the common level. It was also claimed for this process that a current density of from 30 to 40 amperes per square foot of cathode surface could be employed at a voltage of about 1.6 per vat. This process

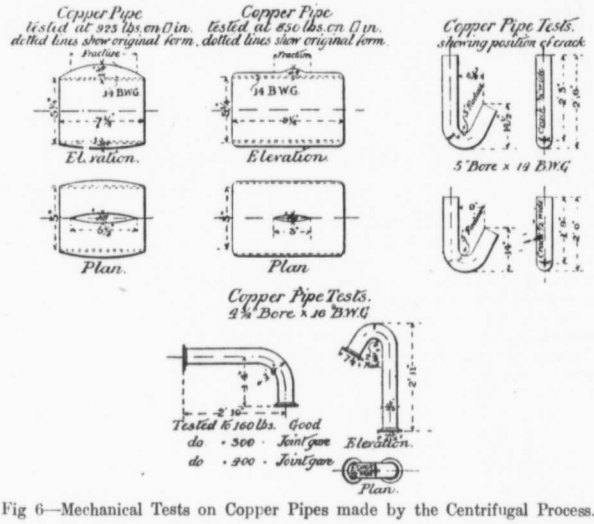

Fig 6—Mechanical Tests on Copper Pipes made by the Centrifugal Process.

was tried on a large scale in England but was soon abandoned.

Other Processes.

Attempts have been made at various times to further increase the rate of deposit by Swan, Elmore, Thofehrn, Graham, Poore and others, by impinging jets of the electrolyte against the cathode surface. The quality of the copper is liable to vary in density if impinging jets alone are employed; it is, therefore necessary to move the cathode, otherwise the copper is deposited in the form of annular rings of varying density and smoothness.

The author, when carrying out some experiments on the production of copper tubes and sheets by electro-deposition on rotating cathodes, observed that when the speed was greatly increased entirely new results were obtained and that a current density of 200 amperes or more per square foot could be employed, the copper remaining smooth and having a tensile strength equal to the best rolled or drawn copper, and in some cases a tensile strength some 50 per cent higher than that obtained by the ordinary process of casting and rolling, the tensile strength increasing with the rate of rotation of the mandrel. The result of revolving a mandrel at a comparatively high speed is that every molecule, as it is deposited, is burnished or rubbed down so as to produce a tough fibrous copper, the usual order of things being reversed, the present practice being to put the mechanical work into a mass of copper by rolling or drawing instead of treating each molecule separately.

The Centrifugal Process.

This observation led to further experiments, which resulted in evolving the process now known as the centrifugal copper process for the manufacture of sheets, tubes and wire, which will now be described in detail, together with the results obtained.

After a long series of experiments had been made to determine the best composition for the electrolyte and the most economical current density to employ, the critical speed was accurately determined by means of revolving cathodes in the form of cones. By observing the point at which the copper remains smooth, and by measuring the circumference of the cone at that point and multiplying it by the number of rotations per minute, the critical speed is readily determined; 200 amperes per square foot is found to be the most economical current density, although a current density up to 500 amperes per square foot can be employed by increasing the rate of rotation, but the increased cost due to increased voltage renders such a current impracticable for ordinary commercial work.

One of the chief difficulties inherent in any electrolytic or wet process for the production of copper tubes and sheets is having any working parts, such as bearings, in an acid copper sulphate solution, and this was one of the first troubles encountered when working the centrifugal process on a commercial scale. This difficulty was eventually overcome by constructing vats in the form of an annular ring, as shown in Fig. 1. It will be observed by such an arrangement all working parts are outside the vat and do not come into contact with the electrolyte, so that the bearings can be lubricated in the ordinary way; only the actual face of the mandrel on which the copper is to be deposited is immersed in the electrolyte. The cathode consists of a steel or cast iron cylinder closed at one end, to which is attached on the inside a steel rod projecting below the edge of the mandrel to guide it into position; the cylinder can be 5 or 6 feet in diameter or even larger so as to produce a copper sheet of say 20 feet long by 4 or 5 feet broad. Anodes composed of crude copper are placed around the mandrel with intervening spaces and are fed forward by suitable mechanical means, Figs. 2 to 5, as the copper dissolves away so as to keep the voltage constant.

One great advantage of the centrifugal process is that a very low voltage is required even when employing a very high current density; for instance, only 0.8 of a volt is required at the terminals of the vat when working at a current density of 200 amperes per square foot of cathode surface. The effect of revolving the cathode is five-fold; firstly, it keeps the electrolyte agitated, so that there is always a fresh supply of copper ions in proximity to the cathode; secondly, each molecule of copper as it is deposited on the cathode is burnished or rubbed down by means of the skin friction between the revolving cathode and the electrolyte; thirdly, the rotation prevents any foreign matter that may be in suspension in the electrolyte settling on the cathode and becoming entangled by further copper being deposited around or over it; fourthly, it brushes away any air bubbles on the cathode, which are the cause of nodules forming; and fifthly, the rotation of the cathode ensures the thickness of copper being uniform even when a mandrel of say 8 feet in length is employed.

Making Tubes and Sheets with Centrifugal Process.

The method of making tubes by the centrifugal process is as follows:—A mandrel somewhat smaller than the finished internal diameter of the tube is prepared by coating it with an adhesive coating of copper by first depositing copper upon the surface from an alkaline solution and then thickening it up in an acid solution, the surface being highly burnished and treated chemically to ensure the easy removal of the deposited tube. The mandrel thus prepared is then placed in a vat as shown in Fig. 1, according to the diameter of the tube and its length. When the desired thickness has been obtained the mandrel is removed and placed in a horizontal or vertical lathe, and a round-faced roller run over the surface so as slightly to expand the deposited copper, which can then be readily drawn off.

Copper sheets are prepared in a similar manner, the only difference being that the mandrels are of much larger diameter, and a narrow insulating slip is fitted down one side so that the sheet can be easily removed

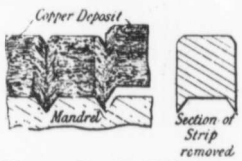

Fig. 7—Diagram Showing Method of Forming Weak Line of Cleavage Due to Crystalline Structure.

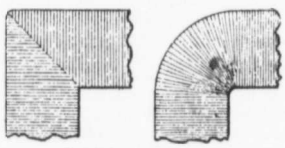

Fig. 8—Diagram Showing the Effect of Sharp and Rounded Corners on the Crystalline Structure of Metal Castings.