INSTRUCTIONS FOR THE REPAIR OF H.T. BRASS PROPELLERS

Particulars of methods which can be used and the precautions which are necessary to repair H.T. Brass propellers by straightening and welding operations have been given previously in D.E.T.Ms. (2) and (20) and in the *Journal of Naval Engineering*, Vol. 2, No. 2. These instructions considered together provide a complete guide to the repair of H.T. Brass propellers and in the following they have been incorporated into a single comprehensive instruction. D.E.T.Ms. Nos. 2 and 20 are to be regarded as cancelled.

General Properties of H.T. Brass Castings

H.T. Brasses are essentially duplex structure (alpha plus beta phases) copper zinc alloys to which small additions of other elements have been added to improve Proof Stress and U.T.S.

They all have a " hot short " or brittle range between 200°C. and 500°C. which is of importance in connection with straightening operations. Further, it has been found that some H.T. Brasses with compositions complying with E.-in-C. Specification for H.T. Brass Castings are unsuited to welding repairs because, even when normal precautions of preheating followed by slow cooling are taken, an unsatisfactory single phase structure of beta persists adjacent to the weld, which renders the alloy liable to stress corrosion cracking.

It is essential therefore that in all operations involving heat reasonably accurate methods for temperature measurement of the material should be available.

Technique for Straightening Operations

In view of the " hot short " range in H.T. Brasses the following rules are to be observed during repairs :—

(*a*) Where slight mechanical damage is involved cold straightening is to be adopted followed by heating to 250°C.—300°C. to effect stress relief.

(*b*) In cases where mechanical damage is severe straightening must be carried out at a temperature above 500°C., but preferably not above 700°C.

(*c*) On no account is straightening to be attempted between 200°C. and 500°C.

(*d*) In every case where it has been necessary to heat H.T. Brass above 450°C., whether for straightening or any other reason, it must be cooled slowly by surrounding the component with asbestos cloth or by other suitable means.

(*e*) " Tempilstiks " or other temperature measuring methods of comparable accuracy should invariably be used when carrying out repairs to H.T. Brass components involving the application of heat.

Welding Repairs—General

Welding operations on propellers may involve the following repairs :—

(*a*) Re-tipping.

(*b*) Repair of major cracks.

(*c*) Repair of eroded and cavitated areas.

(*d*) Repair of grooves in the boss as the result of rope damage, etc.

(*e*) Repair of minor cracks and edge damage.

