MATERIALS

USED FOR

NAVAL CONSTRUCTION PURPOSES

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THE ROYAL INSTITUTION OF NAVAL ARCHITECTS
AUSTRALIAN BRANCH

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1. STEELS

The Andrew Laing lecture delivered by a good friend of the R.I.N.A. (in Australia) - Sir Alfred Sims - in 1961 dealt with the development of British Admiralty M.O.D. (Navy) steels.

Up to about 1961 the Royal Australian Navy used these Admiralty steel specifications almost exclusively and it is fair to say that some R.A.N. ships are at present being constructed with these same steels. Although with the rapidly expanding Australian steelmakers capability to produce a steel incorporating features required by Naval Architects, an ever increasing amount of Australian made steels is being incorporated into the hulls of R.A.N. vessels.

The summary of steels used for ship construction in the R.A.N. is as shown on Sheet 1

Steel Compositions and Specifications

Steel has been used for shipbuilding since about 1875; and steels with higher strength than mild steel have been made use of since about 1900 to enable higher working stresses to be used in design, and savings to be made in structural weight. These early "high tensile" steels were specified by their mechanical properties and by their ability to withstand without cracking the usual shipbuilding operations of punching, drilling, shearing and flanging. Their higher strengths derived in general from higher C and Mn contents.

"D" steel was introduced for British warship building in 1923, its composition being 0.3% C with up to 1.4% Mn and its U.T. strength 37-44 tons/in.^{2}, with a limit of proportionality of 17 tons/in.^{2}. For some years this steel was used as well as mild Steel with U.T. strength 26-30 tons/in.^{2} and High Tensile Steel, with U.T. strength 30-34 tons/in.^{2}.

The more extensive use of welding in shipbuilding directed attention to the need to restrict chemical composition to ensure satisfactory weldability. Difficulties were experienced with the higher strength steels, especially in thicker sections. In 1938, therefore, based on tests carried out by the Institute of Welding the British Admiralty introduced "D.W." steel. The C content was restricted to a maximum of 0.23% and the strength was limited to 35-41 tons/in.^{2} U.T.S. with 16 tons/in.^{2} yield for plate of 1 in. thick and below, and to 33-39 tons/in.^{2} U.T.S. with 15 tons/in.^{2} yield for plate thicker than 1 in.

International maritime experience during the 1939-45 war stressed the importance of notch ductility and the necessity to exercise a closer control over shipbuilding steel quality to meet the requirements of welded construction. Before 1949 Lloyds rules required only that ship steel should be made by the open hearth process and should comply with limited tensile and bend tests. In 1949, as a result of the investigation of fractures in American welded ships, additional requirements were added. The S and P content were each limited to 0.06% and, to achieve better notch toughness, the Mn/C ratio was required to be not less than 2.5 for material over $\frac{1}{2}$ in. thick. For material over 1 in. thick used in the main structure of welded ships the properties and process of manufacture of the steel were required to be specially approved.

Various steels were approved to meet Lloyd's Rule P.403 and, in 1957 a full specification, Section P. 5 of the Steel Rules, was introduced. The steels to this specification are, in general, low carbon-high manganese steels similar to Admiralty "D.W." steel. At about the same time, to meet a demand for further improvements in notch toughness on account of the increasing size of welded tankers similar steels, fully fine-grained with silicon and aluminium, and supplied in the normalised condition, were provided and approved by Lloyds as XNT steel. Subsequently (1968) Lloyds EH2 Grade.

The Admiralty decided that a steel of higher strength than D.W. was required for warship construction and, in about 1950, produced a specification for "U.X.W." steel, with a maximum strength in the range 34-43 tons/in.^{2} and a proof stress of 25 tons/in.^{2}. This was a low carbon-high manganese steel strengthened with Nickel, chromium and molybdenum and it was supplied in the normalised and tempered condition.

Shortly afterwards specifications were also formulated for Admiralty "A" quality and "B" quality steels. These are low car high manganese steels. "A" quality having maximum strength in the range 28-32 tons/in.^{2}, and "B" quality in the range 30-38 tons/in.^{2}. Both steels have to meet specified charpy impact requirements. "A" quality steel less than $\frac{3}{4}$ in. thick may be supplied "as-rolled" or normalised; thicker "A" quality and all "B" quality plates are supplied in the nor alised condition.

The requirements for even higher strengths, combined with the need to limit composition on account of weldability, now led to consideration of the use of steels for warship construction in the fully quenched and tempered condition. A steel of similar composition to U.X.W. but with carbon limited to 0.17% maximum and Manganese at 1.3% maximum was found to give a proof stress of 28 tons/in.^{2}, with a maximum strength of 35 to 45 tons/in.^{2} and a notch toughness of 40 ft. lbs. Charpy-V at -20°C when quenched and tempered. This steel, developed for submarine construction, is called Q.T.28.

Later it was found possible to achieve a steel of higher strength and better notch toughness by further increases in alloy content, although this reduced the weldability and called for more careful control of welding conditions in the shipyard. This steel is Q.T.35, also used for submarine construction.

The U.S. Navy specification for structural carbon steel plate for shipbuilding is Mil-S-22698A. In addition the U.S. Navy provides for a low-carbon high-manganese steel of maximum strength 41 t.s.i., depending on thickness. This is Mil-S-16113CH.T. steel. During the last few years the U.S. Navy has used a low-alloy, high yield strength steel known as H.Y.80. This is supplied in the quenched and tempered condition and gives a yield strength of 35.7 - 42.5 t.s.i. and Charpy-V notch performance of 30 to 50 ft. lbs., depending on plate thickness, at -120°F.

The three American built Australian Charles Adam Class Destroyers (D.D.G.s) are constructed mainly of High Tensile Steel to Mil-S-16113C with selected areas in either Medium Steel to Mil-S-20166 or HY80 steel to Mil-S-16216

THE USE OF SPECIAL QUALITY STEELS

To enable Australian warship construction to keep up with overseas trends, development of a medium (yield) strength carbon/manganese steel with good notch toughness at low temperatures together with good welding properties was considered to be essential. Preparation of a steel specification aimed at securing the best "compromise between the technically desirable and the economically acceptable". At present, most specification writers have hesitated to set limits which will give the steel-maker any difficulty in meeting them, or which would restrict the amount of steel which the steel industry could meet with existing facilities. These specifications thus give a relatively cheap steel, but do not produce the properties attainable in steel at its best. In the search for higher strength, notch-tough, weldable steels closer control by specification will enable the best to be got from any particular composition. It may be possible, for example, to obtain the improved properties required for a particular service by a careful choice of one of the many "mild steels" properly heat-treated, rather than by looking for these properties in a less weldable alloy steel.

The use of special quality steels in warships' hulls may be considered under the following categories:-

1. Notch Tough Material - incorporated in selected regions of the main hull girder to provide safeguards against the initiation or propagation of brittle type fractures under normal conditions.

2. Medium Higher Tensile Steels - used to varying extents in the main hull girder to reduce the scantlings and weight of the structure.

3. Steels for low temperature service - used for refrigeration spaces and adjacent hull structure.

4. The steels must be capable of being welded without cracking in the weld metal or the heat affected zone of the parent plate.

