

## THE DIRECT PRODUCTION OF COPPER TUBES, SHEETS, AND WIRE.

---

BY MR. SHERARD O. COWPER-COLES, *Member, OF LONDON.*

---

### SYNOPSIS.

Introduction. Description of different methods of increasing the rate of deposit—Wilde's process; Elmore's process; Dumoulin's process; other processes; the Centrifugal process. Effect of centrifugal action. Method of making copper tubes and sheets. Mechanical tests. The formation of copper trees and nodules. Crystalline structure of electro-deposited copper. Method of forming weak line of cleavage so as to enable the deposit to be unwound from a cylindrical mandrel in the form of strip. Description of filter and atomiser. Conclusion. Appendix. Comparative costs. Analysis of copper produced. Rate at which copper can be deposited. General arrangement of a unit Centrifugal plant for producing copper sheets, tubes, and wire. Cost of plant. Cost of working Centrifugal process.

---

*Introduction.*—The numerous processes involved in the production of suitable copper and its subsequent conversion into copper sheets, tubes, and wire by a series of operations, such as rolling, drawing, and annealing, would occupy too much time to be referred to even briefly; therefore the author has limited the Paper to the direct production of copper tubes, sheets, and wire by electrolysis from impure copper.

The methods described are all based on the work of Davy and the law of electrolysis established by Faraday in 1833, namely, that when a current of electricity is passed through a solution containing metallic salts and two or more electrodes, one of which is soluble in the solution, a known quantity of metal is transferred from one electrode to the other for a given quantity of electric current; that is to say, if the soluble electrode (the anode) is connected to the positive pole, and assuming the metal and the electrolyte employed to be pure, a weight of metal will be deposited upon the cathode connected to the negative pole, corresponding to the amount of current employed. If the anode is of impure metal many difficulties are introduced, and if the current is increased to a sufficient density to enable the metal to be deposited at such a rate as will give commercial results, other serious difficulties arise. Electro-metallurgists have been working for thirty years or more devising methods to overcome the difficulties experienced in applying Faraday's law to the commercial production of copper tubes, sheet, and wire from comparatively impure copper having the physical properties of wrought copper, when deposited at a sufficiently rapid rate.

The refining of copper by electrolysis has now assumed vast proportions, and the annual output of electrolytic copper in the year 1907 has been estimated at 400,000 tons, equal to 56 per cent. of the world's production, and the capital sunk in the industry at about £15,000,000. The whole of the copper thus produced is in the form of rough slabs or cathode plates which have to be smelted and worked to the desired forms.

Electro-metallurgists have been striving for many years to devise a process which does away with the smelting of copper after it has been electrolytically refined, and to electro-deposit copper after the refining operation in such a form that it can be placed direct on the market as finished sheets, tubes, and wire.

*Wilde's process.*—It was observed shortly after Elkington practically applied Faraday's law to the refining of copper in the year 1865, that the electric current density, or the rate at which the

copper is deposited, could be considerably increased by circulating the electrolyte or moving the electrodes. It was soon found that circulating the electrolyte alone was unsatisfactory, and that the best results could be obtained with a vertical mandrel revolved in the electrolyte. Wilde was one of the first to use a cylindrical cathode, his object being to deposit copper on iron rollers suitable for textile printing purposes, for which he took out a patent in the year 1875. The anodes consisted of copper cylindrical tubes, and the iron cylinder to be coated with copper (the cathode) was placed in the centre of the cylindrical vat and caused to rotate on its axis. Such an arrangement, in conjunction with a circulating propeller placed in the electrolyte, ensured an even distribution of copper over the whole of the surface uniformly along the length of the roller by means of the motion imparted to the solution, and the equal density thus maintained. The current density was low, considerably under 20 ampères per square foot.

*Elmore's process.*—The next development of importance was the Elmore process, which consists of using horizontal mandrels on which copper sheets or tubes are deposited, while agate burnishers travel continuously over the copper, so as to consolidate it, and at the same time prevent the growth of copper trees or nodules. Even with the use of a burnisher the current density could not be increased beyond 30 ampères per square foot, and the mechanical difficulties introduced by the burnisher are considerable. Large works were erected to operate this process near Leeds and on the Continent, and are principally engaged in the production of large tubes and cylinders for special purposes.

*Dumoulin's process.*—Dumoulin introduced, at a later date, a process for burnishing copper during deposition with sheep-skin as a substitute for agate, and claimed that the process had also the advantage of insulating any projections that might be formed on the deposited metal, the sheep-skin impregnator coating all projecting parts with a thin film of animal fat, thus preventing further deposition until the surrounding depressions are raised to the common level.

It was also claimed for this process that a current density of from 30 to 40 ampères per square foot of cathode surface could be employed at a voltage of about 1.6 per vat. This process was tried on a large scale in England, but was soon abandoned.

*Other processes.*—Attempts have been made at various times to increase further 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 as shown in Fig. 1, Plate 18, which is a photo-micrograph of a lead plate coated with copper by an impingement process at a current density of 160 ampères per square foot ( $9.29 \text{ dm}^2$ ), temperature  $50^\circ \text{C.}$ ; the electrolyte being forced at a pressure of a few pounds through a lead box perforated with  $\frac{1}{8}$ -inch ( $0.32 \text{ cm.}$ ) holes at a distance of 1 inch ( $2.5 \text{ cm.}$ ) apart from centre to centre.

*Centrifugal process.*—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 ampères 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.

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.

