SSC-195

RECOMMENDED EMERGENCY WELDING PROCEDURE FOR TEMPORARY REPAIRS OF SHIP STEELS

SHIP STRUCTURE COMMITTEE

MAY 1969

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May 1969

Dear Sir:

The enclosed copy of a *Recommended Emergency Welding Procedure for Temporary Repairs* has been prepared for shipboard personnel performing temporary repairs at sea and in ports where requisite materials are unavailable. Additional copies can be obtained from the Ship Structure Committee in accordance with its responsibility to disseminate information for the ultimate purpose of increasing the safe operation of ships.

Please address any requests or comments concerning this report to the Secretary of the Ship Structure Committee.

Sincerely yours,

D. B. Henderson

D. B. Henderson
Rear Admiral, U. S. Coast Guard
Chairman, Ship Structure Committee

Report

from

Project SR-177, "High-Strength Low-Alloy Steel Weldments"

to the

Ship Structure Committee

SSC-195

RECOMMENDED EMERGENCY WELDING PROCEDURE FOR TEMPORARY REPAIRS

by

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Southwest Research Institute
San Antonio, Texas

under

Department of the Navy
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U. S. Coast Guard Headquarters
Washington, D. C.

May 1969

ABSTRACT

The new merchant cargo ships use a large variety of steels in their construction; the steels range in yield strength from 40 to 100 ksi. Since some of these steels require a close control of the welding procedure as well as other special techniques to assure serviceability, it was felt that a special repair welding procedure must be developed. The procedure must be applicable for all strengths of steel used in construction and should require a minimum amount of proceaure control.

The recommended temporary welding repair procedure and a discussion of the survey which led to the recommendation are described in this report.

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INTRODUCTION

The use of high-strength, low-alloy steels for the construction of merchant ship hulls makes it possible to produce ships with improved cargo weight to ship weight characteristics and thus improve the economics of ship construction and operation. However, along with these improved engineering developments, there are some necessary changes in fabricating procedures which result from the introduction of the new steels. The primary differences between conventional ABS-classification steels and the new steels are the alloy content, strength, heat treatment, and microstructure, all of which make the new steels more difficult to weld. To assure crack-free welds and good toughness, the alloy steels must be preheated for welding, a relatively low welding heat input must be maintained, and special electrode handling procedures must be employed. Such controls are possible in shipyard application but may be difficult to maintain aboard ship or in remote repair yards. Consequently, a survey was made of methods which could be used for repairing cracks or to replace sections of plates, or even whole plates, on a temporary basis.

As the results of the survey were reviewed, it was clear that the problem of welding was not restricted to repair of cracks or replacement of plates but was also an important consideration in the operation of the ship. It is common practice for an operator to weld clips, handrails, etc., either on a temporary or permanent basis, to hold down deck cargo or for other reasons. The recommended welding repair procedure is also applicable to such required welding, although additional recommendations are included for preengineered welding pads which will permit welding with any normal carbon steel welding procedure.

RECOMMENDED EMERGENCY WELDING PROCEDURE FOR TEMPORARY REPAIR OF SHIP STEELS

Scope

This procedure is intended for use only on an emergency basis to accomplish a temporary repair when repair cannot be made using the materials, procedures or controls of construction, or when a mechanical repair cannot be made.

Base Materials

This includes all ferrous alloys used in the decks, hull, and other structures.

Filler Materials

This is ASTM A298-62T Type 310-16 stainless steel electrodes. Type 310-16 electrodes are most useful because they can be used with alternating as well as with direct current. Use 1/8-, 5/32-, or 3/16-in. diameter electrodes, depending on the position of welding.

Welding Process

Manual shielded metal arc process shall be used. The current shall be AC or DC reverse polarity.

Position

Any position is acceptable for use.

Preheat

No preheat is necessary except when the ambient temperature is below 32°F. Below 32°F, the base metal in the vicinity of the weld shall be warm to the hand.

Determination of Extent of Cracking

One of the problems which is faced when using any repair procedure is that of locating the extent of a crack. In order to insure that the ends of a crack are located, it will be necessary to have inspection personnel available who are preferably qualified in the use of penetrant and/or magnetic particle inspection techniques. These inspection methods should also be used after the temporary repair is complete to insure that more cracks have not been generated.