5. Low cycle fatigue properties within acceptable limits.

A number of steels are available in Australia to meet these requirements and some of these steels are as shown in figure 2

The use of higher strength steels for main structural members

Consideration is being given to the use of higher strength steels for ship structures because the higher working stresses which can be allowed enable modifications in design which can effect savings in the structural weight and give an overall saving in total cost, even with the higher cost of the stronger steels. In addition, the reduction in dead weight allows an increase in pay-load.

There is a limit also to the dead weight capacity, which is imposed by the need to maintain free-board in the sagging condition. By careful attention to the arrangement of cargo distribution the maximum dead weight can be achieved with the minimum sagging deflection.

The reduction in longitudinal bending stiffness gives rise also to problems affecting the propulsive machinery shafting; and to increases in the effects of vibration and whipping.

When thinner sections of higher strength steel are used, attention must be paid to the possibility of the buckling of stiffened plate structures.

A reserve of thickness has to be made to allow for corrosion in certain parts of a ship's structure. Unless improved techniques of preservation can be depended on, similar allowances must be made when high strength steels are used in the main ship structure. This may reduce the saving in thickness that can be effected by the use of the special steel.

Notch Tough Material

A great deal of literature has been published on the brittle fracture problem which arose in welded ships during and shortly after the last war and a further review is not considered necessary. In the course of the many extensive investigations which have been carried out into this problem it was realised that a primary cause of brittle failure of steel structures was the fact that normal mild steel could be notch brittle at temperatures that were well within the service range. The loss in notch ductility of ferrous metals with decreasing temperature had long been recognised, but it was the early experience with welded ships that led to the need for some improvement in steel quality, especially for larger all-welded ships.

While it is readily agreed that precautions must be taken against the possibility of brittle behaviour, it is more difficult to decide the level of performance in material tests which will ensure safety in service of the complete welded structure. Many different tests have been developed, some more difficult to apply than others. It is not clear that all the different tests measure the same material properties or correlate among themselves in their results or in their relevance to the behaviour of the final structure in service.

The Charpy-V notch test is probably the most widely used. Some difference of opinion still exists as to the relative importance of the energy criterion and the appearance of the fracture surface criterion. The specification of a minimum energy absorption at a particular test temperature may represent a higher or lower level of notch toughness than the requirement for a minimum amount of crystallinity in the fracture face included in the same specification. Mr. J. Hodgson and Mr. G.M. Boyd of Lloyd's Register of Shipping presented a classical paper to the Institution of Naval Architects, July 1958, which contained a valuable mass of data from samples of material from ship casualties accumulated over a long period. From this data they derived recommendations for the standards in the Charpy test which have been incorporated in Lloyd's Rules.

Another approach to the problem of assessing material notch toughness has been developed by the U.S. Naval Research Laboratory, with their drop-weight test assessment of the material's "nil ductility" transitiontemperature and the explosion bulge test with which it correlates. This has now been followed by a "Fracture Analysis Diagram Procedure for the Fracture - Safe Engineering Design of Steel Structures" - N.R.L. Report 5920 by Pellini and Puzak. Choice of steel for a particular service would depend on (i) the design criterion used which depends on the conditions of the service required, and (ii) a knowledge of the N.D.T. temperatures of possible steels, of appropriate thickness and heat treatment.

In a welded structure consideration must be given to the notch toughness which can be achieved in the weld metal. It is more difficult to get high ductility in higher strength weld metals. The figure 3 shows that a weld metal of strength H.T.100 achieves a Charpy - V energy level of about 30 ft. lbs. at -40°C. This is similar to experience in U.K. Q.T. 35 steel plates are required by specification to give at least 40 ft. lbs. Charpy at -40°C, but weld metals of matching strength give only about 30 ft. lbs. at -40°C. Although the U.S. H.Y.80 steels shown in figure 3 have such very low transition temperatures, the electrodes to match give, only 20 ft. lbs. in the Charpy test at -50°C.

Typical Notch tough curves are as shown in figure 4

Weldability

The steels used in shipbuilding must be capable of being welded without cracking in weld metal or in the heat-affected-zone of the parent plate, making a sound structure of required strength and notch toughnessin every part of the weldment.

The tendency to hot cracking in the fusion zone of the weld is related to the chemical composition of the plate. For good weldability the carbon must usually be less than 0.25% and sulphur and phosphorus each less than 0.o5%. It is possible that higher values of Mn/S ratio reduce the tendency to hot cracking. In higher strength alloy steels there is evidence of the possibility of hot cracks at the fusion line caused by the formation of lower melting point complex products. Investigation of this phenomenon is being carried out by the British Welding Research Association.

Cold cracking in the heat-affected-zone is related to the hardenability, i.e. the chemical composition, of the parent plate and to the cooling cycle due to welding i.e. to the pre-heat and post-heat procedures and the plate thickness. Ordinary structural and boiler quality steels with ultimate tensile strengths up to about 36 tons/in.^{2} are readily weldable without special precautions against heat-affected-zone cracking, so long as the composition is restricted and the higher strengths, above about 30 tons/in.^{2} U.T.S., are achieved by such practices as aluminium fine-grain control and normalising after rolling. Special steels of higher strength and plates of greater thickness require special precautions to avoid heat-affected-zone cracking.

Recent work at the Naval Construction Research Establishment, Great Britain, suggests that the pre-heat temperature which will avoid the formation of the heat-affected-zone martensitic microstructure in plates of thickness about $1\frac{1}{4}$ in. and thicker, can be estimated from the chemical composition of the steel, expressed as a "carbon equivalent", using the formula:-

$$C.E. = C\% + \frac{Mn\%}{6} + \frac{Si\%}{24} + \frac{Ni\%}{40} + \frac{Cr\%}{5} + \frac{Mo\%}{4}$$

The pre-heat temperature to avoid a "susceptible microstructure" is then, in ^{o}C:-

$$T = 210\ (C.E.) - 25$$

Thinner plate requires a lower pre-heat temperature.

When such a martensitic H.A.Z. structure is allowed to form, the presence of hydrogen or a sufficiently high state of stress will cause the formation of H.A.Z. cracks. The use of low-hyrogen electrodes, therefore, may avoid cracking in joints of not too high restraint.

<u>Low Cycle Fatigue</u>

Low cycle fatigue can be defined as the phenomenon associated with the cracking of structural details under the more severe loading conditions of service within the life range of 1 to 100,000 cycles.

In the design of the structural members of ships little attention has been given to the fatigue strength of their components, the dimensions of which are mostly determined from the viewpoint of the statical breaking strength, yielding, buckling or plastic failure of the structures. This is mainly due to the fact that there have been few systematic investigations made on the fatigue strength of ship structures, especially for those members with discontinuous parts where a high stress concentration is anticipated. When using high strength steels, it becomes quite an important problem whether the fatigue strength, in particular, under the stress concentrated condition, could be expected to be proportionally as high as their statical strength, in comparison with ordinary mild steels.