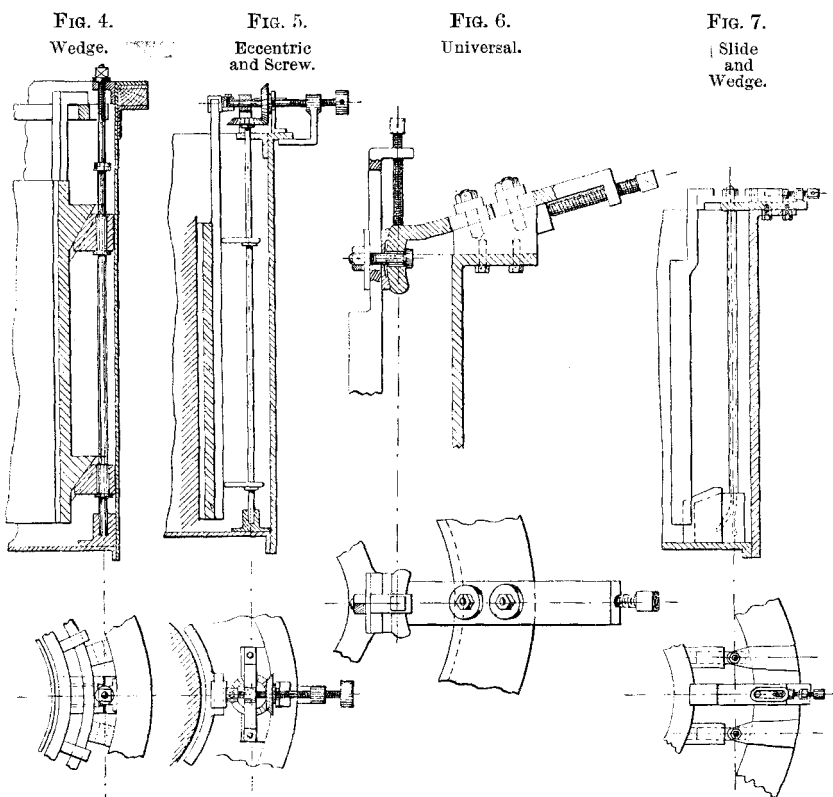
After a long series of experiments had been made to determine the best composition for the electrolyte and the most economical current density to employ, the critical speed was accurately determined by means of revolving cathodes in the form of cones, Fig. 2, Plate 18. By observing the point at which 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 ampères per square foot is found to be the most economical current density, although a current density up to 500 ampères 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. 3, Plate 18. 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. 4 to 7 (page 630), 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 ampères 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;

*Anode Adjustments.*



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.

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. 3 or Fig. 8, Plate 18, 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 strip is fitted down one side so that the sheet can be easily removed by inserting a tool under one of the edges of the deposited copper. It is no more costly by the centrifugal process to make thin sheets than thick ones; copper foil can be made in five minutes direct from crude copper. A modification of the process has been successfully applied to the recovery of the copper from scrap brass in the form of finished copper and zinc sheets.

Copper tubes produced by this process without any drawing have given a maximum stress of 17 tons, and tubes after drawing have withstood a pressure of 3,000 lbs. per square inch without showing any signs of distress, as shown by the following test made by Mr. W. G. Kirkaldy:—

Diameter outside.	Thickness of Metal (mean).	Length.	Weight per Foot.	Subjected to a Pressure.
Inches.	Inch.	Inches.	Lb.	Lbs. per sq. in.
1·123	0·063	4·94	0·814	3,000

Sheets made without any rolling have given a maximum stress of 28 to 30 tons and more per square inch according to the peripheral speed at which the mandrels were revolved. The following are some tests made by Mr. W. Harry Stanger :—

TABLE 1.

Dimensions.	Area.	Reduction of Area at Fracture.	Extension on 8 ins.	Elastic Limit. (Yield Point.) On Original Area.	Maximum Stress.	Remarks.
Inches.	Sq. in.	Per cent.	Per cent.	Tons* per sq. in.	Tons* per sq. in.	
1.109 × 0.006	0.0066	31.8	21.1	20.4	25.5	Fair break in centre.
1.135 × 0.007		17.7	20.4	28.4	28.4	Fair break in centre.
1.114 × 0.005	0.0055	—	6.3	22.4	34.6	Specimen broke outside datum points on slightly larger area.
1.124 × 0.008	0.0089	—	14.4	22.6	27.7	Specimen broke outside datum points on slightly larger area.
1.114 × 0.01	0.0111	18.9	12.0	—	27.3	Fair break.
1.121 × 0.011	0.0123	24.4	20.0	18.2	27.3	Do. Do.

Bending test. Strip bent three times upon itself. No cracks.

Fig. 9 shows the result of some comparative mechanical tests on copper pipes made by the centrifugal process and subjected to hydraulic pressure, giving results far above those required by the Board of Trade.

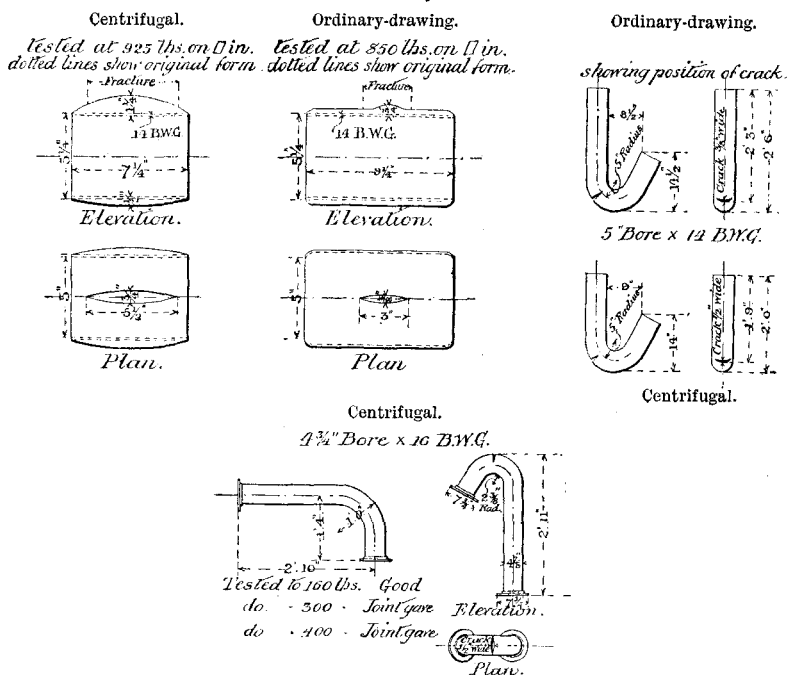
The formation of copper trees and nodules was another difficulty that had to be overcome, but which has been reduced to a minimum in the centrifugal process, for the reason that impurities held in suspension in the electrolyte have no opportunity of settling on the cathode, and all gas bubbles are swept from the surface on which the copper is being deposited.

\* Tons of 2,000 lbs.



