GENERAL CATALOGUE

OF

THE MANUFACTURES

OF

ADAM HILGER, Ltd.

October, 1924

75a CAMDEN ROAD, LONDON, N.W. 1
ENGLAND

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(Entrance: 24 Rochester Place, adjoining)

ENGLAND

"THE position of a line in the spectrum is most generally indicated by the wavelength (λ) of the vibrations which produce it. The unit of wavelength is the Ångström Unit, or "angstrom," as it is now beginning to be called. It was intended to equal 10^{-10} metre, and is accordingly often called the "tenth-metre." It is also equivalent to 10^{-8} cm., or 0·000μ, where μ is the micron, or thousandth of a millimetre. Wavelengths in the visible spectrum range from about 3,9000 A to 7,600 A (A being the modern abbreviation for the angstrom). For the long waves in the infra-red, however, μ is often taken as the unit, so that λ 12,500 A, for example, would be indicated by 1·25 μ." *

The thousandth of a micron (millionth of a millimetre) is often denoted by μμ.

* A. Fowler: *Report on Series in Line Spectra.* Fleetway Press, Ltd., London, for the Physical Society of London, 1922, pp. 1-3.

4.

INDEX OF SECTIONS

(For General Index see back pages.)

TERMS OF BUSINESS

Cash with order, or good London references.

FOREIGN ORDERS should be accompanied by a remittance, or credit with an English Bank or first-class Firm, who will pay on presentation of invoice. This condition does not apply in the case of official orders from recognised Colleges and Scientific Institutions.

The prices are for net cash at our Works, and in no case subject to discount.

The very greatest care is exercised in packing, which is charged at cost price, and ADAM HILGER, Ltd., cannot hold themselves responsible for injuries, which should be claimed for from the carrier. Cases should always be examined on arrival in presence of the carman for any external signs of damage, and his recognition of any such damage obtained.

Inland cases returned carriage paid and in good condition will be credited at two-thirds.

Cheques to be crossed "The Midland Bank, Limited."

October, 1924.

ADAM HILGER, Ltd., 75a Camden Road, London, N.W. 1
Entrance:—24 Rochester Place (adjoining)

Telegraphic Address—"Sphericity, Phone, London."
Telephone Nos.—North 1677 and 1678.
Cable Code—Western Union.
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SECTION B

ECHELON DIFFRACTION GRATINGS AND LUMMER-GEHRCKE PARALLEL PLATES

Considerable improvements have been made by us during the past few years in the methods of testing the glass plates for Echelons during their polishing. These improved methods enable us to include in the following list a price for Echelons of 56 plates, which can be made of 10, 15, or 20 mm. thickness. The prices for intermediate numbers of plates will be quoted on application.

SIZES OF ECHELON DIFFRACTION GRATINGS USUALLY SUPPLIED

For our Echelons with plates 10 mm. thick the approximate Resolving Power may be obtained by multiplying the number of plates by 10,000.

Catalogue No.	Number of Plates.	Catalogue No.	Number of Plates.
B 1	10	**B 14**	23
B 2	11	**B 15**	24
B 3	12	**B 16**	25
B 4	13	**B 17**	26
B 5	14	**B 18**	27
B 6	15	**B 19**	28
B 7	16	**B 20**	29
B 8	17	**B 21**	30
B 9	18	**B 22**	31
B 10	19	**B 23**	32
B 11	20	**B 24**	33
B 12	21	**B 25**	35
B 13	22	**B 26**	40
		B 27	56

The above prices include a suitable mount arranged for the edges of the plates to be vertical.

If the plates are required to be used with the edges horizontal instead of vertical no extra charge is made; if to be used with the edges both horizontal and vertical an extra charge is made.

The following proportions have been adopted by us after due consideration, and will be adhered to unless special directions are given to the contrary.

Height of Plates: For a 10-plate Echelon about 32 mm.
" 11 " " ... 32 "
" 12 " " ... 32 "
" 13 " " ... 36 "
" 14 " " ... 36 "
For a 15-plate and all larger numbers about 40 mm.

PRICES OF HIGHER PLATES IN PROPORTION.

Thickness of Plates, about 10 mm. (but see below).
Width of Step, 1 mm.