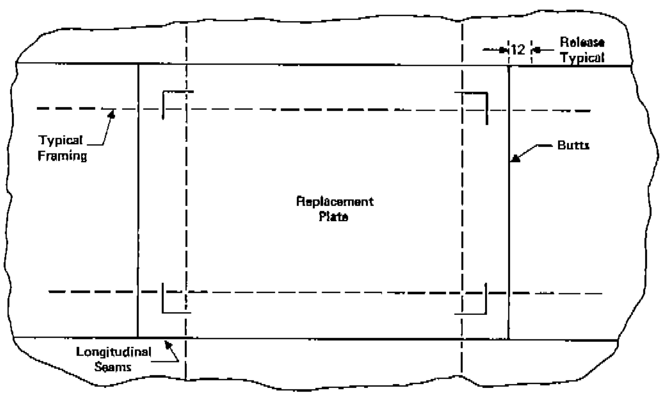
Any welding machine can be "rigged" for use as a magnetic particle inspection machine. This can be done with the use of commercially available prods equipped with a remote contactor which helps prevent arc strikes. If commercial prods are not available, a piece of bar stock or plate which has been bent or cut in the form of a yoke or horseshoe, then wrapped with the welding lead to form a magnet, can be used. The yoke is easy to use since no current passes to the plate, thereby eliminating the chance of arc strikes. The prods or yoke should be placed across the crack at 45°; then, a fine powder of iron or steel filings should be sprinkled in the area near the end of the crack. The crack will be readily visible due to the lining up of the particles along its length. Progress toward the end of the visible crack and beyond until no indication is present, and mark this point as the end of the crack. Care should be taken to prevent gross overheating of the welding leads or of exceeding the duty cycle of the power supply.

If a hole is to be drilled at the end of the crack, the edges of the hole should be liquid penetrant inspected to insure that the crack does not extend past the hole. There is always the possibility that the crack can run subsurface for some distance.

Preparation of Base Material

After the extent of the crack has been located in accordance with the section above, the area shall be cleaned so as to be free of paint, scale, rust, etc. The crack shall be removed to at least half of its depth by chipping or grinding. After the first side is welded, the second side shall be prepared in a like manner.

If the repair is a replacement of material which involved framing, the joint shall be sequence welded. A guide for welding sequence is shown in Figure 1 of this report. Temporary repairs which do not involve framing (such as small patches) should be welded so as to minimize base metal distortion.



Note that a release length of 12 in. is provided in the longitudinal seams at each corner of the insert plate, and that the release length is a part of step 4.

Welding sequence:

1. Weld framing to within 12 in. of all unwelded butts and seams.
2. Weld vertical butt complete.
3. Weld unwelded framing in way of butts.
4. Weld longitudinal seam including release lengths.
5. Complete framing in way of longitudinal seams.

Fig. 1 Welding Sequence for Repairs (With Framing).

Welding Procedure

Welding shall be accomplished by using the stringer bead technique. No bead should be wider than three times the diameter of the electrode core wire. Each bead of weld metal shall be inspected visually (after slag removal) to assure that no blowholes, cracks, or lack of fusion are visible. All defects shall be removed by grinding and/or chipping prior to subsequent welding.

The backside of the groove shall be ground to sound metal prior to welding. The weld reinforcement shall be contoured by grinding so as to fair smoothly with the adjacent base metal.

Inspection

The completed weld and the base metal adjoining the weld shall be inspected by using magnetic particle and/or liquid penetrant techniques whenever possible. The austenitic/ferritic interface will give a defect indication when the magnetic particle inspection method is used. This indication should not be mistaken for a crack, and, for this reason, the liquid penetrant inspection method should be used when available.

Records

When any repair is made (either cracking or replacement), the area shall be mapped or logged so that the area may be located and adequately repaired upon return to the proper facilities. This is very important since this austenitic material must be completely removed before any permanent repairs can be made using ferritic weld deposits.

EQUIPMENT AND SUPPLIES

The following is a list of the minimum amount of equipment and supplies which will be necessary to effect temporary repairs on an emergency basis:

(1) Welding machine of at least 300 amp and associated equipment.