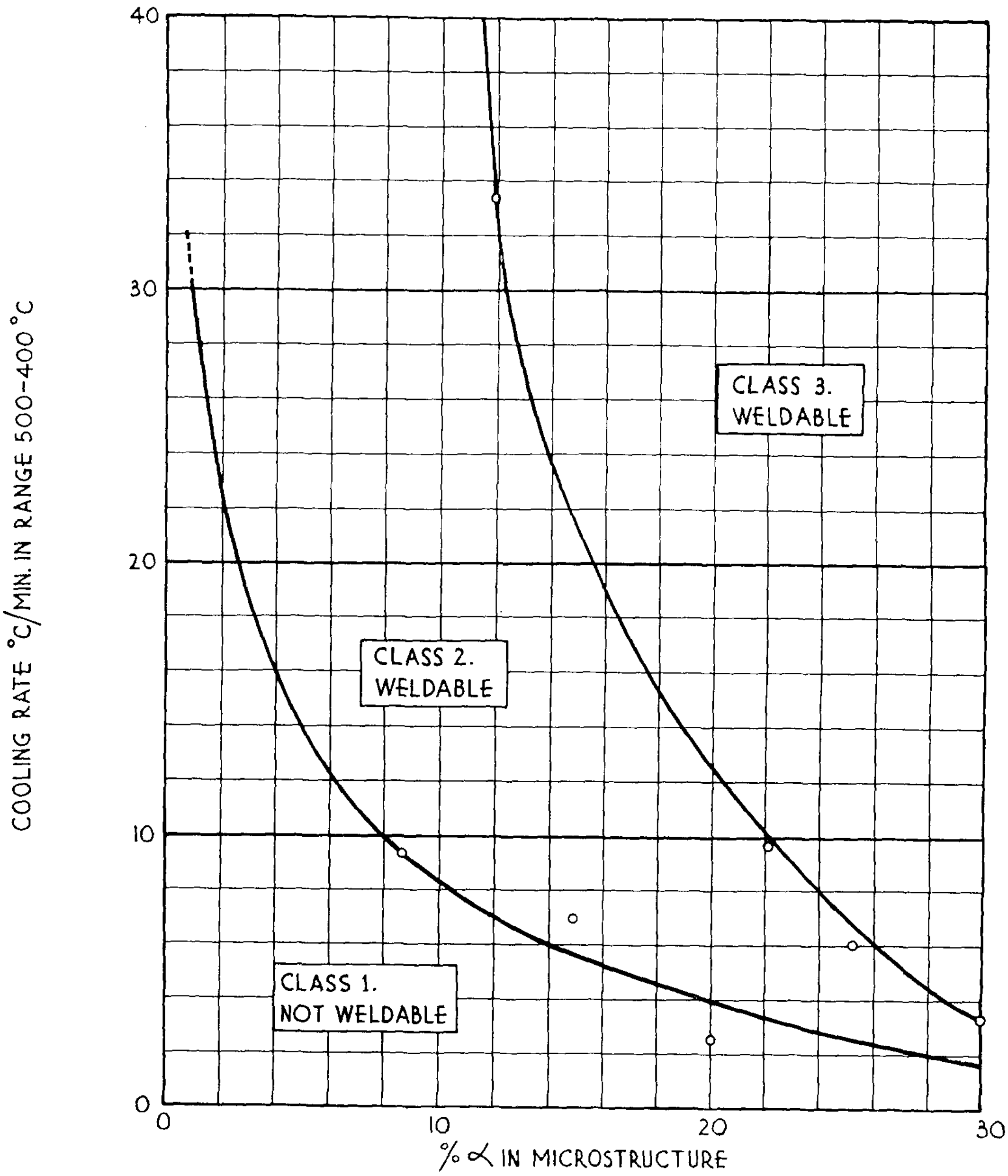

FIG. 1. COOLING RATE V/S α CONTENT OF H.T. BRASSES

All H.T. Brass propellers are not suited to repairs (*a*) and (*b*) and wherever possible the following test should be performed on the propeller and new tip materials to determine their weldability.

The test requires that specimens approximately $\frac{1}{2}'' \times \frac{1}{2}'' \times 1''$ be cut from the propeller and new tip materials ; these are soaked at 800°C. for 10 minutes and afterwards cooled at a known rate. The mean cooling rate through the range 500°C.—400°C. is estimated and subsequently the alpha content is measured on a cross-section of the specimen either visually or in doubtful cases by the line intercept method. Reference to Fig. 1 gives a guide to the weldability of the material.

Welding Processes—General

Carbon arc welding using duplex aluminium bronze filler rod is preferred for repairs (*a*), (*b*), (*c*) and (*d*) where mechanical strength and resistance to

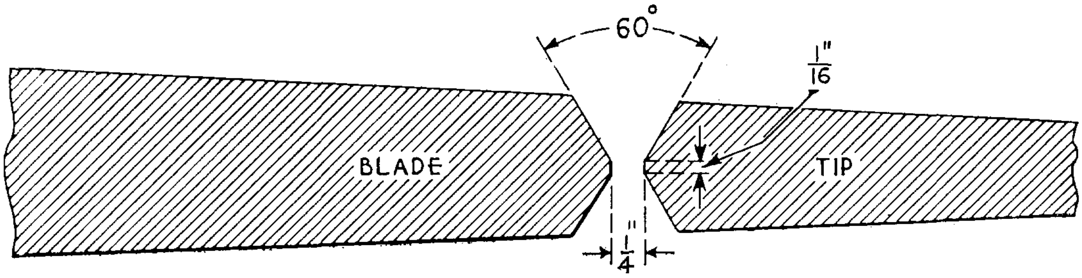

FIG. 2. RECOMMENDED DOUBLE VEE PREPARATION

erosion and cavitation are the main requirements. Flame welding should be used for repair (*e*) except in cases of minor repairs where the flame cannot be conveniently employed ; in such cases metallic arc welding may be employed.

Alternative processes for repairs (*c*) and (*d*) are carbon arc welding using bronze filler rods and metallic arc welding when suitable equipment for carbon arc welding is not available.

