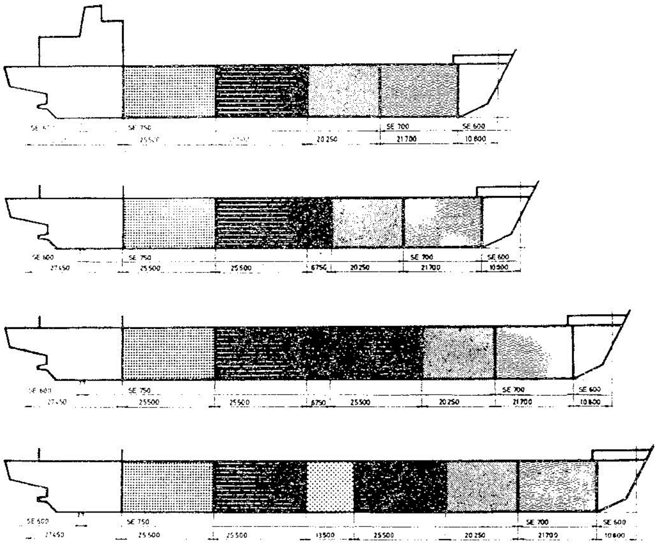


Fig. 9—Modular system of B&V Pioneer

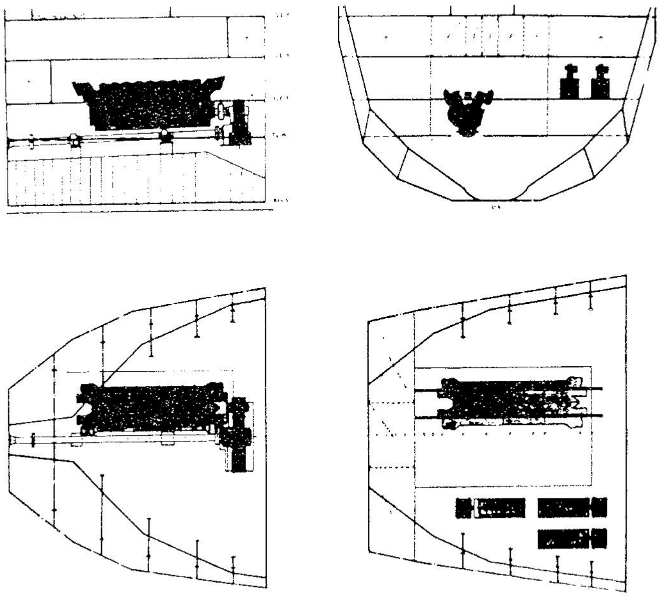


Fig. 10—Engine room of B&V Pioneer

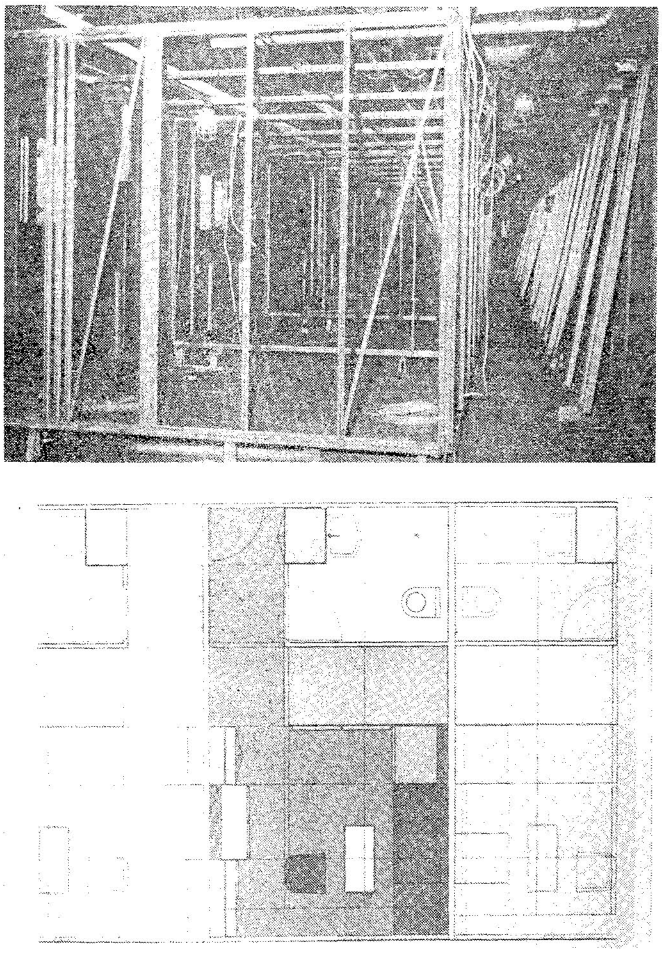


Fig. 11—Accommodation system M1000

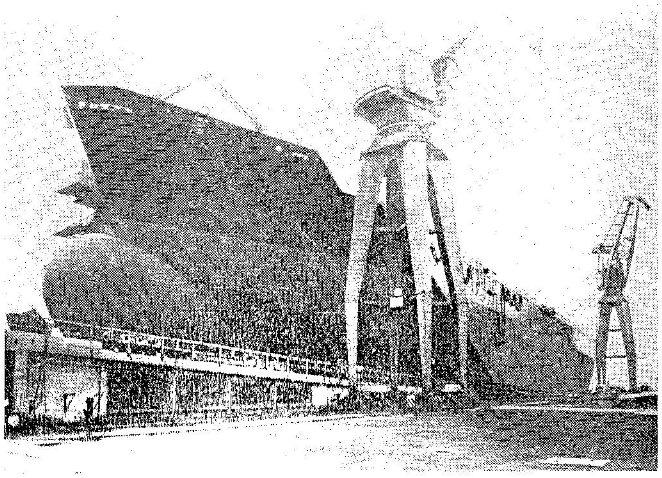


*Fig. 12—*Pioneer *ship before launching*

careful arrangement of the edges in the stream lines (fig. 13) and limitation of the angular values between two adjacent flat surfaces, propulsion power values close to those of the equivalent round form were obtained. For the *BASIC PIONEER*, at service speed, the difference was 0,2 kn or 5,5 per cent hp (fig. 14a). For the *CONTAINER PIONEER* the curves for power versus speed of flat and round forms were at the service speed tangent (fig. 14b). The results of the full scale trials (fig. 15) were a big surprise. The real ship needed between 8.5 and 25 per cent less power than calculated from the model tests (fig. 16). Repeated trials[30] showed better results versus the model tests by 15 per cent. The flat sided hull was, in any case, not inferior to the round one. Nevertheless the expected rush of orders do not come. In total 15 ships of the Pioneer type have been built so far. The savings of the flat sided hull were probably not enough to cancel both the shipowners' reluctance towards the unconventional form and the handicap of the high wages level of Germany at that time, when related to worldwide competition. The medium speed diesel on a bulkcarrier was unusual, at least at that time, thereby, losing, I suppose, another big group of shipowners. The modular system of the structure sections did not show its advantages clearly, because of lack of orders (only 3 ships were built in the original shipyard, 12 under licence). But what remains and what I will always remember, is an exciting time of creative teamwork under an enthusiastic management, open to inventiveness and research.

