due to the fact that the silver gradually shades off towards the clear glass. Occasionally, however, each band, in passing from the glass-air to the glass-silver surface, is joined to *both* the nearest bands on the silver. It was due to this cause that Quincke was unable to say whether an acceleration or retardation was produced.

Wernicke states that a retardation is only produced when the silver is of a friable nature, and could be readily rubbed off the glass. The accompanying photograph was obtained with a silver film that easily bore polishing, and showed no want of adherence to the glass.

E. EDSER.
H. STANSFIELD.

## *MICRO-STRUCTURE OF ALLOYS.*

AT the Royal Society's conversazione this year, Mr. J. E. Stead exhibited a series of photographs illustrating the micro-structure of various alloys. In many cases the structure portrayed was very complex and interesting, and in some cases beautiful.

Many series were illustrated by Mr. Stead, but it would take much more space than is available in a short notice to more than point out briefly the main features of a few.

The photographs showed that when the antimony exceeded 7·5 per cent. in antimony-tin alloys, the excess over that amount separated out with an equal atomic proportion of tin as more or less perfectly formed cubes. That they were crystals of definite chemical atomic composition Mr. Stead had verified by several careful analyses after having dissolved away the eutectic, or what was once the mother liquor, with nitric acid, which left the crystals intact. The photographs of alloys of tin containing phosphorus and arsenic had the appearance of very straight bright lines, which cut up the surface into irregular figures. These lines are the edges of flat plates, which, when separated by dissolving away the tin, have been proved by analysis to have the composition of $Sn_3P_2$ and $Sn_3As_2$, respectively. The photographs of the separated compounds indicate that they had both the same crystalline form of hexagonal plates. A photograph of one of the free ends of a plate showed several pointed crystals having angles of 60°.

The structure of tin-copper alloys rich in tin was illustrated by several photographs, which showed that in alloys containing from 2 to 0·10 per cent. copper acicular crystals were present, and that with each addition of copper the separated compound assumed a more plate-like structure, until when 35 per cent. copper was present, apparently it was all in the form of plates. All these compounds have been separated and analysed by Mr. Stead, with the following results :—

| Alloy. | Crystals separated. Copper. | Tin. | |
|---|---|---|---|
| 98·0 % tin, 2·0 % copper ... | 34·58 % | 65·42 % | SnCu (approximate.) |
| 97·0 ,, 3·0 ,, ... | 36·50 ,, | 63·50 ,, | |
| 95·0 ,, 5·0 ,, ... | 39·80 ,, | 60·20 ,, | |
| 90·0 ,, 10·0 ,, ... | 44·60 ,, | 55·40 ,, | $Sn_2Cu_3$ ,, |
| 85·0 ,, 15·0 ,, ... | 47·20 ,, | 52·80 ,, | |
| 80·0 ,, 20·0 ,, ... | 53·00 ,, | 47·00 ,, | |
| 65·3 ,, 34·7 ,, ... | 56·12 ,, | 43·88 ,, | $SnCu_2$ ,, |

It will be seen that although the compound separated from the 2 per cent. alloys approximates to the composition of SnCu, each addition of copper to the alloy results in the formation of a compound which after separation proves to contain a greater proportion of copper than that from the alloy containing less copper.

It has not yet been proved whether these compounds are amorphous mixtures or combinations of one or more atomic chemical constituents.

It appears that in all the solid alloys of lead and antimony the elements are in a free state. There is a eutectic which contains 12·7 per cent. antimony. Those having more than that quantity of antimony contain large crystals of free antimony, which until 50 per cent. is present are found at the upper part of the alloy if the cooling of the liquid alloy has been sufficiently slow, but between these crystals the eutectic is clearly visible. When the antimony is increased to 50 per cent. the white crystals and dark eutectic occupy nearly equal areas, and with each addition of antimony the dark areas diminish until when 100 per cent. is present the surface presents a homogeneous white appearance free from the dark eutectic.

With alloys containing less than 12·7 per cent. antimony the polished and etched surfaces clearly show the presence of dendritic crystals of lead.

