Bending Thin-Walled Tubing, Moldings and Extruded Shapes

• The bending of pipe, tubing and molding causes a stretching or thinning of the outer curved section and a compression or thickening of the inner curved section. These unequal and opposite stresses, especially in thin-walled tubes, tend to cause buckles, flattening or wrinkles. To prevent such distortion, external and internal support is necessary.

External support is provided by grooved rollers or a pressure shoe and a grooved forming block to almost completely enclose the tube at the bending point. Internal support is provided by a temporary filler and for this a number of materials have been used with varying success. Lead, sand, tar and rosin among other materials have been most commonly used with certain attendant disadvantages- Lead, because of shrinkage on solidification, does, not snugly fill and gives only fair support. The high melting temperatures of both lead and rosin rule them out for use in tubes whose temper is affected by high temperatures, such as aluminum alloys in the cold-worked or heat-treated condition- Complete cleanout is difficult and uncertain- The inflammable nature of tar and rosin makes these materials undesirable because of fire hazard. Sand is difficult to pack tightly enough to properly support thin-walled tubing. Particles of sand which may remain in tube after bending may cause trouble when it is placed in service.

For bending thin-walled tubing up to 13/4" in diameter*, CERROBEND®s the ideal filler. The eutectic alloy of bismuth, lead, tin and cadmium, CERROBEND melts sharply at 158° F--54 degrees below the boiling temperature of water- CERROBEND eliminates the disadvantages of other filler materials because:

1- It is easy and safe to handle.
2- It flows freely as water in the molten state.
3. Its slight *expansion* after solidifying in tube assures snug fit and accurate, uniform bends.
4- It is reusable- Properly handled, CERROBEND can be repeatedly used without appreciable loss or deterioration.
5- It melts out easily in boiling water.
6. Low pouring and removal temperature do not harm the temper or finish of any metal-
7. Chromium or nickel plated tubes can be bent with little danger of flaking off.
8. CERROBEND filled tubes can also be rolled, swaged or drawn.
9. It acts as an inspection gauge- CERROBEND in the molten condition is so extremely fluid that it will expose defects such as cracks, pin-holes, etc., in the tubing, even though of minute size. Tubes which have passed rigid inspection will have defects revealed after filling with CERROBEND. Undetected thin spots will become evident when the alloy expands causing a bulge or crack at the weak spot. This feature is of especial value in fabricating aircraft tubing in which too much care cannot be taken to assure safety in operation.

CERROBEND is supplied only in two pound "CERROBEND" branded hexagonal cakes.

EQUIPMENT

Melting Equipment Required:

Melting equipment does not have to be elaborate, but certain precautions must be observed:

1. AVOID OVERHEATING
2. AVOID CONTAMINATION

CERROBEND should not be kept molten in contact with air. If a water jacketed stainless steel vessel is used for melting, then both overheating and contamination by rust and dross will be largely avoided.

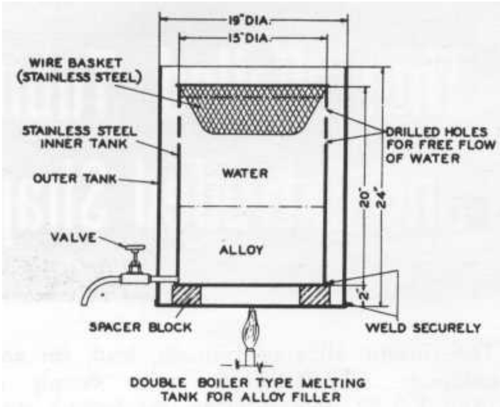

Fig. 1 - A typical melting tank suitable for continuous production work.

Either a stainless steel basket of wire or perforated sheet, or hooks should be provided to support finished bends while melting-out.

In this simple arrangement hot water circulates between the jacket and the melting tank. The hot water keeps air from contacting the molten metal, preventing oxidation and' it is also used for melting out alloy from completed bends. Used CERROBEND is collected on the bottom of the melting tank, ready for re-use.

Figure 2 shows the production set-up used by Electric Service Mfg. Company, Philadelphia, Pennsylvania. Note hooks in place of basket (figure 1) suspended over inner tank for holding formed tubing while melting out CERROBEND filler. Thermostatically controlled, electrically heated melting tanks are commercially available and function very efficiently.

