SHOP PRACTICE—WORKING AND WELDING STAINLESS STEEL—TUBE BENDING—BUILDING RADIATOR CORES USING HIGH MELTING POINT SOLDER

(A.C. Specification 11064)

(REPAIR BRANCH REPORT)
SHOP PRACTICE—WORKING AND WELDING STAINLESS STEEL—TUBE BENDING—BUILDING RADIATOR CORES USING HIGH MELTING POINT SOLDER (A.S. Specification 11064)

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DATES AND PLACE OF TESTS
June 1, 1932, to May 1, 1933.
Metal shop, repair branch, Wright Field, Dayton, Ohio.

OBJECT
The following information concerning the practice of working and welding stainless steel in its various forms, tube bending, and the methods of building radiator cores with the use of high melting point solder has been prepared as a result of many inquiries from aircraft manufacturers and the service. It is not intended that these methods are the only ones by which the desired results may be obtained, but they are the most practical methods which have been tried and are now in use at the Matériel Division.

DESCRIPTION, METHOD, AND PROCEDURE
SECTION I

Working of stainless steels:
(b) Tube stock, A.C. Specification 10233 (seamless).
Tube stock, A.C. Specification 10234 (welded).
(c) Bar stock, A.C. Specification 10079.

1. Drawing work—stainless steel.—Stainless steel must be annealed before an attempt is made to draw it. Materials obtained from the mills in the annealed states do not require annealing before working. It has been found that the following procedures for local annealing give the best results.
   (a) Sheet stock, .064 inch or less in thickness, should be heated to 1,900° to 2,100° F., and air quenched and all scale removed. The higher temperature gives the softest sheet but a lower strength and larger grain.
   (b) Sheet stock greater than .064 inch in thickness should be heated to 1,900° to 2,000° F., and quenched in cold water.

2. Hand working of stainless steel.—Excessive hammering, bumping, or rolling will cause the material to harden and if these procedures are employed it will be necessary to re-anneal the piece in most cases before completion of the work.

3. Spinning of stainless steel.—Spinning of stainless steels is a very difficult operation. Only shallow draws should be attempted and sharp unrounded corners should be avoided. The steel becomes very hard from the use of a spinning tool, and when re-annealed, scales will form on the metal which makes a continuation of the operation impossible. For satisfactory results, spinning of this metal should not be attempted except with material specially annealed for the purpose.

4. Welding (gas).—(a) Before an attempt is made to weld stainless steel in any form the parts should be thoroughly cleaned and free from scale which may have formed from local annealing. This scale cannot be satisfactorily removed only by sand blasting the parts or by using a stiff scratch brush.
   (b) It has been found that the best welds can be accomplished by using the smallest welding tip possible for the particular work and with an excess of acetylene gas. A slightly carbonizing flame will produce a better metal flow than a neutral flame on this metal.
   (c) Welding flux should be applied with a brush to both sides of the metal to be joined as well as to both sides or edges of the seam. Oxweld Cromaloy flux or its equal is recommended.
   (d) Welding rods cut from the material to be welded will not give as satisfactory results as those manufactured commercially for the purpose. These rods contain sufficient cadmium to cause a more rapid and even metal flow at the seam.
   (e) Stainless steel sheet stock and chrome molybdenum steel, or mild carbon cold rolled steel, can be welded together by using the manufactured stainless-steel welding rod, Oxweld Cromaloy flux, and a carbonizing flame.
   (f) Stainless steel and monel metal (copper-nickel-alloy, A.C. Specification 57–168–A), can be successfully welded together by using the stainless steel welding rod and Oxweld Cromaloy flux. It has also been found that the stainless steel welding rod flows more freely on monel-metal than the monel-metal welding rod. This can be used in all monel-metal-welding.
   (g) All materials used in the above welding processes are corrosion resistant to the atmosphere and salt spray.

SECTION II

1. Tube bending.—(a) A tube bending machine has been built and installed in the shops. This machine is capable of making any bends up to 90° with an inside
radius equal to the diameter of the particular tube to be bent. The machine and tools have been designed to bend tubing up to 0.064 inch wall thickness, 2 to 5 inches in diameter and up to 6 feet in length without heating or annealing the tubing (chrome molybdenum steel excepted). The bends are made without wrinkles and with very little distortion by means of a mandril and ball, the travel of which is synchronized with a semicircular rotating table in which the tubing is steamed excepted. (See figs. 5 to 9.) A chart has been prepared giving the mandril and ball clearances which give the best results for tubing of various sizes and materials. (See table 1.)

(b) It has also been found that for odd sizes of tubing for which tools are not available, excellent bends can be made by filling the tube with standard half-and-half solder and detaching the mandril and ball mechanism from the machine. To bend any steel tubing, it must first be annealed. Before filling, the tube must be perfectly dry to prevent the sudden explosion of the molten solder due to the formation of a steam. The tube is then plugged at one end, either with a wood plug or a welded-on disc. The inside wall should then be oiled lightly with machine oil to prevent the filler from sticking. Only half-and-half solder is recommended as a filler. It has been found that lead alone is too brittle and tin not sufficiently flexible to make a good bend. The half-and-half solder is of the proper hardness and flexibility to make a good bend.

(c) Tubes of stainless steel, carbon steel, chrome molybdenum steel (annealed), copper and brass tubing can be bent without filling. Aluminum tubing 0.050 inch and greater in wall thickness can be bent without filling. Lighter aluminum tubing must be filled. There is not sufficient strength in the wall of thin gage aluminum tubing to strip over the forming ball without fracturing the tube wall.

(d) Chrome molybdenum tubing (A.C. Specification 57-180-2), should be annealed and bent as soon as possible after filling. When high tensile strength is required the tube should be heat treated to the desired strength after bending.