Fig. 10, Plate 19, is a section of two nodules which illustrate the way in which they crystallize radially from a microscopic nucleus, differing in their structure from the copper sheet which crystallizes at right angles to the surface of the cathode, as is clearly shown in Figs. 10 and 11, thus forming a weak line of cleavage enabling the nodules to be easily separated from the copper sheet;

FIG. 9.—Mechanical Tests on Copper Pipes made by the Centrifugal and Ordinary-Drawing Processes.



for which reason it is impossible to produce a good sheet by any after-process of rolling. The form of the nodules or trees is largely dependent on the amount of free acid in the electrolyte; if the percentage is high, the form is rounded; if the percentage is low, then the growth is more fern- or tree-like, Fig. 12. The percentage of free acid employed in the centrifugal process is high, amounting to 12 or 13 per cent. The electrolyte, the usual composition of which is 12.5 per cent. of copper-sulphate and

13 per cent. of sulphuric acid at a temperature of 40° C. (104° F.), is kept in the cupric state, and the impurities in suspension are separated by means of a centrifugal filter provided with arc lights and an atomizer for breaking the solution up into a fine spray, as shown in Figs. 13 and 14, Plate 20. It has been found that subjecting the solution to a strong light the impurities are more easily precipitated, and the solution is kept in the cupric state.

The production of copper wire by electrolytic means is a more difficult problem than the production of copper tubes and sheets. Various processes have been suggested and tried from time to time, such as the electro-deposition of copper on thin wire, until it has obtained a considerable thickness, and then drawing the thickened wire down to a comparatively fine wire. Swan and Sanders have both experimented with such processes, but so far they have not been worked commercially.

Elmore's process consists of producing copper tubes by his burnishing process, cutting them into long spirals and then drawing them into wire.

Other experimenters have tried placing an insulated spiral strip on a cylindrical mandrel so as to produce long copper spirals, but such an arrangement only allows of a very low current density being employed, on account of the nodules which form on the edges of the strip, even at very low current densities, rendering the strip unsuitable for drawing down into wire.

Copper wire is made by the centrifugal process in the following manner:—A mandrel similar to that used for making copper sheets is employed, around which a spiral scratch is made, the pitch being determined by the size of wire required.

The effect of the spiral scratch (which need only be very light but must be angular), is to cause the crystalline structure of the copper to form a cleavage plane, as shown in Fig. 15 (page 635). It will be observed that the copper divides exactly at the apex of the scratch, that is, the copper deposited in the scratch is equally divided and forms a small V-shaped fin on two sides of the copper strip, Fig. 20, Plate 20. If the scratch is not angular, but rounded at the base, the copper will not divide, as the crystals are radial, as shown in Fig. 16. After the desired thickness has been obtained,

approximating the pitch of the spiral scratch, the mandrel is removed from the depositing cell and placed in a vertical position on a lathe, Fig. 18, Plate 20, and the copper strip is unwound at an angle of about 45 degrees to the face of the mandrel, Fig. 19. During the process of unwinding, the small fin or burr is removed by passing the wire through a suitable die and then through a wire-drawing machine provided with three or more draw-plates to reduce the strip to the desired diameter. By employing a mandrel of 6 or 7 feet in diameter, lengths of wire 4 or 5 miles can be made in one operation. Very fine wires are produced by making a fine scratch on a hard wax disc or cylinder.

FIG. 15.—Diagram showing method of forming weak line of cleavage due to crystalline structure.

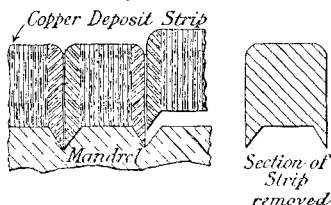
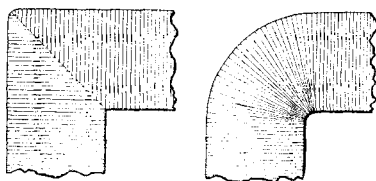


FIG. 16.—Diagram showing the effect of sharp and rounded corners on the crystalline structure of metal castings.



**Conclusion.**—The advantages of an electrolytic process as compared with a smelting process are many, and the day is not far distant when copper will no doubt be leached direct from the ore and electrolyzed with insoluble anodes, to produce finished copper sheets and tubes in one operation direct from the ore without the intermediate process of smelting and refining.

The centrifugal process is a step in this direction, as it is capable of depositing copper from its solutions by using insoluble anodes in the form of finished tubes or sheets in one operation. The centrifugal process is at least ten times faster than any existing electrolytic process, and a high current density can be employed without deteriorating the quality of the copper. There is no risk of lamination, as no burnishers are employed. The plant is simple and free from mechanical complications, and the amount of copper locked up for a given output is small compared with other processes. The process is of interest to mechanical engineers, as it conclusively proves that to obtain a high tensile strength in metals combined with

ductility, it is not essential to put a large amount of work into the metals as hitherto has been considered necessary, by the processes of swaging, rolling or drawing, but that a very small amount of energy will suffice when applied in the manner described in the Paper. The centrifugal process ensures the copper being deposited in a close coherent form with a crystalline structure like wrought-copper.

In conclusion, the author hopes the special apparatus designed to overcome the mechanical difficulties that were encountered may prove of interest to the members of the Institution.

The Paper is illustrated by Plates 18 to 20 and 7 Figs. in the letterpress, and is accompanied by an Appendix with 2 Figs.

## APPENDIX.

Fig. 21 gives the comparative cost of producing copper sheets by the process of smelting, refining, casting, and rolling, as compared with the centrifugal process.

*Comparative Cost of producing Copper by the present method and the Centrifugal Process. (Exclusive of trade allowances.)*

FIG. 21.  
SHEETS.

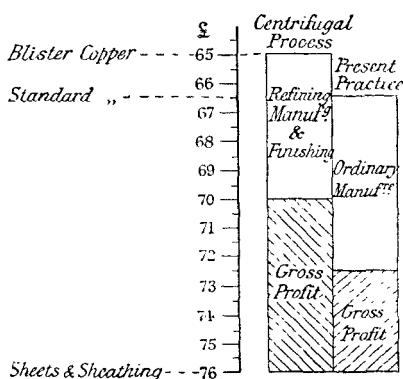
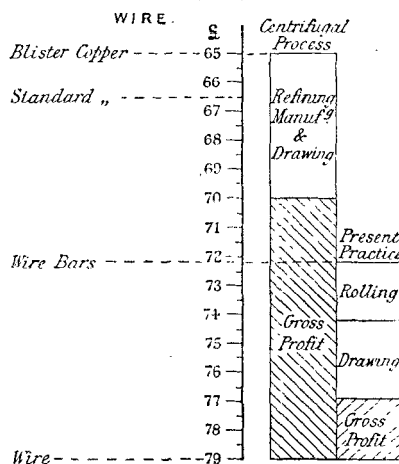


FIG. 22.



NOTE.—The cost of power in the above comparison was taken at a higher rate than that of the estimate in Table 3 (page 639). On the basis of that Table the dividing line between "Refining, &c.," and "Gross Profit" in Figs. 21 and 22 should be raised as far as the figures £67½.