Fig. 2 -Photo courtesy *of* **Electric Service** *Mfg. Co.*

Figure 3 shows the CERROBEND Heater manufactured by Sta-Warm Electric Company, Ravenna, Ohio. This model is made in two sizes which will hold approximately 400 lbs. and 800 lbs. respectively. Provided with eyebolts, such a heater can be supported overhead and tubes are easily filled from the petcock.

Fig. 3
Photo courtesy of Sta-Warm Electric Company.

Fig. 4
Photo courtesy of Sta-Warm Electric Company.

The smaller glue pot type heater by Sta-Warm Electric Co., is designed for short runs. Tubes are filled from this pot by hand ladle.

For the small shop having occasional small bending jobs to do, a simple double boiler of the oatmeal cooker type, agate or enamelled, will serve adequately as melting equipment. *Never* use aluminum, copper or galvanized containers for melting CERROBEND -they will contaminate it. Plain steel or iron in constant service, in contact with water will rust and rust is a contaminant. Merely placing water on top of the alloy in a single vessel may not prevent overheating. CERROBEND is a poor conductor of heat and if it is melted in this manner, the temperature of the alloy at the bottom of the vessel can be as high as 300° F. while the water on top is only boiling. See Figure 5.

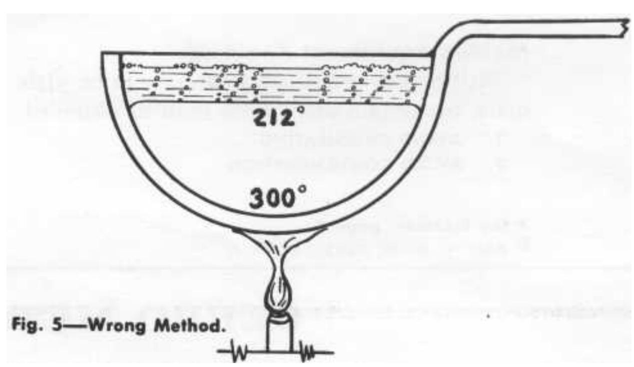

Fig. 5—Wrong Method.

QUENCHING EQUIPMENT

The secret of successful bending of CERROBEND filled tubes lies in proper quenching or chilling of the molten alloy *immediately* after filling.

CERROBEND cools very slowly in room atmosphere- Slow cooling results in a coarse crystalline structure which is brittle and will break when bent. Quick *chilling* from molten to solid state is necessary to produce a fine grained crystalline structure of high ductility. The elongation factor of properly cooled CERROBEND is from 140 to 200%, far in excess of that of any tubing in which it will be used and will permit bending thin walled tubes to the shortest radii allowable for given tube materials.

Rapidly circulating cold water is necessary to effect a good quench. Chilling should start *at the bottom* of the filled tube and gradually progress upward to the top. Cold water inlet to the quench tank should be in the bottom with the outlet at the top. Generous water pipe size is essential to assure good volume of water flow.

Quench tank may be made of wood, sheet iron, steel or concrete. For long length tubes it may be necessary to arrange the quench tank below floor level, inserting tubes through an opening in the floor. A simple tank may consist of a suitable length of 4" or 6" steel pipe, provided with an inlet for water at the bottom. If used near a floor drain, water may overflow from top of pipe and no additional fittings for drain would be necessary-

BENDING EQUIPMENT

Practically any form of bending equipment can be used to form tubing, provided the forming is done slowly, under *constant load* and at *uniform speed.* If forming is done at too high a speed, or power is unevenly applied failure will result- *Figure 6* illustrates a type of bending device well suited to forming CERROBEND loaded tubes. To obtain perfect bends, it is very important that the radial distance between the bending roller and the central pivot be carefully adjusted so that the distance between the points at which bending pressure is applied, (dimension "X"), shall be correct. If this distance "X" is too small, the tube may be squeezed or flattened during bending. If distance "X" is too large, the tube wall at the inside of the bend may be buckled or bulged.

