QUALITY CONTROL OF WELDING IN WARSHIPS

To write a paper on the above subject I found rather difficult. To begin with I do not consider that I have sufficient depth of knowledge of the subject to do it justice, there are plenty of knowledgeable people around who can do just that, and I feel I am not saying anything new.

Secondly, a written definition of the title is very difficult - for in essence the Quality Control of Welding in Warships is not materially different from that of any other welding, except perhaps Submarines, and therefore is well known and documented in all the various codes, specifications, practices etc. However, in an endeavour to produce something rather than nothing I have put together this collection of thoughts and observations in the hope that there will be something of interest in it.

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QUALITY CONTROL OF WELDING IN WARSHIPS

Modern warships like most other ships are a large welded structure which contains many varied types of welding and this paper will deal principally with the achievement of Contract requirements for Structural Electric Welding.

It must be borne in mind that there are two facets of welding in Warships - New Construction and Repair and Refit work, each of which requires a different approach which to put it simply is - New Construction welding is to a large part done under ideal or near ideal conditions - in prefabrication shops, comfortable attitudes, sheltered conditions, in jigs and with a minimum of difficult positional work. Refit work on the other hand is done under far from ideal conditions where a minimum of work can be prefabricated under ideal conditions and has to be done as a where it occurs often under appalling conditions - positional, climatical, and with frequent interference.

These facts must and do have a bearing on the Quality Control approach to the task.

All the above is relevant with regard to Submarines but this aspect of welding is not dealt with here.

The Welding of Warship structures is carried out to basically 'normal' quality standards - this is so because it is not possible to build or repair the required number of units under a higher standard or strict Naval Control in the time , or with the capacity available, therefore they have to be built and repaired, particularly in times of emergency at ordinary commercial establishments. There are of course other considerations outside the scope of this discussion which affect this method of production apart from mentioning perhaps the requirement to maintain skills and standards required to be used in warship production during emergencies.

Also by putting Warship Production and refitting out to Contract in between emergencies the Quality Control methods and organisation relating to Warship Production can be developed by commercial establishments.

An important aspect of Warship Production is that Standards are more clearly defined than in merchant shipbuilding, there are nowadays many Naval vessels built basically under Classification societies rules with Naval Specifications applied to particular sections or equipments of the vessel, but by whatever system the vessel is built, the ultimate aim is the offering to the customer of acceptable work only - Fitness for Purpose, this means that with the reductions of fleet numbers practiced today it is essential that what vessels we have are available for service on as many days of the year as possible i.e. Reliability, therefore must be one of the first considerations - and to achieve a high degree of reliability some form of Quality Control is essential and can range from no apparent organisation right through to a large department depending on the attitude and formation of the companies concerned.

But whatever system the company operates there are fundamental constants which should be present if reliability is to be obtained.

In the beginning the design must be correct - defining suitable materials, economically and efficiently connected with appropriate welding configuration - the whole produced in a readily understood manner, drawings, specifications, information sheets etc if this can be achieved then there is a very good chance of success - how is this known to be achieved? - apart from waiting for performance returns it can be done by an audit system which actively checks that the design meets the customers requirements.

Having got the design right and issued in a manner that the workforce can understand it is essential that the equipment in the shops, on the berth and aboard the ship is suitable for the task and in good condition - the audit system is designed for just this purpose - all too often the grids are out of alignment, or the cranes are unserviceable or a welding set requires re-setting up, all these examples may seem far fetched or even obvious, but it is by no means uncommon to find simple things like this disrupting production at a critical time - as mentioned above the Audit system is designed to prevent these occurrences.

A vital part of the Quality of Welding in a warship is the welders. To produce the Quality level called for there must be welders capable of achieving it with the minimum of supervision and rework, by that is meant that the welding team must be to a great extent self motivating and adequantly informed. It is not sufficient to assure that a welder can weld - meeting the acceptance standards that may be required in a warship proves that often this is not so, we have to examine how the man on the job is welding and to educate him - correcting those things that he is doing wrongly then we must be sure that he is receiving the correct instructions - such as written procedures which basically tells him which rod to use, and what to weld first - how to work to a sequence, balancing his welding to avoid restraint and minimise distortion and moving himself from side to side - sitting on an 'orange' box and pouring in electrodes is just not good enough.