By the way, one of the novelties of the Pioneer design, the M1000 accommodation system, taken separately, proved to be a success.

Minimal risk in ship design does not imply only a

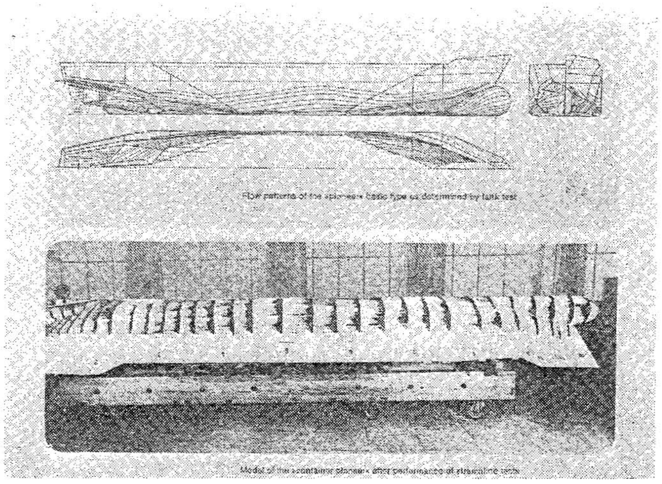


Fig. 13—Knuckles lines and flow pattern of B&V Pioneer

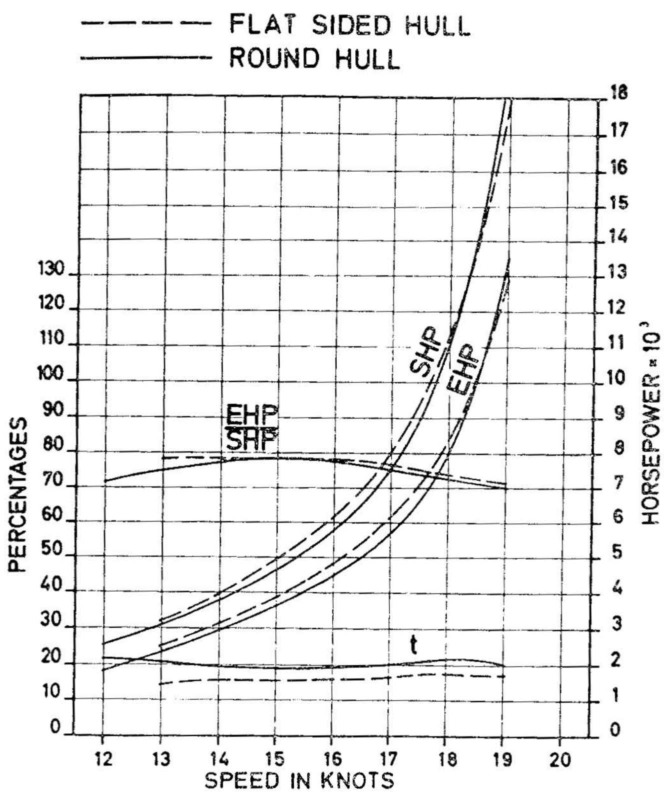


Fig. 14a—Comparative tests between flat sided and round hull. Basic Pioneer *in Vienna*

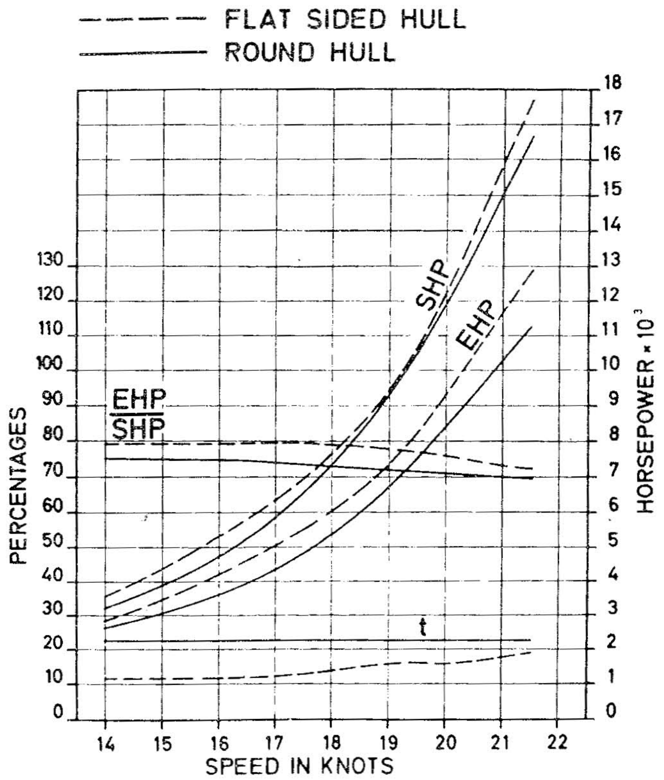


Fig. 14b—Comparative tests between flat sided and round hull. Container Pioneer *in Washington*