On no account should metallic arc welding be used for repairs (*a*) and (*b*) unless the cooling rate test indicates the alloy to be in Class 3 (see Fig. 1).

Operator Tests

All welders employed on repairs (*a*) and (*b*) should have received suitable training in the process to be used and have proved their ability by producing a satisfactory test piece. The test piece should consist of two pieces of H.T. Brass to E.-in-C. Specification, 12″ long × 5″ wide × 2″ thick, butt welded together using double vee preparation (see Fig. 2).

Plant and Equipment

Carbon Arc with Aluminium Bronze Filler Rods

Welding Generator : Sets with variable voltage control essential which should have a continuous rating of 600 amps. and an intermittent rating of 750 amps. Lincoln S.A.E. 600 preferred.

Electrode Holder : Lincoln " Vulcan " heavy duty carbon holder (600 amps.).

Polarity : Negative to carbon.

Electrodes : ⅜″ and ½″ diameter graphitic carbons, plain or copper coated.
Makers : Lincoln Electric Co.
Fuller Electrical and Manufacturing Co.
Morgan Crucible Co.

Filler Rod : Duplex structure extruded aluminium bronze.
Makers : Manganese Bronze and Brass Co., Ltd., Ipswich.

Flux Aluminium Bronze.
Makers : British Oxygen Co. " Alda."
Suffolk Iron Foundries Co. Ltd.

Exhaust Fan : Fan fitted with flexible suction and discharge tubing exhausting to open air. The suction tube to be of sufficient length to permit handling by an assistant and to follow closely progress of weld.

Cleaning Tools : Wire brush and high speed light pneumatic peening hammer.

Preheating :	Gas, propagas or kerosene burners.	

Carbon Arc with Bronze Filler Rods

Plant and Equipment :	Same as above.	
Filler Rods :	Phosphor Bronze (Sn. 7—10% P.O. 5%) :	
	" Everdur "	British Oxygen Co. Ltd.
		I.C.I. Ltd. (Metals).
Fluxes :	Sifbronze :	Suffolk Iron Foundry Co. Ltd.
	Brazotectic :	British Oxygen Co. Ltd.
	Gunmetal :	Fuller Electrical Co. Ltd.

Metallic Arc Welding

Welding Generator :	400 amps, 100 volts, D.C. generator. Preferably single operator set.	
Polarity :	Normal : negative to job.	
Electrodes :	For major repairs (*a*), (*b*).	
	Tenal (white) :	A.S.E.A. Electric Ltd.
	Bronalex :	Murex Welding Process Ltd.
	For minor repairs :—	
	Bronze C.6 :	Murex Welding Process Ltd.
	Bronze C.66 :	Murex Welding Process Ltd.
	OKB 4 :	Welding Supplies Ltd.
Preheating :	As for carbon arc welding.	

Flame Welding

Filler Rods :	Bronzotectic Alda No. 4 :	British Oxygen Co. Ltd.
	Phosphor Bronze :	British Oxygen Co. Ltd.
Flux :	Bronzotectic :	British Oxygen Co. Ltd.
	Brazotectic :	British Oxygen Co. Ltd.

Recommended Technique for Propeller Re-tipping by Carbon Arc Process

Preparation for Welding

The damaged tip is cut off along a suitable chord and the new tip, previously cast, is machined to correct finished size. Sufficient metal is then removed from the face of the tip to be welded to ensure a gap of $\frac{1}{4}''$ minimum. The edges of the propeller and tip are then marked and subsequently machined or chipped to the joint preparation shown in Fig. 2.

The tip is now aligned with the blade and secured by cramps situated towards the edges of the blade as illustrated for a typical case in Fig. 5. The root gap must be carefully checked over the length of the weld and maintained at $\frac{1}{4}''$.

The underside of the vee is now sealed with $\frac{1}{2}''$ diameter carbons and supported by moist pulped asbestos held in place by sheet metal suitably supported. The line of the weld should be arranged in as level a position as possible.

Preheating

The temperature of the propeller and tip along the line and to the sides of the weld is to be brought up to and maintained at 100—150°C. The use of asbestos cloth to minimise convection losses is advantageous.