Before engaging on Warship work it is a requirement that welders pass a test such as three fillet welds, three butt welds flat, vertical and overhead, the results are visually examined, crack detected and then the fillets broken and visually examined. The butts are visually examined and then Radiographed, these tests may be repeated should the standard of work on inspection indicate a change in performance by the welders, but only after investigation into a possible reason which frequently has nothing to do with the welders capabilities. For higher quality work such as is required on Submarine pressure hulls or pressure vessels, special welder training and tests are carried out, those for Submarine pressure hulls being very similar to D.L.I. tests for pressure vessels and are laid down in Department of Defence specifications based on Ministry of Defence (Navy) U.K. specifications and Australian, American and British Standards.

Having the welders is one thing, but to produce consistent acceptable quality welds they must have good supervision and back up trades - Boilermakers, Platers, Shipwrights - for fit up and alignments, Chippers, Caulkers, Burners for edge preparations, weld cleaning, back gouging etc, these trades are lacking, both in numbers available and in appreciation of what is required. Supervision of welding operations in WARSHIP construction plays an important part in the ultimate quality and reliability of the complete product and every opportunity must be taken to aquaint supervision with the latest trends and requirements on the basis that if there is knowledge of why it is required the way it is, then the welders too will be able to understand and deliver the required results.

Taking the R.A.N. as an example, the fleet consists of ships built to many varying standards - ships built in U.K. to MOD (N) standards in commercial shipyards, ships built in similar circumstances to Lloyds rules with MOD (N) specifications added, American built ships to U.S.N. and Bureau of ships standards, ships built in Australia to R.A.N., MOD (N) and Australian standards, Submarines built in U.K. to MOD (N) standards and various other combinations, this widespread of types and standards requires a comprehensive knowledge of methods and standards which only an alert and progressive Quality Control System can deal with.

To illustrate the above notes, a typical Quality Control Procedure for Welding work inspection in the shipyard or dockyard would contain the following:-

1. To supply welding information to Yard personnel, regarding:-
   (a) Dimensions of Welds, as provided by Tech. Department.
   (b) Sequence of Welding.
   (c) Procedure of Welding.
   (d) Details of edge preparations, as provided by Tech. Dept.
   (e) Suitability of Electrodes.
   (f) Pre-setting procedure and details.

2. To examine welding during progress of work on 15% basis of spot checks, examples of types of welds, e.g. Downhand, Vertical and Overhead, on various components forming the area under review, e.g. Butts, Seams, Beams, Girders, Boundary Welds etc., and ensure that they conform to required standard of dimensions, contour, appearance and free from slag, undercut, and inclusions. The number and type of defects will be noted and compared with the number of examinations made, e.g. Twenty checks made, and defects found were, 4 stations undersize, 1 station undercut, 3 stations not deslagged. This information will be noted, analysed, and passed back to Production Department for corrective action.

   As it is the responsibility of the Production Department to maintain the standard of quality and completeness. The Q.C. Inspectors will not under any circumstances be responsible for defects or omissions of work. It is expected however that they will co-operate with Production Foremen and other Inspectors by reporting any malpractices, defects, and omissions foundduring the course of their normal duties, to the respective departments.

3. To note fit up of work set up for welding and advise on method of correction where discrepancies exist. It will not be their responsibility to decide on extent of inserts on discrepancies which may occur on major structural items, e.g. Shell strength decks etc. These will remain a matter for arrangement between the Ship Manager, Technical Dept., Ship Surveyor, and Department concerned.

4. All defects will be logged and information passed to the Department concerned for corrective action.

   In cases where the defects are not dealt with promptly, a report should be made to higher authority e.g. (a) Head of Department concerned, (b) Steelwork Quality Control Manager for further action.

5. Investigate Weld fractures to ascertain the cause of same if possible, and superintend any repairs found necessary. Details will be logged and a written report drafted together with a photograph of the fracture.