Few test data concerning the cyclic effect on the fatigue strength at high stress levels are available, and it seems still premature to draw a definite conclusion. Yet, of these test data, notable are the results of cantilever type bending fatigue tests on a pressure vessel material carried out in the U.S.A./7/, according to which the fatigue strength of high strength steels of 60 kg./mm^2 tensile strength in a 100,000 cycle repetitive loading was approximately proportional to the tensile strength in comparison with the case of mild steels. It was also found from the results of rotatory bending fatigue tests on cylindrical specimens with a semi-circular notch that the fatigue strength in a 1000 cycle repetitive loading was approximately proportional to the tensile strength of the steels.

These are the results of fatigue tests conducted in such a manner that the maximum and the minimum of the repeated loads are kept constant, while in the case of fatigue tests with constant strain amplitudes the results indicate a somewhat different tendency from those mentioned in the previous paragraph. In Figure 5 illustrated is an example of the constant-strain-amplitude test data, where steel A is a mild steel of which the yield/tensile strength ratio is 0.62 and steel B is a high strength steelof the ratio equal to 0.75. It is seen from this figure that when the strain amplitude is small, steel B withstands larger number of cyclic loading than steel A, whereas if the strain amplitude is large enough, then the results become reverse. This is mainly because the high strength steel could not sustain such large plastic deformations applied repeatedly.

Thus it is concluded that, in the case of simple tension or compression, namely, under a constant-load-amplitude the use of high strength steels becomes advantageous from the viewpoint of fatigue strength, but if the high strength steels are used in a region of stress concentration where they are locally subjected to plastic deformations of a constant strain amplitude, then their fatigue strength would be reduced.

According to the results of the measurements on the longitudinal bending stresses at sea, the maximum stress amplitude encountered during twenty years (once in a life of ships) was approximately 15 kg./mm.^{2}. It was also found that, when expressing the stress frequency in a diagram where stress amplitude is taken as the ordinate and the number of repetitions linearly increase with the reduction of the stress amplitude, the stress amplitude being 3 to 4 kg./mm.^{2} in 1,000,000 cycles.

British Welding Research Association use a figure of 1 x 10^6 oscillation as minimum requirements for low cycle fatigue.

Comparison of Fatigue Strength between High Strength Steels and Mild Steels.

The relationship between the tensile strength and the fatigue limit of high strength steels is shown in Figure 6 although the data given in the figure are rather out of date and the steels may be of different kind from those ordinary in use in shipbuilding, it still gives some standard for their correlation. It is seen from this figure that, in the case of plain specimens, the fatigue limit of high strength steels (tensile strength between 50 and 60 kg./mm^2) is almost proportional to the tensilestrength, whereas in the notched specimens there seems little increase of the fatigue limit in the steels of higher tensile strength. Furthermore, it c an be said that the corrosion fatigue strength of high strength steels is independent of their tensile strength, This fact was also confirmed by test results in which the fatigue limit of high strength steels in salt water was almost the same as that of mild steels. It was shown, however, that the coated specimens with paint regained their fatigue, limit in the salt water up to about 75 to 90% of that in the air.

Conclusions.

As well as using the tried and proven Admiralty (M.O.D. Navy) steels in warshipconstruction, the R.A.N. is obtaining ships from the U.S.A. constructed of H.Y.80, H.T. and Mild Steels to U.S. Military Specifications.

In addition a number of vessels are being constructed in Australia using Australian Department of Navy steel specifications for mild and medium steels.

Efforts are being made to introduce a medium yield carbon manganese steel, [illegible] notch tough, with good welding and fatigue qualities.

2. COPPER ALLOYS

Introduction.

Until 1954 the copper alloys used in R.A.N. ships were mainly Naval Brasses, Phosphor Bronzes and Gunmetals. Dezinafication has led to banning the high tensile Naval Brasses and their replacement by Aluminium Bronzes, Silicon Bronzes, and Nickel Gunmetals.

The 90/10 and 70/30 Copper Nickel Alloys are used almost exclusively in R.A.N. ships and submarines for sea water services because of their resistance to impingement attack.

The aluminium bronzes are used extensively for fastenings, rudders, anchors and chain cables for the Ton Class minesweepers, because of their high strength and non magnetic properties.

Corrosion Resistant Materials.

Copper: In clear sea water which is not moving at any great speed, copper is protected by a complex film which forms. If the film remains intact a corrosion rate in the region of 0.002 inch per year is to be expected. If, however, any condition is present which will tend to prevent the formation of or remove this film, then the corrosion rate will increase considerable. Thus, contaminated water may remove or prevent the formation of a protective film and erosion by solid particles or fast moving water may erode the film. Both these factors which prevent the full benefit of the corrosion resistance of copper being made available have become more prevalent: it has therefore been necessary to develop new alloys.

Copper - Zinc Alloys: As with copper, the corrosion of a simple brass depends on the conditions of service to a very marked degree and it is unusual to find a simple copper-zinc alloy in service. Usually the principal mechanism of corrosion of these alloys is dezincification particularly with alloys containing a high content of zinc. The addition of antimony, tin and arsenic, to brasses has the effect of inhibiting dezincification under moderate corrosive conditions. Aluminium Brass (76% Copper 22% Zinc, 2% Aluminium 0.03% Arsenic) with its small content of arsenic resists dezincifications while the aluminium builds up a protective film of alumina with rapid self healing properties.

Phosphor Bronze: i.e. alloys of copper and tin which have been modified by addition of small percentages of phosphorus to the basic copper tin alloy renders the molten metal more fluid with little if any loss in corrosion resistance. The development of the gunmetals, with their ease of casting, has caused the phosphor bronzes to be overlooked for corrosion resisting purposes. However, interest in them is maintained because of their bearing properties.

Gunmetals: The difficulty of casting phosphor bronzes can be overcome by the addition of the alloying elements, zinc and lead. Zinc serves the dual purpose of increasing fluidity of the molten metal as well as being a limited substitute for tin, enabling the tin content to be reduced. "Leaded gunmetal" provides a material resistant to impingement attack and other forms of corrosion likely to occur in sea water systems which can readily be cast into pressure tight castings for pumps and valve bodies etc. It must be noted, however, that under certain conditions, gunmetal may become highly cathodic and stimulate attack on adjacent more anodic areas.

Aluminium Bronze: In the sea water environment the major application of aluminium bronze has been for castings in which the basic composition is 9-10 per cent aluminium with minor additions of other alloying elements. Their resistance to corrosion, erosion and wear is good and in addition, they retain their mechanical properties at elevated temperatures. To obtain the maximum corrosion resistance to sea water it is necessary to pay close attention to chemical composition and heat treatment of aluminium bronze.

Silicon Bronze: These alloys possess high strength and good toughness and exhibit good resistance to corrosion by sea water. The high silicon content alloys have excellent casting qualities and are superior in this respect to aluminium bronze.

Nickel-Copper (Monel): The alloy of nickel and copper containing 70 per cent nickel and 30 per cent copper with minor additions of manganese and iron, known as Monel, is used in a wide variety of applications in marine engineering. It is resistant to attack by sea water, combined with good mechanical properties which can be obtained both from wrought and cast monel products. Monel should not be used in contact with aluminium bronze as severe pitting will result on the aluminium bronze.

