

THURSDAY, DECEMBER 20, 1900.

## A MODERN SCIENTIFIC INDUSTRY.

*Jena Glass and its Applications to Science and Art.*

By Dr. H. Hovestadt. Pp. xii + 429. (Jena : Fischer, 1900.)

THIS is a volume of some four hundred pages, in which Dr. Hovestadt has collected a mass of information about the Jena glass.

In a report on the scientific apparatus of the London Exhibition of 1876, Abbe called attention to the need for progress in the art of glass making if the microscope were to advance, and to the necessity for obtaining glasses having a different relation between dispersion and mean refractive index than that found in the material then at the disposal of opticians.

He referred to the attempts made in England by Harcourt and Stokes with this object, and to the causes of their failure.

The task thus indicated was undertaken in 1881 by Abbe himself and Schott at Jena. The first catalogue of the Jena Laboratory, published in 1886, contains these words: "The industrial undertaking which is here announced for the first time arose out of a scientific investigation into the connection between the optical properties of amorphous fluxes and their chemical constitution."

The experimental work was only rendered possible by repeated and large subventions from the State. The immediate consequence of the undertaking was that by 1888 nearly all the glass required for optical work in Germany was of home manufacture; in a few years more an export trade in the raw glass began, the value of which in 1898 was over 30,000*l.*, while the value of the optical instruments, such as telescopes, spectacles, field glasses and the like, exported in the same year was nearly 250,000*l.* The trade at present employs some 5000 workmen.

When Abbe and Schott began their work, some six elements only entered into the composition of glasses. By 1888 it had been found possible to combine with these six quantities, up to at least 10 per cent., of twenty-eight additional elements, and the effect of each of these on the refractive index and dispersion had been determined.

Thus, for example, these investigators had found that by the addition of boron the ratio of the length of the blue end of the spectrum to that of the red is reduced; while fluorine, potassium and sodium produce opposite results.

Now an ordinary achromatic lens, uniting two colours of the spectrum, is formed by combining a crown glass lens with one of flint glass having equal total dispersion; but though the total dispersion is the same for the two it is differently distributed throughout the spectrum. In the flint glass the dispersion of the blue end is greater, that of the red less, than in the crown; hence the light from a white source is not white after traversing the lens; a "secondary" spectrum remains, and it was the existence of this which rendered the progress of the microscope so difficult. Abbe's experiments showed how

the difficulty was to be met. By combining a high proportion of boron with flint glass, its spectrum became more nearly the same as that of a crown glass. Such a glass had been made by Harcourt many years previously, while a glass containing phosphates instead of silicates is found to have the same dispersion as, combined with a higher refractive index than, the ordinary crown glasses, and therefore serves better to achromatise the borate-flint glass. In fact, Abbe showed that with two such glasses it is possible to combine three colours instead of only two; the outstanding spectrum is greatly reduced in length, and is called a "tertiary" instead of a "secondary" spectrum.

Again, the ordinary microscope lens of two glasses can be corrected for axial spherical aberration for one colour only. Abbe showed that the new borate-phosphate lenses could, by combination with a lens of fluor-spar, have their axial spherical aberration corrected for two colours. These lenses he called apochromatic.

It was found more difficult to reduce the secondary spectrum by lengthening the red end of the spectrum of the crown glass. This required the addition, as we have said, of fluorine, potassium or sodium. The effect of sodium is small; glasses with a large amount of potassium can be made, but are very hygroscopic, while the introduction of fluorine though it was successfully effected, is involved with many difficulties.

The book under review gives, in its first two chapters, an account of the preliminary work of Abbe and Schott, and full details as to the optical properties of the glasses now made. The next four chapters deal with the optical instruments manufactured out of the glasses.

We have already referred to the fundamental improvement in the microscope rendered possible by their use; the problem to be solved in the case of a photograph lens was somewhat different. It follows, from the work of von Seidel, that, with the ordinary crown and flint glasses, the conditions for achromatism and for flatness of field cannot be satisfied together. To do this it is necessary to find a glass of high refractive index and low dispersive power, or *vice versa*. In ordinary glasses refractive index and dispersive power go together.

Thus, ordinary hard crown glass has a refractive index of 1.518 and a dispersive power of .0166, while for extra dense flint the figures are 1.717 and .0339. An achromatic lens might be constructed out of these two glasses, but the field could not be flat.

By introducing barium, however, into the crown glass, a change is produced in this respect. Thus for barium silicate crown the refractive index and dispersive power are 1.573 and .0173, while for soft crown they are 1.515 and .0177. With these two glasses, the problem of constructing a photographic object-glass possessing achromatism and flatness of field becomes possible. For the various methods of solution we must refer to the book<sup>1</sup> itself, in which also will be found details as to the use of the glasses for telescopic lenses.

The mechanical properties of glass are next considered, and in Chapter ix. we come to a careful discussion of the imperfect elasticity of glass, specially in connection with thermometry.

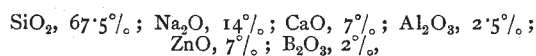
<sup>1</sup> See also "Contributions to Photographic Optics," by Dr. Otto Lummer, translated by Prof. S. P. Thompson.

