Light-Waves as Units of Length*

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COMPARISON OF THE RESULTS

WITH the exception of Sears and Barrell, none of the investigators seems to have realised the full implication of the fact that, while the yard or metre are purely distances, the paths observed by means of all forms of interferometers are 'optical paths', or the product of the metrical distance and the refractive index of the space concerned. The two quantities only coincide when the space is a vacuum, so that if a given standard is said to contain so many waves in air, the nature and consistency of the air must be specified to such limits that its index cannot vary by an amount greater than the percentage accuracy within which the value is specified. Not only are the temperature and pressure of importance, but almost equally so the constitution and composition of the air.

The primary importance of the work of Sears and Barrell lies not so much in the accuracy and thoroughness with which the investigation has been carried out, as in the fact that they have provided us with the vacuum wave-length of the red cadmium line, carrying out a direct comparison with evacuated units as well as with air. It is very disquieting to find that the refractive index of air thus accurately observed is considerably different from that given by the Meggers and Peters tables¹⁹, which is the standard conversion table in general use by spectroscopists for obtaining the vacuum frequencies of spectral lines.

The humidity of the air was not observed in the earlier work of Michelson; at 15° C. the index increases by 7 parts in 10⁷ when saturated air is replaced by dry air. If we assume the air to have had an average humidity of 50 per cent, Michelson's value for the wave-length must be reduced by 0.0023 Å. to obtain the result for dry air.

Neither Michelson, nor Benoit, Fabry and Perot, took account of the percentage of carbon dioxide present during their experiment. Normal 'fresh air' is supposed to contain 0.03 per cent carbon dioxide, but the amount present in a closed room may be far in excess of this due to the presence of observers. Pérard²⁰ has shown that an observer will contribute approximately this amount to the air of a room of 100 cubic metres capacity in the time required for a single set of observations, namely, 1½ hours. An increase of 0.03 per cent in the carbon dioxide content decreases the wave-length by 0.0003 Å., so that only the more recent determinations can with strict fairness be inter-compared.

The values of the wave-length of the red cadmium line in dry air containing 0.03 per cent carbon dioxide at 760 mm. pressure and 15° on the normal temperature scale are given below:

Standard No.	Year	Investigators	Value in 10 ⁻¹⁰ metres
*26 and T ₂	1906	Benoit, Fabry, Perot	6438.4703
10 and 20	1928	Watanabe and Imaizumi	6438.4682
16	1933	Sears and Barrell	6438.4708
18	1934	Küstner	6438.4672
Mean			6438.4687

* The results have been corrected in terms of the more recent determinations of the lengths of these International Sub-standards.

For the present, this is probably the best value that can be taken for the wave-length of this line in 'normal' air. It differs but little from the accepted value of 6438.4696 Å., which was primarily based on the determination of Benoit and his co-workers. The difference of 0.0036 Å. between the values of the Reichanstadt and the National Physical Laboratory seems far too great, since it amounts to almost a whole wave-length in the number of waves in the metre. The discrepancy has most probably arisen in the initial comparison of the national standards with the Sèvres sub-standards. The preliminary Japanese results showed a difference of 0.002 Å. between the values obtained from the two standards No. 10 and No. 20. These were later sent to Paris for re-measurement against the international sub-standard No. 26 and others. The corrections of +0.2 μ for No. 10 and -0.11 μ for No. 20 brought the wave-length values into close agreement. The result of Benoit and his co-workers has been included in the above table in spite of the uncertainty regarding the carbon dioxide content. The probability is that the lengths of No. 26 and T₂ are more accurately known than those of the National Standards, and the greatest source of error undoubtedly lies in this portion.

It seems imperative that the rule prohibiting the actual use of the prototype metre itself will have to be waived, and the German and British standards be compared with it as soon as possible. The difficulty of this work can best be appreciated from Fig. 1. This photograph (reproduced by courtesy of M. Pérard) shows, with a magnification of 300, one of the fiducial lines of the International Sub-standard No. 26 which has been used in the earlier determinations. The centre of the whole is supposed to be the actual position of setting, and metrologists claim that they can inter-compare two standards to within ±0.2 μ. This is equivalent to finding the centre of Fig. 1 to within ±0.03 mm., which is clearly impossible. By

* Continued from p. 461.

reducing the magnification a sharp image is obtained, which is more of the diffraction pattern of the comparator objective than an image of the actual line itself. The result in a great measure will then depend on the conditions of illumination of the line comparator.

