# PROPELLER TIP WELDING BY THE CARBON ARC PROCESS

by

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*The possibility of effecting a major repair to a manganese bronze or high tensile brass propeller by welding interested the author, because if the method proved successful the way would be shown to effect repairs in many cases otherwise impossible ; also it might result in a saving of both time and money over the usual foundry method of burning-on, and it was hoped that a thorough examination of the completed work would show that the welded repair was the superior of the two methods.*

*After many tests and disappointments using various filler metals, aluminium bronze was tried, and when a technique suitable to this filler rod had been worked out, the test plates became very promising and finally resulted in repairing an escort carrier's propeller by this method.*

The damaged propeller was 20 feet in diameter and of 20 tons weight with four blades, two of which were bent. One blade was straightened, but this was impracticable for the second, the damage having occurred at too great a depth from the tip.

It was decided to cut off a portion at a depth of 24″, which resulted in a chord of 56″ and a maximum section of $2\frac{15}{16}$″ with aerofoil shape. The tip was cast in Stones ingot and being all new metal an additional 1″ in depth was allowed to ensure sound metal upon which to weld, and after machining to permit a gap of $\frac{1}{4}$″. The edge was chipped to "double vee" preparation of 60 degrees with a root face of $\frac{1}{16}$″ as shown in Fig. 1. The propeller was similarly prepared, after which the tip was jigged into position using clamps formed of angle iron, with suitable bolts and wedges to accommodate the contour of the blade. Fig. 2 shows a similar arrangement for another propeller in course of repair.

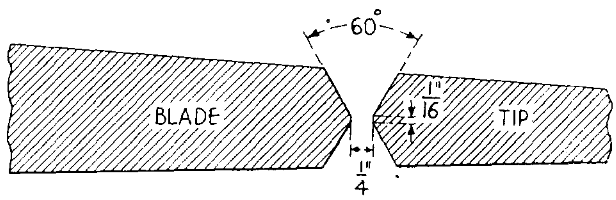


FIG. 1

The underside of the blade was backed up with carbon electrodes broken into suitable lengths, the carbons being retained in position with asbestos, kept firm by pipe supports from the floor. An exhaust fan, fitted with flexible suction and discharge tubing conducted the zinc oxide fumes away from the work. The suction tube was sufficiently long to permit handling by an assistant, who closely followed the progress of the weld.

### Voltage and Current requirements

A preheat of 212° F. was given by the use of paraffin torches, and the voltage control of the Lincoln S.A.E. 600 was arranged to provide an open circuit of 80 volts which was subsequently adjusted to give an arc of 30-32 volts with the current regulator set to give 600 amps. The current was checked by the