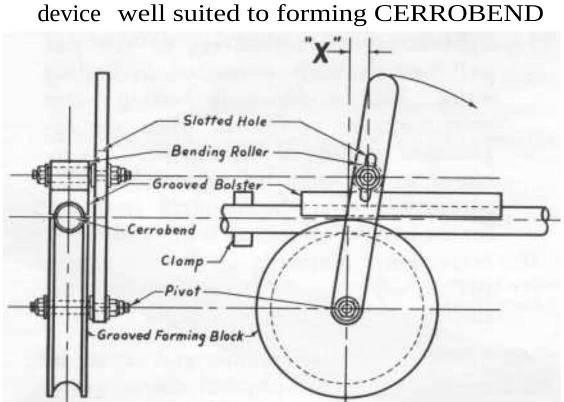

Fig. 6

In general, the proper value for distance "X" is approximately two-thirds of the tube diameter, but may vary considerably for different metals and wall thicknesses. Therefore optimum value must be determined experimentally in each case. The Di-Acro Bender, Figure 7, is one of many good makes of equipment designed to properly adjust distance "X" and is a widely used hand-operated bender made in several sizes.

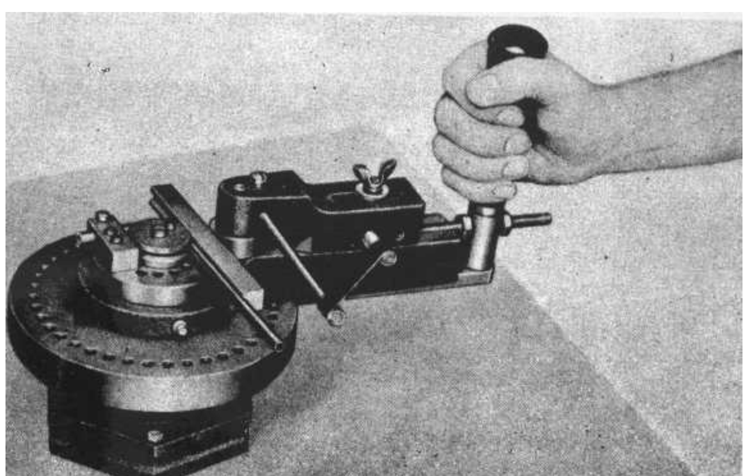

Fig. 7—Photo courtesy of O'Neil-Irwin Mfg. Co.

INSTRUCTIONS FOR BENDING THIN-WALLED TUBING

1. *Heat Treatment:* Tubing is rendered fully workable by the prescribed annealing process immediately before bending. It is essential that all working be performed before any age hardening develops.
2. *Preparation:* Tubing is cleaned internally to remove dirt and oxide scale by the use of a dry, tight fitting pull-through. If oxide scale is heavy, cleaning by sand blasting may be necessary. Under no circumstances should tubes be cleaned by pickling or any wet process as retention of acid or salts from such process will interfere with the subsequent development of a continuous oil film and should the oil film become broken during loading or unloading operations, the salts will act as a flux and seriously increase the tendency for CERROBEND to "tin" the tube wall.
3. *Oiling:* Tightly plug one end of tube with a wood or rubber plug and completely fill with oil and drain out all but about one tablespoonful. In general, high grade, straight mineral oil of viscosity equivalent to S.A.E. # 10 proves satisfactory. Detergent additives in regular modern automobile oils tend to cause sticking when the alloy is melted out, hence straight mineral oil, obtainable from leading refiners should be specified. Never use reclaimed crank case oil.
4. *Preheating:* The oiled tube is placed in hot water up to within 2 or 3 inches of the open end for 2 or 3 minutes, i.e. long enough for tube and oil to attain correct working temperature of 185° - 195° F. Tubes 1/4" I.D. or smaller should be placed in water at 212° F. while filling. Hot water should not be allowed to enter the tube.
5. *Loading:* CERROBEND is allowed to flow gently into the tube while it is still standing in the hot water in an inclined position, care being taken to avoid air locks, and to avoid breaking the oil film.
6. *Quenching:* The loaded tube is lifted from the hot water tank and immediately lowered into a cold water tank provided with a steady flow of rapidly circulating cold water. Satisfactory bending depends entirely on rapid quenching and thorough cooling. This takes approximately 15 minutes for 1 inch tube, and 20 minutes for a 11/2 inch tube-other sizes pro rata. The loaded quenched tube should then be withdrawn, and left for sufficient time for filler to assume shop temperature, 65 ° - 70° F., throughout before attempting to bend. Never attempt to bend below this temperature.
7. *Bending:* Bending should be performed slowly and *steadily* with no jerkiness, over a forming block or in a regular bending machine. In cold weather it may be advisable to plunge loaded tube in warm water for a *few seconds* before bending, but under no circumstances should the temperature of filler be raised above 100° F.
8. *Unloading:* The formed tube is immersed in the hot water tank at a temperature approaching boiling point and gently maneuvered to allow CERROBEND to drain away. Violent agitation should be avoided as this tends to wash away the protective oil film. The unloaded tube is then plunged in the cold water tank for 2 *minutes to* solidify any drops of CERROBEND retained in the oil film. DO NOT USE TORCH.
9. *Cleaning:* The tube is cleaned by passing a tight fitting pull-through twice from each end of tube. Normally this removes every trace of CERROBEND. However, in a few special cases due to varying local conditions very minute particles of CERROBEND may be detected in the tube after the foregoing treatment. These minute particles may be completely removed by scrubbing the tube internally with a tight fitting oil soaked rag or felt pad pull-through while immersed in boiling water. This scrubbing in boiling water must never be performed when any appreciable quantity of CERROBEND is retained in the unloaded tube and is only permissible after the standard treatment for the removal of minute traces of alloy.*
10. *Inspection:* Normally it is sufficient to section, say one tube in 200 to check the efficiency of the cleaning process.