Tack Welding

The generator is set to give an open circuit voltage of 80 which should be

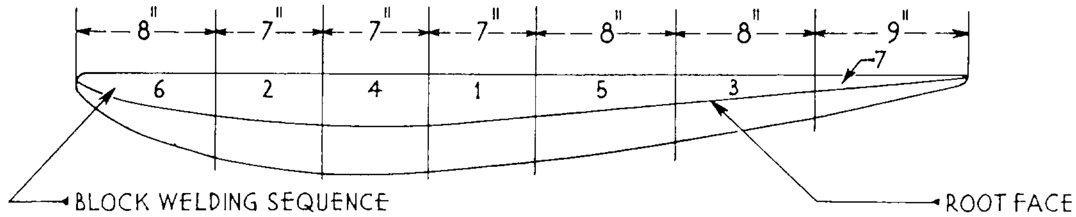

FIG. 3. POSITION OF ROOT FACE AFTER PREPARATION, ILLUSTRATING TYPICAL SPACING OF BLOCKS, AND SEQUENCE OF WELDING (THICKNESS EXAGGERATED)

adjusted, if necessary, to give an arc voltage of 30-32 with the current regulator set to give 600 amps ; a Tong tester should be used to verify the current. The exhaust fan should then be started.

Tack welding should commence at the centre and in two or more places as desired. Filler rod ¼″ diameter is used and a carbon of long taper, held in a vertical position. A small quantity of flux is sprinkled on the spot to be welded and with the filler rod in an almost flat position, the arc, not more than $\frac{3}{16}$″ long, is fed across the end of the filler rod, not over it. After dwelling momentarily along the sides of the vee to ensure fusion, the arc is advanced to make a strong tack.

First and Second Root Runs

Welding is commenced at the centre using an arc length between $\frac{3}{16}$″ and ¼″, and is advanced approximately 6″. Subsequent steps of approximately the same length should alternate either side of the centre step, and be continued until the jigging clips are reached. A second run is then made in a similar manner.

Upon brushing, a uniform rippled surface should be seen ; doubtful areas should be chipped out and rewelded using a minimum of flux.

Subsequent Runs (Block Welding)

Block welding is adopted to control distortion, a typical sequence of operation being illustrated in Fig. 3 ; the number and size of blocks may be varied according to the length of weld joint to be made on any particular propeller blade.

The centre block (Fig. 3, position 1) is started first, the full length being welded by the technique given in 8 (*c*) and with an arc length of between $\frac{3}{16}$″ and ¼″. A slight sideways movement should be given to the electrode and the filler rod maintained almost stationary with very little feed in. Alternate blocks (positions 2 and 3) are then welded similarly to the centre one, successive runs on each block being made slightly shorter to obtain a ramp ended effect.

Welding is continued on these blocks and the size of the filler rods increased as necessary to ⅜″, and finally to ½″ diameter to maintain a ⅛″ thick layer of weld metal per run across the whole vee ; the thickness of the layer is to be checked occasionally with a depth gauge and must not be exceeded. It should be noted that a 1¼″ width of run is quite practicable with a ½″ diameter rod. When an angular movement of 1½° is obtained as measured by means of a straight edge laid radially on the segment of the blade, welding should cease on these blocks.

A third run is now made in the spaces between the blocks (positions 4 and 5). The jigging clips may then be removed. The parts of the joint, previously covered by the clips, are then welded (positions 6 and 7) using more blocks, if necessary ; the current may be lowered to 450-500 amps, maintaining the original open circuit voltage as the edges of the blade are approached.

First Turn

The propeller is turned over and after brushing and chipping where necessary followed by preheating to 100-150°C., welding is continued as before. For the first run a $\frac{3}{16}''$ diameter filler rod and 650 amps current are to be used to obtain adequate penetration with the original root run. The welding is then continued, working in blocks opposite those already welded and in the spaces between up to half the depth of the blocks until the angular distortion has reached $1\frac{1}{2}°$ (total movement 3°).