(2) A total of 500 lb of ASTM-A-298-61 Type E310-16. The size distribution of this electrode should be as follows:

(a) 100 lb of 1/8-in. diameter electrodes

(b) 200 lb of 5/32-in. diameter electrodes

(c) 200 lb of 3/16-in. diameter electrodes.

This quantity will allow the replacement of an 8 × 30-ft plate of 1-1/2-in.-thick material.

(3) Magnetic particle inspection yoke or prods and associated metallic powders.

(4) Dye penetrant inspection kit (preferably a water washable red dye) and associated developers.

(5) Gas-air or gas-oxygen cutting equipment.

(6) Grinding equipment and a supply of associated consumable items.

SURVEY OF EXISTING WELDING PROCEDURES AND RECOMMENDATIONS

A survey of the welding procedures presently used for new construction of merchant cargo ships was undertaken in order to appraise their potential for serving as emergency repair welding procedures for making temporary repairs to any practical combination of ship steels. As a portion of this survey, a questionnaire was sent to all United States ship builders and ship repairers listed in the 1969 edition of the International Shipping and Ship Building Directory. This questionnaire requested information with regard to the procedures presently being employed to fabricate and/or repair ships containing the HSLA steels.

In addition to the above contacts, shipyard welding engineers, research laboratory personnel (Marine Engineering Laboratory, Naval Research Laboratory, and U. S. Naval Applied Science Laboratory), and members of regulatory bodies (American Bureau of Shipping and the U. S. Coast Guard) were contacted. A review of response to the above contacts provided some guidance to a suitable approach to repair of ship steels, including HSLA Q & T steels.

As the state-of-the-art with regard to welding the low-carbon and/or low-strength steels is quite well advanced, and as one must assume that a part of the joint in an emergency repair might be on HSLA Q & T material, the major effort of the survey was to obtain information on the welding of the HSLA Q & T steels. The survey of welding procedures produced information on welding processes, filler metals, strengths, and techniques. This information is summarized briefly in Table I.

As HSLA Q & T steels require the use of low-hydrogen electrodes for construction, it is evident that no rutile (XX12, XX13) or cellulose (XX10, XX11) coated electrodes can be used for repair welding. Some people contacted suggested the use of low-strength, low-hydrogen electrodes for repairing the A514/517 class of steels. This type of filler metal has the advantage of producing a weld with lower residual stresses and plastic strains in the heat-affected zone. However, the use of these electrodes would require the same moisture and preheat control as would the matching filler metal. In addition, electrode manufacturers do not hold the moisture content of low-strength electrodes to the same low limit as they do the E11018 class. Any of the low-hydrogen processes would require experienced welders, using proper equipment and good procedures, to assure that sound deposit is made. For these reasons, we do not recommend the use of any ferritic electrode for repair welding when the proper controls, facilities, and supervision are not available.

It is also evident that procedures that require the use of automatic or semi-automatic processes cannot be considered for emergency repair, as the availability of the necessary equipment at sea or in remote ports is questionable.

The unanimous concensus of the people contacted was that, if at all possible, a mechanical method of repair should be used. When conditions are such that a welded repair is necessary, the general concensus is that the filler metal should be of the austenitic variety. The austenitic filler metal suggested most often was type 310 stainless steel.

TABLE I

Process	Procedure	Filler Metal	Gas or Flux	Heat Input*	Tensile Strength (ksi)	Weld Joint Detail
Metallic Arc Inert Gas	Automatic	Airco 632 or Equivalent	Argon- 1 to 2% O_2	A	120	V
Metallic Arc Inert Gas	Semi-automatic	Airco 632 or Equivalent	25% CO_2 75% Argon	A	120	V
Submerged Arc	Automatic	Linde 100	Linde 709-5	B	120	
		Armco W25	Linde 709-5	B	120	V
Shielded Metal Arc	Manual	E11018 M or G		A	120	V
		E7018		A	70-80	V & Fillet
Shielded Metal Arc	Manual (Single Pass Fillet Welds)	E8018 C3		A	120	
		E9018 M		A	120	Fillet

A. 45,000 joules/in. for thicknesses less than 1/2 inch.
55,000 joules/in. for thicknesses 1 in. and greater.

B. 25,000 joules/in. for thicknesses to 1-1/4 inch.
45,000 joules/in. for thicknesses 1-1/4 in. and greater.

$$\text{*Heat Input (joules/in.)} = \frac{\text{amperes} \times \text{volts} \times 60}{\text{travel speed (in./min)}}$$

If the problem to be corrected is a crack, then a procedure such as the Navy Emergency Crack Stopper Procedure was recommended. This procedure is explained in the following section.