Copper-Nickel Alloy: Copper-nickel alloy piping is commonly used where impingement has proved too severe for other ferrous and non ferrous piping. However this material may even suffer impingement attack at bends, in the discharge side of pumps and downstreams from valves and flanges where water speed and turbulence are excessive. Sea water speeds in piping made of 90/10 copper nickel alloy should be limited to a maximum velocity of 10 ft/sec. At higher velocities extreme care must be taken to ensure turbulence is kept to an absolute minimum. 70/30 copper nickel alloy is used mainly in submarines where failure of highly stressed piping could impair the safety of the submarine. It is also used in condensor tubes where maximum resistance to pitting is required.

Titanium: It is convenient to refer briefly to the commercial grades of titanium at this stage as they represent one of the four families of alloys of current or future naval interest, which depend on the presence of an oxide film for their corrosion resistance.

Titanium and its weld metal has outstanding corrosion resistance, excluding stress corrosion, in sea water and is immune to crevice corrosion. Titanium acts as a noble metal and will accelerate the corrosion of most metals to which it is joined. It is compatible galvanically with austenetic stainless steels, high nickel alloys and nickel aluminium bronze.

Stainless Steels: In general stainless steels should be used with caution in contact with sea water. Unless care is taken to select the correct grade of stainless steel serious failures due to crevice corrosion or pitting may result. The most satisfactory grade of stainless steel for resistance to crevice corrosion and pitting is the 18/8/Mo grade of stainless steel (BS970 EN58J) and this should be used exclusively for equipments and fastenings where stainless steel is required in contact with sea water.

Where welding and hot forming without subsequent heat treatment is required BS970 EN58B/C should be used.

Aluminium Alloys

Prior to 1939 the use of aluminium alloys had been restricted to non-structural work. Aluminium-silicon alloys in the wrought and cast forms had been employed but, owing to lack of experience with these alloys and in connecting dissimilar metals, the results were disappointing and corrosion troubles were common.

Subsequently aluminium was only used for minor internal fittings until portions of the superstructure of the "Daring" Class destroyers were fabricated in clad sheet with 5 per cent Mg aluminium alloy rivets and HE 10 - WP sections.

Once again the performance was poor, the sheared edges of the sheets corroding very rapidly, the surfaces lasting only slightly longer until the cladding was damaged in spots by general misuse or by the use of chipping hammers prior to repainting. At these damage spots corrosion was extremely rapid until complete perforation occurred.

At this time some ex-wartime destroyers were converted into frigates and the fo'c'sle deck was extended from one-third the length of the ship to within a short distance of the stern. The whole of this additional structure and the new superstructure was made in aluminium (5 per cent Mg) alloy. In general, aluminium alloy rivets were used for aluminium/steel joints but steel rivets were fitted at the connexion between the new structure and the old break of fo'c'sle. Again the main troubles in these ships have been corrosion due to stress corrosion of the aluminium alloy rivet material and inefficient joints between dissimilar metals. To overcome the stress errosion problem in the rivets all those which fail are being replaced by rivets containing less magnesium ($3\frac{1}{2}$ per cent).

In the following year work commenced on the minesweeper programme. The low magnetic permeability of aluminium makes it an ideal material for these ships and many of them are of composite construction with frames, bulkheads and decks of aluminium and outer skin of wood planking.

The breakthrough which paved the way to the large scale use of welded aluminium and which has made the fabrication of ship superstructures economically practical occurred in the early 1950's with the development of the inert gas shielded metal-arc (Mig) welding process. This process has since reached such a degree of reliability that it has become a standard production welding method for all applications lending themselves to shop fabrication and subsequent site erection.

The Mig process, it will be recalled, is fluxless and utilizes a D.C. arc of reverse polarity, the arc being struck between the workpiece and a continuously fed aluminium wire which acts as both filler and electrode. The arc, which is self-adjusting within limited movements of the torch, acts as an efficient cleansing medium while an enveloping argon gas shield effectively prevents reoxidation. The process, in its most widely applied form, is semi-automatic with the wire fed continuously from the end of the welding gun at a speed balancing the rate of burn-off which is determined by the current setting needed to make the weld. For aluminium, conditions are normally set for "spray-transfer" welding.

Suitable Aluminium Alloys

The large scale use of aluminium in shipbuilding, which automatically implies prefabrication, takes advantage of the suitability of the non-heat-treatable range of aluminium alloys containing from 3 to 5 per cent of magnesium. They combine good strength and corrosion resistance with satisfactory weldability.

The alloys were used in the form of plate and sections on the welded superstructures of the "Gergensfjord," "France," "Oriana," and "Canberra," and are being used in similar form on the new Q.E.II liner where the plate conforms to B.S.1477-NP8, and extruded sections to B.S.1477-NE8M. The composition of this material, which fulfils the requirements of Lloyd's rules for ship construction is as follows:

Copper	0.010 per cent max
Magnesium	Not less than 3.3 per cent; not more than 5.5 per cent.
Silicon	0.6 per cent max
Iron	0.5 per cent max
Manganese	1.0 per cent max
Zinc	0.2 per cent max
Chromium	0.4 per cent max
Titanium Zirconium	0.2 per cent max

When using non-heat-treatable aluminium alloy plates and sections in shipbuilding. Lloyd's Rules call for an ultimate tensile strength of 17 tons per sq in. minimum with an elongation measured on an 8 in. gauge length of 10 per cent minimum (or 12 per cent on 2 in.); these requirements are also being met on all material used; and weld strengths in the order of at least 90 per cent of that of the unwelded material have been obtained.

Aluminium Alloys are being used extensively in Naval Ship construction at the present time, and the types of alloys being specified for this purpose are as shown in figure 7

The use includes superstructures, masts, bridges, boats, composite (non magnetic) minesweepers, decks, furniture, lockers, watertight doors. Considerable use of Aluminium Alloy plates and sections was made in the construction of the "Attack" class patrol boats and H.M.A.S. "Swan" and "Torrens".

In the older "T" class submarines in service with the R.A.N. extensive use of aluminium alloys was made in fin, casing, and stiffeners. The more modern 'O' class carry very little aluminium external to the pressure hull, but internally some minor bulkheads furniture and fittings are of aluminium.

It is anticipated that because of its greater strength/weight ratio aluminium alloy will be used more extensively in future in Naval ship construction. However, care should be exercised in its use, because of the breakdown of boundaries in ship fires, and by the large deflections of structure in the wake of gun blast, and by its inefficiency in protection against bomb splinters, missile and small arms attacks.

Marine aluminium alloys are vitually indestructable in a salt water environment, however, when attached to other metals in the presence of an electrolyte (e.g. sea water) galvanic action can occur unless the joint is adequately protected.

The method adopted for the protection of steel/aluminium boundary connections is,

(i) Grit Blast ground bar
(ii) Metal spray (aluminium) to .003" the ground bar
(iii) Paint with Zinc Chromate primer faying surfaces.
(iv) A P.V.C. tape is inserted between the joint
(v) Stainless Steel huckbolts are inserted and driven up tight.

Insulation Materials

The insulation of ships of the R.A.N. has progressed since World War II when wood decking was largely abandoned and insulation of compartment boundaries became a necessity.

As air conditioning was introduced in an increasing scale, efficiency in insulation became mandatory.