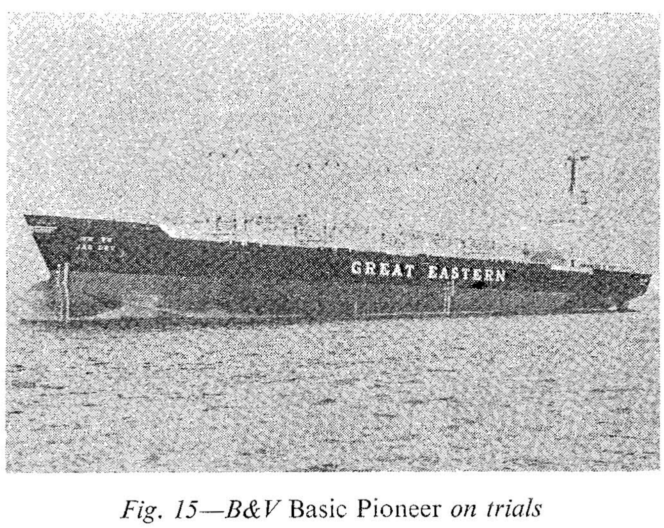


Fig. 15—B&V Basic Pioneer *on trials*

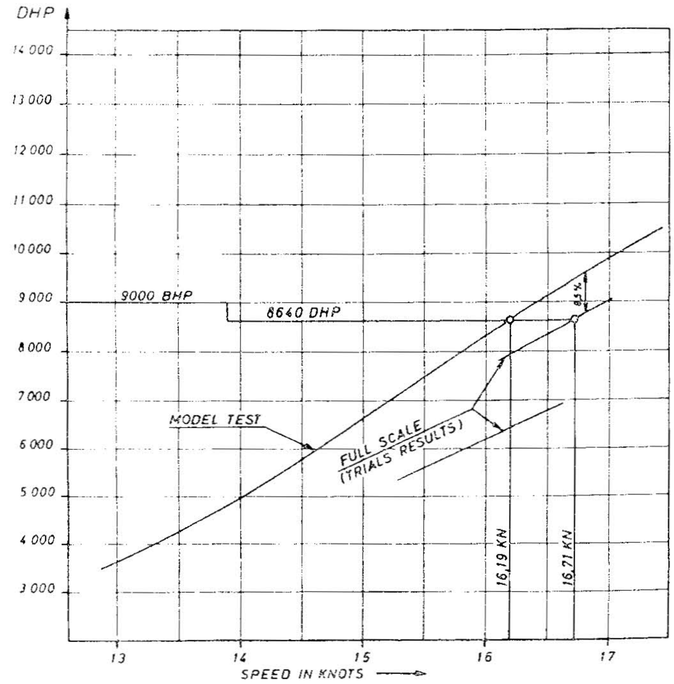


Fig. 16—Trial results with B&V Pioneer

reduced number of innovations, there is also the reliability of the invention itself. Thus, the next principle should state:

An invention to be accepted in a ship design has to be first of all reliable.

Professor Bacon[12] had the right words for this: "When a new system seeks to displace an old established method, the newcomer is almost certain to be less reliable than the old-stager. It is then a good plan where practicable to retain the old-stager as standby till the newcomer is fully fledged". Bacon's advice is therefore to "plan to retain reliability during translation". His example is the development of the steamship, steam was at first auxiliary to sails, next, sails became auxiliary to steam. Finally sails were dropped altogether, but, simultaneously, twin screws were used in place of single screws.

In an association of ideas, Schneekluth,[7] recalls the first welded ships, whose shell plates were still overlapped. Such a development may be regarded as inefficient, but 'safety first' should read in this context 'safety in operation'.

Our code of principles for inventiveness in ship design follows with:

To be reliable an invention has to be built up as far as possible of conventional parts and has to be easy to maintain and repair, and that means it has to be simple.

A very successful example of simplicity in inventions fitted into a ship design is, in my opinion, the MacGregor single pull steel hatch cover. The first patent was on the sealing of the hatches and was applied for (in the Netherlands) in 1937 by Joseph MacGregor of Whitley Bay, Northumberland.[31] In 1949 Robert MacGregor invented the single pull steel hatch cover, which was first fitted on a small New Zealand ship, the *MAMAKU.*[32] The MacGregor brothers were two Scottish naval architects of Whitley Bay, forming a company consisting of themselves and a lady who served the tea and did the typing. Today, 30 years later, about 16,000 ships have been fitted with hatch covers made by MacGregor companies in 33 countries.[33] The single pull system is so simple, even a child can understand how it works (fig. 17). The advantages on the other hand, compared with the former wooden hatch cover comprising hundreds of pieces, are multiple and substantial. They are:

increased security on board;