6. To ensure that the agreed welding sequence and procedures are carried out.

7. To check that the correct type of electrode is used for work in hand.

8. Carry out random checks of welding amperage and record same.

9. Check plans for welding details and ensure that they conform to specification and Yard practice, any queries will be reported to Steelwork Quality Control Manager who will investigate.

10. To random check on 10% basis edge preparations as delivered from plate shop. In view of the accuracy expected of Burning Machines, Tolerances will be +1/32" - 1/16" on the bull Nose' dimension bearing in mind that the cause of many Radiographic defects is lack of link up between welds. Should defective preparation be extensive or persistant, Steel Shop Manager's attention will be drawn to them for action on his part.

    The maintenance of quality standards is the responsibility of Steel Shop Foremen.

11. The Q.C. Inspectors will co-operate with the Radiographic Department in supplying weld details, positions of Radiographs i.e. Frame station etc., and seeing that defects are removed by Caulking Department. He will not be responsible for them being re-welded, but will observe that proper procedure is adopted. He is at liberty to request a Radiograph to be taken should he deem it necessary to do so. The number of Radiographs taken and their disposition will be the responsilility of the Radiographic Department.

12. To report any plate laminations found, to the Production Department Foremen for their attention and action.

13. To co-operate in preventing any weld attachments other than normal welded butts, taking place on sheer strake edges above the line of the strength deck.

14. To enforce procedure for stopping and starting plates for machine welds, sheer strake and strength deck free edges, as laid down in Welding Standards.

15. To examine areas of special treatment, e.g. Shot Blasting, Zinc spraying etc., to ensure that all welding and attachments are complete. This is essential as many of these special coatings seriously impair the quality of any welding done afterwards, apart from impairing the efficiency of the coating.

16. Stern Frames, Stern Tubes and similar important structures will have 100% visual welding inspection check. The welding of these structures and procedures employed will be the responsibility of the Welding Department. The inspector will check that all conform to Welding Standard required.

17. A random check on 10% basis will be made for alignment and shape on Butts and Seams of major structural items, e.g. Shell Strength Decks etc., to be welded, no tolerance will be allowed before welding, but as movement may take place during welding a similar check on basis of 10% will be made, when tolerance of misalignment will be 20% of thinner plate up to ½" thickness and not more than 1/8" on thickness above ½".

    The welding Inspector will not be responsible for any misalignment found at any stage.

18. The Inspector will satisfy himself that pre-setting arrangements are being carried out to his satisfaction.

19. Back Gouging Butts and Seams.

    A 10% random check of quality of back gouging for welding on major structural importance, e.g. Shell, Strength Deck, Strength Deck Girder Butts etc., will be carried out by Quality Control Inspectors. The maintenance of the required standard will be the responsibility of the Foreman Caulker after gouging, and the Foreman Welder before Welding. The Q.C. Inspector will not be responsible for defects which may be found during subsequent inspections or examinations.

20. A 100% visual Inspection will be carried out on all welded Hull penetrations.

21. Burning

    A random check will be made on burned in edges where they effect welding preparations for Butt or Filler welds. The number of defects noted will be compared with the number of examinations made, and analysis drawn up. The Foreman Caulkers attention should be drawn to defects and curative action taken by him.

    It is the responsibility of the Foreman Caulker to ensure that the proper guide devices are used, and the quality and accuracy of work done.

22. Care to be taken to ensure that welded Butts etc., adjacent to riveted Seams are fair and do not effect the line of the Seams.

Suggested routine for Q.C. Inspectors.

A period at each starting time should be spent in the alloted area of Assembly Shop. Then proceed to the berths and check that major Hull items are starting off in the proper manner, thereafter, proceed on particular Inspections of quality.

This is further amplified by the following:-

1. Weld dimensions as specified by classification societies are minimum requirements, therefore no minus tolerance can be permitted. A small plus tolerance is permissable but will be governed by the conditions on the job, i.e. accessibility, limits of electrode deposit, Welders ability etc.