The types of insulation used up to the present day are as follows;-

(a) Sprayed limpet asbestos which was applied to R.M.A. ships obtained from R.N.;
(b) Cork insulation, granulated and stuck to the bulkheads, deckheads and piping;
(c) Glass fibre insulation fitted in bats in loose form between wooden grounds and lined; and
(d) Resin bonded glass fibre faced with a puncture resisting glass cloth treated with phenolic plastic to ensure a vapour barrier. This form of insulation was fitted by impaling it over studs welded to the ships structure. A spring steel washer encased in polythene being fitted to each stud to hold the insulation in place. The joints are covered by adhering glass cloth tape over them, the whole insulation covering being painted with at least two coats of oil bound paint.

Developments in recent years of glass fibre have produced mineral fibre boards, in addition to glass fibres, and lightweight density boards.

The method of fixing to the structure is still by studs but as the studs can seriously impair the strength of plating, especially under shock loading, and reduce the efficiency of the insulation, other methods such as fixing with adhesives are being investigated. However, due to the poor interlaminar adhesion of the locally manufactured material, this is not yet a practical solution.

Machinery Spaces.

Machinery spaces were insulated with "insulwool" faced with perforated aluminium alloy sheet, current policy is mineral fibre resinbonded slabs faced with perforated aluminium alloy sheet, acoustic damping fitted as necessary.

Refrigerated Spaces Insulation.

Cool and cold rooms have been insulated with the following insulation materials:-

(a) Cork which was not satisfactory as it became waterlogged;
(b) Expanded ebonite which was abandoned due to penetrative odour;
(c) Glass wool which could not be packed evenly enough to ensure sufficient constant temperature control.

The present policy in the R.A.N. is to use rigid expanded polyurethane foam, covered with sheet aluminium.

Acoustic Insulation.

Sound insulation is required:-

(i) To insulate the structure from absorbing sound and carrying it to other parts of the vessel.

(ii) To absorb the sound made within the compartment.

The material initially used for the purposes was made of asbestos fibre compressed into rigid sheet boards or tiles of various densities. When used for sound absorption, the surface is perforated with holes about 1/8" diameter to the extent of 12-15% of the thickness.

Glass fibre was introduced faced with perforated aluminium alloy sheet. The practice of fitting aluminium alloy sheet was abandoned due to radio interference caused by the sheet. Perforated fibreglass sheet on 1/8" perforated board is now used in lieu.

The recent development of grouping fans into centralised compartments for damage control purposes has necessitated careful insulation and current policy is to use mineral fibre insulation covered with perforated aluminium.

Consideration is being given at the present time to the use of lead impregnated vinyl as an acoustic insulant. In addition, experiments are proceeding with resilient foams in engine boxes of boats to cut down resonance and rebounding of sound waves.

Piping Insulation

Up to about 1950 main service and fresh water pipes were insulated with granulated cork fixed to the pipes with a suitable adhesive and for hot water systems asbestos cloth covered with canvas was adopted.

More recently with the introduction of air conditioning and consequently chilled water, the economy of the plant dictated the need for high quality light fire resistant and vermin proof insulation of low thermal conductivity.

The insulations used for chilled water lines were preformed sections of mineral fibre attached to the pipe and covered with cotton canvas fitted lengthwise on straight sections and and bandage fashion on bends, the seams being stuck with adhesive, or, preformed sections of cork attached to the pipe and wrapped bandage fashion with 3" wide pressure sensitive, self adhesive tape, ensuring a 50% tape overlap.

Because of the advancing techniques in plastic foam insulation materials this type of pipework insulation is currently on trials in the fleet for hot and cold water pipeline insulation.

Extruded or preformed sections of flexible expanded P.V.C. or urethane vapour sealed at the joints and painted with compatible paints, have shown to give good results at an economical cost.

Ventilation and A/C trunking.

Insulation was not fitted to ventilation trunking until air conditioning was introduced, except for electrical compartments (radio offices) where the trunking was plywood to trduce the interference and sound problems. This method was discarded due to fire problems.

Insulation applied to ventilation and A/C trunking was as follows:-

(a) Cork slabs fitted with cotton canvas sewn and painted.

(b) Mineral fibre board sealed with fire retardant paint.

Present policy for insulation of air conditioning supply and recirculation trunking and mechanical ventilation supply and exhaust where it passes through air conditioned spaces is as follows:-

(i) Mineral fibre board with glass cloth facing.

(ii)

(a) Flat surfaces of trunk P.V.C. rigid expanded foam with vapour barrier.

(b) curved surfaces, flexible plastic foam sheet with vapour barrier.

Acoustic lining of trunking is at present being used to reduce fan noise to an acceptable level, but investigations are being carried out into the suitability of "packaged silencers" which are positioned in trunking in on the upstream side of the compartments where noise is a problem. This method of application is much lighter, cheaper and, if proven satisfactory, will enable easier handling for installation, bearing in mind that it could substitute for 20-200 feet of conventional acoustic lining.

TIMBERS

Although the usage of timbers in R.A.N. ship and boat construction is diminishing, there are large numbers of wooden craft, fittings and equipments fitted to R.A.N. ships. Indeed for vessels like minesweepers timber has been recognised as the best material with which to construct these vessels. Timber furniture in officers' accommodation areas is also very popular because of its comfort, ease of fitting and aesthetics.

A list of commonly used timbers together with their end uses is as shown in figure 8 .

Rot or Decay

Breakdown of wood by fungi, commonly called rot or decay, can occur in timber whenever the moisture content rises above 20 to 25 per cent. The fungi which cause decay spread by means of microscopic spores which are usually present in the air, so that any moist susceptible timber, even in almost completely sealed cavities, is subject to attack. Highly durable timbers such as ironbark, tallowwood or huon pine and timbers impregnated with a suitable preservative will resist attack even under severe conditions, whilst some less durable but non-absorbent timbers such as kauri, oregon and silky oak will not decay when subject only to intermittent wetting. Decay susceptible and absorbent timbers such as ramin and P.radiata will decay readily when wetted by fresh water and should not be used in boats unless treated.

The sapwood of all timbers behaves in similar fashion and care should be taken that no untreated sapwood is present on boat building timbers.

Marine plywood is completely waterproof but its resistance to decay depends on the species used to make the veneers. These are chosen for their strength, toughness, weight and finishing qualities but they are not necessarily durable, in fact many of the species used are quite susceptible to decay. The latest standard specification (ASS.086) contains a warning to this effect.

Paint is not a preservative and while it can and usually does prevent decay starting because it slows down moisture absorption it can also make wood rot faster by retarding the drying out of the wood if it becomes moist by intermittent or localised wetting. It also conceals the evidence of decay and makes its detection more difficult.

Preservation - Wood preservation can very often make a susceptible timber immune or a naturally immune timber more immune. However, in the latter case such as in impregnable wood it is a waste of time and money to attempt to apply preservation materials.

A good timber preservative must have the following characteristics:-

(a) Be toxic to fungus spores;

(b) be permanent and leach out;

(c) be there in sufficient quantity to ensure protection; and

(d) distributed evenly throughout the timber.

Draft Australian Standard Specification AS 115/68 on the "Preservation of Timber and Plywood" is expected to be available by the end of 1968.