CERROBEND is only a filler and cannot be expected to change the physical characteristics of a tube. If the tube material will not with stand the tensile stress at outside of bend without rupturing under bending, CERROBEND will not cure this condition.

A torch must never be used to melt out CERROBEND or other alloys. Uneven and uncontrolled heating by torch will cause "hot-spots" in which the filler alloy will bond with or poison the tube metal to form weak spots, if not holes, in the tube wall.

SMALL DIAMETER TUBES

Tubes of 1/4" or less in diameter must be immersed in boiling water while filling. Tubes of extremely small diameter or cross section not readily filled by pouring may be filled by pressure or suction. One manufacturer of small Bourdon tubes immerses the tube vertically in the molten CERROBEND. A special pair of tongs were made to hold the tube near the open end being submerged and when the tube is im. mersed to the desired depth, the submerged end is pinched shut to prevent alloy from running out. A layer of oil floats on the surface of molten CERROBEND and thus the tube is lubricated as it passes down through the oil.

BLACKBURN PRECISION PIPE BENDING METHOD

The British firm, Blackburn Aircraft, Ltd., developed and introduced a new technique in pipe and tube bending which is of interest to all who have much bending to be done, particularly exact duplication of complicated shapes. A supplement will be issued in the future giving details of this British patented process- Fully illustrated accounts have appeared in *Aircraft Production, London, May* 1942; *The Iron Age, June* 11, 1942; *Commercial Aviation, June* 1942; and *Aero Digest, August* 1942.

BENDING MOLDINGS OR EXTRUDED SECTIONS

The use of Cerrobend assists in the bending of irregularly shaped moldings or extruded sections. The molding (Figure 8) is suspended in a mold (Figure 9) in the form of a long metal pan or trough. After the mold is closed it is oiled, filled with CERROBEND and quenched quickly in the same manner as tubing.

The extruded section is located in a steel mold having a removable side provided with a rubber gasket. Locating pads of rubber or chaplets of known thickness are used to support the section in the mold near the ends to assure uniform thickness of alloy surrounding the section, and this thickness determines the amount by which the radius of the forming block must be undersize to give the required radius to bend the section. -The removable side of mold is screwed or clamped in place. From here on the assembly is treated as tubing- Each step of the procedure for tube bending should be carefully followed, bearing in mind the importance of oiling before pouring in the CERROBEND or CERROBASE and thorough, quick quenching. Preheating of the mold and section to near the melting point of the alloy will permit pouring at lower temperatures- After the alloy has been quenched the bar is removed from the mold and bent to shape- Removal of alloy is done in hot water (212° F.) if Cerrobend is used or in hot oil (450° F.) if Cerrobase is used.