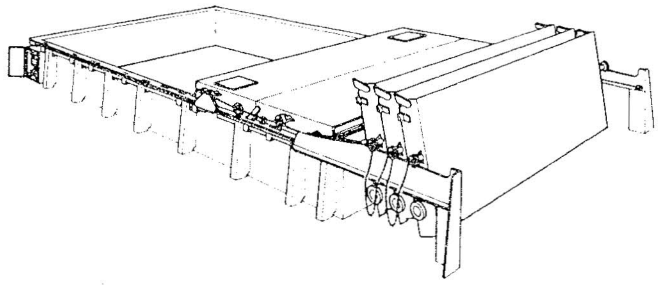


Fig. 17—MacGregor Single Pull hatch covers

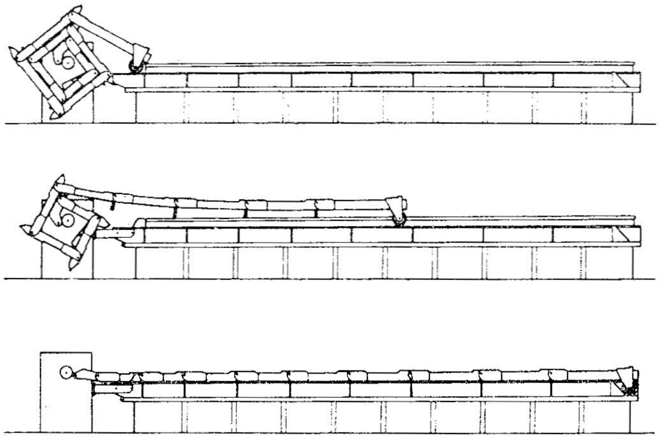


Fig. 18—Advanced automatic rotary hatch cover system

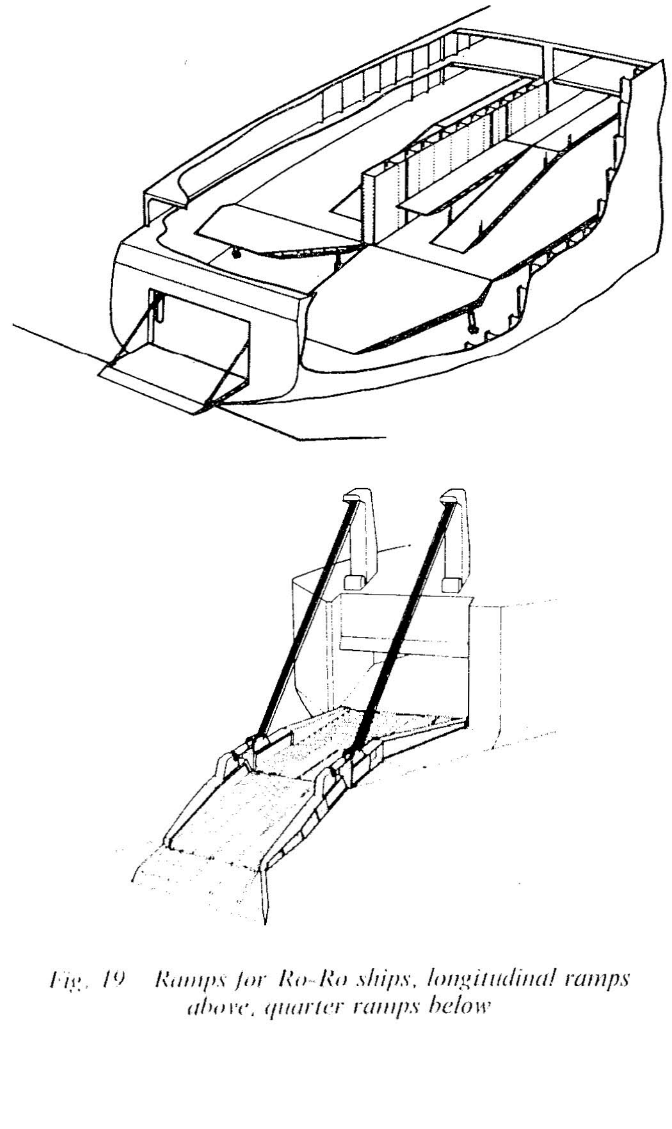
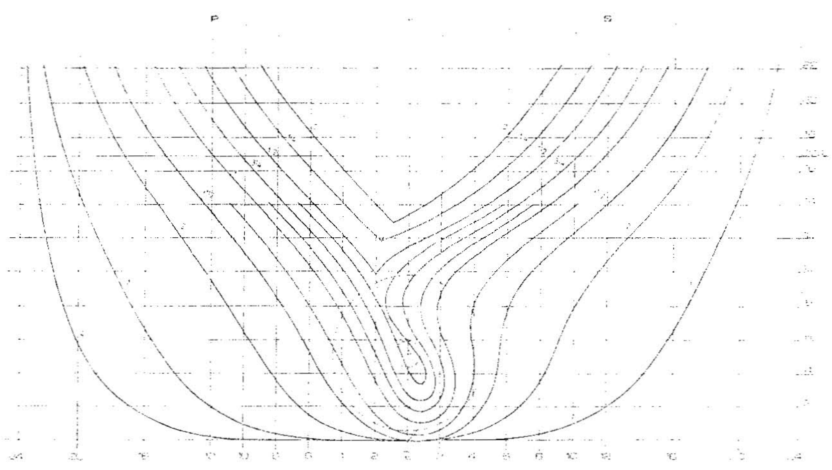
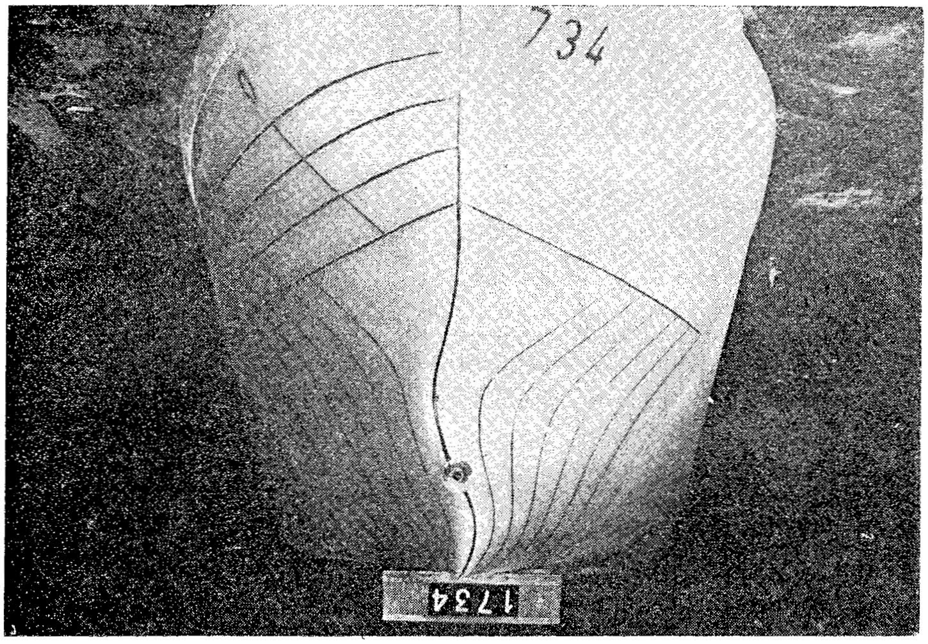


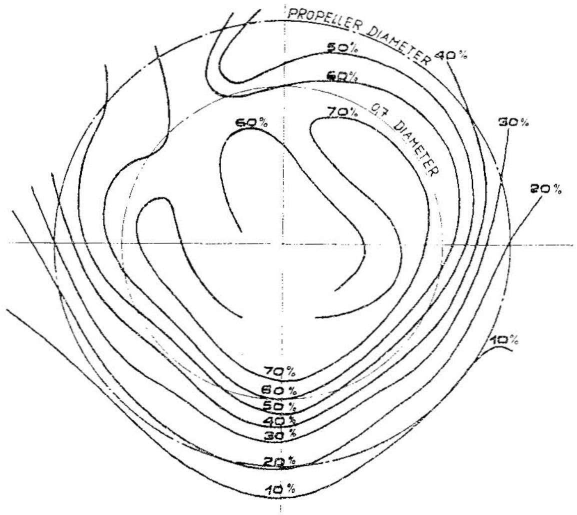
Fig. 19 Ramps for Ro-Ro ships, longitudinal ramps above, quarter ramps below



(*a*) *Frames design principle*



(*b*) *Model*



(*c*) *Wake pattern*

Fig. 20—Asymmetric afterbody

smaller freeboard, i.e. higher deadweight allowed;
reduced man hours spent on opening and closing hatches and reduced time in port leading to quicker turn round.

The development of the hatch covers systems justifies the already discussed principle of step by step innovation and/or continuous improvements. Countless patents, for better construction details, for other advanced automatic hatch covers systems (fig. 18), and for ramps and lifts, especially for today's ro-ro ships, have been granted and have proved efficient in practice. Such are the oblique ramps to give access from a normal quay to the ship's stern quarter, an innovation expanding rapidly in recent years (fig. 19).