REPAIR PROCEDURES

Crack Arrest Procedure

The Navy has developed a technique for stopping a crack from propagating. This technique has been used successfully when dealing with conventional and high-strength carbon steels. The procedure, known as the Navy Emergency Crack Stopper Procedure(1)*, is shown in Figure 2. This procedure is not intended to be a repair, but it is a method to arrest the propagation of the crack, thereby preventing further damage.

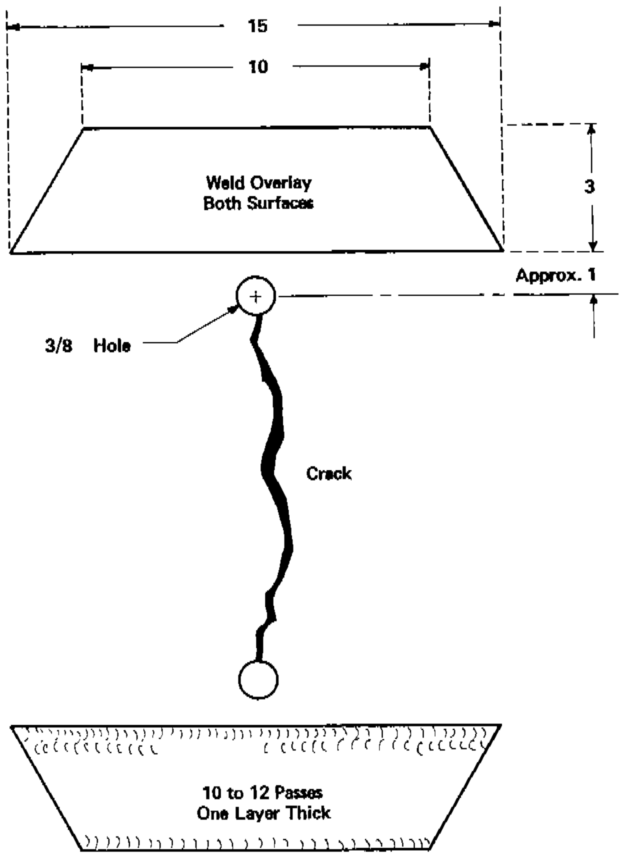


Fig. 2 Welding Overlay and Hole Emergency Crack Stopper (Plain View).

*Superscript numbers in parentheses refer to the List of References at the end of this report.

The extent of the crack is determined, and a hole is drilled at each end. A simple method of determining crack length is described in the section of this paper entitled Determination of Extent of Cracking. Then, a layer of austenitic weld overlay (Type 310 stainless steel) is applied in the shape of a trapezoid normal to an imaginary extension of the crack at both ends and on both sides of the plate (see Figure 2). This weld overlay is basically to inhibit propagation of the crack by fast fracture by providing a tough, ductile material through which the crack must propagate. The effectiveness of such an overlay deposit in imparting a high order of resistance to the propagation of a crack is shown by the work performed by Puzak and Pellini(2). Their work indicates that an austenitic weld metal overlay could stop a rapidly propagating crack in an explosion bulge test specimen. In addition, it is our belief that the heat of welding may tend to relieve stresses which are present in the area ahead of the crack.

Since the drilling of holes alone does not guarantee that a crack will not continue to propagate, it is important that the overlay portion of the procedure not be omitted. The weld overlay procedure, with Type 310 stainless steel electrodes, does not require preheating except to remove surface moisture or when the temperature is below 32°F. As in all welding, it is necessary that the surface to be overlayed be clean and free from paint, scale, rust, etc. The Navy recommends that the overlay be made using 3/16-in. diameter electrodes; however, this size of electrode may be excessive when the welding is performed out of position.

