Modern Merchant Shipbuilding*

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INTRODUCTORY SURVEY

The title of this paper indicates that the only restrictions to the general subject of shipbuilding are that it should be (*a*) modern and (*b*) merchant, as opposed to naval. Otherwise it deals with shipbuilding in the widest sense. It is impossible, of course, in a single lecture to give any but the sketchiest description of the world shipbuilding scene as a whole: this paper consists primarily of the consideration of some aspects of current trends in shipbuilding and marine engineering with special reference to the United Kingdom and Scandinavia. For the most part the information submitted refers to the period since the beginning of World War II. As far as naval work is concerned the whole subject is best left to those far better acquainted with it than myself.

Although shipbuilding practice and design will be considered principally as applicable to Britain and Scandinavia, it is, nevertheless, necessary to consider developments in these countries against the background of world shipbuilding as a whole. The first part of this paper will therefore describe some current trends in shipbuilding generally before detailed attention is given to actual shipyard practice.

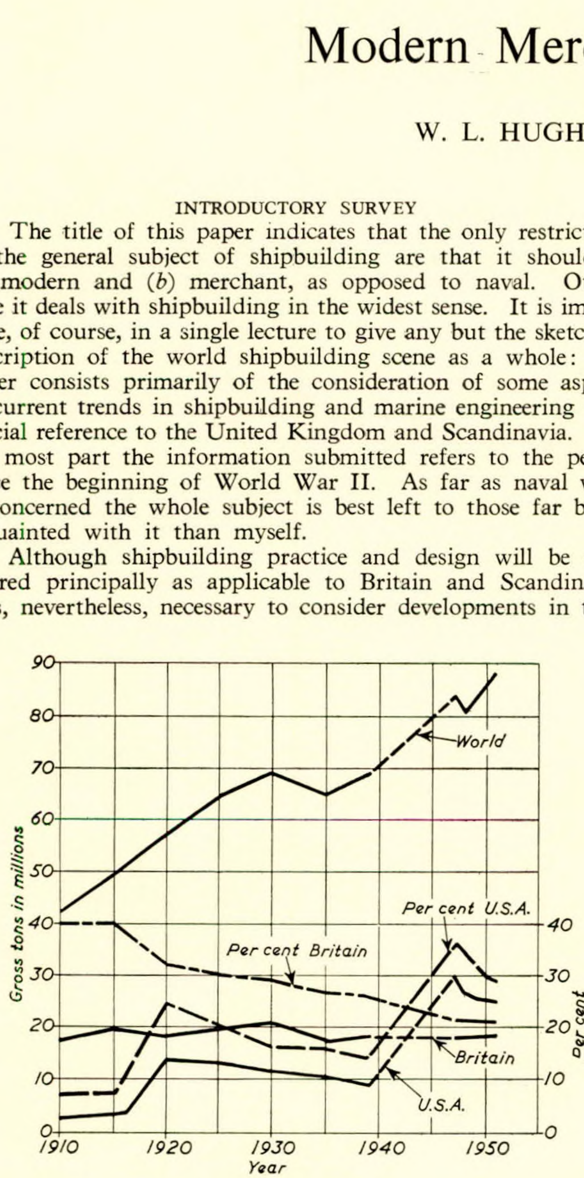

FIG. 1—*World tonnage*

Shipbuilding is perhaps the most international of all industries in that shipbuilders are dependent upon shipowners for orders; owners are dependent upon shippers for cargoes and freights; and freights are directly dependent upon the general condition of world trade and economic prosperity. Wars, and the threat thereof, have an all-important bearing on the factors enumerated above. When, in addition to these things the effects of government planning and subsidization of shipping and shipbuilding are considered, it is easy to see how impossible it is to isolate, as it were, chemically pure shipbuilding in any locality. In other words, the element of perspective is vital and all developments, technical or otherwise, must be considered in the light of that perspective.

Fig. 1 shows the sizes of the merchant fleets of the World, Britain and America over the last forty years. It will be seen that during this time the total merchant tonnage afloat has almost exactly doubled itself. Note the comparatively constant size of the British merchant fleet and its steady decline as a percentage of the world total. Note also the tremendous increase in American tonnage during this period, due almost entirely to expansion during the two world wars. America now possesses by far the largest merchant fleet in the world—about twenty-five million gross tons—although, of this total, some eleven million gross tons consist of ships laid up since the

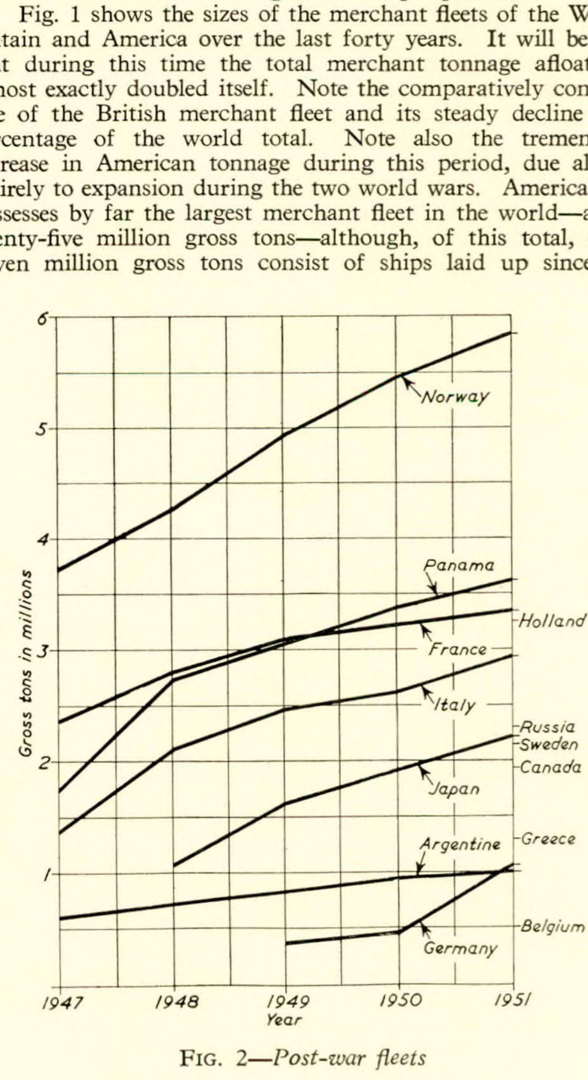

FIG. 2—*Post-war fleets*

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end of the last war. The present position is that Britain with her long experience and efficiency in the building and running of ships has now given way to a nation which has had little experience in these things and whose cost of operation is much higher than Britain's. This has had, and will have, a great effect on the structure of world trade—another illustration of the impact of the dollar on world economy.

Fig. 2 illustrates the development of the post-war fleets of the smaller shipowning nations and indicates relative sizes of merchant fleets as at July 1951. It will be noticed that all of these fleets are steadily expanding in contrast to the practically constant size of the British fleet. Apart from the construction of new ships either at home or abroad, most of these nations have benefited by the acquisition of a considerable amount of American surplus tonnage, the Panamanian fleet, for instance, containing about $1\frac{1}{4}$ million tons of such ships. Norwegian owners were into the market very soon after the end of the war and placed orders for many ships, especially tankers, both in Britain and Sweden. Japan, under the beneficent guidance of the United States, has been steadily rebuilding her fleet, while that of Germany has shown a remarkable increase since all restrictive limits on shipbuilding were lifted in that country.