2. Sequences for welding must be arranged to allow freedom of movement in the joints for as long as possible. Welding must commence at a central point and proceed to outer boudaries in all directions and work simultaneously on both sides of the ship, or large assemblies; or as decided by the Q.C. Inspector. Each Butt or Seam must be completed on both sides before passing with adjacent Butt or Seam, e.g. in case of Tee Junction or cross over junction. One side of each butt or Seam must be completed in one operation, i.e. between each stopping and starting times, if this is not possible the "block" method of welding must be used. Taking care to pre-heat the ends of each block on recommencing welding of next "block".

   Finishing Angles must be fitted as shown for the manual weld of all sheer strake and strength deck stringer butts. Welds to be extended 1" beyond free edge of plate. After welding of butt is completed the angles are to be burnt off proud and the free edge of plating flushed and then buffed smooth. The angles must on no account be hammered off.

   When both riveting and welding are employed in connections, all welding must be completed before riveting.

3. Edge Preparations will be as defined in Yard Schedule of edge preparations.

4. Back Gouging. All manual welded butts will be back gouged to depth sufficient to ensure link up with first side weld, and to remove any slag inclusions visible.

5. Machine Welds.

   a. The sequence for machine welds must be arranged to begin from after end.

   b. When one machine is engaged, welding must commence at one end of the butt or seam and proceed to the free end.

   c. Two machines must be used for long welds in shell and strength dk, starting in the centre.

d. Plate edges must be free from rust and grease, rotary wire brushes being used where necessary.

e. All Fusarc welds must be tested for porosity. The surface of the weld must be chipped 1/8" deep for ¾" at each end of the weld and at 6'0" or 8'0" intervals in between.

6. Starting and finishing plates 9" x 6" must be fitted, made up of 2 plates 9" x 3" with edges prepared similar to job in hand and of same thickness of plating and welded to edge of plate. On Butts and Seams of square edge preparation the plates may be fitted 9" x 6".

On completion of welding all starting and finishing plates to be burned off proud, and edges of plating chipped smooth and dressed to standard of finish required. On no account must plates be removed by hammering.

Starting and finishing plates are to be fitted for all machine welds, the fit-up for plating butted square with no air gap is similar. After welding of butt is completed the plates are to be burned off proud and the free edge of plating dressed smooth. The plates must on no account be hammered off.

7. Low Hydrogen Electrode - Procedure.

a. No. 8 Gauge should be used for vertical and overhead welding.

b. Before using they must be dried out at a temp. of 100°C for 1 hour.

c. Care to be taken in handling to avoid damaging the coating.

d. The arc length must be kept as short as possible.

e. When starting or re-starting the arc should be struck ½" in advance of the start of the weld and working back over this distance before continuing in the required direction.

f. The runs should be deposited with the least possible weaving motion.

g. It is essential that the recommended current values are strictly adhered to.

8. They will be used in conjunction with the appropriate heat treatment on -

(i) X Ray repairs.
(ii) Heavy sections of special nature e.g. Stern Frs. etc, and in some cases Mild Steel members over 1¼⅛ thickness.
(iii) Heavily stressed or "locked in" areas.
(iv) At any time as and when the Q.C. Inspector may direct.
(v) On heavy mild steel over 1 1/8" thick and High Tensile Steel due consideration to be given to heat input via welding, short light deposits should be avoided, and preference given to heavier passes.

9. Pre-Heating

Pre-heating will be carried out before Welding, Burning Flame Gouging or Arc Air Gouging is carried out on items and to temperatures stated.

a) Cast Steel 200°C.
b) High Tensile Steel 100°C including "D" Quality.
c) Mild Steel over 1.125" thick 100°C.
d) Highly stressed welds 100°C.
e) On radiograph repairs 100°C.
f) On repairs to fractured welds 100°C.

All above include fairing lugs, bolts etc.

In frosty weather all Butts and Seams on major structural items e.g. Shell, strength dk, U.Dk. girders etc. to have chill taken off the plate in weld area and surround. Tempil sticks to be used for checking temperatures, or in some special cases Thermal Heaters with Thermo Couples.

10. Weld Fractures

In all cases weld fractures will be reported to the Q.C. Inspectors who will investigate and ascertain cause, and report in writing on same, and logging details.