Decay preservatives can be of two main types:-

(a) Oil borne preservatives such as creosote and pentachlorphenol (P.C.P.):

Creosote is generally regarded as unsatisfactory because of its objectional odour and non drying qualities. P.C.P. on the other hand is used extensively in America and Holland with satisfactory results but Australian experience to date is that it is difficult to apply good quality paints over;

(b) Water borne preservatives are available. The leachable types which include such items as Boron, Borax and Sodium fluoride which as well as being good fungasides are in addition insecticides. Application of the above should be not less than half a pound per cubic feet.

Fixed water borne preservatives such as Copper Chrome Arsenate (C.C.A.) is used extensively for timber preservation and a 2% solution giving not less than half a pound per cubic foot is quite satisfactory although for large timbered baulks half inch impregnation all around is quite satisfactory. This is usually done by pressured impregnation methods.

Fire Retardents. Fire retardents of monomonium phosphate type are recommended and complete impregnation is not required for prevention of spread of flame. Surface coating only is sufficient. No known method of completely making timber fire proof is available. However, monomonium phosphate will enable the requirements of AS O30 (half hour rating) to be met.

Toredo Infestation - Ship worm. Experiemtns carried out by C.S.I.R.O. and borne out by experiences overseas have shown that timbers naturally high on the free silica have a resistance to the toredo,and in this regard timbers such as turpentine have proved quite satisfactory. Impregnation of timber with silica salts have given good results.

PLASTICS

Plastics materials are being used increasingly in Naval ship construction at the expense of more conventional (traditional)? materials.

The plastics proper fall apart in two groups with different thermal behaviour: the thermoplastic and the thermosetting materials. Thermoplastics, built up of long chain molecules, are supple or hard, depending on structure and temperature. On heating, they will always soften and ultimately melt; consequently, all form-giving can be achieved by the physical process of heating, forming and cooling. Easy form giving and the possibility of always making an article suitable for re-forming by simple heating (e.g. for bending a pipe) are among the advantages of thermplastics, while relatively low upper temperatures of applicability (60-150°C) for most thermoplastics) represent a limitation.

Articles of thermosetting plastic are made by chemically building up the big molecules in the mould, forming a three-dimensional molecular network. Mostly, this is done by heating (hence the name; the material "sets" on heating), but roomtemperature hardening is also possible. The resulting articles are always hard and will not, in general, soften on heating. They have thus the advantages of a better temperature-resistance and a better creep resistance (the upper temperature of applicability may be 200° and even higher) but once formed, cannot, in general, be reformed otherwise than by machining. If the mazes of the three dimensional molecular network are relatively large, as is the case with polyester resins, a limited softening and re-forming is possible.

The rubbers or elastomers, both natural and synthetic have the same long chain molecules as the thermoplastics, but their molecules have re-active spots where they can be chemically interlinked by means of sulphur. By this interlinking (the process of vulcanization), a limited amount of chemical knots are formed. As a result, the chain molecules remain free in their movements, but when stretched, cannot glide along each other. Thus the vulcanized rubbers are purely elastic also at higher temperatures and cannot, after vulcanization, be reshaped.

Synthetic fibres are, in most cases, drawn out thermoplastics; they are made by melt-spinning, followed by stretching. The chain molecules are then drawn parallel to each other and as a result the fibre obtains its strength. Parts of the chain molecules will even snap into a crystal lattice; the crystallites formed will act as physical knots between the chains.

To evaluate the general properties of plastics - a balance of properties should be made. With some danger of generalization, such a balance looks as follows:

Advantages	Limitations
High corrosion resistance	Relatively narrow temperature-range of applicability (especially with thermoplastics)
High resistance against weathering (certain types)	Combustible (though in very different degrees)
Low weight: easy handling, low transport costs, light structures possible.	For structural applications: low stiffness
Easy shapeability (also of complicated articles)	For thermoplastics: attack by certain solvents
Low maintenance costs	Relatively expensive (depends on application)

A table of the plastics, synthetic rubber and fibres being used in the R.A.N. are as shown in figure...

Reinforced Plastics

A number of G.R.P. boats have been designed by and are now in service with the R.A.N. These vary in length from 16 feet to 33 feet and results to date have shown that G.R.P. has many advantages over traditional wooden craft.

The use of G.R.P. for small craft, which are to be carried on the deck of bigger ships, has certain advantages over wood: lower weight and no attack by toredos or insects. The lower weight is of increasing importance due to problems of stability and weight encountered in present-day war vessels. Wooden boats require much maintenance, especially in the tropics, due to drying-up and attack by insects. Polyester ships need less keep-up than wooden- aluminium or steel vessels. Since wood has to be avoided progressively, thus diminishing fire risks on war vessels, there are many instances where non-flammable G.R.P. can be used. Repair of polyester boats is quite easy and can be done, in emergency cases, by unskilled labour.

G.R.P. is being used in a number of other applications, e.g. liferaft containers, survival pack containers, repair outfits, submarine casings, submarine mast shrouds, etc., whilst consideration is currently being given to fabrication of targets, minesweeper floats, and rope reels in G.R.P.

ACKNOWLEDGEMENT

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FIGURE 8

TIMBERS FOR R.A.N. SHIP & BOAT CONSTRUCTION

Name	Usage	Weight lbs/ cu.ft.	Modulus of Rupture lbs/sq. ins.	Modulus of Elasticity 10^6 lbs/ sq.ins.	Compression Strength. lbs/sq. ins.	Shear Strength lbs/sq. ins.
Hoop Pine	Furniture, Plywood, Cabinet Work.	32.5	13000	1.90	7060	1650
Huon Pine	Boat Planking, Decking, Timbers.	33.5				
Douglas Fir	Joinery, Planking, Engine Beds, Deck Framing.	33.75	11855	1.90	7555	1190
Queensland Kauri	Cabinet Works, Patternmaking	29.1	9210	1.13	5586	1260
White Pine	Cabinet Work, Patternmaking.	24.0	8505	1.33	4755	810
Klinki Pine	Planking, Spars, Decking.	16.75	10605	1.70	6705	1330
King William Pine	Oars, Patternmaking.	35.33	10000	.90	5410	1310
Sitka Spruce	Stringers, Deck Framing, Masts, Spars.	26.75	10605	1.50	5955	1190
Coachwood	Plywood, Mouldings.	39.0	14900	2.18	7250	2115
Jarrah	Keels & Engine Beds of Boats.	53.9	16200	1.88	8870	2135
Meranti (White)	Planking and Decking.	33	10605	1.70	6705	1830
Mountain Ash	Steam Bent Timbers.	41	16000	2.38	9180	
Queensland Maple	Ships' Furniture, Planking.	38	11100	1.48	6440	
Spotted Gum	Timbers, Stringers Chines, Gunwales.	58	21500	2.70	11000	2510
Teak	Decking, Gratings.	45	11855	1.19	9505	2375
Tea Tree	Worked Knees	49				
White Beach	Oars, Planking and Decking	32	10200	1.50	3780	7065