Fig. 22 gives the comparative cost of producing wire by the ordinary process of smelting, refining, rolling, and drawing, and the centrifugal process.

The following is a typical analysis of the copper produced by the centrifugal process :—

Iron . . . . .	0·0189
Arsenic . . . . .	0·0015
Lead . . . . .	0·0013
Antimony . . . . .	0·0010
Bismuth . . . . .	0·0008
Silver . . . . .	absent.
Nickel . . . . .	absent.
Sulphur . . . . .	absent.
Copper (by difference) . . . . .	99·9765
	<hr/>
	100·000

Under favourable conditions almost the theoretical weight of copper is obtained, and Table 2 (page 638) gives the weights and thicknesses of copper deposited in an hour at the current densities usually employed.

The capital expenditure of a plant, Fig. 17, Plate 20, for the centrifugal process both for the manufacture of sheets, tubes, and wire, compares very favourably with an up-to-date rolling mill and wire-drawing plant. The cost of such a plant, with buildings, is about £80,000 for an output of 100 tons per week or 5,000 tons per year. The following is an estimate of the cost of a plant for the centrifugal process capable of dealing with 10,000 tons of tubes, sheets, and wire per annum :—

*Estimated Cost of Plant for producing 10,000 tons of Tubes, Sheets, and Wire per annum by the Centrifugal Process.*

	£
Cost of 95 vats and accessories . . . . .	64,000
Machinery for finishing tubes, sheets and wire . . . . .	5,000
Cranes and lifting gear . . . . .	1,500
Building . . . . .	15,000
Plant for mandrel-making . . . . .	2,000
Machinery for fitting shop . . . . .	1,500
Pumps, atomizers, filter tanks . . . . .	5,000
Driving machinery for vats . . . . .	5,000
Conductors and electrolyte . . . . .	5,000
	<hr/>
	104,000
Floating capital for copper . . . . .	30,000
	<hr/>
	134,000

TABLE 2.

*Table giving the Weight and Thickness of Copper deposited per hour at various Densities, with metrical equivalents.*

Current density in amperes per square foot.	Current density in amperes per dm <sup>2</sup> .	Weight of Copper deposited per hour per square foot.	Weight of Copper deposited per hour per square foot.	Weight of Copper deposited per hour per dm <sup>2</sup> .	Weight of Copper deposited per hour per dm <sup>2</sup> .	Thickness of Copper per hour.	Thickness of Copper per hour.
		Lb.	Grammes.	Lb.	Grammes.	Inch.	Mm.
150	16·140	0·3893	176·55	0·0419	19·0036	0·00872	0·22155
160	17·216	0·4153	188·32	0·0448	20·2704	0·00930	0·23632
170	18·292	0·4413	200·09	0·0475	21·5373	0·00988	0·25109
180	19·368	0·4672	211·76	0·0501	22·8042	0·01046	0·26586
190	20·444	0·4932	223·63	0·0530	24·0711	0·01105	0·28063
200	21·520	0·5191	235·40	0·0558	25·3381	0·01163	0·29540
210	22·596	0·5451	247·17	0·0586	26·6149	0·01221	0·31017
220	23·672	0·5710	258·94	0·0614	27·8718	0·01279	0·32494
230	24·748	0·5970	270·71	0·0642	29·1387	0·01337	0·33971
240	25·824	0·6230	282·48	0·0670	30·4156	0·01395	0·35448
250	26·900	0·6489	294·25	0·0698	31·6725	0·01453	0·36925

TABLE 3.

*Estimate of Cost per ton of Producing Copper Tubes, Sheets, and Wire by the Centrifugal Process direct from Crude Copper.*

	£	s.	d.
Power per ton (2,240 lbs.) 1,015 kw.-hours at 0·275d. per kw. . . . .	1	2	2
Wages at 8d. per hour, 18½ hours . . . . .		12	4
Management . . . . .		5	0
Interest on copper lock-up . . . . .		1	0
Depreciation on plant and building . . . . .		10	0
Heating electrolyte . . . . .		1	0
Finishing and gauging . . . . .		5	0
Cost per ton . . . . .	2	16	6

These figures represent the actual working cost on which there would be a further reduction of the precious metals recovered, and if £1 10s. be deducted from the above cost, which may be taken as an average difference between Chile-bar and electrolytic copper, the cost per ton is reduced to £1 6s. 6d.

### *Discussion.*

On the motion of the PRESIDENT, a cordial vote of thanks was passed to the author for his interesting Paper.

Mr. F. G. WRIGHT, in opening the discussion, said that it appeared to him that the subject appealed more to manufacturers of copper tubes and wire than to engineers who used them. There could be no doubt, however, that it was a very valuable Paper on the subject, and he would much prefer to hear the opinions of those gentlemen who had to do with the manufacture of copper than of those who used it.

Mr. EDWARD P. MARTIN, Past-President, said he had had the opportunity of seeing the experiments, which had been referred to in the Paper, carried out, and he had been struck with the fact that the

(Mr. Edward P. Martin.)

production of the thinnest sheets, which usually was far more expensive to make than thick sheets, was cheaper than the production of the thick sheets. By this process complicated tubes and other finished articles seemed to be produced easily and cheaply. The process, he thought, might considerably affect the cost of manufacture of iron, steel, and copper into thin tubes and sheets.

Mr. H. H. Cox hoped manufacturers would not be carried away by the idea that the new process the author had described would be everything that was perfect. Before putting it into commercial use he trusted they would give it practical trials, not only in the way of tensile tests but also tests of durability on actual work, especially in connection with copper tubes. Manufacturers knew the disastrous results of some of the work done by another process, which had been tried for marine work and steam-piping, and unless the latter was of dependable material and was well made there was a great risk to life and limb.

Mr. G. T. CHILD said that a good deal of trouble was sometimes experienced by the deposited copper sticking to the mandrel, and he would therefore like to know whether any insulating material was used on the mandrel before the copper was deposited on it.

Mr. WILLIAM LANGDON said that the author had given the typical analysis of the copper produced, but he would like to ask him what analysis he had obtained by his process, from the slimes, compared with other electrolytic processes, because gold and silver were often precipitated to a certain extent from the copper anodes. He had had something to do with the Dumoulin process at Widnes some years ago, and although it was not quite a success, they managed to obtain some precious metal out of these slimes, which was about the only profit they did get. [See page 643.]