(Figure 10) shows a loaded mold being lowered into a sub-floor quench tank:

The bar of CERROBEND with molding embedded is removed from the mold and after it comes to room temperature is bent to required shape. Bending is done around a block or form whose dimensions allow for the thickness of alloy surrounding the section- If the forming block is grooved to accommodate exactly the cross section of the alloy bar to prevent cross sectional distortion it will prevent any ripple or spread in the section and perfect bends will result.

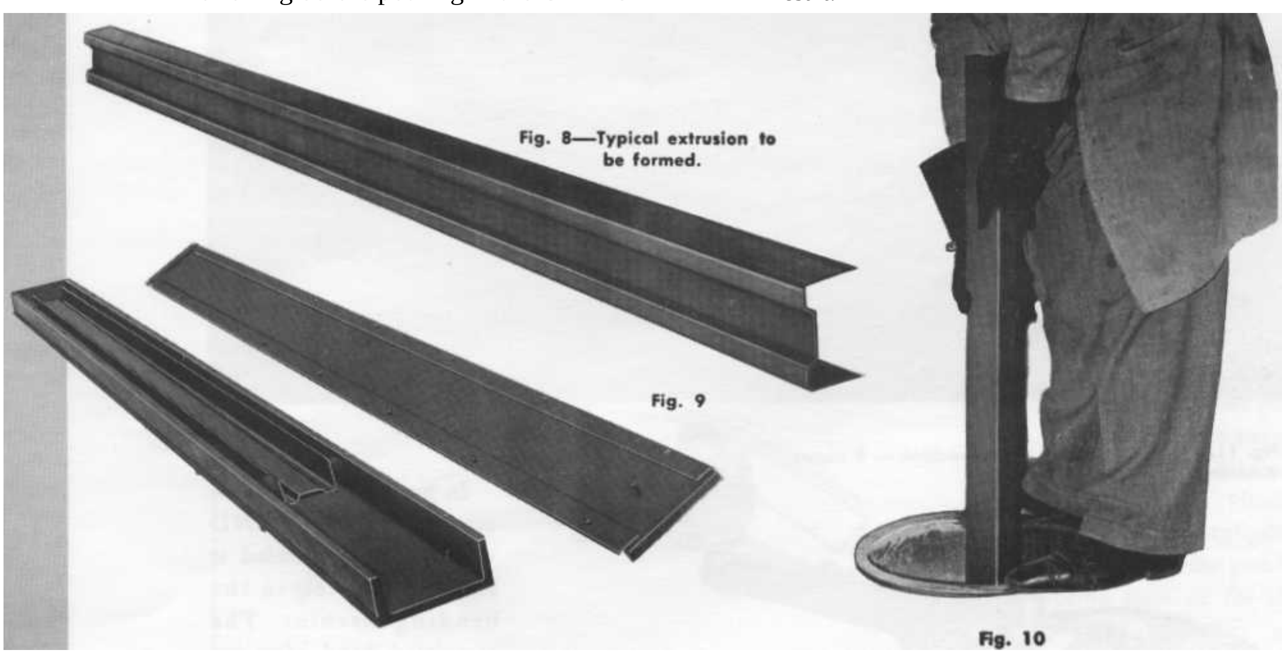

Fig. 8—Typical extrusion to be formed.

Fig. 9

Fig. 10

NOTE: For tubes larger than I ⅟„" I.D. CERROBASE or CdeP Alloy #5250-I are recommended rather than CERROBEND. The poor thermal conductivity of CERROBEND tends to prevent proper quenching of the alloy in tubes in excess of Is/4" I.D. or equivalent mass in other shapes. The grain structure and ductility of these two alloys is improved by quenching in circulating cold water, however this point is not so critical as is the case with CERROBEND.

