MANUFACTURE AND INSPECTION OF CONDENSER TUBES.

This paper is written with a view to giving a brief and concise account of the process of manufacture of condenser tubes for H.M. Service, as it is realised that few engineer officers of the Fleet have opportunities of seeing the actual manufacture of the tubes.

The first operation in the production of a condenser tube is the casting of the "shell," *i.e.*, the cast metal tube from which is formed the finished condenser tube.

The method, of course, varies with different firms; and the size of the cast shell is varied to suit each firm's plant, and also according to the length of tube to be produced.

A typical shell is 2½ ins. external diameter by 1¼ ins. internal diameter by 32 ins. long.

The heats of metal, which are melted in crucibles in an ordinary pot furnace, are made up so as to give a casting with an alloy of 70 per cent. copper, 29 per cent. zinc, and 1 per cent. tin.

The heat consists of ingot metal, except 20 per cent. of scrap condenser tube which is allowed in each charge.

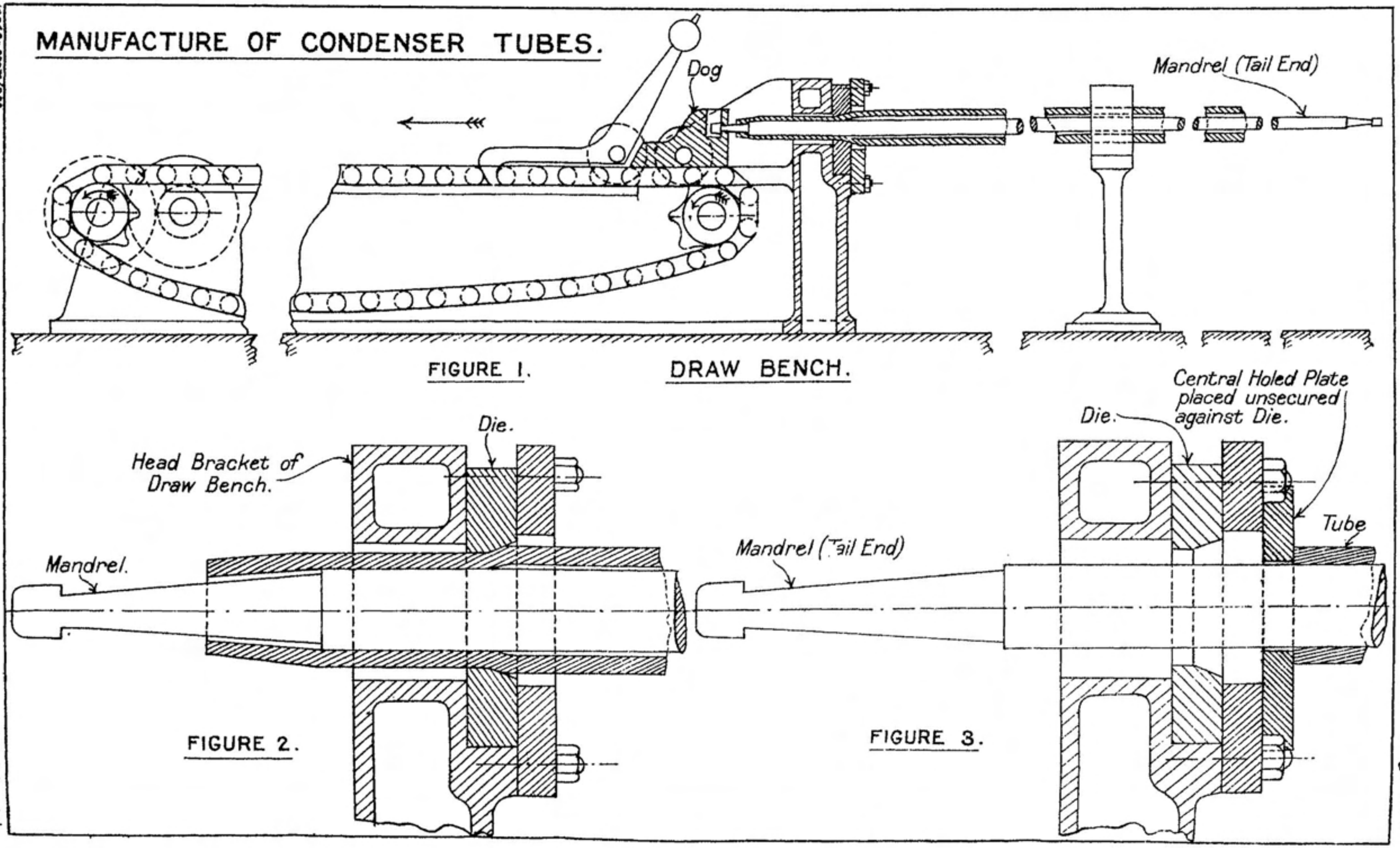
The highest grade of copper (usually electrolytic), zinc, and tin are used, and this standard is maintained by the overseer, who frequently takes samples of the metals from the actual trays in which the heats are made up for assay.

The "shells" are cast in iron moulds, and chilled after pouring by playing water on the exterior of the mould. The moulds are sometimes of the cannon type, but more usually made in two portions, divided longitudinally, and clamped together by steel bands and wedges. The cannon moulds are vertical, and rotated during the process of pouring, while the split moulds are given a small angle of inclination to facilitate the escape of gases and dross.

The core is composed of a hollow steel tube, perforated with holes for vent of gases up the interior of the tube. The steel tube is revolved during the manufacture of the core, and an application made by hand of fibre wood shavings, or hay, covered with a coat of loam, and finished with graphite.

A cast usually consists of five shells, which are removed from the moulds immediately after pouring.