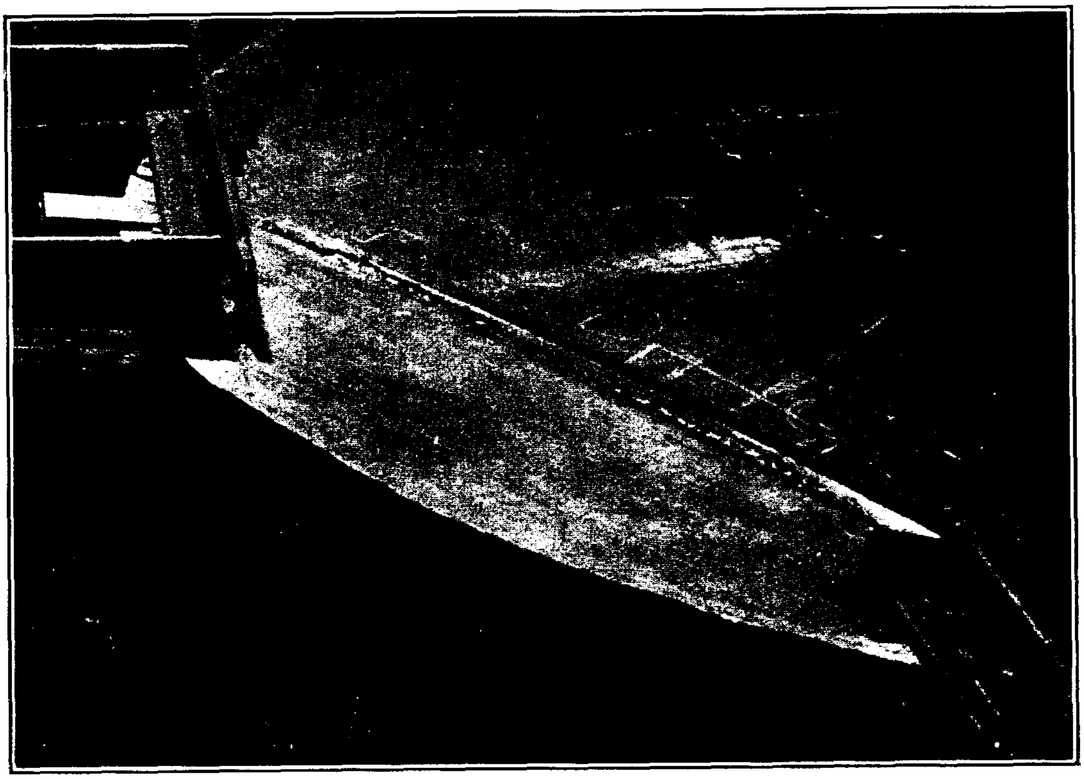

FIG. 2.—ALIGNING TIP TO BLADE FOR INITIAL RUNS

use of a " Tong tester " during the course of welding. The polarity was negative to the carbon, the earth connection being positive. Care was taken to ensure a good earth connection and that leads from dynamo were kept as short as possible to avoid voltage drop. The carbon size was ½″ diameter and about 3″ below the point of grip was allowed in the holder.

The exhaust fan was started with the assistant holding the suction tube, ready to follow the welder.

The tip was secured by tacking in three or more places, starting with the centre. Filler rod of duplex-structure aluminium bronze, uncoated, and ¼″ diameter was held in one hand and maintained in an almost flat position in the bottom of the vee. A very little aluminium bronze flux was sprinkled on the spot to be welded, and the arc established, the welder previously having nodded down his head shield. The arc obtained was held very close, not more than $\frac{3}{16}$″ in length, and was fed across the end of the filler rod, not over it. The arc was allowed to dwell momentarily near the sides of the vee to ensure fusion; the molten filler metal then fused into the melted parent and the arc was advanced along the scarf sufficiently to ensure a strong tack. The remaining tacks were made in the same manner working either side of the centre. The carbon should at all times be in a vertical position and, particularly on the initial runs, of long taper.

The chord was then divided into sections proportional to the thickness of the blade section, so that angular distortion could be controlled by block welding, and the alignment checked along the radial generating lines marked both on propeller and tip.

## Sequence of Runs

Commencing from the centre, a run was made using ¼″ filler rod, the arc length being maintained at $\frac{3}{16}$″-¼″, and the carbon held vertically. Very little transverse movement was required at this stage and the welding was advanced at a constant speed of travel. The assistant meanwhile followed the operator with the suction hose, which permitted a perfectly clear view of the welding. Upon brushing, a uniform rippled surface was presented, free of slag or other trouble. The next run commenced on the other side of the centre and ran towards it. Welding was continued in this manner until the jigging clips were reached ; the part beyond the clips to the edge of the blade was ignored at this stage. Upon brushing, a uniform appearance with complete fusion of the sides of the vee was seen. It is emphasised that when using aluminium bronze as a filler, the process is definitely a quick freezing one and this uniform rippled appearance may be taken as proof that quick freezing has been obtained and should be watched throughout. The cleaning of this and subsequent runs was very simple ; wire brushing to remove carbon throwdown being almost all that was necessary.