(e) Aluminum alloy tubing (A.C. Specification 57-187-1), can be filled and bent. The tube must be annealed to 625° to 700° F. before bending. This heat treatment is accomplished by heating the tube in an electric furnace or a salt bath to 925° to 960° F. and then quenching in cold water.

(f) The curves, figures 1, 2, and 3, are presented to show how the tube dimensions are effected at the 90° bend after the bend has been made on the tube-bending machine.

(g) Where there is no tube bending machine available, tubing of diameters up to 3 inches can be satisfactorily bent by hand. The following methods have been employed.

1. By using hardwood forms or blocks cut to the desired radius of bend and grooved to the tube diameter.
2. By using a tube larger in diameter and approximately 12 inches in length. This tube section should be bell-mouthed at one end and clamped in a vise. The tube bend is made by inserting the tube into the oversized tube and pulling the tube over the bell flange which forms a radius for the bend.
3. By clamping the tube in a vise and pulling the bend in small increments with a long piece of tubing as a lever arm.

(b) Before the above hand methods are used, the tube must be filled with sand, resin, lead, solder, etc., and the wrinkles resulting from the bend ironed out with a raising hammer before the filler is removed.

SECTION III

1. Radiator core dipping, using high-melting point solder (A.C. Specification 1106).—(a) A core box, the shape and size of the core to be dipped should be built of white pattern pine, free from moisture, 2 inches in thickness and the corners of the box equipped with one-half inch draw bolts. One-eighth to three-sixteenth inch should be allowed on the inside dimensions of the box to take care of necessary draw so that the tubes may be clamped firmly in place.

(b) The tubes should be carefully inspected and then thoroughly cleaned. They may be cleaned by dipping them into a cleaning bath for 8 to 10 minutes and rinsing in cold water. The tubes are then dipped into a brightening bath (approximately 50 percent nitric acid and 50 percent sulphuric acid with hydrochloric acid or salt). They must not be held in the acid bath, only dipped, then rinsed in cold water followed by a careful inspection and discarding of all defective tubes, the accepted tubes and side plates are then properly placed into the core box and securely held in place by tightening up on the draw bolts.

(c) The solder bath must be carefully prepared if satisfactory results are to be expected. The dipping tank should be built so that a uniform heat will be distributed throughout the bath. In the bath shown (fig. 6), the gas burners are placed 3 inches apart and the gas led in from 2 sides. With the cover in place, a very satisfactory and uniform temperature can be obtained throughout the bath. Sufficient solder is placed into the tank so as to have a uniform depth of seven-sixteenth inch and then heated to not less than 850° F., nor more than 860° F. The surface of the molten solder is sprinkled with ground or finely crushed Salamonic (ammonium chloride, NH₄CL), so that the solder will not bubble too much when the core is dipped.

(d) The core box and core should be warmed sufficiently to remove the chill and surface moisture and the core then brushed with commercial hydrochloric (muriatic) acid solution cut with metallic zinc until boiling ceases.

(e) It will be necessary before the core is dipped to clean the slag from the surface of the solder bath and reestablish the required temperature. Dip the core slowly by submerging one edge of the core box into the solder and rock the core forward until the entire surface is submerged in the bath 14 to 15 seconds. Re-

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**Figure 1.** Is plotted from measurements of the inside diameters of stainless steel tubes, 0.062 inch wall thickness in sizes from 2 to 5 inches in diameters through the 90° bend.

**Figure 2.** Is plotted from measurements of wall thickness at the inside of the 90° bend, stainless steel tubes, 0.062 inch wall thickness in sizes from 2 to 5 inches in diameter.

**Figure 3.** Is plotted from measurements of wall thickness at the outside of the 90° bend, stainless steel tubes, 0.062 inch wall thickness in sizes from 2 to 5 inches in diameter.
move the core quickly and perpendicularly to the bath and let it remain suspended for 30 to 45 seconds before it is turned over. This procedure is repeated to solder the reversed side of the radiator core.

(f) If a few of the tubes should be clogged or excessive globules of solder should hang to the core, these defects may be corrected by using a small tipped radiator torch. Also, should any minor leaks occur during the pressure test after the core is completed, these may be corrected by using the radiator torch and a portion of the high melting point solder as a soldering rod. A core should not be dipped the second time.

Figure 8 shows a completed radiator. The two cores are shown in the condition as taken from the high melting point solder bath.

Table 1—Tube bender—Mandril and ball clearance

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<thead>
<tr>
<th>O. D. tube dimensions</th>
<th>Wall thickness</th>
<th>Stainless steel</th>
<th>Cold rolled steel</th>
<th>Chrome molybdenum steel</th>
<th>Brass tube</th>
<th>Copper tube</th>
<th>Aluminum tube</th>
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</table>

*Note:* Other dimensions have not been calibrated.

(M) Mandril clearance.

(B) Ball clearance.

Figure 5—Tube Bending Machine and Tools—Metal Shop.
FIGURE 6.—High Melting Point Solder Bath.

FIGURE 7.—Tube Bending Machine—Metal Shop.
FIGURE 8.—Radiator Dipped in High Melting Point Solder.

FIGURE 9.—Stainless Steel Manifold Jig. Showing Assembly of Tubes Ready for Welding.
Fig. 1
Changes in tube dia. at "C" in Fig. 4 after a 90° bend.

Fig. 2
Changes in tube increasing in wall thickness at "A" in Fig. 4 after a 90° bend.

Fig. 3
Changes in tube decreasing in wall thickness at "B" in Fig. 4 after a 90° bend.

Tube diameter - inches

Fig. 4