Mr. W. H. DUGARD thought the process was a considerable improvement on the usual one. According to the Tables it appeared as though it would be considerably cheaper, but he thought there was not sufficient evidence yet of its thorough reliability as to



homogeneity and tensile strength. If more evidence of that nature from actual use under ordinary working conditions was forthcoming it would be useful, and would be more likely to lead to its adoption.

With regard to the production of wire, it appeared to him that unless the small ridge or fin was properly removed, it would be liable to produce two laminated spills in drawing down the wire. He noticed that some of the sheets were very thin, and therefore would like to know whether they had been rolled at all since the deposition, or polished in any way. They appeared to him to be of very uniform thickness, and he would like to know whether a uniform thickness over a large surface for large sheets could be relied upon in the process of deposition.

Mr. EDWARD B. ELLINGTON, Vice-President, asked the author to inform the members what practical use had been made of the sheets and pipes described, or whether the process was at present in a purely experimental stage.

Dr. W. CAWTHORNE UNWIN thought that a remarkably high yield-point was given in Table 1 (page 632). A yield-point up to 28 tons per square inch was very remarkable indeed for copper. Engineers understood very well what the yield-point meant when they were talking of mild steel, but he was not quite sure they understood so well what it meant when referring to copper. He therefore thought it would add very much to the value of the Paper if the author would give an autograph diagram of one of the tensile tests showing exactly where he placed the yield-point.

Mr. LOUGHNAN PENDRED asked whether in all cases cylinders had to be deposited in the way described, or whether it was possible to make bends and various shapes without working the tube up afterwards.

Mr. DANIEL ADAMSON suggested that the author's estimate for power of 0.275*d*, per kw. given in Table 3 (page 639) was very low. In his opinion three times that amount would be more nearly correct.

(Mr. Daniel Adamson.)

He asked the author in his reply to state on what assumption that figure was based.

Mr. W. C. GOODCHILD enquired whether wire made by the author's process would withstand the ordinary torsion and bending tests such as were required by the Post Office, because he noticed the only tests mentioned in the Paper were what might be called "static" tests, that is, hydraulic and ordinary extension tests.

Mr. COWPER-COLES, in reply to Mr. Martin's remarks, said the process showed a greater saving for thin sheets than for thick, as the electrolytic process was a building-up and not a breaking-down process. The centrifugal process as described in the Paper was limited to the production of copper in the form of sheets, tube, wire, and cylindrical vessels. Mr. Cox had referred to the production of tubes for steam-engine purposes, and had mentioned the burnishing process. The great difference between the process he (the author) had described, and other electrolytic processes was that there was no mechanical burnishing during the process of deposition, a feature which had always led to failure in the past. Wherever the burnisher passed over the metal, after a time it was found to laminate. In the process described in the Paper the copper was not treated mechanically, so that there was no fear of lamination.

Mr. Child had asked whether any insulating compound was put on the mandrel to enable the copper to be readily stripped. The mandrels were treated chemically, so as to produce a film of copper-sulphide on the surface, which enabled the copper to be readily stripped off. In reply to Mr. Langdon's enquiry, the slimes obtained by the process were the same as those obtained from any other electrolytic process, with the exception that the percentage of copper was less; all the gold and silver were recovered from the anode copper.

In answer to Mr. Dugard's enquiry, samples of sheets exhibited had not been rolled or treated in any way; they were just as they were removed from the mandrel. In some cases, when produced in the form of cylinders and then cut down the side after removal, a roller was passed over to loosen the cylinder on the mandrel to enable the cylinder to be drawn off, but usually an insulating strip was put

down one side of the mandrel, to enable the sheet to be taken off without any rolling. With regard to the production of wire, the small fins shown had to be removed to produce a good wire, and this was done in the first drawing operation. The first die was constructed in such a way that it drew off the fins; if they were not drawn off, a skin was formed on the wire which was objectionable for electrical purposes.

In regard to Mr. Ellington's question as to whether the process had been applied commercially, for over four years large cylinders had been made for the textile industry, which were put to very severe tests under actual working conditions. The cylinders used for stencilling work were put under a heavy tensile strain as a continuous copper band, the inking rollers being inside. A number of tubes and wires had also been put to the usual tests, which they had withstood as well and in many cases better than similar cast and drawn copper specimens.

The power figures to which Mr. Adamson referred were taken from actual contracts which had been offered by power stations, provided the plant was put down close to the generating station. The load was reduced at certain periods; power could be obtained under such conditions at the present time in several districts at the price mentioned. In answer to Mr. Goodchild's enquiry, wire produced by the electrolytic process would stand the ordinary Post Office torsional tests, and was equal in every respect to drawn wire.

In reply to Mr. Pendred's question, as to whether it was not possible to make bends by the process, straight cylinders had to be made and bent afterwards, although flanges could be made direct on pipes by the centrifugal process.

#### *Communications.*

Mr. WILLIAM LANGDON wrote, in continuation of his remarks at the Meeting, that he would like to ask the author whether any trouble or difficulty arose with his mechanical feeding arrangement, Figs. 4 to 7 (page 630), by dissolving away, with the anodes themselves, as the whole seemed somewhat complicated for an immersion in the electrolyte. Seeing that the anodes were thinned away, often very

(Mr. William Langdon.)

irregularly during the process, the wedges might therefore be liable to work loose or unevenly and alter the vertical alignment, and also voltage. If the feeding apparatus were insulated and protected, possibly this difficulty might not be great.

The vertical cathode with all working parts outside the vat was a great advance over the horizontal position, and overcame one of the chief difficulties encountered hitherto in the electrolytic process, but it would be of interest to know, whether large perfectly smooth sheets, say up to 1 inch in thickness, by 12 feet by 4 feet, such as were produced at Widnes by the Dumoulin process, could be made, and which after annealing required no finishing in the rolling mill to bring them to a uniform thickness and smooth surface. In the thick sheets or plates referred to, laminations were very seldom met with, and the surface by the continual passage of the chemically prepared skin lightly touching it (no burnishing as with agates) produced a very smooth face; a great advance however has been attained if this operation could be suppressed altogether.

There was a considerable difference in the composition, treatment, and temperature of the electrolyte described in the Paper from that used at Widnes; this was certainly an important factor, together with the enormous increase in the current density to 200 ampères per square foot of cathode area.

The author was to be congratulated on having overcome great difficulties met with in successfully producing copper strips (pages 634 and 635) suitable for wire-making, the writer being one of the first to experiment with the spiral scratch on the mandrel as described in Fig. 15; but owing to the brittle nature of the metal produced and other difficulties, was not successful. Therefore Figs. 18, 19 and 20, Plate 20, were of unusual interest.