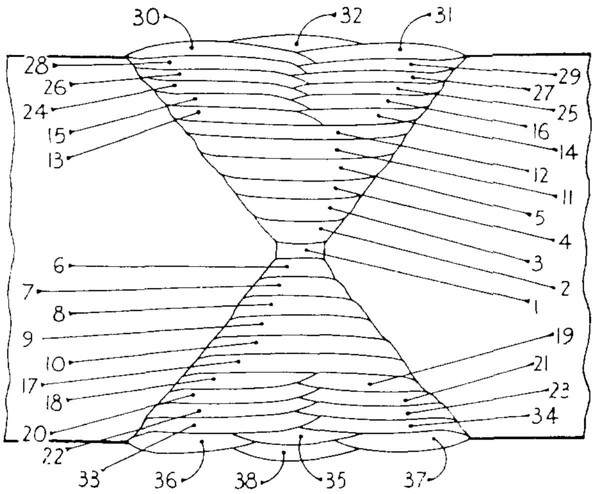

FIG. 3.—SEQUENCE OF RUNS

**Block Welding**

Another run was then made in the manner just described, after which the block welding was adopted. A sprinkling of flux was applied and the length of the block welded. Still using the $\frac{1}{4}''$ diameter rod, a slight sideways movement was given to the carbon, while keeping it vertical with the same short arc length. The arc at all times was passed across the end of filler rod, no matter what its diameter, the rod being maintained almost stationary with very little feed-in. The alternate blocks from the centre were then welded in the same manner, after which a further run was laid on the centre block and again on the alternate blocks. At this stage a depth gauge was used to measure the thickness of one run of weld metal ; this depth should not exceed $\frac{1}{8}''$ and was periodically checked throughout the work. Further runs were laid in a similar manner, taking care that each succeeding run of weld metal was slightly shorter than the preceding one so that a ramp-ended block was obtained, making it easy when welding-in the spaces left between the blocks to obtain fusion of the bottom runs. The angular distortion due to weld contraction was measured. Welding was continued on the blocks until the angles shown were reached. As the welding progressed, the size of the filler rod was increased to $\frac{3}{8}''$, and subsequently to $\frac{1}{2}''$ diameter, in order to maintain the $\frac{1}{8}''$ layer, remembering that the amount of metal deposited is dependent on the size of rod, and this is governed by the width of the vee, because the full width must be welded by traversing across it for every run as far as is possible. A $1\frac{1}{4}''$ width of run is quite practicable with $\frac{1}{2}''$ diameter rod. The current was lowered somewhat in accordance with the thickness as the edges were approached, down to 450-500 amps, keeping the original open-circuit voltage and $\frac{1}{2}''$ diameter carbon, but using one that had been tapered in use. For sequence of runs see Fig. 3.

**The Reverse Side**

The first run on the reverse side was made with an increased current of 650 amps with the same arc voltage and using a $\frac{3}{16}''$ filler rod, in order that a