The most outstanding feature of the development of merchant shipping is the growth of tanker tonnage, which has risen from about five million tons in 1926 to some eighteen million tons at the present day. This increase is illustrated in Fig. 3, which also shows the very rapid percentage increase

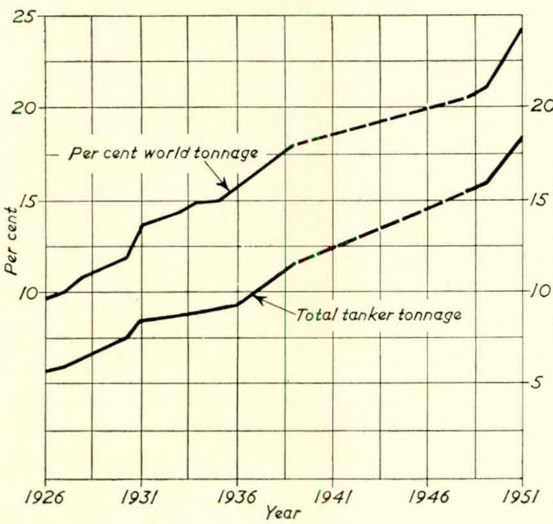

FIG 3—*Tankers, over 1,000 tons gross tonnage*

in tanker tonnage. The particularly rapid rise since 1949 should be noted as it is this increase which has contributed and is still contributing in great measure to the post-war shipbuilding boom throughout the world. The term "boom" is used without apology for it is undeniable that a real boom exists. Whether this may be followed by what has come to be recognized as the inevitable slump remains for the future to reveal. As is well known, shipbuilding has for long been a fluctuating business as indicated by Fig. 4. However, it will be seen that since 1940 production has maintained a uniformly high level both in Britain and the world at large. At present total world production is about $3\frac{1}{2}$ million tons per annum while throughout the world there are on order some 16 million tons of ships (half of which are tankers), hence even a rough estimate indicates that under present conditions the world will be busy building ships for the next five years at least. All major builders are similarly placed—for example, Germany has six years' production on order and the United Kingdom five years' production. In view of this position any prospective

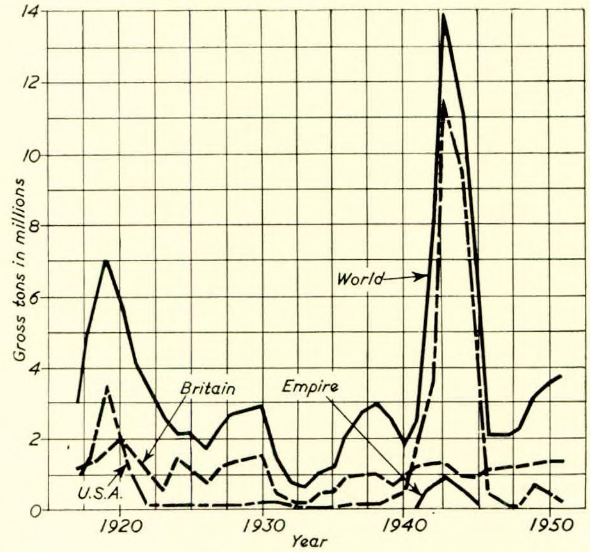

FIG. 4—*Annual launchings (over 100 tons gross)*

owner would have difficulty in having a ship built within less than about three years, regardless of where his order was placed.

Not long ago an entirely different position obtained. Both Germany and Japan had empty berths and were in a very favourable position for the acceptance of orders with an early delivery date. Consequently, orders flowed into both these countries with cost as a secondary consideration, since owners were primarily interested in securing early delivery to take advantage of the high freight rates then obtaining. However, this phase has now passed and delivery times are long in all shipbuilding countries. On the whole things look very rosy for the shipbuilding industry but there is no doubt that this situation is assisted by the existence of considerable international tension. Actually, in 1949, there was a quite pronounced tendency for orders to fall off, but the outbreak of the Korean war and the consequent stockpiling which occurred in all countries gave a new fillip to the placing of orders for ships of all types.

If the Korean incident subsides shipbuilding may well do so too. Reverting to Fig. 4, an examination of the shape of

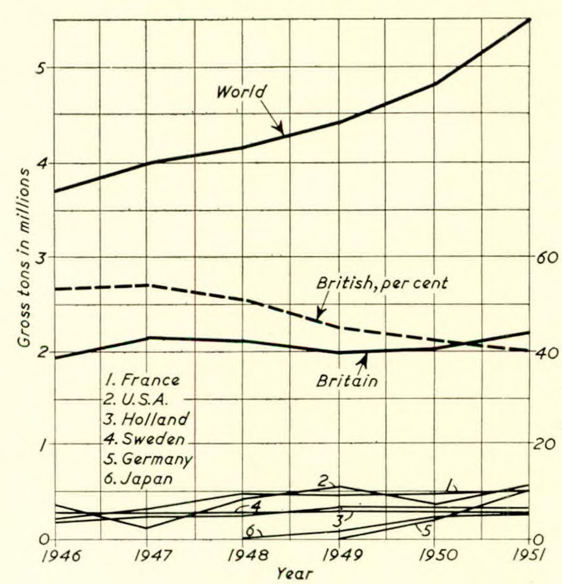

FIG. 5—*Tonnage under construction (over 100 tons gross)*

the world production curve indicates that history *could* repeat itself very closely. This figure shows clearly the steady predominance of British production except during wartime, for it is clear that in both world wars American production was by far the greatest in the world. The phenomenal American output during the last war indicates just what the immense industrial potential of this country can do when necessary.

Whereas Britain has long been the world's major producer of ships, Fig. 5 shows that since the last war the British contribution to total world output has been steadily declining simultaneously with the rise of other shipbuilding nations; in this diagram the particularly rapid rise in production from both Japan and Germany should be noted. British shipbuilding facilities have been working at full capacity for many years, whereas other countries are steadily regaining their prewar output and in some cases expanding their production beyond it.

It has been stated earlier that tanker orders are largely responsible for the present world shipbuilding boom. Just how great a contribution tanker construction is making is clearly indicated in Fig. 6, which gives the percentage of tankers

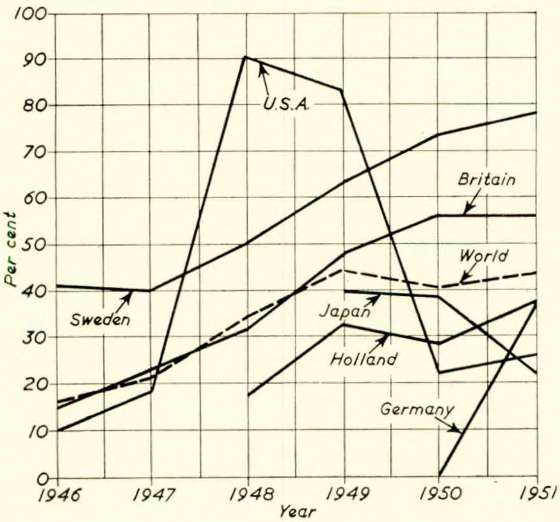

FIG. 6—*Percentage of tankers in tonnage under construction*

under construction in various shipbuilding countries and the world at large over the past six years. At the end of 1951 tankers represented no less than 40 per cent of the total under construction: on a tonnage basis, at least one in every two ships in Britain was a tanker and in Sweden approximately four out of five were tankers.

Table I gives information regarding the major owners of tanker tonnage.

TABLE I.—TANKERS

Country	Gross tons (Over 1,000 t.g.)	Percentage of total fleet
U.S.A	4,400,000	18
Britain	4,100,000	22
Norway	3,000,000	50
Panama	1,700,000	50
World	18,000,000	24

Although the incidence of tanker building has been very satisfactory for the maintenance of a high rate of shipbuilding since the war, it has considerable disadvantages as well. For many shipbuilders with yards equipped for the production of passenger ships with a great proportion of work for fitting out trades, a complete reorganization has been necessary to accommodate the predominance of steel work in the tanker. A second major drawback is the fact that prospective owners of dry cargo liners and tramps have been deterred from placing orders. This aspect particularly affects Britain which has been very busy exporting cargo ships and building tankers for herself and her rivals with the result that her own dry cargo fleet is diminishing not only as a percentage of the world total but also in actual magnitude. In the next five years new dry cargo ships to the extent of about two million tons may be added to the British fleet but by then at least four million tons of the present fleet would be over twenty-five years old and some two million tons would be more than thirty years old. If these ships are scrapped it then appears that there will be a further decrease in the British dry cargo fleet. If they are not scrapped they will constitute a very inefficient section of the British merchant marine. Hence it is imperative that if Britain is to retain her prominence in world shipping she should take active steps to promote the building of dry cargo ships in the immediate future.