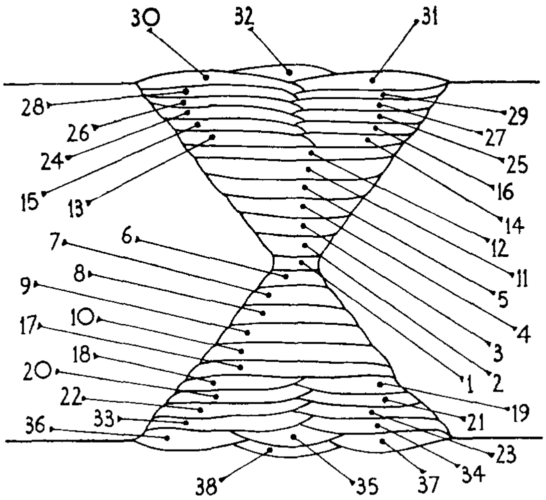

FIG. 4. ILLUSTRATING SEQUENCE OF RUNS ACROSS SECTION THROUGH A BLOCK WELD

Second and Subsequent Turns

The sequence is repeated and the propeller turned when the angular movement reaches 3°. The final weld must be made on the face of the blade and reinforcement carried out, if necessary, until the top is true.

Difficulty may be experienced in the final bridging run on thick sections where arc shielding may be insufficient ; a generous use of flux and a lowering of the current to 500 amps is advantageous.

The sequence of the runs in a typical block weld is shown in Fig. 4.

Finishing

The weld is trimmed to conform to the blade contour. Any small surface defects in *the weld metal* may be spotted by metallic arc welding but those due to undercut should be filled in by carbon arc welding using the full preheat. Finally the whole line of weld and adjacent material is to be stress relieved by heating slowly and uniformly to 250-300°C., maintained $\frac{1}{2}$ hour, followed by slow cooling.

Radiography

All welds on propeller blades involving re-tipping with tips of depth greater than one-twentieth of the diameter of the propeller are to be subjected to radiographic examination.

Welding of Major Cracks by Carbon Arc Process

The suitability of the H.T. Brass for welding should be checked, and if satisfactory, the area concerned should be stress relieved at 250-300°C.

The ends of the crack or cracks should be traced and holes, $\frac{1}{2}''$ diameter, drilled at their ends.

The joint preparation shown in Fig. 2 is to be adopted and the ends of the hole faired into this. Weld using a $\frac{3}{8}''$ diameter carbon if the blade is thin. Except in large propellers block welding is rarely necessary. Finally stress relieve at 250-300°C.