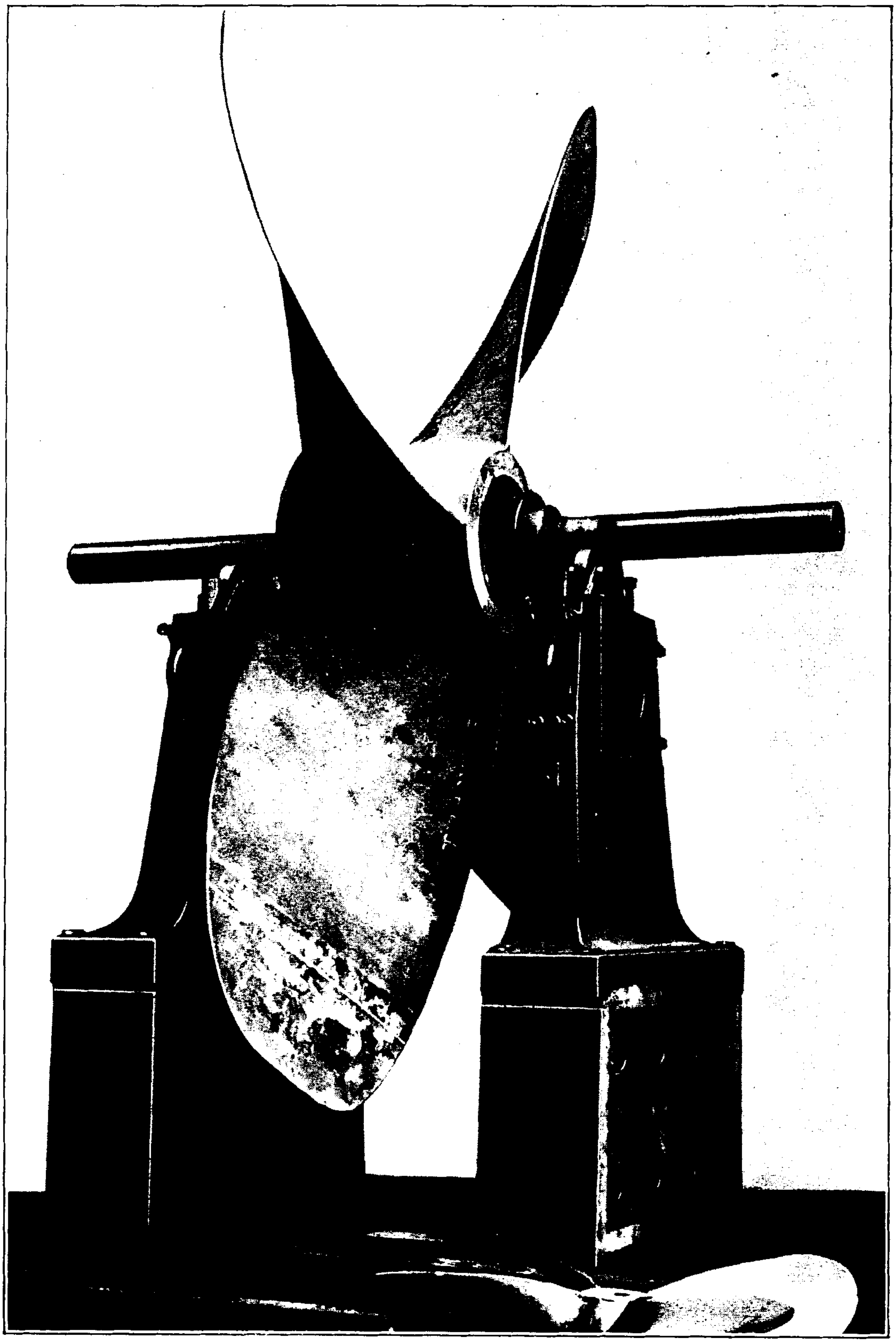

FIG. 4.—GENERAL VIEW OF PROPELLER

minimum of added metal and a maximum of remelted first run was obtained to ensure complete welding at the centre.