Welding Repair of Cracks

Although the Navy Emergency Crack Stopper Procedure is not intended as a method of repair, the technique could be used in conjunction with a repair weld to effect emergency repairs of cracks.

When a weld repair is necessary, and the conditions preclude the use of one of the procedures used in the original construction, or the damaged area is located such that a mechanical repair is not feasible, it is recommended that the welding procedure listed in the second major section be followed. This procedure recommends the use of small-diameter ASTM A298-61 Type 310 stainless steel electrodes. The minimum tensile properties for Type 310 stainless steel weld metal, as specified in ASTM A298-62T, are as follows:

- Tensile strength - 80,000 psi
- Elongation in 2 in. - 30 percent.

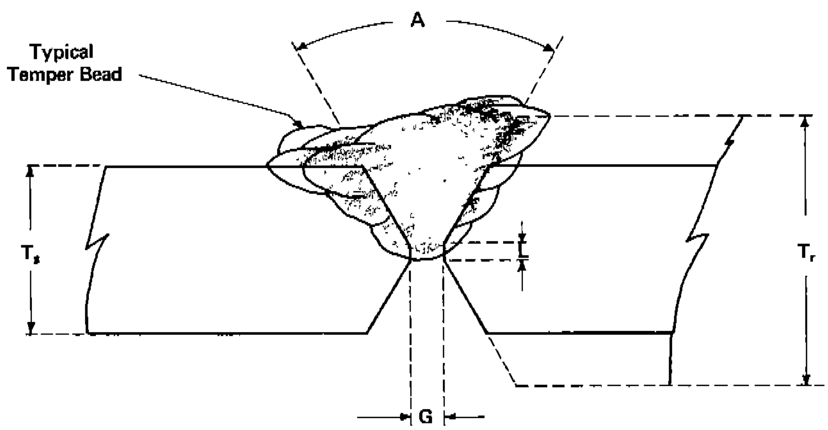
These electrodes are relatively easy to handle, in all positions, by less experienced welders than would be necessary for ferritic electrodes. This repair procedure should be performed on clean, dry metal under the best available conditions. Since austenitic weld metal has a high affinity for hydrogen, it will absorb most of the hydrogen available, thereby protecting the base metal from underbead cracking. Therefore, preheating will be necessary only when the ambient temperature is below

32°F or to provide a dry surface. Below 32°F, the base metal in the vicinity of the repair should be preheated until it is warm to the hand. The preheat should be maintained until the repair is completed.

Replacement of Damaged Material

This same welding procedure (Recommend Emergency Welding Procedure for Temporary Repair of Ship Steels) may be used to weld replacement sections of plates, or even whole plates, on an emergency basis, to effect temporary repairs. In the event that large sections of plating are damaged, it is recommended that the damaged portion be temporarily repaired using mechanical means. When mechanical methods are not feasible, we recommend that the section be repaired on a temporary emergency basis as follows:

(1) Remove the damaged section by torch cutting. The shape of the removed section should be either circular or rectangular. The corners of a rectangular cutout should have a generous radius. This is primarily to avoid the chance of a sharp notch and/or weld defect at the corner by offering a smooth transition from vertical to horizontal welding and eliminating starting and stopping the arc in the corner.



G = 1/16 In. to 5/32 In.
L = Approx. 1/16 In.
A = Approx. 60°
T_s = Thickness of Ship Plate
T_r = Thickness of Replacement Plate

Note: The size and shape of the patch will depend on the replacement needs, however, if at all possible, use a circular replacement plate. If it is necessary to use a rectangular replacement plate then the corners should be generously radiused.

Fig. 3 Recommended Joint Design for Replacement of a Portion of a Plate or a Whole Plate.

(2) If a choice of replacement materials exists, it is recommended that the most weldable of those available be used, preferably, with an ultimate tensile strength of 70 to 80 ksi and a thickness equivalent to the ship material in the area of the repair. However, if a change in thickness is necessary, the transition from one thickness to the other in the joint area should be similar to that shown in Figure 3. The physical size of the replacement plate should be just enough to allow for the joint root gap shown in Figure 3.