It seems certain that minor systematic errors, in the optical portion, chiefly connected with the conditions of illumination of the étalons, still remain uncorrected. Their effects are, however, negligible compared with the real uncertainties of line standard measurements. Even at the present time, there would be a considerable gain in accuracy if a wave-length were accepted as the fundamental standard, but before a change is decided upon, it seems very desirable that the whole position should be reconsidered in the light of recent knowledge. The discovery of the hollow cathode discharge by Paschen and its further development by Schüler have given us a light source that is much more monochromatic than the Geissler tube of Michelson or the argon-filled cadmium lamp as used by Sears and Barrell. The further possibility now exists of finding a more suitable line from a heavier, non-isotopic element of zero nuclear spin, since we are no longer limited to the more volatile elements.

Tilton²¹ has recently carried out a statistical analysis of the data on the refractive index of carbon dioxide-free air, from which he deduces a correlation between the refractivity ($\mu - 1$) and the twenty-three year magnetic cycle of sunspots. Some of the data are admittedly uncertain, but there seems to be evidence of a real variation that

makes it essential to adopt a vacuum wave-length as the ultimate standard, if and when a change is made.

For the moment, we cannot do better than accept the mean value given in the above table as the wave-length of the red cadmium line in

FIG. 1. One of the fiduciary lines of the International sub-standard. No. 26. ($\times 300$.)

'normal' air, and to adopt Sears and Barrell's value, 1,000,276.49, as its refractive index. The vacuum wave-length then becomes 6440.2493 Å, and the Imperial yard, defined as a length at 62° F., contains 1,419,818.31 vacuum wave-lengths.

¹⁹ Meggers and Peters, *Bull. Bur. Stand.*, **14**, 697; 1918.

²⁰ Péard, *Proc.-verb. Com. int. Poids Mes.*, p. 27; 1927.

²¹ Tilton, *Bur. Stand. J. Res.*, **13**, 111; 1934.

Obituary

PROF. BOHUSLAV BRAUNER

PROF. BOHUSLAV BRAUNER, one of the best-known representatives of Czech chemistry of the last half century, died in Prague on February 15, after a short illness. He was born on May 8, 1855, in Prague, the son of Dr. Francis Brauner, who was a noted Prague lawyer and Czech political leader. His mother Augusta, a very talented and spirited lady, was the daughter of Prof. K. A. Neumann, the first professor of chemistry at the Polytechnic Institute of Prague, and the grand-niece of the well-known German pharmacist, Prof. Caspar Neumann (1683-1737), one of the founders of pharmaceutical chemistry.

Thus Brauner seems to have inherited his liking and ability for chemistry from his mother's side. Great attention was paid in the Brauner family to languages, amongst which besides the Czech mother-tongue, Russian, English, German and French were equally cultivated. There the foundation was laid of Brauner's astonishing practical linguistic knowledge. He showed a refined taste for fine arts like the

other members of his family; his sister Zdenka Braunerová being a well-known Czech painter.

In 1873, Brauner went to the University and to the Technical School in Prague, where one of his teachers was the physicist Ernst Mach, at that time professor in the University of Prague. Before attaining the doctor's degree, young Brauner went abroad for training in research; contrary to the fashion at that time, when "every chemist had to embark on organic chemistry", he preferred inorganic training under Bunsen in Heidelberg in 1878. Two years later, Brauner went to Manchester, attracted by the work of Sir Henry Roscoe on rare elements.

The school of chemistry in Owens College, Manchester, had a profound influence upon Brauner, who learned there to love the original Anglo-Saxon spirit of experimental investigation in natural philosophy. During his years in Manchester, Brauner was eagerly investigating the rare earths, and he succeeded in preparing a double fluoride of tetravalent cerium and potassium which on gentle heating gave off free fluorine, thus for the first time obtained