Britain's position is a particular illustration of the general shortage of cargo ships throughout the world. In 1939 the total world tonnage was about sixty-eight millions of which eleven millions were tankers and fifty-seven millions dry cargo ships. In 1951, although the total world tonnage had risen to eighty-seven millions, the active dry cargo tonnage had increased to only fifty-eight millions, eleven million tons of American shipping being laid up. By contrast, in 1951 there were eighteen million tons of tankers—none laid up—representing an increase since 1939 of about sixty-four per cent. This situation, allied with the present international tension, has resulted in particularly high charter rates over the last two years.

The figures quoted so far have been in tons gross: roughly speaking each gross ton may be taken as representing 1·5 deadweight tons. For determining numbers of ships being produced at the end of 1951, it may be of interest to note that the "average ship" under construction was as follows:—

	Gross tons
World	4,600
U.S.A.	8,600
Britain	6,000
France	6,000
Italy	5,500
Japan	5,000
Sweden	5,000
Germany	2,800
Holland...	2,200

Fig. 7 is of interest in showing the relative stability of the shipbuilding industry in various countries during the year

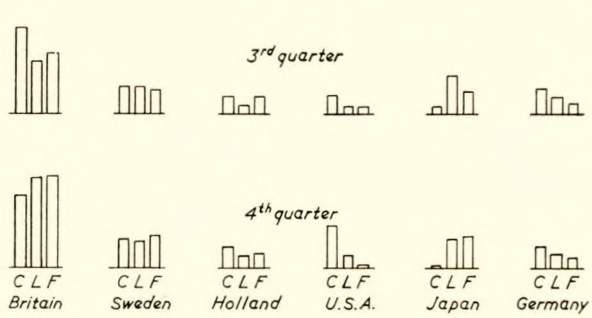

FIG. 7—*Tonnages commenced, launched and finished during 1951*

1951. It will be seen that in Britain, Holland and Sweden the tonnages commenced, launched and finished throughout the year were approximately equal. In Germany this condition was approached only in the last quarter, indicating that the tonnage under construction was expanding throughout the year. In Japan the exact opposite occurs, indicating that berths were becoming saturated and few keels being laid. In America the rapid increase from quarter to quarter in the tonnage commenced indicates the beginning of a new shipbuilding programme, very few ships being completed by comparison with the number laid down.

FINANCIAL CONSIDERATIONS

Enough has now been said to indicate that shipbuilding is big business on a world scale, and highly competitive on both national and international bases.

In practically all countries except Britain this international form of competition is reflected in some form of State assistance to either shipbuilders or shipowners, or both. In Germany, for instance, the rebuilding of merchant fleets was assisted after the war by State loans covering 40 per cent of building costs in the case of old-established shipping lines and 20 per cent for newly-formed companies. In a recent programme initiated by the Federal German Republic for sixty Diesel vessels totalling 160,000 tons, owners will contribute only 115,000,000 D.M. of the total estimated cost of 240,000,000 D.M., the State supplying 50,000,000 D.M., while a further 35,000,000 D.M. will come from funds made available by the European Recovery Programme. In various other European countries great use has been made of counterpart funds available under the Marshall Plan for the financing of shipbuilding programmes and the expansion of shipbuilding facilities.

In America, of course, both the building and operating of merchant ships is highly subsidized by the State; and even in Australia a building subsidy of about 25 per cent is now operating.

On the other hand, in Britain there are no subsidies of any kind for either shipbuilding or shipowning, both industries remaining purely private enterprises operating under their own initiative and resources. Under the circumstances the rebuilding during and since the war of Britain's merchant fleet to replace some 12,000,000 tons lost during the war years is a remarkable indication of the courage, determination and resilience of British shipping.

Since the end of the war the British shipowner has been placed in a very difficult position. The cost of ships has risen to between two and three times its pre-war value, and will, of course, remain high while the shipbuilding market is good. At the same time freight rates have generally been high, so that a ship in commission has been a well-paying proposition. But, remembering the slump in 1921, each owner has had to bear in mind the possibility of being caught with a high-priced ship on his hands at a time when the bottom falls out of the freight market. To add to the difficulty of financing new building, Government compensation for wartime losses generally fell far short of replacement cost, while there has been little accommodation in the form of taxation relief to provide for increased replacement costs, so it has been a most courageous decision on the part of owners to proceed at maximum pace with the reconstruction of their fleets to practically pre-war strength.

Some indication of the chancy predictions which an owner must make is given by Fig. 8, which shows comparative charter rates over the post-war years for both wet and dry cargoes. It will be seen that a marked recession occurred in 1949. For a short period during this year a buyer's market in ships did exist, some shipbuilders even being pressed to give fixed prices without the customary fluctuation clauses which before and since seem to have become part and parcel of shipbuilding contracts. However, the outbreak of the Korean war immediately sent freight rates soaring. The sudden fluctuations during 1951 represent variations in the height of international tension.

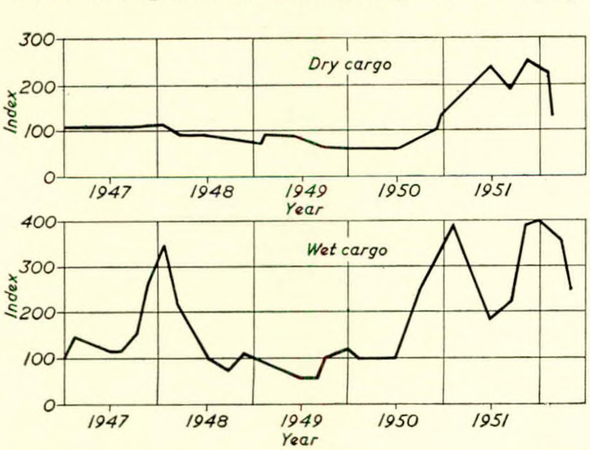

FIG. 8—*Charter graphs*

The essential feature distinguishing British shipbuilding from that in other countries is its highly competitive nature within the country. In normal times an order goes to the yard which can deliver the ship at the right time and the right price and when orders are scarce the competition is fierce. An important factor is the speed with which preliminary design and tenders can be prepared. In one yard with which the writer was associated, more than eighty estimates were prepared within a year by a design staff of six and an estimating staff of two. This estimate is one of "cost"; the "price" is naturally somewhat different, being fixed at director level and depending upon the condition of the market, knowledge of competitors' movements and whether the order is really desired or not.

On the subject of cost it will be of interest to refer to Fig. 9, which illustrates the continual rise in "building price index" since 1939 for a plain deep sea cargo ship. In fairness to the shipbuilder it must be stated that the greater part of this rise is outside his direct control, as witness the comparative price indices as at 1948 for various "bought-in" items.

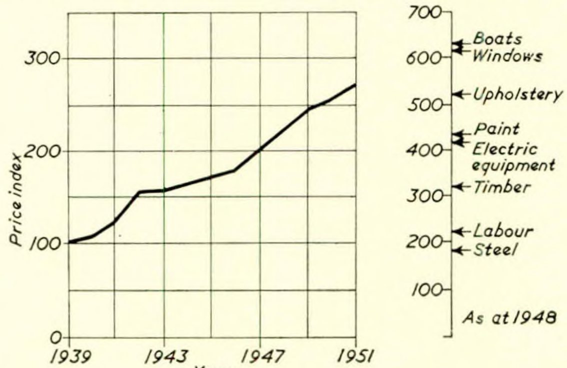

FIG. 9—*Plain tramp steamer, 5,000 tons deadweight, 10½ knots*

A very rough dissection of the total cost of such a ship is given in Table II.