Cdels Alloy #5250-1 melts at 203° F. and CERROBASE melts at 255 ° F. Since pouring temperatures of these alloys will be above the boiling point of water, the water jacketed equipment for melting will not be suitable and instead, a dry type, thermo-Statically controlled melting unit will be required. A thin film of oil on surface of molten alloy will retard oxidation. Melting out these alloys is best done in an oil bath, held at 400° F. - 425 ° F- or lower if possible. Lower oil bath temperature will prolong its usefulness- Socony Vacuum Company's "Gargoyle Super Cylinder Oil Hecla Mineral" has long been in use for this purpose and is recommended. Melted alloy should be drained from oil bath tank frequently and returned to filling tank. The oil should be discarded when it thickens.

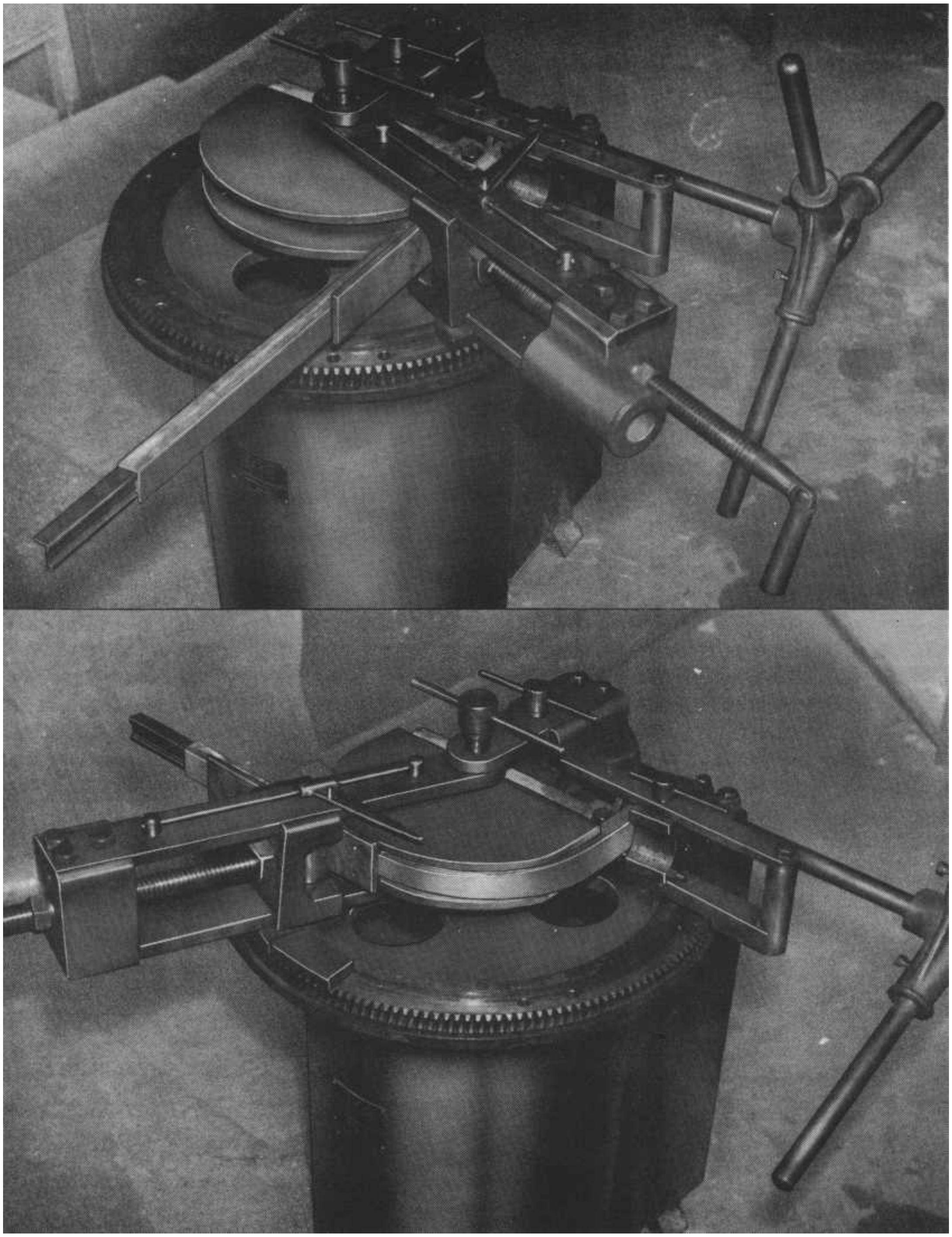

Fig. 11A —A shows British made machine — B shows American made machine.