11. Pre-setting of Butts and Seams for Welding. Each type of job to have separate consideration, the Q.C. Inspectors, will be consulted and their instructions carried out. Where applicable, members with structural curves should have extra set worked in to counteract any loss of shape due to welding.

Built up girders, gunwhale bars, hatch covers and similar structures should be welded in back to back position to minimise distortion.

12. Sequence for welding Dk, Chocks (Lapped or butted and where welded above and below)

Above (1) Weld short butt at inboard side of frame toe.
Above (2) Weld both chock ends to frames.
Above (3) Weld to shell.
Below 4 Weld underside of short butt at frame toe.
Below 5 Weld underside to frames.
Below 6 Weld underside to shell.
Below 7 Weld underside to deck.
Above 8 Complete weld to deck top side.

Note: not more than 4 chocks to be welded above, before completing welds on underside.

13. Plug Welds - Oval or circular slots in plate.

a) Oval minimum dimensions 3" x 1½" but width not less than T + ½", (T = thickness of slotted plate).

b) Circular dia. not less than T + ½" with minimum of 3".

c) Slots to be welded with a continuous fillet. On no account should the slots be filled with weld metal.

14. Inaccurate edge Preparation

	Procedure
Fillet weld Gap up to 1/8"	Weld one side and chamfer other side to half plate thickness.
Over 1/8" up to ¼"	Weld one side and chamfer other side to weld metal.
Over ¼"	Cut back to fit parallel packing same thickness as abutting member, and width 4 times the thickness.
Over that covered by above	Cut back and fit insert not less than 6".
Butt Welds.	
Gap up to 3/16"	Weld solid. Welding Inspector to decide if 1/8" thick backing strip is required.
Over 3/16" to ¾"	Reinforce one edge using 1/8" thick backing strip. After the building up weld is completed the backing strip to be removed and plate edge re-chamfered. Fairing of butt to be re-checked by Foreman Welder and normal welding procedure followed. Continuous welds must be substituted for Intermittent welds where fit up is not satisfactory. The correct method will be decided by the Welding Inspector.

15. Brittle Fracture

It is important that parts of the ship, where there are discontinuities and high stresses, should be designed and welded with every precaution against cracking. The following items should have careful consideration.

1. Sheerstrake

There should be not welded attachments to the top edge of the sheerstrake above the line of deck. The edge should be free from notches, serrations and other blemishes, and buffed to required finish. Bulwarks, side screens etc., where attached should be riveted; or supported from deck only by stays. Fairleads or chain plates should be attached to the deck or bulwark only. Stray arcing to be avoided.

2. Strength Deck Stringer plates

The edges abutting the sheer strake shall be free from notches, serrations and blemish. Ends of Butts where runn off angles have been fitted to be removed and edge ground to required finish. The edge to be examined before fitting Gunwhale Bar.

3. Hatchways and Deck Openings.

Great care must be taken to avoid notches in all deck openings, and special attention should be given to design and construction at the corners.

Main strength Dk. Hatchway Corners are to have a radius of not less than 1/24th x breadth of hatch opening (minimum radius 6").
Hatch coamings at corners to be kept as free as possible from welded attachments, Winch Girders must not be welded to coaming corners.

Stray arcing in way of corners and free deck edge must be avoided.

16. Bulwarks.

These should run in easy curves, tapering gradually at endings and in way of breaks, notches in plating are to be flushed.

17. Girders

Girders not passing through Bhds, must line up exactly with the stiffener, Brkt, etc. on the other side of Bhd.

All notches in the flanges in way of Butts are to be chipped flush or to a smooth taper.

18. Continuity of Decks, stringers etc.,

Care must be taken that continuity is maintained where stringers or brackets and non continuous decks abut on opposite sides of a bulkhead. It is particularly important that the toe of the bracket is in line with the deck on the other side of the Bulkhead.

19. No welding to take place on Hull below waterline of ships afloat, or on tanks containing water, oil or other liquids.

20. These standards apply to normal work.
On specialist Work the appropriate standards and regulations will apply.

21. Burning

When burning plate edges and holes by the manual process the proper guide bars, trammels or other guide devices must be used.

It will be the responsibility of the Foreman Caulker to ensure that these are used and for the quality and accuracy of work done.