TABLE II.—COST DISSECTION

		Per cent
Hull	Material	42
	Labour	23
Machinery ...	Material } Labour }	22
Charges		13
		100

This dissection, of course, varies with the type and speed of ship and type of machinery; the table presents a case where machinery is brought in and fitted by an outside contractor. It will be seen that the shipyard is directly responsible for only about one-quarter of the total cost, represented by direct labour on the hull. Some control is also exercised over the third item, "Charges", but for the most part these are fixed and not capable of much reduction.

Absolute values of ship costs are almost impossible to quote at a time when they are varying so rapidly. Where published prices are being compared it is important to bear in mind the distinction between price and cost and to remember that shipbuilders always submit the very best price they can hope to secure. In other words, contract prices reflect the state of the market, rather than actual cost to the builder.

Again, anybody who publishes shipbuilding prices usually does so for a very good reason—an owner may wish to impress on his Government the high cost of replacement; a builder may want to indicate that some form of State assistance is required to make his prices internationally competitive; and a government may have a variety of reasons for advertizing the price of ships built under its *régime*. Added to this, it is rarely possible to obtain prices for exactly similar ships built in different places at the same time, and variations in specification and the year of building do have important effects on cost. Finally, it is not always possible to determine whether the prices quoted are fixed or fluctuating, a factor which may be all-important.

Bearing all this in mind the following prices published in 1951 are given for what they are worth:—

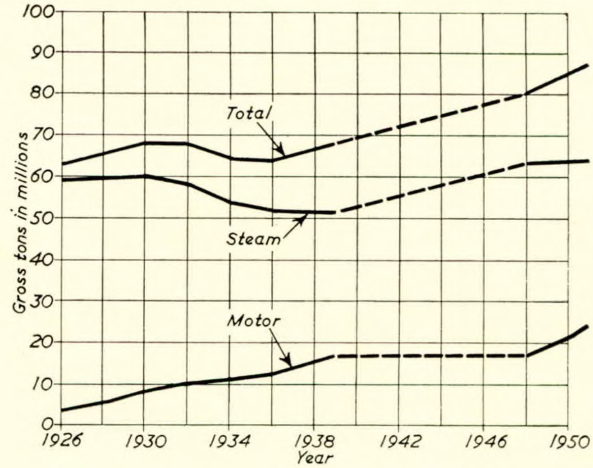

FIG. 10—*Rise of the motorship*

steady building of steamers, the steam tonnage afloat is practically stationary, and even now very little above its value twenty-five years ago. In other words the net increase in tonnage afloat over this period is due almost entirely to the increase in motorships.

The preponderance of motorship construction is shown in Fig. 11, motorships constituting about 62 per cent of world tonnage under construction during the period covered.

TABLE. III—1951 PUBLISHED PRICES

Type	Builders	Deadweight Capacity	Speed	Engines	Cost per ton, d.w.
Cargo	Alexander Stephen and Sons, Ltd.	5,300	12·0	Motor	£73
Cargo	Fairfield Shipbuilding and Engineering Co., Ltd. ...	6,500	14·5	Motor	£77
Cargo	Eriksbergs Mekaniska Verkstads A/B	9,000	15·0	Motor	£68
Cargo	Charles Connell and Co., Ltd.	10,000	—	Motor	£80
Cargo	Charles Connell and Co., Ltd.	12,000	16·0	Steam	£62
Tanker	Kaldnes Mek. Verksted A/S	18,000	14·5	Motor	£46
Tanker	British Tanker Co., Ltd.	26,500	16·0	Steam	£47

When the complications of international exchange rates are added to the many factors enumerated above, it becomes a very difficult problem to establish reliable cost figures between different shipbuilding countries. However, broadly speaking, costs in Britain, Sweden, Germany and Denmark are within competitive limits, and these countries are the low-cost producers. Holland may be regarded as intermediate, and then at the high end of the scale come France, Italy, U.S.A., Japan and Belgium.

TRENDS IN DESIGN

As to the design of modern ships, it is possible to deal here only very briefly with a few selected aspects of general design trends.

Members of the Institute of Marine Engineers will be interested primarily in trends on the marine engineering side, with special reference to main propulsion machinery. On this score the most obvious feature of post-war powering is the overwhelming preponderance of the Diesel engine in its various forms. For some twenty-five years now the motorship has gained steadily in popularity, as Fig. 10 clearly shows. At no time has there been a reduction in the motor driven tonnage afloat, whereas steam tonnage did fall back considerably during the 'thirties. Note the rapid increase in motor tonnage since 1948, which accounts for 91 per cent of the total increase in tonnage afloat since that date. The actual percentage of new ships built does not approach this figure, as Fig. 11 reveals, the difference being due to the higher incidence of scrapping among steam vessels, generally of riper vintage. Thus, in spite of

When considered on the basis of actual numbers of installations, the proportion rises to about 72 per cent as shown by the dotted curve. In many countries in Europe, practically all vessels under construction are motorships.

Fig. 12 illustrates the continuance of the elimination of the coal-fired vessel from the world picture, a trend which has

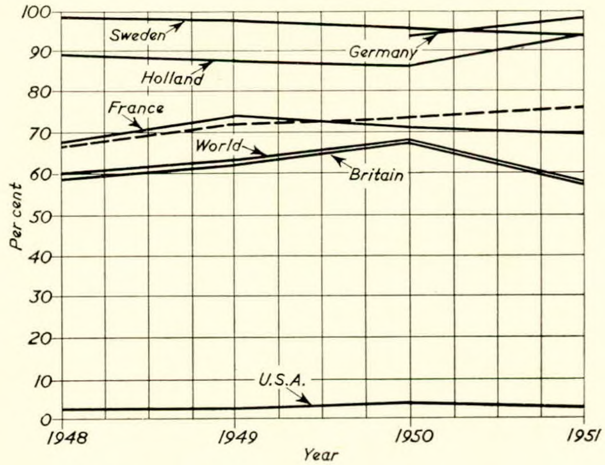

FIG. 11—*Percentage of motorships under construction*

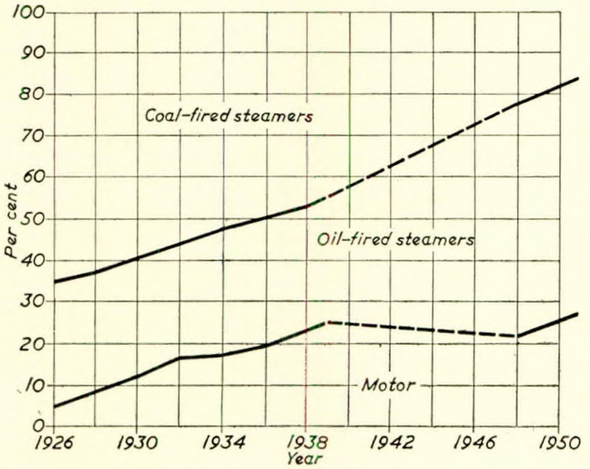

FIG. 12—*Fuel analysis on tonnage basis*

proceeded at practically constant pace for twenty-five years. Although this figure shows the percentage decrease only, the *actual* coal-fired tonnage has also decreased by about 3½ million tons between 1948 and 1951.

The subdivision of machinery types is indicated in Fig. 13.