"About twenty years ago" (the quotation is from the catalogue of the German Instrument Exhibition at Paris) "the manufacture of thermometers had come to a dead stop in Germany, thermometers being then invested with a defect, the liability to periodic changes, which seriously endangered German manufacture. Comprehensive investigations were then carried on by the Normal Aichungs-Kommission, the Imperial Physical and Technical Institute, and the Jena Glass Works, and much labour brought the desired reward."

Dr. Hovestadt's account of the labour is most interesting and instructive.

The ice point of a newly made mercury thermometer is known to rise as the thermometer gets older; this rate of rise decreases with the time, finally becoming very slow. If, however, the thermometer be heated to, say, 100° C., and its ice point be taken very shortly afterwards, the reading will be below that observed prior to the observation of the steam point. This depression of the zero varies in amount in different thermometers. It was found (Weber in 1883 and Wiebe 1885-1886) to be specially large in the case of thermometers made of Thuringian glass, amounting in the case of one thermometer examined to 0°·65. As a consequence, the readings of the thermometers were quite uncertain, depending greatly on the past history of the instrument employed. It was this defect which Schott and Abbe set out to cure. Weber had observed that glasses which contained a mixture of potash and soda gave a very large depression. He succeeded in 1883 in making a glass entirely free from soda, in which the depression was only about 0°·1. The work was then taken up by the Aichungs Commission and the Jena factory. A number of thermometers of varying age and manufacture were examined as to the depression, and the glass of these thermometers was then analysed. Weber's conclusions were abundantly verified. An old thermometer of Humboldt's, containing 0·86 per cent. of Na<sub>2</sub>O and 20·09 per cent. of K<sub>2</sub>O, had a depression of 0°·06; a new instrument, in which the percentages of the two substances respectively were 12·72 and 10·57, had a depression of 0°·65. It is possible that this last thermometer was too new to give quite trustworthy results, but the difference is very marked. An English standard thermometer, with 1·54 per cent. of Na<sub>2</sub>O and 12·26 per cent. of K<sub>2</sub>O, had a depression of 0°·15, while a French "verre dur" thermometer, with 12·02 of Na<sub>2</sub>O and 0·56 of K<sub>2</sub>O, showed a depression of only 0°·008.

The next step was to manufacture a German glass with a low depression. The now well-known normal thermometer glass distinguished by the mark 16" was the outcome of the experiments. This is a pure soda glass having the following composition:—

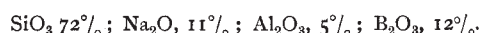


and the depression observed is 0°·05.

The hydrogen thermometer is, however, the ultimate standard of appeal in thermometry, and it was necessary, therefore, to compare the new instruments with such a thermometer.

Details of the work are given in the book. It appeared, from the results of Wiebe and others, that at a tempera-

ture of 40° there was a difference of 0°·12 between the two instruments. Experiments showed, however, that it was possible to produce a glass agreeing more closely with the gas thermometer than this, and this fact led to further work and to the manufacture of the boro-silicate glass 59" with the following analysis:—



This was found to show a smaller ice point depression, amounting, according to Hovestadt, to 0°·02, and to agree more closely over the range 0° to 100° with the hydrogen thermometer, the difference being greatest at 30°, where it amounts to 0°·038. For temperatures above 100° the differences are considerably greater than those given above, and the agreement between the scales is better for 16" than for 59".

For details, however, of these comparisons, and of much more work of great interest as to the properties of these special glasses, reference must be had to the book. It constitutes a great record of what is to be achieved by the application of science, that is, "organised common sense" to an important industry. In England we have done nothing to compare with it. As a consequence, Germany can claim that "the manufacture of thermometers has reached in Germany an unprecedented level, and now governs the markets of the world." Such are the results obtained in twenty years by Abbe and his colleagues.

R. T. G.

#### ESSAYS BY DR. WALLACE.

*Studies, Scientific and Social.* By Alfred Russel Wallace. 2 vols. Illustrated. (London: Macmillan and Co., Ltd., 1900.) Price 18s.

IN addition to being one of the originators of the modern doctrine of animal evolution and one of the leading pioneers in the study of the geographical distribution of the earth's fauna, Dr. Russel Wallace is a writer noted for such a fascinating style and such a happy mode of presenting his views, that any work from his pen is sure of a hearty reception on the part of the more thoughtful section of the reading public. And even those who by no means agree with all his views—whether on scientific or social questions—cannot fail to admire the fairness with which he treats debatable points, and the temperate manner in which he replies to and discusses the objections raised by his critics.

The essays and articles collected in the two volumes before us embrace an extraordinarily wide range of subjects, and cover a period of no less than thirty-five years, the earliest of them being published as long ago as 1865, while the latest saw the light as recently as 1899. The variety of subjects discussed is alone a testimony to the wonderful mental capacity of their talented author, while the number of the periodical publications from which they have been culled bears evidence to the popularity of his writings. Those embraced in the first volume relate exclusively to various branches of geological and biological science, while those in the second are devoted to educational, political, sociological and kindred subjects. With the exception of a brief reference to two articles in the second volume dealing with museums as educational