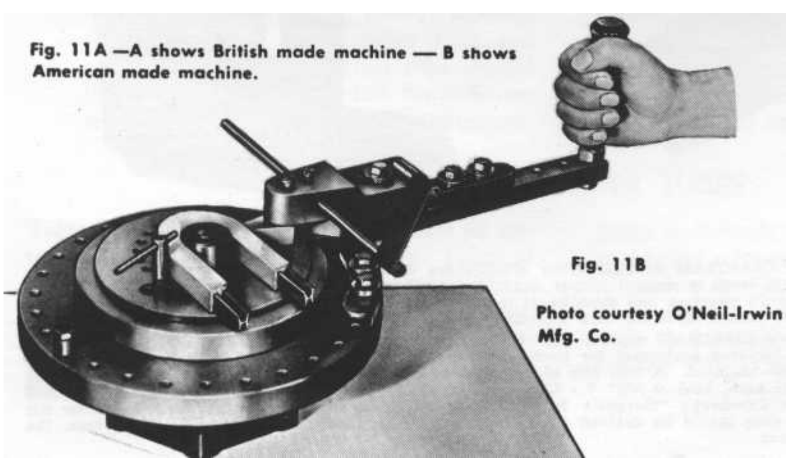

Fig. 11B

Photo courtesy O'Neil-Irwin Mfg. Co.

In figures 11A, 11B the block of CERROBEND with section embedded is shown mounted in the bending machine. The completed bend after removal of alloy is seen in Figure 12 showing no evidence of ripples or spreading.

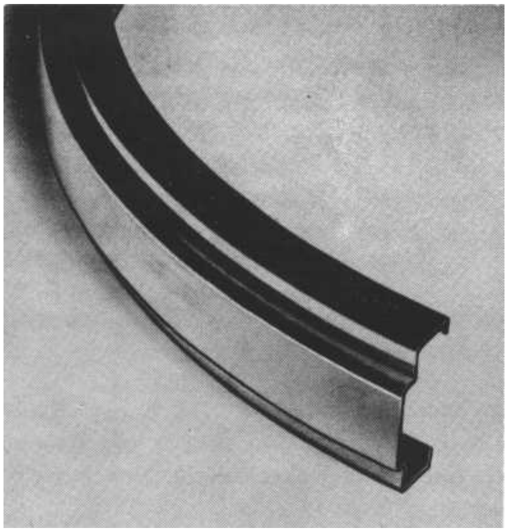

Fig. 12

This method is successful for most types of materials, but some difficulties have been encountered in forming light-gage work. A method described by Kenneth C. Cathcart of Lockheed Aircraft Corporation, Burbank, California, and published in the March 1945 issue of *Machinery* follows: "An excess of spring-back and buckling is prevalent in flanges or other extremities of the part being bent. This is due to the fact that these flanges or extremities are on the compression side of the neutral axis in the CERROBEND bar, which creates a condition during the forming operation that tends to compress some of the fibers while other fibers in the section are being stretched. Since compression of thin material is almost impossible, wrinkling of the flanges or other portions of the section on the inside of the radius is a natural result, as indicated in Diagram A, Fig. 13."

However, accurate parts of thin materials in their hardened condition can be produced by a slight change in the forming technique, which consists of shifting the neutral axis completely outside of the part being formed. This is accomplished by bolting a steel rod or bar to the side of the part which will be on the inside or compression side of the contour. The bar and part should be equal in length, and the bolts should be placed at each end, as illustrated in Figure 14, so that the portion of the part containing the bolt holes can be trimmed off after the forming operation.