Briefly, a good invention is indeed simple when, after getting to know it, somebody can say: "How is it possible that this idea did not come to me before!" Or in other words: where simplicity ends, genius is gone.

The considerable economical advantages of the mechanically driven metallic hatch covers combined with the risk aversion of shipowners leads to another self evident principle:

An invention to be accepted by a shipowner should offer substantial economical profit.

What should be understood under 'substantial' is relative. Relative to the complications and risks involved, capital invested, circumstances and, last, but not least, the owner's mentality.

Another example from personal experience. The beneficial influence on propulsive efficiency of contra-rotating the water before a ship's propeller is well known to naval architects from the Star-Contra systems, the design of shaft bossing contra rotating propellers, etc.

An inventive naval architect, Mr. E. Nõnnecke of Hamburg, once proposed, to my 'employer' shipyard, a patented asymmetric aftbody,[34] such as shown in fig. 20a, b. Hydrodynamically correct, accurate model tests, managed by the speaker himself, showed improvement of propulsive efficiency with no significant resistance increase, and confirmed a 6–7 per cent reduction in required propulsive power, at constant speed, as claimed by the inventor. A better wake distribution, due to the asymmetric flow of water of the propeller was expected too (fig. 20c), but that is outside this discussion. Everyone was happy and the proposal was forwarded to the shipowner. The extra building costs for the asymmetric afterbody were estimated under pressure of time, the keel plate of the ship being already on the slipway. The disillusionment of the designers was not small when the shipowner declared that 5–6 years were needed to recover the additional costs and that this, to him, seemed too long. This happened before the oil crisis and the shipowner was more interested in supplementary deadweight than in fuel savings. The ship was a bulkcarrier, with an already high block coefficient. A hasty effort to transform the reduction of propulsive power into additional displacement failed. A good invention missed its accomplishment, because the recovery of the capital outlay was too slow for the shipowner in those circumstances.

So, the chain of principles of inventiveness in ship design continues as follows:

The profit of an invention should be presented in the most attractive manner for the customer.

It seems to be a matter of course, but it is not implicit. A designer naval architect has many ways of transforming the benefit of an innovation but first of all he has to evaluate it correctly *from the shipowner's point of view*. An example of this can be found in a paper read in November 1976 before a meeting of the Schiffbautechnische Gesellschaft in Berlin.[35] It started with a patented proposal to arrange the main engines of a cargo ship on deck, to reduce, thereby, the engine room length in favour of the cargo holds.[36] To be competitive, i.e. not to lose efficiency, mechanical transmission to the propeller (fig. 21) has to be maintained for merchant ships. The size of merchant ships has increased considerably in the last two decades, propulsive power by a smaller amount. Furthermore, modern medium speed diesel motors are light and compact, so their arrangement on deck should not affect stability. There are also other advantages, and disadvantages, to this unusual arrangement, but they are outside this discussion. One major disadvantage is the limitation in the maximal output of the necessary bevel gears for the mechanical transmission, a technological limitation of today, which must remind us of the previously discussed principle of opportunity of invention.

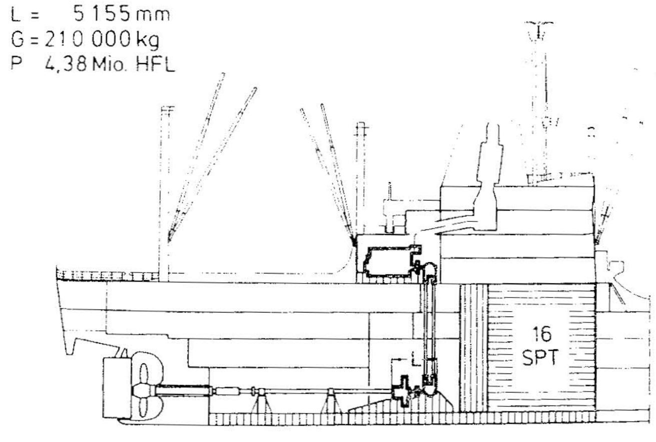


Fig. 21—Cargo ship with main engines on deck

Anyway, the shortening of the engine room could be applied as follows (fig. 22):

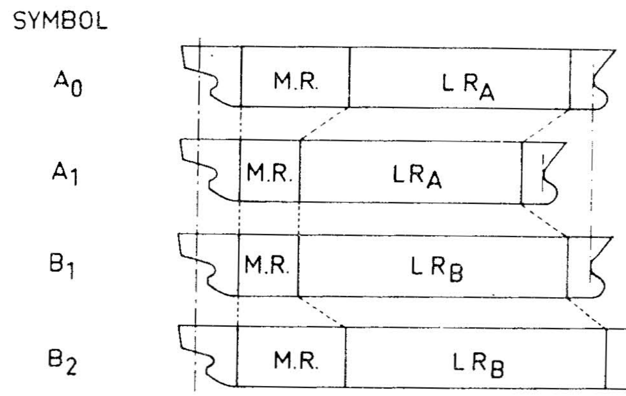


Fig. 22—Alternative use of shortening the engine room

at constant cargo hold size, to shorten the ship length, i.e., to reduce building costs;
the ship length remaining the same, to increase the cargo hold capacity and consequently the freight earnings;

and finally:

the engine room length is not altered at all, the ship is lengthened for the same investment and, therefore, the cargo capacity is enlarged.

Independently of design alternative, the evaluation of shortening the engine room is worthy of discussion, briefly. In consideration of the shipowners' point of view, the Internal Rate of Return, IRR, was chosen as an economic criterion. Normally the technical design of the engine room alternatives would have been worked out

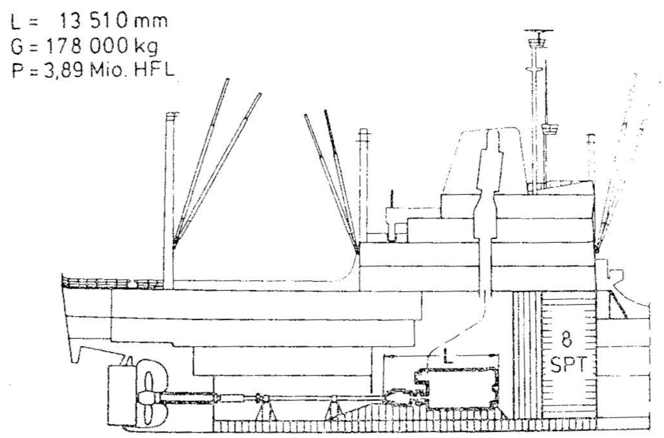


Fig. 24a—Conventional arrangement of the medium speed diesel main engine(s)—one motor