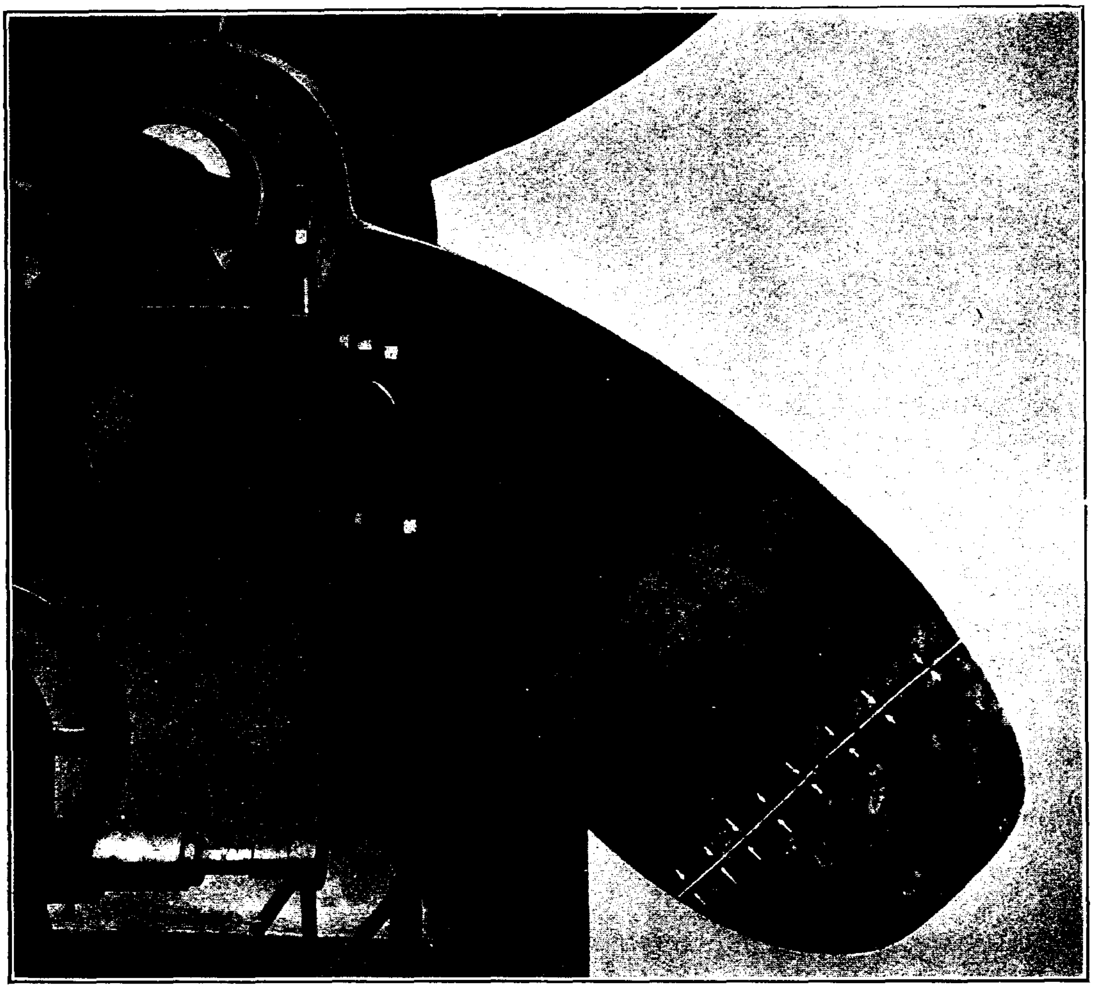

FIG. 5.—CLOSE-UP OF REPAIRED BLADE. MOTTLED EFFECT IS DUE TO REFLECTIONS FROM POLISHED BLADE

The jigging was removed after the initial stages on the first side—the ahead face—so that the first run on the astern face and all subsequent runs were made with the tip free.

The propeller was turned, and welding completed without any difficulty, with the exception of the top centre runs, that is, when depositing aluminium bronze upon aluminium bronze over a wide area. Due to absence of side walls, the arc-shield is localised and offers little protection against oxidation unless flux is used in undesirable quantities, the metal otherwise becoming covered with an oxide film, is lumpy in appearance, and may contain an oxide inclusion. In consequence, an electrode " Murex Bronalex " was employed to spot a few defects exposed after grinding. Care was taken to employ the correct technique and to remove thoroughly all slag.

Copper-coated carbons have since been used which have a longer life owing to the reduction of incandescence over the length of the carbon below the grip of the holder and, what is more important, they suppress the side arcing when welding deeply in the groove upon thick sections. After welding, excess weld metal was removed by grinding and then polished with a flat sanding machine before stress relief.

