EXAMINATION OF FRACTURED COPPER OIL-FUEL PIPE.

An accident which occurred recently in the boiler room of a T.B.D. during a full-power trial as a result of failure of an oil-fuel supply pipe, brings out the necessity for the greatest care in maintaining the close inspection of such parts. In this case the failure was immediately due to maltreatment at some time after it had been fitted, but it was considered desirable nevertheless to closely investigate the case from the material and manufacturing aspect. The following report is of general interest in that it indicates potential sources of weakness in brazed joints of this type and the precautions necessary to be observed in manufacture.

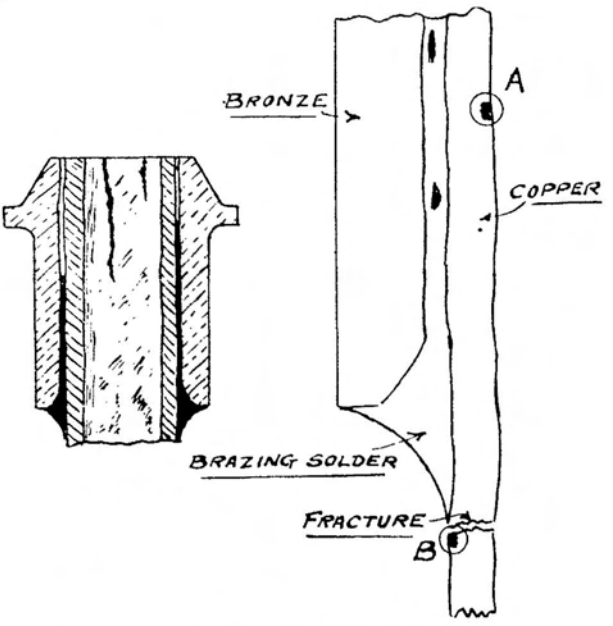
The copper oil pipe, which was of $\frac{3}{8}$-in. internal diameter, had fractured transversely immediately outside the nipple into which it was brazed. The end of the pipe and nipple had thus become completely detached from the rest of the pipe. The surfaces of the fracture had been much smoothed and worn, as well as clogged with dirt, and tarnished since the accident, so that little information could be gained from its examination. The fracture, however, appears to have been a clean one straight across the tube.

The nipple with the broken end of the pipe was cut open and examined. The appearance of the interior surface of this part of the copper pipe is indicated in the sketch. This surface was covered with a black deposit which was partly oily carbon and partly black oxide of copper. Beneath the oxide the metal was finely roughened as is the usual result of oxidation. The interior of the copper pipe inside the nipple was uneven in a very marked wavy manner, probably as the result of hammering to make the end of the pipe fit the nipple, and near the end were a number of longitudinal cracks, some of which extended nearly half the length of the nipple.

Two photographs, Figs. 1 and 2, Plate I., show the structure of the copper tube in the positions marked A and B respectively on the enlarged view of a longitudinal section of the copper pipe, the brazing metal and the bronze nipple.

The brazing metal, except for a few holes, formed a fairly continuous layer between the bronze and the copper over, on an average, about two-thirds of the length of the nipple, and apparently formed a perfectly tight joint, the metal being well alloyed to both bronze and copper. At the junction of the brazing metal with the copper, *i.e.* at the place where the fracture occurred, the thickness of the copper tube had been reduced slightly by filing, and it will be noticed that where the brazing metal is thickest and where, presumably, it was hottest, the

thickness of the copper tube has been further reduced by alloying.



With regard to the general quality of the copper pipe, examination shows that this was of sound copper in the soft condition. There is no sign of general " burning " of the copper in the neighbourhood of the brazed joint. The interior surface inside the nipple, however, shows some signs of " burning "—or probably, more correctly, " gassing "—but this extends only a short way into the tube (as shown in Fig. 1), and may possibly have resulted after the fracture occurred. There are also visible a few small cracks in one place on the outer surface of the tube, just below the brazed joint and at the point where fracture occurred. This is shown in Fig. 2. Although the general structure of the pipe shows that the copper is in the annealed condition, the crystals near the braze are of considerably larger size than those of the rest of the tube, indicating that during the brazing the copper had been subjected to a higher temperature than that of the ordinary annealing operation.

It should be pointed out that at the point where fracture occurred the stresses due to any vibration of the pipe would probably be at a maximum, owing to the end of the pipe being held rigidly in the nipple. In any case, therefore, if fracture is to occur, the chances are that it will take place at this point, *i.e.* just at the commencement of the brazed joint, where there is the sudden change from the comparative flexibility of the copper pipe as a whole to the stiffness of the end held firmly in the nipple. In view of this, it is evident that any weakening of the pipe in this region is to be avoided. In the present case

the evidence of any burning or gassing of the copper during brazing is not strong, since the superficial effect of such action noticed on the interior surface of the pipe inside the nipple may have been produced after fracture occurred, while the slight cracking and weakness on the outer surface of the metal, illustrated in Fig. 2, was not general. On the other hand, slight as such injury may have been, it must, together with the coarser crystalline structure of the copper in the neighbourhood of the brazing compared with that of the rest of the tube, be considered as a source of weakness. A more serious fault which the dissection of the nipple revealed is the mechanical injury due to the rather severe treatment of the end of the pipe in its preparation for brazing into the nipple. It seems to have been very roughly hammered, and the amount of filing seems to have been unnecessarily large and roughly done.

The conclusion is, therefore, arrived at that the brazing operation in this case had not been carried out in an entirely satisfactory manner.