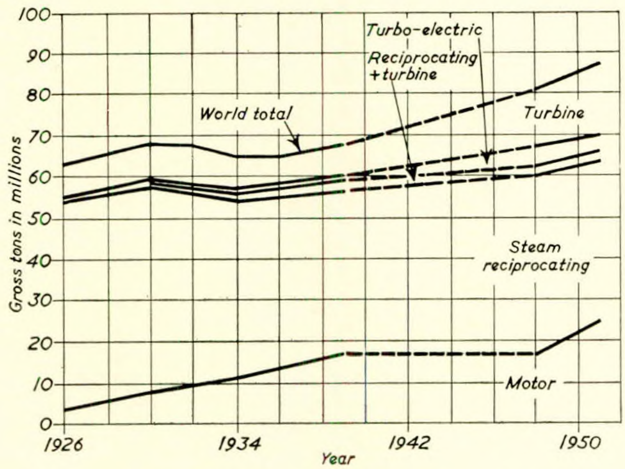

FIG. 13—*Propulsion analysis (tonnage basis)*

Twenty-five years ago 80 per cent of the world's tonnage was propelled by reciprocating steam engines; today, in spite of the steady rise in turbine and Diesel drive, it is interesting to note that about 45 per cent is still fitted with this form of engine, largely due to the Liberty Ship programme in U.S.A. However, since the end of the war, turbine and Diesel drive have propelled the great bulk of new construction, and the proportion of steam reciprocating propulsion is rapidly decreasing.

The above observations are general; in individual cases there still remains healthy competition between all forms of engines, with the steam reciprocator in some of its new forms a strong competitor up to about 3,000 s.h.p. From 3,000-6,000 s.h.p. the Diesel appears to hold the field; from 6,000-8,000 s.h.p. the Diesel and the geared turbine fight it out, and above this power the geared turbine is generally most popular. The resurgence of improved steam reciprocators of low power and the invasion by the turbine of the pre-war "motorship" field in moderately-powered cargo liners are two of the most interesting post-war developments in powering.

Turbo-electric, Diesel-electric and geared-Diesel drive all have their adherents and applications in special services, but the total number of these installations is very small compared with straight Diesel and geared turbine.

The most attractive field for electric drive is in vessels where the electrical load is high when the propulsion load is small or non-existent; for this reason it has recently been applied in dredgers, self-unloading bulk carriers, fire-floats, ice-breakers and a few tankers. A large proportion of existing turbo-electric machinery is, of course, fitted in the American T-2 type tankers, but since the war most American built tankers have reverted to geared turbine installations. Electric propulsion is also attractive on the score of flexibility in manœuvring and for this reason has lately been employed in some ferries and ships for short coastal service. Up to 3,000 s.h.p., d.c. is employed; above this power the installation is usually a.c.

Similarly, geared Diesels are comparatively rare although gaining somewhat in popularity in the last few years. Such equipment has generally been of low power, below 3,000 s.h.p., but there are one or two notable exceptions. This form of drive has been used considerably in Germany since the war to make use of a surplus of submarine engines suitable for the purpose, the manufacturers of the M.A.N. engine having been pioneers in the development of this machinery. While normally fitted with some form of mechanical, electrical or hydraulic flexible coupling, at least one "solid" design is in service based on accurate calculations of torsional vibration characteristics. If this installation is trouble-free it may point the way to a new development in this field.

The rarity of these special types of drive is indicated by the following table.

TABLE IV.—MACHINERY TYPES; VESSELS LAUNCHED IN 1950

Type	Number of ships	Tons gross	Percentage of tonnage
Oil engine ...	696	2,111,000	60·5
Geared turbine ...	98	1,072,000	30·6
Steam reciprocating	168	208,000	6·0
Combined reciprocating and turbine	43	83,000	2·4
Turbo-electric ...	1	10,000	0·3
Diesel-electric ...	6	6,000	0·2
	1,012	3,490,000	100·0

Volumes can be and have been written on the respective merits of the Diesel and turbine drives for moderate powers of about 8,000 s.h.p. At this power both types can be accommodated on a single screw so that the lower weight of the turbine installation must be balanced against its greater bunker consumption for any particular length of voyage to determine the overall effect on deadweight capacity. The cost of fuel in the past was approximately the same for each because of the lower cost of bunker oil as compared with Diesel fuel, but the burning of high viscosity fuels in Diesels, which appears to be giving every satisfaction, will weigh the balance in favour of the latter. The first cost of both types is roughly equal, but maintenance is generally considerably higher with oil engines.

When the power required increases much above 8,000 s.h.p. it becomes necessary to employ at least two oil engines and the resultant loss of propulsive efficiency by the use of twin screws weighs heavily against the Diesel. In this field the geared turbine is generally preferred.

Without entering any detailed discussion of the relative technical advantages of the various forms of main propulsion machinery, it is as well to point out that as far as the ship-owner is concerned his choice of engine is dependent upon many more important and pressing factors than mere technical excellence and low fuel consumption. At present perhaps the most important factor is availability; the delivery of machinery must fit in with delivery of the ship and in many cases this automatically decides the type of engine to be installed. Other important factors are reliability, maintenance costs, size, weight, fuel consumption, first cost, availability of fuel and availability of suitable engine room staff.

As a guide to modern weights and fuel consumptions (all purposes) the following approximate figures are given for an installation of 7,500 s.h.p. Weights shown comprise the total machinery installation.

TABLE V.—RELATIVE WEIGHTS AND CONSUMPTIONS

Type	Percentage weight	Percentage consumption
Geared turbine ...	750 tons = 100	0.61 lb. per shp. hr. = 100
Diesel	150	67
Geared Diesel ...	125	71
Diesel-electric ...	120	74
Turbo-electric ...	115	103

As to the future, the development of the internal combustion turbine and the "atomic" ship will be watched with the greatest interest, but neither of these innovations is likely to have any serious impact on merchant shipbuilding for many years to come.

Closely connected with the choice of machinery is the question of ship speed, which for tramp ships and cargo liners is showing an ever-increasing tendency. Many modern ships have speeds of 16, 18 and even 20 knots in the case of the projected American Mariner class. There is no doubt that this tendency has been largely influenced by defence requirements, for in these days of decreased port efficiency and increased turn-round time its commercial logic would be difficult to justify. Even now there is a school of thought which advocates a return to lower speeds and fuller coefficients but this principle is likely to receive short shrift while the possibility of future wars exists. The sensible alternative is to attack the problem at its roots by improving port and cargo-handling efficiency so that modern technical improvements in machinery may be used to full advantage in the matter of increased speed.

On the ship side, isolated owners have already played their part by the introduction of improved methods of handling and stowing cargo. The pallet system using fork-lift trucks, the stowage of cargo in standard containers, the Farrell rolling wing deck, the use of deck cranes and the development of self-unloading gear in bulk carriers may be cited as instances of this tendency. The increased adoption of rolling, sliding or hingeing steel hatch covers also reduces cargo-handling time.

Since the war, the power entrusted to a single screw has progressively increased. One well-known company has a complete fleet of turbine driven vessels operating with 14,000 s.h.p. absorbed by a single screw, while the American Mariner class has been designed for 22,500 h.p. on a single shaft. Considerable advantage is gained from the increase in propulsive efficiency over that of the twin-screw installation, and the upper limit of power on a single screw now appears to be set only by the ability of manufacturers to supply propellers of the required size.

This tendency is assisted by the current trend towards larger ships, which is especially marked in the case of tankers. Up to 1939, 12,500 tons deadweight represented a large tanker, but since the war the maximum size has rapidly increased to 16,000, 24,000, 28,000, 40,000 and now 45,000 tons deadweight. Where limits are not set by existing port facilities and dimensions of waterways such as the Suez and Panama Canals, the larger ship generally shows economies in increased deadweight to displacement ratio, lower crew charges and lower fuel bills per ton deadweight. Increased waterline length reduces resistance per ton and so higher speeds are obtainable.

Aluminium and its alloys have proved capable of making worth while contributions to increased deadweight and stability in certain types of ship, but just when their use was beginning to expand international stockpiling rendered their cost almost prohibitive. Nevertheless, light alloys are often used for wheelhouses and funnels and in many cases for lifeboats. As a main structural medium, however, its use is still extremely limited.