(3) Flame cut or grind the joint design to the general configuration shown in Figure 3. The actual joint design will depend upon the thickness of the plate; however, the root spacing and land dimension should be approximately as shown. It should be pointed out that the included angle should be kept as small as possible but should still give the welder enough room to manipulate the electrode. The smaller the quantity of weld metal required, the less the residual shrinkage stresses and subsequent distortion.

(4) The surfaces to be welded should be ground to bright metal to eliminate introducing the excess cutting scale into the weld deposit.

(5) Fit the replacement plate using such fitting devices as available. These devices can be quite simple in nature, such as pry bars, key plates, blank nuts, wedges, etc.

During the fitting operation, it may be necessary to tack-weld some of these devices to the ship plate as well as to the replacement plate, and it may require tacking in the joint. The same precautions for electrodes, preheat below 32°, etc., of the weld should be applied to the tacks. All tacks should be kept within 8 in. of the weld seam. Extreme care should be taken to avoid arc striking the plate material. An arc strike on any steel is a serious defect, but, on HSLA Q & T materials, it is particularly objectionable.

(6) The welding should be accomplished in accordance with the second major section. The sequence of the welding operation should be as recommended in Figure 1.

After the welding is complete, it will be necessary to remove all fitting devices. Care must be taken not to tear the base plate during this operation. The best method is to grind the tack out. All traces of the tack should be removed, and the area should be inspected in accordance with Inspection section of the welding procedure.

(7) The completed joint should be inspected by the liquid penetrant or magnetic particle technique.

The resulting repair will have an ultimate tensile strength of 70 to 80 ksi, and the ductility will exceed that of the base plate and weld-heat affected zone. When the permanent repair is made, the austenitic material must be completely removed.

WELDING OF HOLDDOWN FIXTURES

Although the welding of holddown clamps, handrails, etc., is not considered repair, it should be pointed out that improper procedures could lead to trouble. It has been brought to our attention that a considerable amount of welding of permanent as well as temporary fixtures is performed after the ship has been turned over to the owner. This welding is not always first-class, nor is it always performed by qualified welders using proper procedures and materials. For this reason, this type of welding should be discouraged, in general, and not be allowed when HSLA materials are involved.

It would be possible to avoid the detrimental effects of welding of temporary fittings by providing pads of carbon steel plates or low-strength weld metal to permit welding with any normal carbon steel welding procedure. These pads should be preengineered to provide the proper pad area and in the correct location, and could be constructed as a pad of weld metal. The weld pad could be overlayed on the deck, using E7018 weld metal. The pad thickness should be from 3/8 to 1/2 in. thick. As an alternate method, a carbon steel plate (approximately 1/2 in. thick) could be fillet-welded to the deck. For joining these pads to the deck, the same electrodes and precautions would be necessary as in the main structural welds of the deck material.

EXPERIMENTAL CONFIRMATION TESTS

Austenitic weld deposits, such as Type 310 stainless steel, have been used to repair hardenable ferritic steels for a number of years; more specifically, on materials such as armor plate and Cr-Mo steels. This procedure has been recognized by the American Welding Society[4] in their Welding Handbook, Section 4. As in any welding repair, satisfactory results will depend to a great extent on the welder's skill; however, the use of the austenitic deposit will avoid many of the pitfalls associated with the lack of ideal conditions and inadequate supervision.

It is impossible to foresee the actual materials-thickness combinations that might be necessary for an emergency repair. Therefore, this precludes the meaningful qualification of the welding procedure. As the procedure is to be used only for emergency repairs, and, for the reasons stated above, we see no reason for any confirmation tests.

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13. ABSTRACT

The new merchant cargo ships use a large variety of steels in their construction; the steels range in yield strength from 40 to 100 ksi. Since some of these steels require a close control of the welding procedure as well as other special techniques to assure serviceability, it was felt that a special repair welding procedure must be developed. The procedure must be applicable for all strengths of steel used in construction and should require a minimum amount of procedure control.

The recommended temporary welding repair procedure and a discussion of the survey which led to the recommendation are described in this report.

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