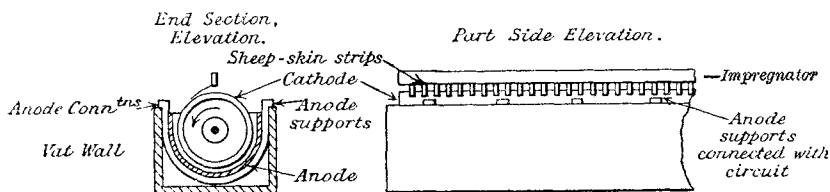
In considering the progress and improvements introduced by the author over other centrifugal processes for the production of copper sheets, tubes, and wire by electrolysis, the writer, who was for nearly two years manager of the works in Widnes operating Dumoulin's process, had therefore experienced most of the difficulties described in the Paper (page 629). He regretted the author did not state what the annual output of the works was, and where his plant was working.

The following is a short description of the "Dumoulin" process :—

*Plant.*—The dynamos are direct current machines, yielding 1,300 ampères at 75 volts, equal to 97·5 kw. There are thirty vats for depositing sheets, each being a shallow wooden trough, lined with lead provided with supply and exit pipes, for the circulation of the electrolyte. This contains about 7 per cent. of sulphuric acid, 40 per cent. of cupric sulphate, density 22–23 Beaumé, temperature 24° C.

*Cathodes or Mandrels* are hollow cylinders of copper, 12 feet long by 16 inches in diameter, capped at each end and mounted on insulated bearings, and they are immersed horizontally. The electrolyte covers about two-thirds of their surface, and is kept in constant

FIG. 23.—*Depositing Vat (Dumoulin), Centrifugal Process.*



agitation during the passage of the electric current by the centrifugal movement of the cathode; the sheep-skin impregnators (from which all the fat has been extracted by chemical treatment), which give coherence and density to the deposit, are fixed in a light metal frame, extending from end to end above the cathode, and are kept in motion sliding to and fro, the travel being varied by an eccentric operating a pall and rack so as to alter the position of contact with the cathode. The lateral speed or travel of the impregnator for a 16-inch diameter cathode making 45 revolutions per minute was found to give best results when making about 60 strokes. The surface of the cathode is covered with a thin film of tallow or plumbago, to prevent the deposit adhering, and to facilitate the removal of the sheets, at the end of the operation.

(Mr. William Langdon.)

*Anodes.*—These are cast in halves in a semi-circular form, 2 inches thick, 4 feet long, with oval holes to aid circulation of the electrolyte; they rest on eight copper supports, provided with flanges resting on the tops of the vats. Fig. 23 (page 645) shows the Dumoulin arrangement of anodes and cathodes. Aluminum supports were first tried, but without success.

After the deposit has “struck” all over the surface of the mandrel, the bar holding the strips of sheep-skin is brought into the vertical position, and the deposition of copper proceeds without further attention. The mandrel is revolved at a high speed, and the electrolyte is kept in rapid circulation during the whole period of deposition.

Under normal working conditions it requires about 10 hours to deposit 44 lbs. copper in one vat, and the tube thus obtained is about 25 gauge in thickness and weighs about 14 ounces to the square foot. The current density used is between 35 and 40 ampères per square foot of cathode area, whereas 20 ampères is the maximum now attained in electrolytic refineries with stationary cathodes; and formerly the current density used in these rarely exceeded 4 ampères. The gain in the time to deposit large amounts of copper at the cathode is very marked, and the output of a plant could therefore be greatly increased by use of rotating cathodes. The voltage required is about 1.6 per vat, but this rises as the anodes are eaten away. When the deposit has attained the desired thickness, the mandrel, with its casing of pure copper, is bodily removed from the vat by a travelling electric crane, and is carried to a specially designed lathe, where a longitudinal cut is made from one end of the cylinder to the other, and the resulting sheet of electrolytic copper stripped off with ease. The whole operation does not occupy more than five minutes, and after applying a special composition to the surface of the mandrel, it is again ready for immersion in the electrolyte. The sheets of copper formed in this manner weigh about 44 lbs., and have a superficial area of 48 square feet. In the case of boiler-tubes, the removal of the mandrel from the interior of the deposited copper tube is effected by means of a hydraulic press. The depositing building at Widnes contains 30 vats similar to the above, and

therefore, when worked to its full capacity, can produce 60 sheets per working day. The sheets of copper are carried from the depositing house to an adjoining building where they are annealed in a muffle furnace at a dull red heat, and then pickled in dilute sulphuric acid to remove the scale of oxide formed during the annealing process. Opening out of the depositing house is a large building in which the electrolyte of copper sulphate is filtered, cooled, and pumped to the storage tanks, from which it flows by gravity through the depositing vats back to the well in the same building. The filtration and cooling of the electrolyte after each passage through the depositing vats is found to be essential to the successful conduct of this process.

A large machine shop, a laboratory, and a store house for the finished copper complete the works. Tests of the sheet copper produced by this process have shown a tensile strength of  $18\frac{1}{2}$  to 24 tons and an elongation of 28 to 30 per cent.

Mr. R. D. SANDERS wrote that the author, in alluding to what had been done in this direction by Mr. Swan and the writer, said that the process of depositing upon a thin wire had "not been worked commercially" (page 634). That was a statement which required correction. As a matter of fact very many tons had been deposited upon a thin wire by the writer's process, and used in nearly all foreign countries and by principal users in this country. Orders and repeat orders had been received far in excess of what their works were able to produce, and they were only waiting for the erection of larger works to take in hand the very extensive contracts which had been offered.

It would seem that the author's experiments led to the conclusion that a very rapid revolution of the cathode was necessary to produce a smooth homogeneous deposit, and that high current densities were only applicable with such high speeds. The writer's experience during the manufacture of over 100 tons of wire rather pointed in the opposite direction, and his opinion was that the best deposit was obtained when the natural formation of the crystals at the cathode was not interfered with. With this communication he sent a piece

(Mr. R. D. Sanders).

of deposited wire cut from one of his 100 yard coils, just as it came from the vat. This was deposited in practically a *still electrolyte*. Its conductivity was 102 per cent. of Matthiessen's standard, thus proving it to be pure copper. Its surface and density showed that rapid rotation was not essential to a good deposit, and power so employed was so much waste energy and expense.