PLASTICS USED IN R.A.N. FIG.9

Class	GROUP NAME	FORM	EXAMPLES IN R.A.N. OF APPLICATION
THERMOPLASTICS	Poly vinyl Chloride (P.V.C.)	Sheet	Table Tops, Deck Covering, Bi-Metallic Joints, Bulk-head cladding.
		Extruded	Pipes, Stair Treads, Skirting, Handrails.
		Coating	Upholstery, Leathercloths, Awnings, Weather Deck-covers.
		Foams	Insulation, Buoyancy Materials
	Acrylics	Sheet	Clear Screens for Boats, Bunting
	Polyamides	Moulded	Bearings, Pump Impellers, Door Hinges.
		Coating	Stanchion - Fan Impellers.
	Polystyrene	Sheet	For Lockers (Experimental)
THERMOSETTING	Phenol Formaldehyde	Liquid	Glue
	Urea and Melamine Formaldehyde	Sheet	M.P.L., Table Tops and Furniture, Signs
	Polyester	Resin	G.R.P. Boat Hulls, L.R. Stowages, Insulating Board, Repair Kits.
	Epoxy	Resin	Sheathing of wooden boats Adhesive
	Polyurethanes	Foam	Insulation, Mattress, Cushion, Sandwich Core on Boats, Lifesaving Appliance, Inbuilt Buoyancy in Boats.
SYNTHETIC RUBBERS	Polychloroprene		Deck Coverings, Oil Resistant Rubber for Manhole Joints etc., Replacement for Rubber, Ships Shaft Bearings.
	Butadiene		Valve Seats
FIBRES	Polyamide	Filaments	Ropes Cordage, Carpets
	Polyester	"	Ropes Cordage, Sails.
	Polypropelene	"	Target Tow Ropes
	Fibreglass	"	Rovings) Mat) G.R.P. Work Cloth) Curtains and Drapes

MATERIALS

USED FOR

NAVAL CONSTRUCTION PURPOSES

BY

MR. A. R. ASQUITH

ON

23RD OCTOBER 1968

DISCUSSION

Mr. R. Campbell, Australian Shipbuilding Board.

Does Mr. Asquith know what steps are being taken for a uniform standard of demarcation of the properties of aluminium alloys and steels? I know designers are confused by the various standards for virtually the same material. Does I.S.O. have an international uniformity in this matter.

Mr. A.R. Asquith,

S.A.A. are making positive endeavours to do this with the setting up of the Shipbuilding Standards Committee of which the Navy is a member. There are a number of Sub-Committees such as Nomenoclature, Piping, Equipments, etc and it is intended in due course to deal with aluminium. With regard to aluminium alloys in particular the Australian aluminium companies have set up an aluminium development council which has nominated standard types of aluminium alloys related to the appropriate Australian, British, American and Canadian standards. These alloys are known as DC alloys and are as shown in Fig. 7.

Mr. A.R.L. Lait, Bureau Veritas

I would like to speak for all the classification societies. They foresaw this problem with steels some time ago and agreed to form what is a unified steel specification. You will find that all the grades of steel put forward by the Classification Societies are identical. The American Bureau of Shipping have another one or two additional grades to those covered in the Rules and Regulations of other Societies. They foresaw the difficulties because there were only slight discrepancies and steels for merchant ships are now the same. This has been in operation since 1960. There are five grades of steel A, B, C, D and E, Some Societies have adopted all of these but others have not.

Of course there are steels for different purposes such as D grade knotch ductile material also several tempers like DH and AH.

Mr. A.R. Asquith

In a comparison between the relevant specifications the U.S.A. steels have more copper than the Australian or British steels, also they include other materials such as niobium as referred to in Fig. 2 of the paper.

Mr. A.R.L. Lait, Bureau Veritas

Unfortunately with the prolification in shipbuilding that is now taking place there are not definite specified grades as such. There are for instance, nickel steels used in cryogenic tanks for gas tankers which come under special consideration for the particular construction itself rather than as a laid down set of rules that would embrace everything.

Mr. A.R. Asquith.

It is agreed that special steels with particularly low temperature requirements could have application in shipbuilding.

Mr. R. Pearce, Evans Deakin Co. Ltd.

I can confirm what Mr. Lait says as we have just had experience with this by building under the American Bureau Classification. They will go even further and accept Lloyd's grades of steel provided we have this in stock and also accept Lloyd's certificates for their own grades of steel. The American Bureau does go a bit further as they are very strict on cold flanging of steels and require this to be to their standards but for the general grades of steel they will take either or.

Mr. A.R. Asquith.

In recent papers by the Japanese they are introducing five ranges which are similar to Lloyds and ABS and I have mentioned one of them in my talk, Japanese WES 135 which is the bottom of the range. No doubt these will also be acceptable alternatives.

Mr. R.D. Grant, Department of the Navy

With reference to the R.A.N. Welding Code that has recently been re-issued could you tell us whether this procedure that you outlined tonight for determining pre-heat temperatures is clearly laid down in that code.

Mr. A.R. Asquith

Yes, all the information that I gave you tonight is from the R.A.N. Welding Code. This may be new to some of you and this was prepared as a designer's code not an operator's code. It relates to formulae and readings from curves which you can not expect the operator to work out. It is intended in the future to bring out an Operator's Code.

Lt. V. Gazio, H.M.A.S. Nirimba

In relation to rot and fungus development there was a problem in this regard on one of the Ton Class Minesweepers in 1963. Have you had experience of any further problems of this nature associated with these ships?

Mr. A.R. Asquith

The basic problem of rot on these ships was a result of the type of materials used in the construction. It was Gaboon plywood. This plywood is specifically mentioned in the BSS code on marine plywoods as being susceptible to rot and should not be used. It was an unfortunate choice to make the marine plywood from it as the base material itself was susceptible to rot. Certain timbers such as hardwoods have a natural resistance to rot while others like Radiator fire are highly susceptible to rot.

It is a waste of time trying to chemically rot proof hardwood as there is practically no penetration of the timber fibres. Soft wood such as radiator fire which is very porous can be successfully protected using pressure impregnation methods thus making them more durable to rot than natural hardwoods.

Mr. S.M. Rodgers, Eken & Doherty Pty.Ltd.

There is a point on your method of joining aluminium to steel where you listed five (5) items of which the first and last are straightforward but the other three are all of an anti-corrosive nature. What is the respective importance of these and is it essential that all three are used together.

Mr. A.R. Asquith

The first essential is to grit blast the steel ground bar to bore metal to enable a good coating of alumihium to be deposited to a thickness of 0.003 inches. Secondly, it is essential to ensure an insulation medium between the steel and aluminium which is done by inserting a PVC tape between the joint. In addition it is usual to apply a mastic compound around the Huck bolt and on the top and bottom edges.

This method of joining dissimilar metals has proved satisfactory and with few failures in present ships.

Mr. S.M. Rodgers, Eken and Doherty Pty.Ltd.

Are you satisfied that this method on this type of joint gives sufficient practical resistance to corrosion or are you still looking for a better corrosion resistant joint that is cheaper.

Mr. A.R. Asquith

No. We are sure that this method using huck bolt fastenings will give satisfactory results in service. However further investigations into Kaiser Aluminium bi/metallic strip is being made. This material appears to have application in Naval Service.

Mr. R.J. Luft, University of N.S.W.

I understand that when the stainless steel huck bolt is inserted it is coated with a mastic and then tightened. Isn't it possible there could still be metallic contact even with this mastic.

Mr. A.R. Asquith

Yes, this is true. The mastic will squeeze out but we are not too worried about contact of stainless steel to aluminium which are close on the galvanic series scales.