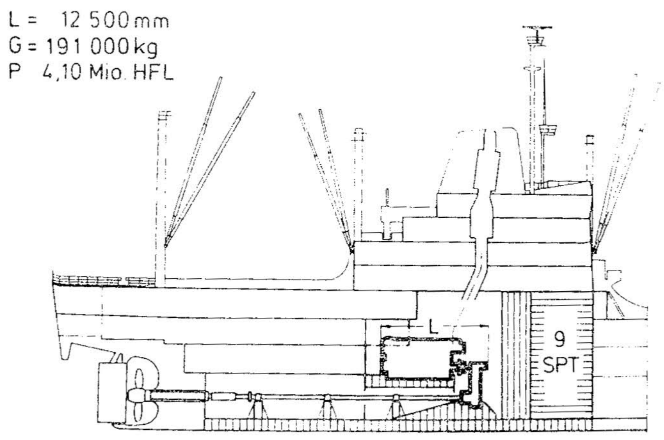


Fig. 24b—Conventional arrangement of the medium speed diesel main engine(s)—one motor reversed

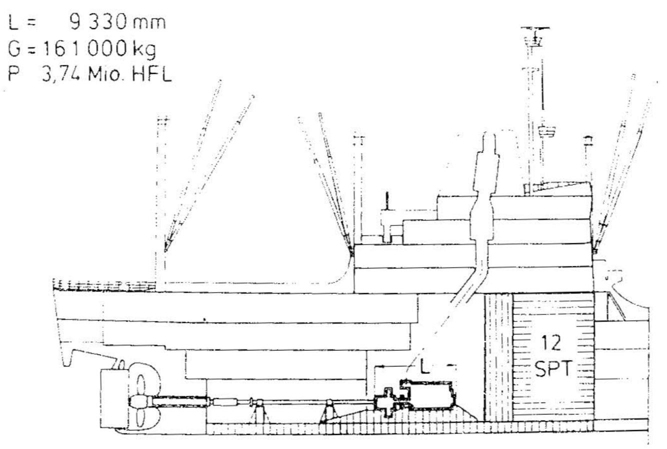


Fig. 24c—Conventional arrangement of the medium speed diesel main engine(s)—two motors

first, and the economic evaluations second. This succession proved to be time consuming, because of the many alternatives, for conventional reduction gears and engine room arrangements, to be compared (figs. 24a, 24b and 24c). To make a virtue of a necessity, an inverse sequence of work has been adopted. A computer programme written to calculate the IRR for a given route, for the assumed shortenings, by X frames, of the engine room and assuming arbitrary Y per cent in additional building costs. By varying X and Y deliberately (computer work does not mean too much) a diagram of IRR values was obtained (fig. 23). The curves of constant IRR represent ships of equal economic performance, that going through zero, the basic ship. By plotting the X and Y values of completed technical designs in the diagram, an opinion can quickly be formed as to their viability, thus eliminating from the beginning non-viable technical design work. Incidentally, with the bad freight of the present days, the conclusion of the study was that the effort to reduce the engine room length only made sense for high price fast ships, needing larger cargo hold capacity and not for bulkcarriers, product tankers and so on. The conventional propulsion plant, with two medium speed engines, acting, via reduction gear, on one propeller (fig. 24c), remains one of the best and a very attractive proposal, compared with a slow running diesel in direct drive (fig. 25). The lengthening of a ship instead of shortening the engine-room is, provided that enough cargo is available, not far away in IRR from the extravagant alternative with the engines on deck, and less risky.

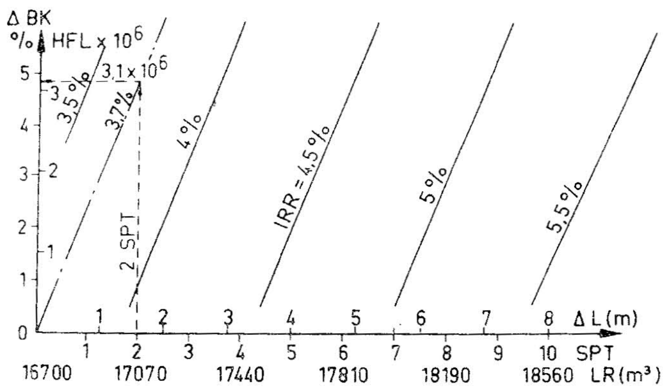


Fig. 23—Results of shortening the engine room

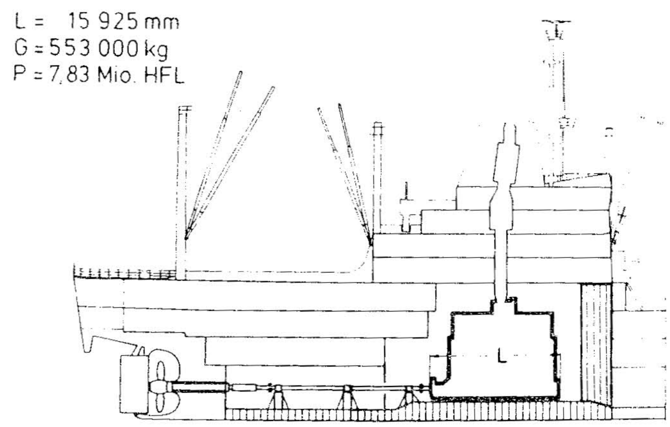


Fig. 25—Conventional arrangement of slow running diesel main engine

The element of 'surprise' is implicated in the results of an invention. Out comes another principle;

A designer should not hang on to the whole of an invention, he should accept partial results or whatever comes out. In this sort of business you know where you start, but you do not know your destination. This does not mean that you should not be assidious or consequent, but rather adopt a sporting attitude towards inventiveness, ready to lose eventually.

A final example, more for entertainment:

A graduating student came to me with the inventive proposal of designing a container ship of the third generation with one diagonal beam on the main deck, with a view to improving her torsional strength (figs. 26 and 27). He accepted, in consequence of the diagonal beam, losses in container storage capacity, that means losses in freight rates, but hoped for a greater reduction in steel weight, i.e. building costs. I like inventive students and I immediately changed the task for his post-graduate work into the study of the proposal.[37] Long computer calculations with the finite elements method showed just the contrary of what we expected. Thanks to the diagonal beam, the double shell of the conventional comparison ship could be eliminated and therefore the container capacity increased instead of decreasing, but the steel weight increased also, because of the heavy diagonal beam. The economical balance was not favourable and we forgot the matter; the student became a naval architect and not a patent applicant.