In connexion with rigging, the modern idea is the complete abolition of standing rigging and the use of stayless masts and derrick posts. These give a much cleaner appearance and a deck space uncluttered by wires and eyeplates. Incidentally, they are a much simpler problem for the designer. The Bipod mast, developed in Sweden, is a special application.

Passenger comfort is receiving attention in the increased adoption of the Denny-Brown activated-fin stabilizer developed during the war to give steadier gun platforms for the Navy but later made available for merchant use. While the most spectacular application has been in larger passenger vessels such as *Chusan,* many Continental cross-Channel ships have also been fitted with the device.

Provisions for the comfort of the crew have developed enormously since the end of World War II. In some countries this has largely been the result of direct pressure from organized labour, but it would be unfair to disregard the fine work done during the 'thirties by many individual owners, quite regardless of Government regulations. Much of this work went by the board during the war due to the exigencies of standardization and speedy production, but has since been taken up with renewed vigour. Tankers have always had superior accommodation because of the risk originally associated with sailing in such ships and because it was felt that personnel deserved compensation for the small amount of time in port. In these vessels with engines aft the provision of high class accommodation is fortunately relatively easy. However, practically all new ships now building have crew accommodation at least equal to that of the tanker, provided, in some cases, at the expense of reduced carrying capacity or increased height of superstructure. The provision of separate bathrooms, messrooms, and recreation rooms for various sections of the crew is standard practice. Where possible the entire crew is housed amidships above the weather deck, the resultant improvements in catering, comfort and safety being obvious. And the provision of single berth cabins throughout, though not yet universal, is becoming increasingly frequent.

SHIPYARD PRACTICE

In examining the methods by which the foregoing results are achieved it is proposed to deal with the subject in only general terms, since details of organization and procedure vary widely between countries and between different districts in the same country. Unless otherwise stated, the following remarks apply to shipyards in Britain, where methods are today fairly representative of general shipbuilding practice.

Primarily the discussion will be restricted to the activities of the steel trades as they normally constitute up to 70 per cent of the total shipyard labour force.

Beginning in the loft, the general trend is towards the all-templated shell, with only an odd plate lifted from the ship. Isolated yards retain the older method of lifting practically everything from the ship, but they are few and far between. In order to obtain the necessary accuracy for welded shell butts, new methods of expansion have been developed and, where double curvature is pronounced, the degree of subdivision is increased. In some yards template wood has been largely displaced by steel strip templates and the use of steel tapes for fixing dimensions, thus overcoming difficulties due to differential expansion of wood and steel under varying climatic conditions. Where large scale welded work is concerned some firms employ special steel tapes which embody an allowance for contraction on the same lines as a pattern-maker's rule. However, in practice, the contractions due to this cause are largely ignored without serious effects. On the building berth, and even in assembly shops where large prefabricated sections are constructed, the use of the theodolite and level for lining-off and fairing is becoming more common.

A revolutionary change has recently been introduced by a Hamburg firm which has developed an optical and photographic method of marking plates and bars, thereby eliminating loft work entirely. Although still in its infancy, this method has already been used extensively by some Swedish and Continental yards, but has not yet made any serious inroads on the conventional method.

On the steel fabrication side the most outstanding post-war change in shipyard practice has been the spectacular transition from riveted to welded construction. The reasons for this change are many but two of the most important are often overlooked. The first is the ever-increasing dearth of riveters and riveter apprentices which has compelled many yards to swing towards welding, in some cases against their will. Like inflation, this trend has a spiral effect. As more yards turn to welded construction, so the riveter sees less future in his trade; less men come into it and so even more yards turn to welding. This consideration, in my opinion, has been the major cause for the general adoption of welding. It was obviously given impetus by the response in the riveter's psychology to the spectacular results of the use of welding in U.S.A. during the war.

The second factor is the high incidence of tanker building throughout the world since the war. In this type of ship the advantages of welding in attaining and maintaining the degree of watertightness necessary for efficient isolation of various grades of cargo are so outstanding that the process is almost a *sine qua non* for the building of tankers. Certainly, many yards would not have had the necessary skilled labour to produce a first class riveted tanker, the building of which was the prerogative of relatively few high class yards prior to the war. With the post-war flood of tankers, some of the remaining yards would have been lacking orders but for the advent and use of welding which has now made the tanker one of the easiest types to construct.

The switch to welding has not been without its opposition, an opposition arising mostly from the inertia of the diehard "traditional" shipbuilder who stoutly asserts that the riveted vessel is both cheaper and quicker to build than its welded counterpart. Even if this were correct—a point which is still highly debatable—it must be borne in mind that the shipyard manager's side of the story is only part of the complete picture. It is for the owner to weigh up the full economics of the case and decide from overall considerations. For instance, a properly designed welded vessel contains from 10-15 per cent less steel, with corresponding improvement in deadweight capacity. It probably has a few per cent less resistance, resulting in smaller fuel consumption. And in some trades such as the tanker business, its service performance is immeasurably superior. These factors obviously must be considered in conjunction with initial cost and speed of building to get the true perspective.

The attitude referred to above is most often encountered in yards which have been caught unawares in the transition to welding. In such yards the original design is not good; riveting and welding are mixed with the result that full advantage can be taken of neither process; the men are not jobwise in their work, and the firm is attempting to build a welded ship in a yard laid out and equipped for riveted construction. Under such circumstances it is apparent that the welded ship will be dearer and take longer to build; but after this transitional stage is safely traversed—as it has been in most British shipyards by now—welded construction may easily prove to be both cheaper and quicker. It is practically impossible to obtain a direct comparison because of the intrusion of so many extraneous influences, but responsible Clydeside shipbuilders have recently expressed the opinion that the welded ship is up to 20 per cent cheaper.

The introduction of welding on a large scale has brought about a complete revolution in the traditional organization of the British shipyard. Under the pre-war system of riveted construction and plate-by-plate erection, the "squad system" was a highly efficient method of auto-organization and one which demanded very little organizational skill or effort on the part of shipyard management. Under this system the squad was responsible for procuring each plate from the stockyard, marking, punching, countersinking, shearing, planing and bolting the plate fairly in position on the ship; throughout these operations, the squad was responsible for the transport of the plate from place to place, a most important item. Side by side with the squad system was its necessary ally, the piece-work system by which the squad was paid so much per square foot or per ton of plating handled. Under these conditions it is easy to appreciate that the yard practically ran itself. Apart from the functions of hiring and firing, rate-fixing, correcting faulty work and maintaining discipline, the managerial side had little real organizing to do. In addition, there was generally plenty of labour available at the gate so that if a bottleneck did arise it could be resolved fairly readily by the employment of extra hands.

Under post-war conditions much of this has gone by the board with the introduction of the extensive prefabrication needed to allow the maximum of downhand and machine welding, without which it is impossible to get full economy from the welding process.

A sub-assembly cannot be completed without all its components, nor can it be erected till adjacent sub-assemblies are in place. The achievement of this position now devolves upon the management and requires initially that steel should be ordered and delivered in good time, without odd gaps in the order lists for given sub-assemblies. In any prefabricated section several different components may be involved, e.g. for double bottom sections, shell, tank top, centre girder, floors, intercostals and tank margins may be included; thus the squad system is inevitably broken up and the responsibility for ensuring that all these components are ready on time rests with efficient management, as is also the case with the various components of the completed ship, including the transport and handling into place of the individual sections.

Under these circumstances each tradesman has to be engaged in a particular, and more restricted, form of activity, such as marking, punching or shearing. A marker-off will only mark, and his work will cover shell, decks or bulkheads as required. A puncher will handle material for all parts of the vessel without discrimination; and so on. Hence, in general, fewer machine tools are required than formerly but each is in operation for a greater proportion of time. The whole process may be fairly described as sectionalization and its introduction has disturbed the established structure of British shipyards to no mean extent.