Mr. A.G. Mitchell, Cockatoo Docks.

Seeing the photographs of H.M.A.S. STALWART, also your comments on furniture,what is the present Navy Office opinion on the use of chip board and other particle boards none of which are mentioned in your paper.

Mr. A.R. Asquith

In my opinion they are not suitable for Naval ship construction. Fire tests conducted in accordance with SAA code A30 gives them an early fire hazard index of 60/70 which means that although these materials may deal with the onset of fire they are not fire-proof.

It is our intention that any flammable articles on board ship should be ultimately replaced and this includes shipboard timbers and other flammable plastics.

Mr. A. Hunter, RANATE

Is it likely that pumping, flooding and draining services, piping, valves, etc will be taken over by plastics?

Mr. A.R. Asquith

Plastics are being used in piping services to a limited extent. Such applications are on pre-wetting, wash down systems, drains from washbasins and other wastes, circulating water to small auxiliary units.

On some of the more complex pipework systems where smooth bore high velocity flow is required consideration has been given to the use of G.R.P. piping.

Neoprene seated butterfly valves for sea water isolqtion purposes and ventilation shut down valves have been introduced and are giving good service.

Mr. Chapman, Australian Shipbuilding Board

In regard to the use of plastics, power stations for electricity generation are using plastics extensively in conjunction with instrumentation.

In discussing the history of steels your paper starts off quoting yield stress then proof stress and completes with yield stress again. Proof stress of course is a requirement with aluminium alloys because the yield point is not apparent as it is with steels. It is inferred from this that by quoting the proof stress for these special steels that the yield point is not apparent and the proof stress must be used? At what percentage of elongation is this proof stress located?

Page 2 of the paper refers to the D.W. steels of 35-41 tons for square inch U.T.S. with 16 tons per square inch yield. UXW a stress of 34-33 tons for square inch and that range does not show much advance on the previous one but the proof stress is 25 tons per square inch. It is not known which side of the yield point this is on. Could you state what the percentage proof stress would be?

Mr. A.R. Asquith

Plastic yielding as determined by the yield point is of extreme importance in questions of design, for in structural members subjected to static loads, it is necessary for the load to be sustained without deformation. Medium grade Carbon/Manganese steels have a definite yield point beyond which the steel will permanently elongate.

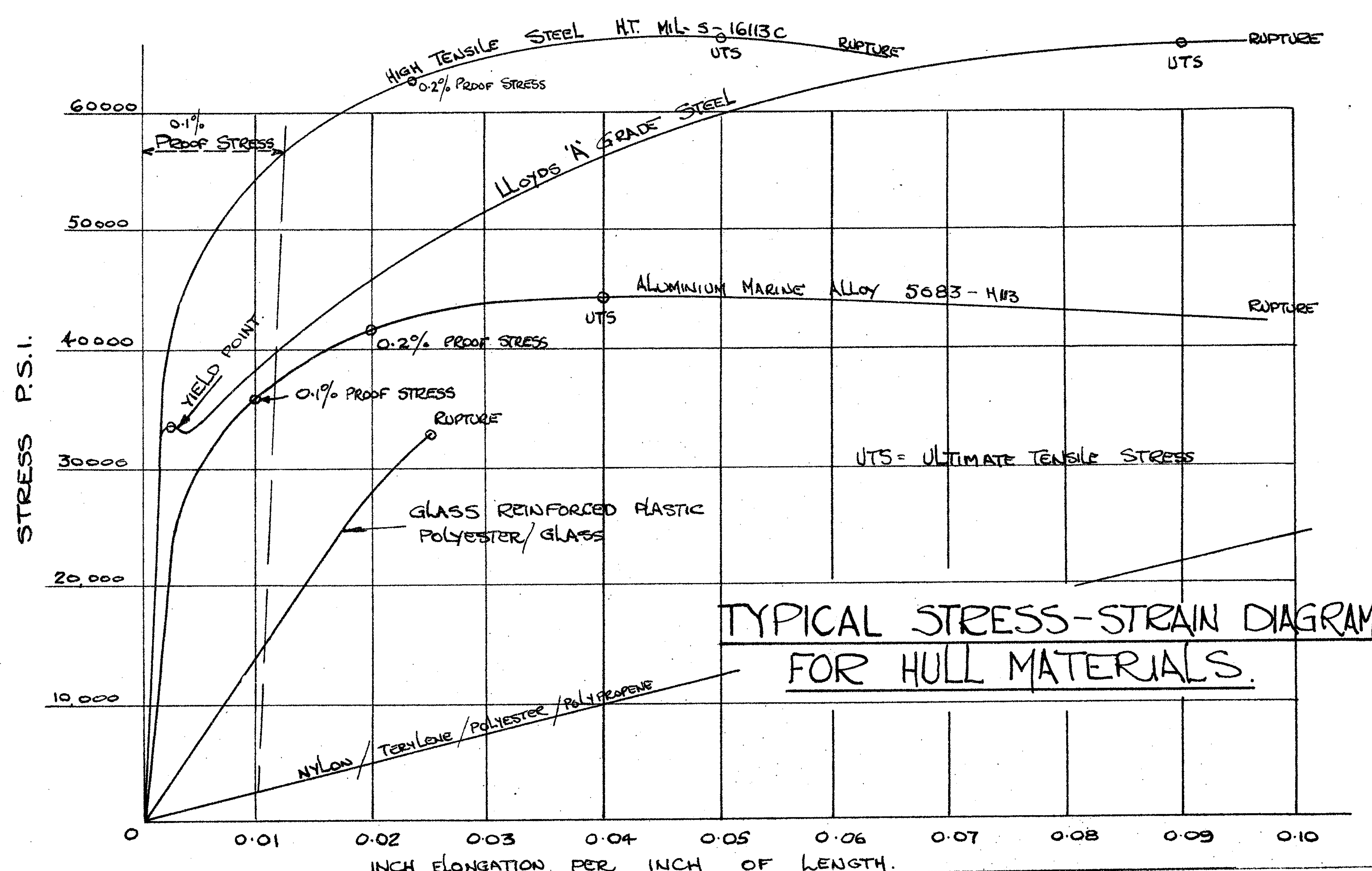
With aluminium however no definite yield point can be established and it is usual to nominate a figure of 0.1% proof stress as being the design value (equivalent to yield point).

Plastics on the other hand usually elongate under stress with straight line proportion and the ultimate point is reached rather suddenly.

In the low carbon steels the yield point as shown in Annexe 'A' is well defined, whereas in stainless steels and hardened steel it lacks precision and in these cases the proof stress is taken as the permitted stress. Proof stress can be defined as the load which applied for not less than 15 seconds produces a permanent set of 0.1 percent (0.1%) of the original gauge length.

Mr. R.J. Luft, Branch President.

I would like to thank Mr. Asquith for coming along and giving such an interesting paper. The question of materials always exercises the minds of designers because the whole success of a design depends on the materials with which it is constructed. We can all do a considerable amount in bringing ourselves up to date which is very difficult as it is always changing and for this reason we are very grateful to Mr. Asquith for his paper tonight.



TYPICAL STRESS-STRAIN DIAGRAM FOR HULL MATERIALS.