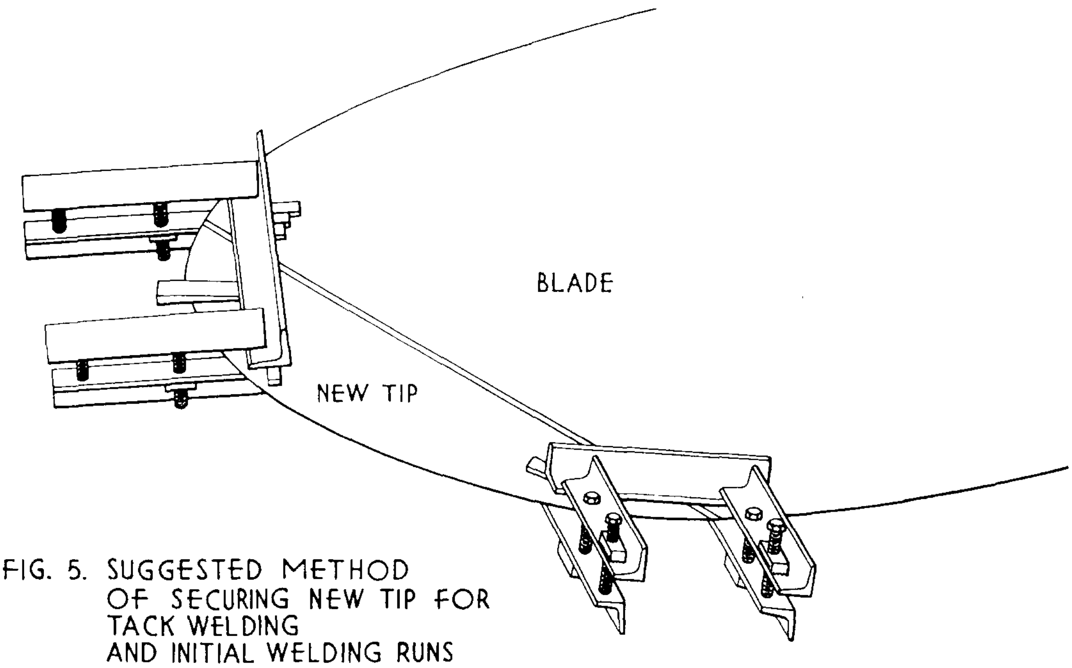

FIG. 5. SUGGESTED METHOD OF SECURING NEW TIP FOR TACK WELDING AND INITIAL WELDING RUNS

Repair of Cavitated and Eroded Areas

A. Carbon Arc Process using Aluminium Bronze Filler Rods

Preparation for Welding, Preheating

Excavate the eroded area by chipping, keeping the transverse cross-section of the cavity of uniform depth. Cover the whole job away from the area to be welded with asbestos cloth and preheat to 100-150°C.

Welding

This should be performed in a similar manner to that described in paras 3 and 4 of the technique for re-tipping but a more generous use of flux is advised on the initial runs. Clean area and repeat process until the cavity is filled.

In the case of large areas it may be desirable to cut down cleaning times by welding from two or more positions in the cavity ; in such cases the cavity may be sub-divided by laying down transverse runs, dividing it as necessary into sections.

Finishing

Dress the weld in the usual manner by grinding and where defects or depressions in the deposited metal are evident fill in by carbon arc or metallic arc welding. Undercut between deposited and parent metals should be filled in by carbon arc welding using full preheat to avoid beta formation in the propeller material. Finally stress relieve in usual manner.

B. Carbon Arc Process with Bronze Filler Rods

Preparation for Welding, Preheating

As in A.

Welding

The open circuit voltage of the generator should be reduced to 75 and the current adjusted, in accordance with the thickness of section to be welded, to give instant melting of the parent metal (current may lie between 250-600 amperes).

Flux should be used generously to assist in cleaning the metal and with the arc length held as long as possible, $\frac{3}{4}''$-1″, played on lengths of filler rod either layed in the cavity or fed in. Care should be taken to ensure proper fusion with the parent metal and the arc should be given a circular movement to maintain a molten pool and work out any gas holes as they appear. Repeat process until the cavity is filled.

Finishing

Dress weld and stress relieve in usual manner.

C. Metallic Arc Process

This process should only be adopted for H.T. Brasses in Class 3, but where facilities for carbon arc welding are not available it may be performed for Class 2 alloys, provided adequate precautions are taken.

Preparation for Welding, Preheating

The defective metal is chipped away and the edges of the cavity left inclined at 30° to the vertical. In the case of a deep cavity the depression is stepped and similarly inclined.

Preheating is more important than with carbon arc welding and a minimum value of 150°C. is to be maintained.

Welding

A 400 amps D.C. single operator set with normal polarity (negative to job) is suitable. For electrodes see *Metallic Arc Welding.*

The first run is put down with the largest electrode which can conveniently be used in order that the heat may " burn out " any corrosion products in porous areas. Continue the use of the larger electrodes throughout in order to maintain heat and to secure the flattest possible bead until the cavity is filled. An additional run may be deposited around the perimeter of the cavity to obviate undercut.

With aluminium bronze electrodes (Bronalex, Tenal) it is also important to ensure that the electrode is maintained almost at right angles to the work and welding is carried out with the shortest arc length possible. A weaving movement should be given to the electrode to give a molten pool 4-5 times the diameter of the electrode core and of a thickness between $\frac{1}{10}$-$\frac{1}{8}''$. The arc should be lengthened when approaching the parent metal to obviate undercut.

Dress weld in usual way and stress relieve at 250-300°C.

Repairs to Forward End of Boss, where Damaged by Ropes, etc.

This is a similar operation to 10, and carbon arc welding with filler rods given in first 2 paras. of Plant and Equipment is preferred. Metallic arc welding is not recommended unless adequate preheating to 150°C. can be carried out. Stress relieving is not necessary.

Repair of Minor Cracks and Edge Damage

Due to the thin sections involved flame welding should be adopted ; metallic arc welding should only be used when conditions preclude the use of flame welding ; preheating should be adequate and in view of the danger of beta formation, welds and the surrounding propeller material should be heated by torches to a minimum of 600°C. following welding, followed by *very slow* cooling.

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