The author seemed to insist upon the rapid rotation of the cathode being essential to the employment of high currents and rapid deposition. The writer had deposited good copper with a current density of over 250 ampères per square foot, and he was informed that Mr. Swan had succeeded with a current density of 1,000 ampères per square foot. He did not mean to say that rotation of the cathode was unnecessary for the employment of high current densities, but his practical experience from a commercial point of view had convinced him that excess in either brought about many difficulties and waste of energy. This had been proved in the daily working of 84 vats capable of turning out about 10 tons of  $\frac{3}{8}$  inch copper-wire rods per week. After working six months with a moderate rotative speed of the cathodes, he reduced the speed one half with very beneficial results, both in the quality of the deposit and rate of production.

He agreed with the author's remarks as to the difficulties inherent in an electrolytic process for the production of copper tubes, etc., by which he meant the destruction of the working parts in an acid copper-sulphate solution. Many years ago he manufactured wire on metal cylinders grooved in a similar way to the author's, but owing to their rapid destruction they were abandoned in favour of porcelain, which in like manner had to be discarded.

It would be useful if the author would explain of what metal or substance his vats were constructed, and how he prevented destruction of the stuffing-boxes, glands, and the internal supports exposed to the action of the liquid. The cost of working so far as the power was concerned was easily ascertained, because it was well known what weight of copper a given current would deposit, but the cost and upkeep of an electrolytic plant was a matter of great moment affecting the cost of production. Unless the author had found



perfectly indestructible material for the whole of his apparatus, the cost of maintenance and renewal would be very heavy indeed.

A most important matter, which the author had not touched upon, was the circulation of the electrolyte. Perhaps he would explain how he kept the electrolyte of uniform composition in a series of vats, without which the deposit would not be uniform.

Mr. COWPER-COLES wrote in reply to Mr. William Langdon that, so far, no difficulties have been experienced with the special anode adjustments; the wedges were at the back of the anodes and insulated so that little or no corrosion took place. It would be interesting to have further particulars of the experiments made by Mr. Langdon with spiral scratches on the cathode; the chief cause of the failure of his experiments was probably due to the scratches being rounded instead of V-shaped, which was essential to success. There was no difficulty in making thick sheets, of even larger dimensions than those given by Mr. Langdon, by the centrifugal process without rolling. Mr. Langdon wrongly described other processes as centrifugal; they were not dependent on centrifugal action, but relied on some mechanical rubbing process.

As regards Mr. Sanders' remarks, he had no intention of doing him an injustice by saying that his wire process had not been worked commercially. Those who had studied the question of the rapid electro-deposition of copper were aware that rapid circulation or rapid rotation of the cathode were essential conditions to obtain a smooth copper of high tensile strength which did not require smelting. Mr. Sanders omitted to state that the deposits obtained under the conditions he mentioned were rough and covered with nodules, and therefore useless for commercial purposes.

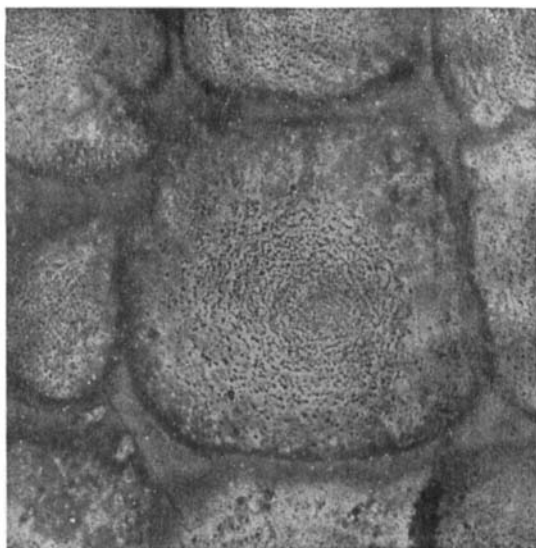
Mr. Sanders' statements with reference to the manufacture of wire on metal cylinders grooved in a similar manner to that employed for the scratch method were liable to mislead those who had not made a special study of the subject. His methods consisted of depositing in grooves with an insulating strip between, so as to produce a triangular or flat-shaped strip which afterwards had to be drawn down. Such a process was impracticable for reasons mentioned

(Mr. Cowper-Coles.)

in the Paper. Mr. Sanders would no doubt observe, on reading the Paper, that there were no stuffing-boxes, glands or internal supports exposed to the action of the liquid; the difficulty had been overcome by using an annular vat as described and as shown in Fig. 3, Plate 18, and Fig. 17, Plate 20. He would also have observed that the solution was circulated by allowing it to enter at the bottom of the vat and flow out near the top, and in addition to this the solution was circulated in series from vat to vat as shown in Figs. 3 and 17, thus ensuring the perfect mixture of the electrolyte.

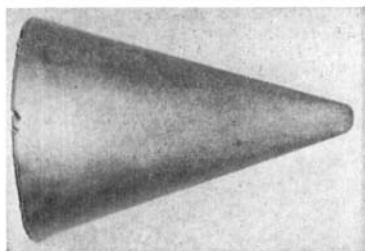
As regards Mr. Sanders' method of making wire by depositing it on a fine wire matrix, it would have been interesting if he had stated how he had overcome the following difficulties which were inherent in any such process:—(1) The high voltage required; (2) the low current density which must be employed to obtain a coherent deposit; (3) the large amount of plant required for a small output; (4) the rough surface of the wire-rod produced which created flaws in the wire, and (5) the difficulty due to lamination between the internal wire core and the deposited copper.

---

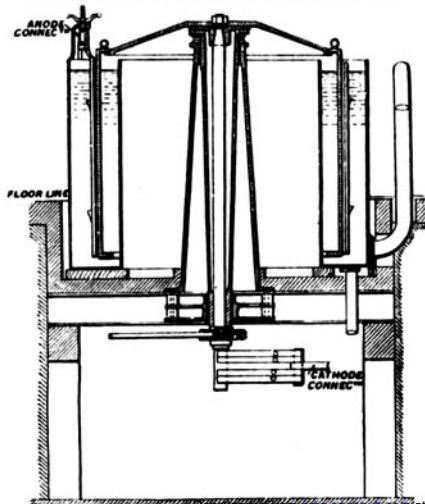


**Fig. 1.**  
*Cathode Surface,  
lead coated with copper,  
showing effect of  
impingement of jets  
of electrolyte.*

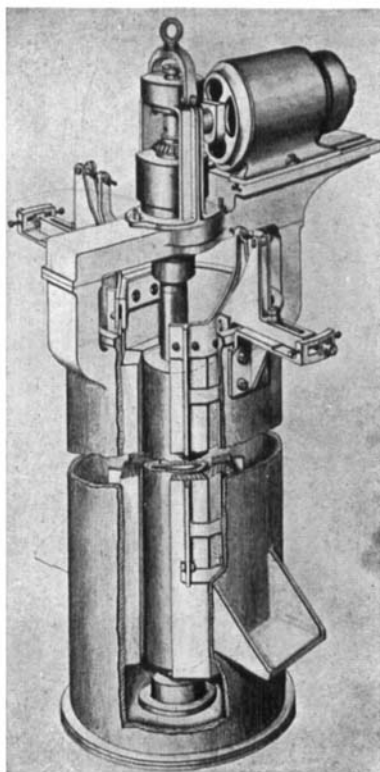
**Fig. 2.** *Copper Cone to determine  
critical speed.*