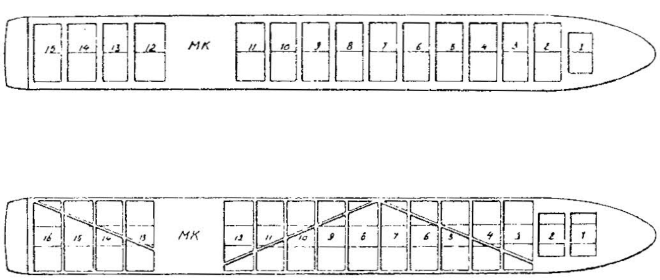


Fig. 26—Container ship with diagonal beam

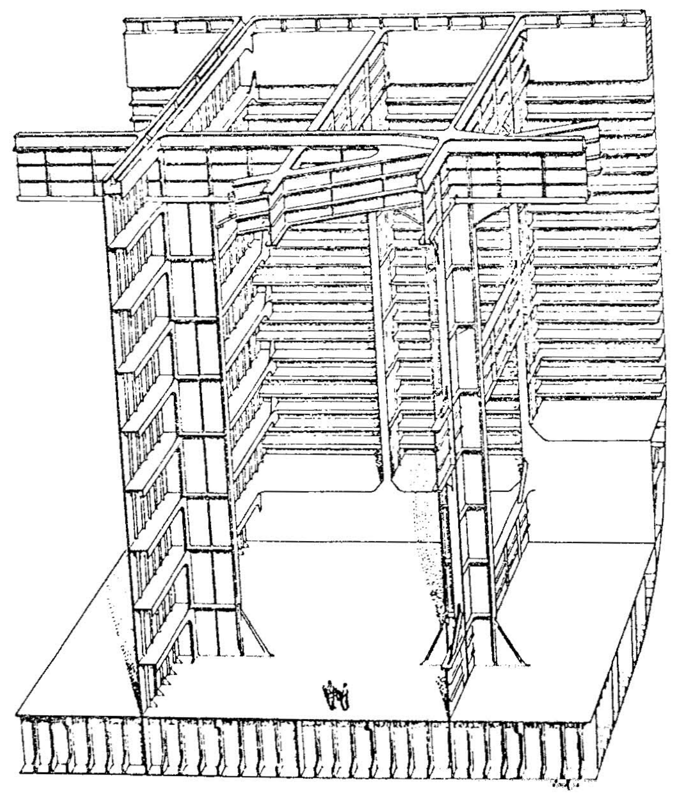


Fig. 27—Container ship with diagonal beam (student-artist impression)

There is one last principle, which is more a conclusion than a principle. In front of progressive students I feel embarrassed to express it; Professor Bacon has in his paper,[12] for the same range of ideas, the limitation 'for adults only'. It is a general observation that a war, the shame of humanity, particularly for cultured and civilised countries, always produces a stimulating effect on inventiveness. A proverb says: "necessity is the mother of invention". In war time the necessity is a matter of life and death, for some nations the necessity to survive. The pressure is enormous. The means at disposal, the concentration of effort are inconceivable in peace time. It is logical, therefore, that the results surpass the normal. The only comfort, perhaps cold comfort, is that those inventions, which were proved in war time are mostly successfully used afterwards, in peace time. The navy has always been a source of innovation for merchant shipbuilding. There are numberless examples. To mention a major one the medium speed diesel engine of about 400 to 600 rpm, using a reduction gear, as propulsion plant for merchant ships. This kind of diesel was introduced in the Second World War, because of reduced sizes and weight, both in favour of bunker capacity, i.e. radius of action and armament. Today, for the same reasons and for price considerations also, medium speed diesels are installed on about 60 per cent of all ships in construction over 2,000 tdw. Comparing a slow diesel propulsion plant of 36,000 hp, with two 18,000 hp medium speed diesels, acting via one common reduction gear on a propeller, all of them from the same manufacturer, the medium speed diesel alternative, reduction gear included, will only have 37 per cent of the height, 42 per cent of the weight and 74 per cent of the price (fig 28a, b, c). The advantages are evident and in the case of ro-ro ships, the smaller height is indispensable.