In many ways, shipyard management immediately after the war was not ready to assume the extra duties incurred by the change. There were few young men of the assistant manager type who had sufficient perspective of shipyard operations to be able to organize and plan the flow of materials and at the same time train the operatives in new methods. This resulted in considerable confusion and comments along the lines that "the old methods were the best". However, by now, management has won the battle and is alive to all the pitfalls which new methods have a habit of concealing.

It is obvious that such new methods bring in their train the urgent necessity for some form of overall planning to ensure smooth production without irritating delays. In the author's opinion, where "planning departments" in shipyards are held in low repute, the planners themselves are largely to blame for tackling the problem at the wrong end and becoming immersed in a welter of detailed paper work which very often serves to impede, rather than assist, production. Top management, too, must carry some of the blame for regarding "planning" as something relatively unimportant which can be left in the hands of a junior executive without either the experience or authority to make his presence felt effectively.

Shipyard production planning takes many forms and varies widely in complexity. At one end of the scale is a particularly efficient Clydeside shipyard whose planning department consists of two "part-time" officers—the shipyard manager and his assistant. In this yard, owing to the complete lack of storage space and to the system of erection adopted (from sternpost forward), it is essential that each unit be produced in correct sequence and exactly on time for a very stringent launching programme. This happy result is achieved by direct and daily personal contact between the manager and the foreman concerned.

At the other end of the scale is a system known as "coding" which is adopted in another Clydeside yard. This system is applied to both plates and bars and in effect means that a separate sheet is made out for every plate or bar which requires different working. All the necessary information is shown on the sheet as well as instructions as to the destination of the item when it leaves the shop. The positions of holes are not marked in detail, but reference is made to standard "Alclad" templates which are used from ship to ship. This system is administered by one draughtsman, five platers and two loftsmen, and it operates with pronounced success.

In other yards either man-hours or tons of steel are used as bases for the prediction of launching dates and the control of production. Such a method, which is in my mind the optimum, has been developed furthest in a leading Swedish shipyard.

The introduction of large scale prefabrication has revolutionized shipyard layout and British and Continental shipyards have been, and are, busy in big schemes of reorganization which have involved a large capital outlay. Sweden, with the advantage of neutrality, was able to prepare for and prosecute such schemes very soon after the war, and Britain and other countries have drawn on Swedish and American ideas to a great extent. The combination of welding and prefabrication has also caused significant changes in cranage and requirements of machine tools.

With regard to yard layout, large scale prefabrication has resulted in decreased time on the building berth with the obvious result that fewer berths are required to maintain the same output per annum. In consequence, most large reorganization schemes have contained provision for a reduction in the number of slipways, the space thereby made available being utilized either for storage of completed sections or the erection of large sub-assembly sheds where welding can be carried on regardless of weather conditions. In general, considerable storage area for completed units is necessary because these units must be finished and ready for erection for some time before they are actually required. Similarly, indoor assembly areas with facilities for assembling, welding and turning the units are necessary unless much time is to be lost from adverse weather.

A Wearside shipyard adopted a post-war rearrangement in which the number of berths was reduced from six to three without impairing production. The space made available has been utilized for storage and assembly areas and extra welded shops. Incidentally, this yard is a good example of the way in which most British yards are restricted from expansion in all directions, especially in depth, a feature which renders a good straight line flow of material practically impossible. Only occasionally does one find this feature; a yard on the Tees took full advantage of the available flat country when it was established in 1919. With a good layout in the first place, very little rearrangement has been necessary to permit the successful building of 24,000-ton all-welded tankers in recent years. Material moves from the large stockyards straight through the shops to the heads of the slipways. Its delivery to any given slipway is facilitated by the crane track running across the heads of the berths. By this means, not only material but cranes also may be transferred to the particular berth where they are most needed. The benefits of such provision need no elaboration.

That the straight line flow is not absolutely essential is indicated in the layout of a highly efficient Swedish yard. The U-shaped flow path means, of course, that shop overhead cranes cannot cover the stockyard but this disadvantage is compensated by the fact that these cranes are not interrupted from their principal function of serving the shop.

This yard incorporates another feature of Continental slipway construction, i.e. the provision of a permanent concrete ramp forming the floor of the slipway. This floor is built at the normal keel declivity, thus minimizing the amount of timber required for keel blocks, shores and staging below the ship. Where the natural groundslope is small, the space below the ramp is fully utilized for stores, offices, canteens and small maintenance workshops.

The modern sub-assembly shed is 1,000 feet long × 270 feet wide, divided into three longitudinal bays. Sufficient height is provided to give headroom for turning over the largest units contemplated, which makes such shops expensive to construct. For flat panels of unstiffened plating, complete turnover skids may be employed, but this is a comparatively rare procedure. Normally, such panels are self-stiffened by beams or frames and are turned after the welding of such members is completed. For flat panels height is saved in other cases by the provision of a floor pit in which the turning is accomplished. This turning over is, of course, required to permit maximum use of downhand and automatic welding, which show great economies over manual "position" welding.

It is apparent that prefabrication reduces the number of lifts required at the berth and increases the size of individual lifts. Hence, while the capacity of berth cranes must be increased, their number can be correspondingly reduced.

To the problem of desirable maximum crane capacity each shipyard seems to have arrived at its own individual solution. Some of the solutions are 10, 15, 20, 25, 35 and 40 tons. Of course, the answer depends entirely on particular circumstances of location and financial situation as regards capital available for the purchase of new cranes and the erection of new buildings, so that there can be no academic solution to the problem. At the risk of appearing to follow the middle course, the writer's opinion is that 25 tons is about the desirable maximum crane capacity and individual unit weight for cargo ship construction. Care must be taken to ensure that the cranes have sufficient radius of action to cover the building berth without the frequent necessity for coupling up on heavy lifts. The 25-ton limit is recommended because if each unit becomes much larger than this, precisely the same difficulties are encountered in its assembly as the process is designed to avoid on the building berth. Further, up to about 20,000 tons deadweight, a ship breaks up very conveniently into 25-ton panels of shell, decks, double bottom and bulkheads.

In odd cases where extra heavy lifts are required to make up a natural unit of the ship or where the lift happens to be beyond the normal outreach of a single crane, it is always possible to couple up two or more cranes by means of an equalizing beam. In such cases, if the crane capacities differ, accurate calculations of centre of gravity are required to ensure that no crane is overloaded.

For maximum efficiency it is obvious that welded construction must have its origin in the design office, i.e. even before the drawing office stage is reached. Space does not permit any detailed description of points to be watched but, where panelled construction is employed, it is a tremendous advantage to have the panel sides straight without shift or butts of individual strakes, as used to be required with riveted construction. This type of continuous butt now has the general approval of Lloyd's Register of Shipping, so that complete panels of side shell, for instance, are becoming standard practice.

The necessity for good edge preparation for welding has raised a controversy as to the relative merits of mechanical planing and oxy-gas cutting for this process.

Recently there have been many advances in mechanical planing technique, giving much higher cutting speeds and depth of cut per stroke. Provided the machine is robust enough, the fitting of a multi-tool head enables up to ½ inch to be taken off a plate at one pass. The plano-shear type of machine has also been introduced, with adjustable cutting rollers, so that bevelled edges can be produced by rotary shearing. This type of machine is made in two models: for plates up to ⅝ inch thick the cutting roller operates against a fixed ledger blade and gives a clean straight cut: for plates up to 1¼ inches thick, two opposing roller cutters are employed, followed simultaneously by a standard planing tool for smoothing up the cut edge. Machines of this type are especially common in Denmark and Sweden.

Plate edge preparation by oxy-gas cutting has been greatly influenced and stimulated by progress made in America in this technique during the war years. The term oxy-gas is used because oxygen is employed with a large variety of heating gases such as acetylene, propane, and even town gas in different places. A modern high-speed mechanical planer cuts at speeds up to 60 feet per minute, whereas the speed of oxy-cutting is of the order of 60 feet per hour. With normal ordering allowances a planer may have to make, say, six passes to remove excess material but even so the ratio of cutting speeds is still of the order of 10 to 1. Hence, to be competitive, the gas cutting process must save time in other ways.