**Stress Relief**

The propeller blade was found to be in correct alignment, and it was then erected upon the balancing arrangement as shown in Fig. 4. Stress relief

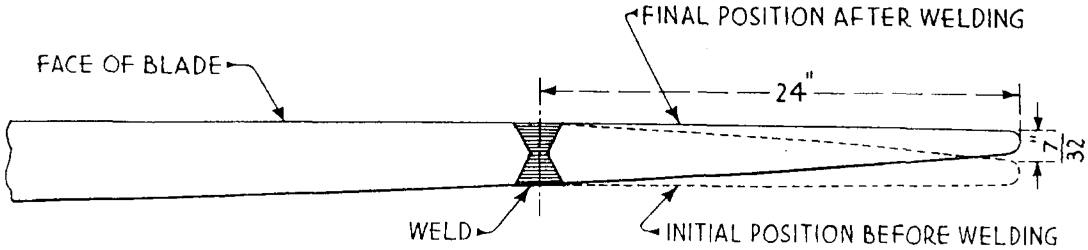


FIG. 6

was carried out by paraffin blow-lamps, one on each side, directing the flames above the weld on the boss side and towards the thicker edge to secure even heating. This was continued until the temperature at the welded area reached 662° F., and this temperature was maintained for 30 minutes after which the blade was wrapped with asbestos cloth and allowed to cool.

A radiographic examination of the weld was then made, one exposure being through the thickest part before stress relief, and the whole weld was subsequently photographed after stress relief with satisfactory result.

An initial downset of $\frac{7}{32}$" was allowed on the face side (Fig. 6) in order that more welding could be carried out before making the first turn, but since the propeller was turned without difficulty, this idea need not be generally adopted; this downset was corrected by a little extra welding.

The maximum movements recorded at the radius of 24" were $\frac{7}{16}$" for the first side, $\frac{11}{16}$" for the second, $1\frac{1}{32}$" for the third, and $1\frac{5}{32}$" for the fourth, leaving $\frac{19}{32}$" for the last weld on the ahead face.

To reduce the amount of turning of the propeller it may be possible to prepare an unbalanced " vee " so that a maximum of welding may be carried out on one side, but it is considered that the calculation of downset against angular distortion would be somewhat difficult. Since the number of turns for this large propeller was only four, each of which occupied rather less than two hours, it does not appear worth while pursuing the matter further.

### Comparison with Burning-on Method

Although comparative time was not the primary consideration in this method of repair, the welding time, including jigging into position of the tip, was approximately 45 hours, and since the tip was cast correctly to size and thickness, the work entailed in the final dressing-up was very little in comparison to that which is required when the tip is burnt on by the foundry method when the riser has to be removed, entailing extensive drilling and planing operations.

FIG. 7.—MACRO PHOTOGRAPH OF WELD

With the welded repair, the subsequent use of a flexible shaft grinder was all that was necessary.

Fig. 4 shows a general view of the propeller with the re-tipped blade and Fig. 5 shows a close-up after grinding and polishing, the position of the weld being indicated by a chalk line. A typical macro photograph is shown in Fig. 7.

It is considered that this repair, in addition to having been proved sound in every way and showing favourable comparative costing against the normal burning-on method, may frequently be the only manner in which the repair may be effected, since the amount of metal required to burn on a tip may well be beyond the foundry capacity in many instances, although sufficient metal may be readily available for casting a new tip.

Outlying or isolated bases should therefore be able, with a variable-voltage dynamo, to carry out repairs which otherwise might be impossible.

The physical properties of the weld were comparable with those of the parent metal, tensile strength of 56,000 lb./sq. in. having been obtained in test plates, together with acceptable impact, nick break, and bend tests. All weld tensile pieces showing 33-34 tons (74,000-76,200 lb./sq. in.) have proved usual.