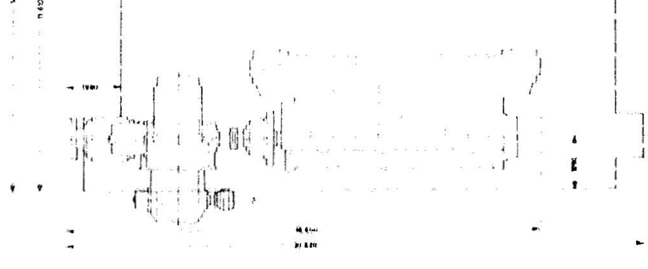


Fig. 28a—Comparison slow and medium speed diesels

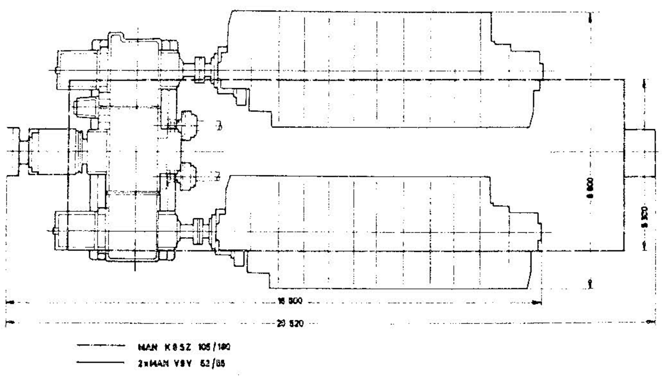


Fig. 28b—Comparison slow and medium speed diesels

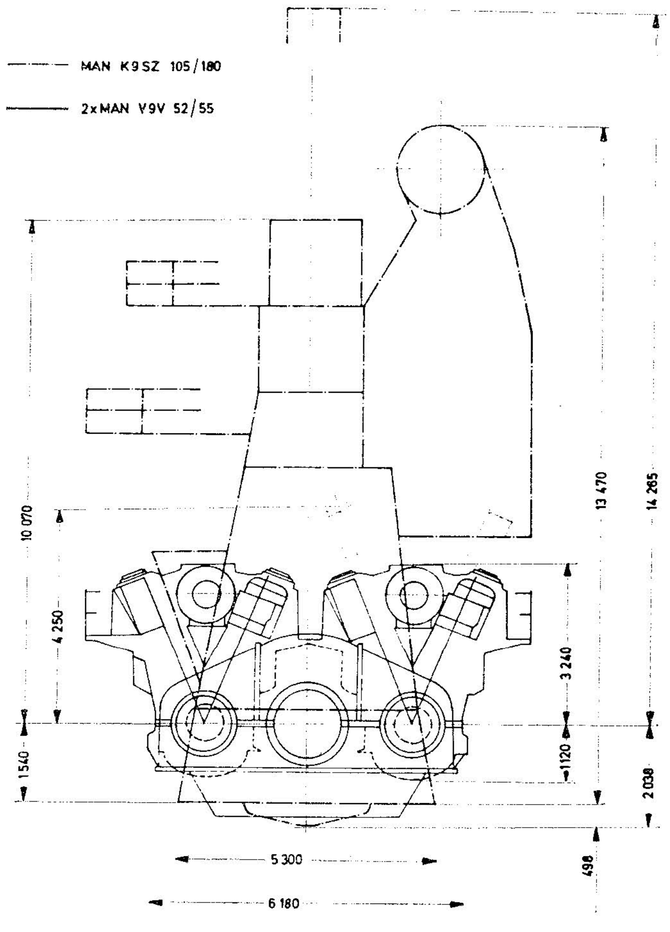


Fig. 28c—Comparison slow and medium speed diesels

Conclusions

We have heard a few tentative principles and have seen some fruitful and some not so fruitful specimens of inventiveness in ship design. We may accept the principles and find the examples pertinent, or we may reject them, it is all up to us. Supposing we find some of the principles right. What does this mean? If we follow them, are we successful? I should say, not at all! The parallel with the roulette player at the beginning of the lecture is present again. As with gambling, systems exist, praised by their authors to be infallible, but there also exists a limit to the stake, and the zero, when the bank takes all!

Back to inventions in ship design, our principles are only a sort of bulkwark to prevent us falling in the water, or a radar at night for safe navigation. But if one is a good captain, to make for port is another matter. I am afraid the question mark must remain over whether inventiveness should be applied in ship design. The right answer depends on so many extra factors and imponderables, to be decided as the case may be. But one thing is sure, the path to having an invention recognised and realised is a long, hard one. This warning should be given to everyone from the beginning!

To start with the patent application is no easy matter. Being unfamiliar with the rules of how to describe an invention, how to formulate the claims and how to present the drawings, an inventor almost always needs a patent agent, if not at home, in any case abroad; he needs to have an address, to have everything translated in the appropriate language and somebody to present his ideas before a foreign patent office. It makes little sense, if benefits are envisaged, to apply for a patent only in one's home country, especially in such international and world-wide businesses as shipbuilding and shipping. The whole procedure is an expensive adventure. I know of some overseas patent attorneys, where only one visit to their luxurious offices amounts to thousand pounds and the poor inventor literally sinks in the thick carpets! For individuals, young engineers, the solitary way is mostly impossible. The help and encouragement from the companies employing them depends upon the benefits in view, costs involved in research and prototype building, company policy and not least it depends upon their own position in the company. And this is just the beginning of the story.

The materialisation of an invention, the building of the prototype is the second big step. Preliminary design, estimates, workshop drawings, model tests, building costs and full scale trials are expensive activities, at least in shipbuilding and marine engineering.

Rudolf Diesel wrote in 1913 in his book "Die Entstehung des Dieselmotors":[38]

—"Never at any time can an idea alone be called an invention . . ., in every case only a completed idea is taken as an invention. An invention is never purely a brain product, but the result of a fight between the idea and the material world . . . , the real time of work and suffering for the inventor lies between an idea and the accomplished invention".

Time of suffering for the inventor because, just in this phase of uncertainty, he needs understanding and encouragement, and money for building the prototype, a lot of money in shipbuilding! So he or his company has to find a shipowner or a sponsor, who is prepared to be 'the first'. And we have already talked about the shipowner's conservatism!

To convince people and to raise money for an invention is not easy. It is a struggle in which, paradoxically, good results meet extra enemies in the form of human jealousy and competition. The innovation baby can die shortly after a healthy birth.

Rudolf Diesel said further:

"The genesis of the idea is the joyful time of creative brainwork, because it has nothing to do with reality. The completion is the creative time when all auxiliary means help to accomplish the idea; still creative, and still pleasant is the time of overcoming the natural obstacles, out of which one emerges strengthened and entranced, even if defeated. The introduction is a time of fighting with stupidity and jealousy, idleness and haughtiness, secret opposition or open conflict of interests, an awful time of struggle with mankind, a martyrdom, even if one succeeds."

The third phase, the time to get the full commercial value from an invention, is like the estuary and the sea for a river. It is big business fending for itself, depending, as business does, on market, customers-views, management, production facilities, sales organisation, again, capital and, perhaps, an element of chance. And if times are bad, as so often in shipbuilding, the best innovation does not receive any help! How would an inventive oil tanker designer earn his living today?

Professor Schimank in his fascinating lecture before the STG in 1964,[39] if my memory serves me right, when referring to a new idea, to the raising of the money, to the creation of the prototype and to the commercial success, said "A cynical commentator could say that the first one, the idea, is the least important". He may be right, but, for all that, the idea is the nicest of all.

In spite of the miseries, and independent of financial results, the inventiveness in itself, the enthusiasm proceeding from it, the impulse for research and accomplishment, the emotion of model or full scale testing, the negotiations with the patent offices, progressing work with your own company or with clients and the increase in self confidence are wonderful.

To young engineers I would like to say therefore: at least, try.

List of principles

An innovation should come out at the right moment.

Not all inventions which have failed should be forgotten, some of them deserve reconsideration periodically.

Most successful inventions do not suddenly appear on the market, they are the result of step by step application of inventiveness in ship design.

Shipowners do not like inventions!

Do not include in a ship design more than one major invention at a time.

An invention to be accepted in a ship design has to be first of all reliable.

To be reliable an invention has to be built up as far as possible of conventional material and parts and has to be easy to maintain and repair, and that means it has to be simple.

An invention to be accepted by a shipowner should offer substantial economical profit.

The profit of an invention should be presented in the most attractive manner for the customer.

A designer should not hang on to the whole of an invention, he should accept partial results or whatever comes out.

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