For instance, the flame-planing table, on which four machines can be operated simultaneously, thus reducing the time of cut to that required by the longest edge, eliminates handling of the plate between successive cuts, as is necessary with mechanical planing. Another alternative is to provide one fixed and one movable longitudinal track but with this set-up it is difficult to guarantee sufficient accuracy for Unionmelt welding.

In like fashion the travograph and longitudinal profiling machines both eliminate plate marking, as the cutting head is guided by a full scale template or drawing. On reproduction work this means a considerable speeding up of the cutting process.

With either mechanical planing or burning, stack-cutting can be practised, but very few yards employ this process because of the accurate setting up and careful bolting up required initially.

On the whole it may be fairly said that plate-edge preparation is evenly divided between the two processes.

Welding has a very able ally in the flanging process for which many new types of press have recently been installed in shipyards. It is much cheaper to flange a corner than to weld it simply for the sake of welding, and the combination of the two processes reaches its acme in the production of corrugated bulkheads. Corrugated bulkheads are becoming increasingly popular, not only in tankers, but in dry cargo ships as well. The usual arrangement in tankers is horizontal corrugations for longitudinal bulkheads and vertical corrugations for transverse bulkheads.

Alluding briefly to welding practice, it may be said that the general tendency is towards a.c. welding throughout. Some yards retain d.c. welding equipment in the berths on account of the increased danger to personnel in the event of accidental shock. However, cases of electrocution are extremely rare and it is doubtful whether the increased tendency to arc blow in adverse weather does not outweigh this advantage.

The great bulk of all ship welding is done manually with electrodes ranging from 10 gauge to ⅜ inch diameter. Even in the yards using welding most, the proportion of automatic welding rarely exceeds 15 per cent. Both the Unionmelt and Fusarc processes are used, the former generally for indoor assembly and the latter for outdoor work, since it is less sensitive to imperfect conditions than Unionmelt. Recently many different types of semi-automatic machines have come into the market, using extremely high current densities on small gauge electrode to give increased penetration. For manual welding also, deep penetration rods are available which effect savings in the amount of edge preparation necessary for butt welds.

Many individual yards have purchased their own X-ray equipment for the radiographic examination of completed welds. Such methods can be of great benefit in stimulating the interest of welders and improving the general standard of welding.

As is well known, payment in British shipyards is almost entirely on a piecework basis as far as steel trades are concerned. The existing piecework formulæ are generally hopelessly out of date and due for complete revision, having been established under conditions and working methods in force at least twenty to thirty years ago. For instance, it is by no means unusual to find a plater's rate of pay calculated on a basis such as this:—

> Rate = n pence per sq. ft. (from Piecework Agreement), plus 7½ per cent plus 10 per cent plus 20 per cent plus 39s. per week, less w per cent for use of templates, less x per cent for burning instead of shearing, less y per cent for welded work as against riveted, less z per cent because erection is not included = m pence per sq. ft.!

In other departments, such as carpenters, joiners, and painters, the contract system has recently come into vogue. Under this system the group is offered a lump sum for, say, the painting of a certain section, based on the amount allowed for this work in the estimate calculated on normal productivity. If the job is done in shorter time the employee receives the same sum but, of course, at a higher time rate: the employer gains by getting a quicker delivery. The system probably worked as designed on the first and possibly the second occasion, but soon the employees began to expect the same increase in time rate regardless of increased productivity. With competition keen in the labour market the employer has no alternative but to acquiese in the payment of what merely amounts to an enhanced time rate of up to 25 per cent in most cases.

For comparison with Australian conditions a few isolated productivity figures for British yards in 1950 are quoted below:—

Hydraulic riveting...	670 rivets per squad per day
Pneumatic riveting...	240 rivets per squad per day
Steel trades labour...	60-70 man-hours per ton of gross steel
Steel trades labour cost	£10-£12 per ton of gross steel

As regards overall productivity, two examples may suffice. In one British five-berth yard with a total of 720 men in the steel trades (400 journeymen, 100 apprentices and 220 helpers) an average of five ships per year is produced of about 12,000 tons deadweight, and containing about 4,500 tons of gross steel each. The total labour force for this yard is about 1,500 men.

In one of the largest Swedish shipyards having three building berths, 900 men in the steel trades produce 11 to 12 ships per year of about 9,000 tons deadweight each, representing a total of some 35,000 tons of gross steel. This means that the average time on the building berth is only three months.

The introduction of large scale welding has naturally caused a redistribution in the balance of the shipyard labour force, especially among the steel trades. The numbers of riveters and drillers are decreased and ranks of the welders, caulkers and burners are increased. The following figures represent the average percentage composition of the steel trades'

Table VI.—Steel trades

	Riveted ship	Welded ship
Platers	42	45
Riveters	38	14
Welders	2	22
Caulkers and burners	9	14
Drillers	9	5

TABLE VII.—ANNUAL LAUNCHINGS

Builder	Country	Number of ships	1949 Gross tons	Number of ships	1950 Gross tons	Number of ships	1951 Gross tons
Harland and Wolff, Ltd.	Ireland	12	97,000	12	133,000	11	120,000
Kockums Mekaniska Verkstads A/B	Sweden	12	94,000	11	101,000	13	119,000
Götaverken A/B	Sweden	11	73,000	10	92,000	9	102,000
Swan, Hunter and Wigham Richardson, Ltd. ...	England	8	67,000	8	88,000	9	99,000
Furness Shipbuilding Co., Ltd.	England	6	80,000	6	75,000	7	90,000
Eriksbergs Mekaniska Verkstads A/B	Sweden	11	87,000	11	70,000	10	78,000
Lithgows, Ltd.	Scotland	11	83,000	9	72,000	7	68,000
Vickers-Armstrongs, Ltd. (Walker)	England	5	58,000	5	55,000	6	67,000
Vickers-Armstrongs, Ltd. (Barrow-in-Furness) ...	England	2	36,000	3	60,000	1	20,000

labour force in three British yards before and after the swing to mainly welded construction.

The final figures depend upon the proportion of welding adopted: it will be seen that the increase in welders comes almost entirely from the reduction in riveters.

Based on gross tonnage launched per annum, the world's leading shipyards are to be found in Ireland, Sweden, England and Scotland, as Table VII indicates. The high outputs of the individual Swedish yards are generally a source of surprise to the layman, as is also the fact that the highest output of all belongs to an Irish shipyard!

TABLE VIII.—ANNUAL LAUNCHINGS IN GROSS TONS

District	1949	1950	1951
North East Coast	535,000	544,000	637,000
Clyde	443,000	433,000	412,000
Rest of England...	142,000	162,000	120,000
Rest of Scotland...	88,000	69,000	71,000
Northern Ireland	97,000	133,000	120,000

As far as British production is concerned, those with sufficient national pride will be interested in Table VIII.

CONCLUSION

As stated at the outset, this paper is intended as a very general review of the whole shipbuilding scene, and will contain little of technical interest to specialists in the various fields of the industry.

However, it is essential that each contributor to the total should have a reasonable understanding of his part in the overall picture, not only that he may realize to the full his own function but also that he may appreciate more fully the problems and difficulties which face "the other half". In particular, it is often difficult for the shipyard manager to appreciate the why and wherefore of what appear to be illogical points of design which make his own job more difficult to accomplish. A better realization of the possible reasons for such enigmas may help him to appreciate that the proper solution to the complete design does not always lie in the method which is cheapest in first cost. Nor, indeed, is a design necessarily "correct" because it happens to embrace the most modern features of shipbuilding or marine engineering.

Rather must the "correct" solution be, in most cases, a compromise between the optimum requirements of the shipowner, shipbuilder, and marine engineer.