The second operation consists in boring and turning the cast shell, and it is specified that at least ¼ in. of metal must be bored from the casting. After boring and turning, each shell is inspected by the Overseer, and any that show blow-holes on either interior or exterior surfaces are usually rejected. Should such blow-hole be at one end of the casting, however, it is



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permitted to cut the shell and use the sound portion for drawing down to tubes. A small external blow-hole is sometimes milled out. The flat caused by this operation disappearing after the first draw.

The firms engaged in this industry have developed such a degree of skill in casting that rejections at this stage average about 2 to 3 per cent. only.

Samples of the metal of the shells are taken by the Engineer Overseer for chemical analysis of the alloy.

The third operation consists in drawing the tube; that is, reducing it from the dimensions of the bored and turned shell to that of a finished tube. The draw bench (*see* Fig. 1) varies in detail, but consists essentially of a long bed plate, similar to that of a lathe, in which travels an endless steel chain, with flat links. At the end of the bed-plate is a fixed bracket containing the steel die through which the shell or tube is drawn.

After the bored and turned shell has been annealed, pickled, and washed, the "git" end (*i.e.*, the upper end of the casting, which has already been faced back until sound metal is found) is coned down so that the mandrel cannot be pulled through the tube. This shoulder is cut off after each pass on the draw bench, and a fresh shoulder coned down, the same end always being used, so that the inferior metal is lost.

After shouldering, a polished steel mandrel, tapered about ·002 in. in 10 ft., is passed into the shell. The mandrel is then passed through the die, and gripped by a dog which is capable of travelling along the bed-plate, when hooked into the endless chain mentioned above (*see* Fig. 2).

This operation gives the tube a "pinch" and a "sink," that is, a reduction of thickness and also a reduction of diameter, at the same time extending it about 33 per cent. in length.

After the tube has been drawn through the die, the mandrel has to be withdrawn and this is achieved by passing the back or tail end of the mandrel through a plate with a central hole, and gripping the back or tail end of the mandrel in the dog (*see* Fig. 3).

It may be remarked that the whole of the "work" necessary to ensure the ultimate tensile strength required, is put into the material in the first draw.

After each pass or draw the tube is first annealed and then pickled in a bosh of dilute sulphuric acid, and washed through with clean water. At about the fourth draw the tube is cut into two lengths for convenience in manufacture; each casting produces about 60 ft. of $\frac{5}{8}$-in. tube, and this would be an unwieldly length to draw in one piece.

The number of draws to produce the finished $\frac{5}{8}$-in. diameter condenser tube from the bored and turned casting, varies in different firms from 7 to 13. After the final draw the tube is left in an unannealed condition in order that it shall have sufficient stiffness to withstand the crushing action of the gromet when being packed in the condenser tube plate. All tube makers carry out a rigid inspection of the tubes at each stage of manufacture, and usually break open and flatten a small percentage of the castings and tubes; this is done in their own interest, as it pays to detect a fault in the early stages and so avoid the time and expense of working a tube liable to rejection.

All firms also carry out a flattening test, water pressure test, sighting test, and chemical analysis, before bringing the finished tubes before the overseer for inspection.

In order to maintain the desired standard of manufacture the overseer at the tube works carries out an internal and external sighting test of the whole of the tubes, also gauging, flattening, and heating test of a proportion. The official tests are carried out at the shipyard or dockyard to which the tubes are consigned, and are briefly as follows (for further particulars, *see* Specifications) :—

(*a*) Examination for dimensions, *i.e.*, diameter, thickness, and concentricity.

(*b*) Flattening at either end (to be selected by the inspecting officer) on an anvil with a hand hammer till the diameter one way is reduced to 7/16 in.

(*c*) Tested internally by water pressure to 1,000 lbs. per sq. in. without permanent practical increase of diameter, and without the slightest indication of weeping; this pressure is to be steadily maintained while the outside of the tube is jarred along its length between suitable mallets.

(*d*) Being dropped on to a hard wooden floor from a height of 3 ft. The tube to be held horizontally before being dropped.

(*e*) Hammering on the end with a hammer when held loosely in the hand.

(*f*) The whole of the outside surface to be carefully examined for any defects.

(*g*) The inside of every tube, after being cleaned to be carefully examined for internal defects by sighting through.

The above examinations and tests (*a*) to (*g*) inclusive, are applied to each tube.

(*h*) The remaining tubes are indiscriminately grouped in parcels of 100, and two tubes from each 100 are selected for heating to a dull red. The tubes are to stand this test without flying or splitting up; failure to comply entails the rejection of the parcel of tubes.

The principal defects liable to originate in course of manufacture are :—

(1) "Spills"—these are caused by small blow-holes in the casting which draw out into a hair-line crack. Such defects are now rare in the finished tube owing to the scrupulous inspection of the bored and turned shell, and of the tube at each stage on the draw benches.

It is possible for a blow-hole in the interior of the casting to remain undetected owing to the "spill" not showing through on either the internal or external surface of the tube. This is, however, probably exceptional as such a defect of any importance causes the tube to break during the pass through the die.

(2) Should the tube not be thoroughly soaked in the annealing muffles, especially in the final stages, it will be passed to the next draw in a condition of stress. This stress is accentuated in the further process of drawing.

Such a tube will sometimes develop a split on " weathering," either in store or in the condenser of a ship, after a considerable period of time.

(3) The slight taper of the tube internally, which is necessary in order to allow the mandrel to be withdrawn from it, may also provide a potential cause of failure.

It is known that perforations are frequently caused by the lodgment in the tube of foreign bodies such as ash, clinker, &c., and should the large end of the tube be placed in the condenser at the inlet end, such a body might be able to enter the tube, but fail to pass through it, in spite of the fact that the taper is only about ·002 in. in a 10-ft. tube.