The eutectic has the very peculiar structure similar to that of nodular radiated pyrites. On treating this compound with dilute nitric acid for a long period, a coherent dark-coloured mass is left free from lead, and which appears to consist when broken up as very fine bright plates, exceedingly thin and easily broken up, with the slightest pressure, into what appears to be an amorphous powder.

FIG. 1.—× 30.
Sn, 75 per cent. ; Sb, 20 per cent. ; As, 5 per cent.

Mr. Stead and Mr. Charpy have simultaneously investigated the alloys of tin-antimony, tin-copper, and lead-antimony, and the results of their micro-examinations are almost identical; but Mr. Stead has supplemented his micro-research with chemical examination, which greatly increases their value.

The micro-structures of ternary alloys are of very much greater interest than those of two metals only, for Mr. Stead

FIG. 2.—Magnolia metal. Magnified 200 diameters.
Pb, 80 per cent. ; Sb, 15 per cent. ; Sn, 5 per cent.

has shown that it is possible to detect two, and sometime three, distinctly different compounds in the same microscopic field. Sometimes two of the elements combine and crystallise together ; sometimes three will so unite. Examples of tin-copper-antimony, and tin-antimony-arsenic (Fig. 1), and lead-antimony-tin (Fig. 2), and tin-antimony-phosphorus were shown at the Royal Society.

The photographs show that in the tin-antimony-copper (tin being in large excess) the copper-tin in the form of needles or plates crystallises out quite separately and independently of the antimony-tin compound which exist as cubes, and both occur side by side in the same alloy. A similar thing occurs with the tin-antimony-phosphorus alloys, the plates of phosphide of tin, and the cubes of antimonide of tin being clearly separate. The eutectic of magnolia metal (lead 80 per cent., antimony 15 per cent., and tin 5 per cent.), under high magnification presents a very beautiful structure, quite different from that of lead and antimony alone, and the fine delicate structure (Fig. 2) apparently consists of crystallites of the cubic system, and these possibly are a combination of the three metals present.

The structures of the tin-antimony-arsenic alloys are very remarkable, and evidently the crystals formed consist of what might be called tin-antimony-arsenides, for they all crystallise together in a fusible eutectic. The alloy, containing tin 75 per cent., antimony 20 per cent., arsenic 5 per cent., presents a most interesting appearance (Fig. 1); the sections of the white crystals are of more or less perfect circular form, and in the solid alloy they exist as spheres, the fractured surfaces proving this to be the case.

Micro-metallography is a comparatively new science, the borders only of which have been but slightly studied, but it promises to give results of the highest scientific interest.

## *MECHANICS AT THE BRITISH ASSOCIATION.*

PERHAPS the most noteworthy feature in the work of this section (G) was the prominence of the Canadian and American papers, apart from the interesting and suggestive address of the President on the education of engineers of the present day; but little of interest was contributed by the English members who attended the meeting. Many members, who in past years have done so much for the section, were unable to be absent from their professional duties for so long a time as attendance at Toronto necessarily involved.

The first paper after the President's address to the section was one by Mr. T. Munro, a Canadian engineer, describing the great works the Canadian Government are constructing to secure the carrying trade from the West, by canalising the rivers between Montreal and Lake Erie wherever the rapids interfere with traffic. The traffic has grown so enormously since the construction of the trans-continental line of the Canadian Pacific opened up the great western plateaus for settlement, that the older systems of canals are practically useless. The actual piece of work described in the paper was the building of Soulanges Canal, on the northern bank of the St. Lawrence, a short distance above Montreal. Two very important departures from ordinary practice were adopted on the advice of Mr. Munro, who was sent on a tour through Europe by the Government before the work was planned: in the first place, the locks are practically all at the Montreal end of the canal, and the lift in each lock was much greater than had previously been attempted in Canada, the locks being also of great size; in the second place, Portland cement concrete has been extensively used. Hitherto Canadian engineers have been afraid to use this valuable material in their canal and harbour work, mainly on account of the fear that the severe Canadian winters would break up such material; partly also, at any rate, until a few years ago, from the difficulty of obtaining trustworthy cement. Recent advances in the manufacture, both in England and the continent, stimulated mainly by the exhaustive series of tests carried out on Portland cement by Bauschinger and others, have resulted in putting at the disposal of Canadian engineers a material thoroughly trustworthy and uniform in quality; and Mr. Munro's experience has proved decisively that with adequate care in the preparation and use of the concrete it is perfectly safe in the most rigorous Canadian winter.