**Fig. 3.** *Vat used for Centrifugal Process.*



**Fig. 8.** *Apparatus for depositing Copper  
on Iron Rolls.*



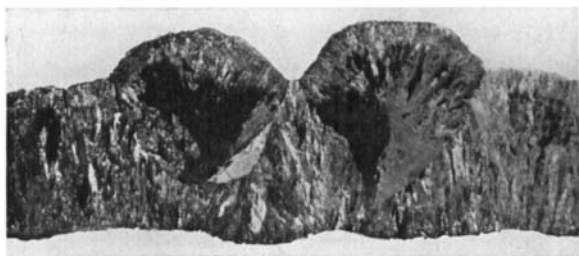


Fig. 10.  
*Radial Crystalline  
Structure of  
Copper Nodules.*

Fig. 11. *Crystalline Structure of Deposited Copper.*

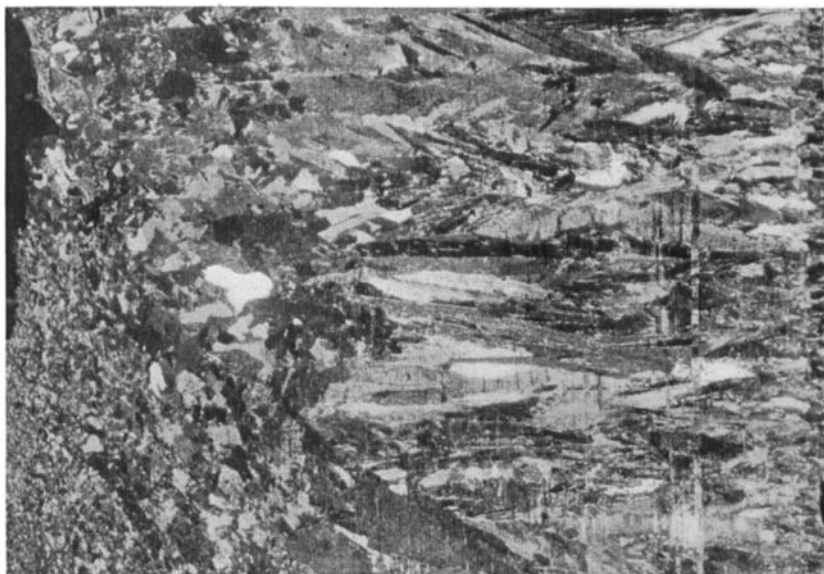


Fig. 12. *Copper Trees, effect of Free Acid on Nodule Formation.*

*No Free Acid.*

*2 oz.  $H_2SO_4$  to gal.*

*6 oz.  $H_2SO_4$  to gal.*



*8 oz.  $H_2SO_4$  to gal.*

*10 oz.  $H_2SO_4$  to gal.*



# COPPER TUBE, SHEET, AND WIRE PRODUCTION. *Plate 20.*

Fig. 13. *Atomiser.*

Fig. 14. *Filter.*

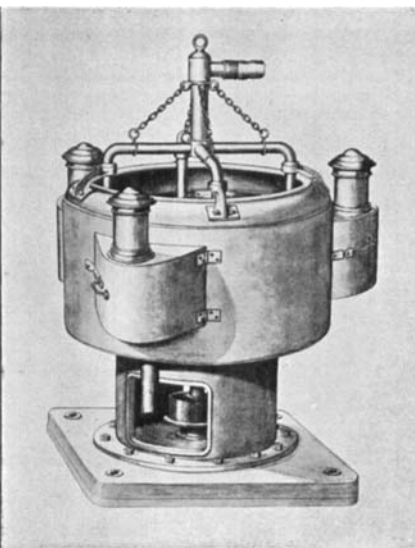
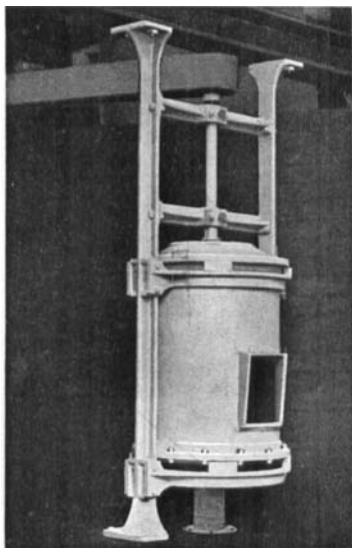


Fig. 17. *General Arrangement.*

Fig. 18. *Lathe for Unwinding Copper Strip.*

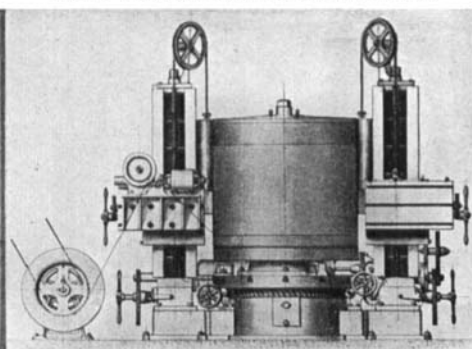
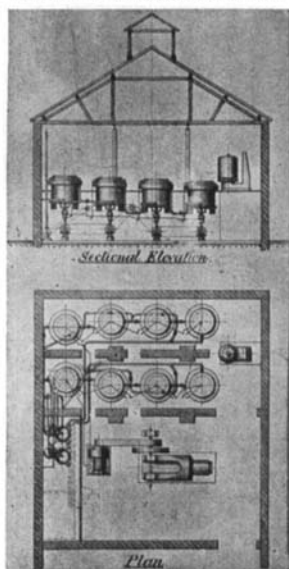


Fig. 20. *Section of Copper Strip, showing cause of cleavage.*

Fig. 19.  
*Mandrel, showing method of unwinding copper strip.*