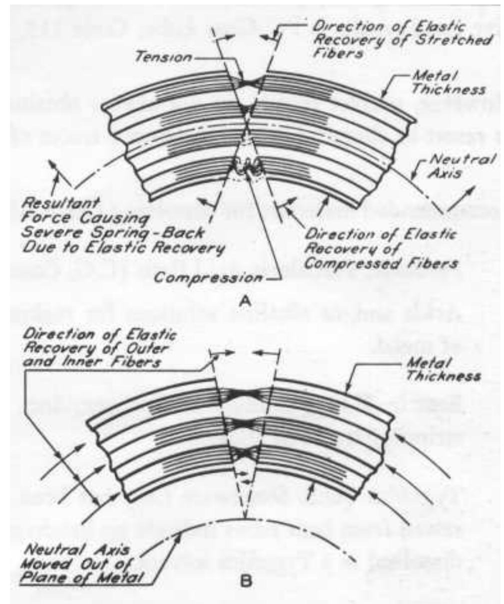

Fig. 13

Now when this unit is cast in a bar of CERROBEND and rolled or formed, stretching will occur in all portions of the part, since the steel bar will not compress, thus eliminating the previous condition of tension in the outer fibers, and compression in the inner fibers. While elastic recovery does exist, all recovery in the part is parallel to the curvature, as seen in diagram B, Figure 12. Hence,- there is only a negligible tendency for the part to spring back or for the contour to open up when the CERROBEND is removed."

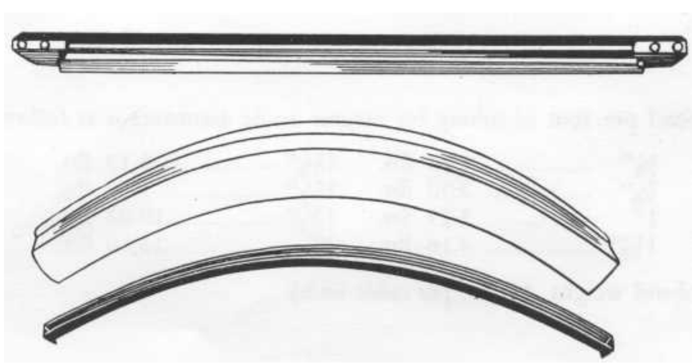

Fig. 14

REMOVING CERROBEND FROM TUBING AFTER FORMING OR BENDING

Users of Cerrobend or Cerrobase frequently find it necessary to resort to chemical means for complete removal of the alloy after a bending, forming or holding operation.

Theoretically, almost any lubricating oil film should prevent Cerrobend from contacting the metal surfaces of tubings, moldings or parts being held in machining operations.

It has been found recently that Dow-Corning DC 200 Fluid, Viscosity *100* at 25°C is very effective in preventing alloy particles from adhering to the tube -wall. Another product that has been found to give good results is PQ Gear Lube, Code 113, American Oil & Supply Co., Newark, New Jersey.

However, perfect results are not always obtained for various reasons, therefore it has been necessary to resort to chemical means to remove traces of filler alloys.

Recommended materials for dissolving Cerro Alloys are:

Peroxide, Perchloric Acid Bath (C.G. Conn Formula).

Acids and/or alkaline solutions for soaking or pumping *through.* Selection regulated by nature of metal.

Enstrip T-L, a product of Enthone, Inc., New Haven, Conn. has been reported to be good for stripping traces of alloy.

Tygofilm (U.S. Stoneware Co.) has been applied to the inside of tubing before bending. Sections sawed from bent tubes indicate no breakage of film and the film can then be either pulled out or dissolved in a Tygofilm solvent.

A method employed at a leading aircraft manufacturer in England involves the use of a sleeve of polyethylene or PVC for heavier gauge tubes. The sleeve being longer in length than the tube is inserted and a cuff of a few inches is folded back over the end of the tube and fastened. The lined tube is then filled with Cerrobend, formed, and the alloy melted out. A weighted string is fed through the tube, tied to the end of the sleeve and the sleeve is then pulled back, turning it inside out and removed.

The approximate weight of Cerrobend per foot of tubing for various inside diameters is as follows:

1/4"	.22 lbs.	3/4"	1.83 lbs.	1 1/4"	5.13 lbs.
3/8"	.47 lbs.	7/8"	2.50 lbs.	1 1/2"	7.39 lbs.
1/2"	.83 lbs.	1"	3.25 lbs.	1 3/4"	10.07 lbs.
5/8"	1.29 lbs.	1 1/8"	4.16 lbs.	2"	13.16 lbs.

(Cerrobend weighs .34 lbs. per cubic inch)

CERRO METAL PRODUCTS