At Montreal the members of the section had the opportunity of thoroughly inspecting the magnificent engineering laboratories of the McGill University, built and equipped by Mr. McDonald, one of the most generous in his gifts of the many public-spirited citizens of that flourishing city. These laboratories are in many respects the most perfectly equipped in existence, especially the hydraulic room designed by Prof. Bovey, where the visitors were shown most ingenious appliances for studying some of the more difficult problems in hydraulics, some of the appliances as, for example, the experimental steam pump, which has just been installed, being on an extensive scale, and fitted for all the requirements of complete research work. Prof. Bovey supplemented this visit by a paper read before the section describing in detail the various appliances in this hydraulic laboratory.

One of the most interesting discussions in the meeting of the section was started by another paper of Prof. Bovey, describing the method of testing Canadian timbers at the McGill laboratories, and the results he had obtained as to the influence of moisture on the strength and elasticity of the various woods experimented on. The timber industry is such a valuable one, both to Canada and the States, that special attention has been devoted to the thorough testing of the economic values of the different forest trees. It should be remembered, however, that Bauschinger indicated the true method of making such tests in his memoirs on testing of timber specimens: all the later experimenters have simply followed in his footsteps The results of the exhaustive tests carried out in the States by Prof. Johnson have been published in a series of Bulletins by the Forestry Branch of the Department of Agriculture at Washington; these form a valuable series for reference.

Prof. Callendar described in a brief, but most valuable paper, which will be published *in extenso* in the transactions of the British Association, the apparatus devised by himself and Prof. Nicolson for studying the rate of condensation of steam when in contact with metal surfaces at various temperatures and pressures. The research is still incomplete, so that it is impossible to deduce any very certain generalisation from the results so far obtained with the apparatus; but one thing has been clearly brought out, namely, that the rate of condensation is not as great as has hitherto been assumed in theoretical investigations into this all-important question in the true theory of steam engine efficiency.

On the Saturday the members of the section had the opportunity of joining an excursion to Niagara, and of seeing while there the various power-houses, and some of the industries which make use of and depend for their existence on this cheap and abundant power. Nothing has been more instructive to English visitors than the constant utilisation of the energy of the falls and rapids, so abundantly distributed all over Canada, and nothing perhaps more striking than the fact that some of these power companies find it difficult to dispose of the power they are ready to supply, a testimony to the truth of the statement that after all in many very important industries the cost of power is not a very serious factor in the cost of production.

As every city of any size, both in Canada and the States, is always well equipped with electric tramcars or street railroads, usually running many miles out into the country around, it was only fitting that the section should devote a good deal of its electrical day to papers on this question, so rapidly becoming one of the leading problems of municipal engineering work in Great Britain.

Mr. Cunningham, the engineer responsible for the construction and working of the very complete system in use in Montreal, read a paper descriptive of that work, but in doing so he dealt fully with the whole question of electric as opposed to other systems of traction. Here, again, many members had had an opportunity of inspecting the power-house of the company at Montreal, and were able, therefore, to follow more readily the author's description of the plant in use.

Mr. Cunningham, no doubt, somewhat overstated his case when contrasting the cost per car mile of the horse system of Liverpool with the electric system of Montreal; it is certainly not a fair comparison to take the mere cost of power as delivered from the power-house, neglecting all the expense of maintaining the generating plant in prime cost condition, repairs to car motors, lines, &c., and then to contrast this with the published cost of haulage per car mile of some horse system, where not only has the cost of fodder and wages of stablemen been included, but also the heavy outlay of up-keep of the horse stock. There can be no doubt that such comparisons have often led municipal and other authorities in Great Britain to look with great suspicion on estimates of electric street railway systems, and have at times hindered their adoption. The distinct economy of electric haulage, when every item of cost has been fairly brought into the bill of charges, is so clear that it needs no such unfair method of comparison to bring it home to those interested in tramway work.

There was a long discussion on this paper, and on a second paper, by Mr. Aldridge, descriptive of a very ingenious but