Echelons of 20 plates and upwards are now made also of 15 mm. thick or of 20 mm. thick plates, the prices being 30 per cent. higher than the above scale in the case of the former, and 60 per cent. higher in the case of the latter ; this increased price including a suitable alteration of the mount to take the increased length and weight of glass.

VARIOUS MODES OF ARRANGEMENT OF THE ECHELON APPARATUS

In the use of the Echelon Spectroscope an auxiliary analysis of the light is required for the purpose of isolating the particular radiation under observation.

In the case of a spectrum consisting of a few isolated lines, a prism and condensing lens in front of the slit are sufficient, monochromatic images of the source being thrown on the slit. In the case of spectra where a more powerful analysis is necessary, any of the following three arrangements can be adopted.

FIRST ARRANGEMENT

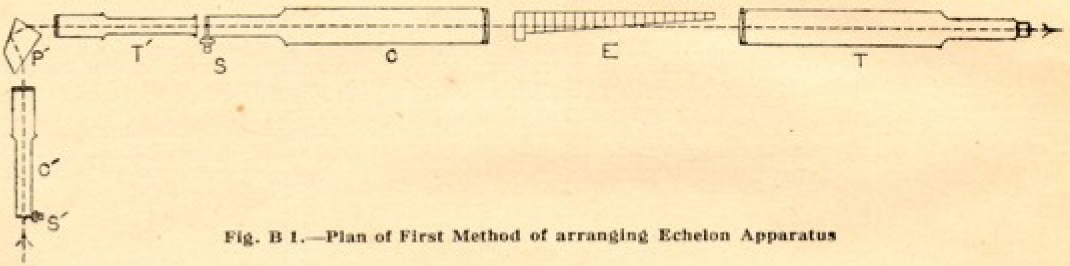

Fig. B 1.—Plan of First Method of arranging Echelon Apparatus

This is illustrated in diagram in Fig. B 1. It consists of the Echelon Spectroscope with slit S, Collimator C, Echelon E, and Telescope T ; and an auxiliary Spectroscope, by means of which a spectrum of the light source under examination is thrown on the slit of the Echelon Spectroscope, any desired line being thus isolated.

Any spectroscope can be used for this preliminary analysis, but the Hilger Wavelength Spectrometer (*see* pp. D 1–D 2), as shown in the plan in Fig. B 1, is by far the most suitable, as it affords means of passing gradually through the spectrum without altering the position of the collimator.

Such an arrangement is shown in Figs. B 4 and B 6, in the case of Echelon Spectroscopes 1 and 3 respectively.

SECOND ARRANGEMENT

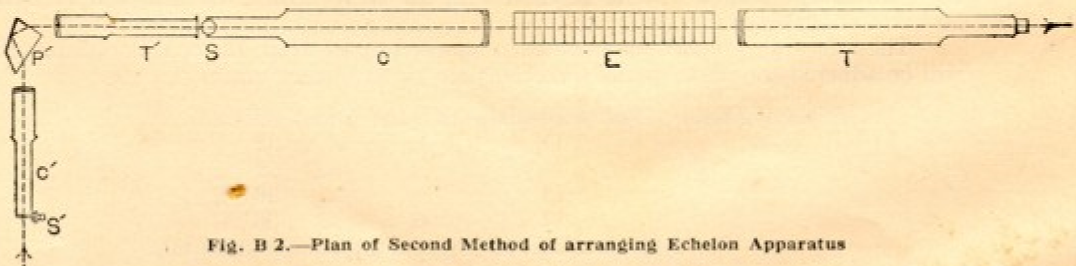

Fig. B 2.—Plan of Second Method of arranging Echelon Apparatus

The only difference between this (Fig. B 2) and the first arrangement is that the slit of the Echelon Spectroscope, and the edges of the plates of the Echelon itself, are both horizontal. Thus instead of only one line a large portion of the spectrum can be examined at once, each line being separately subjected to the analysis of the Echelon. In the Echelon Spectroscopes Nos. 1, 2, 3, 4, and 5 on pp. B 3 to B 8, an equivalent result can be obtained by placing in front of the slit of the Echelon Spectroscope a prism of special shape. The edges of the Echelon then remain vertical (its resolution being in a horizontal plane), while the prism spectrum is dispersed in a vertical sense.

THIRD ARRANGEMENT

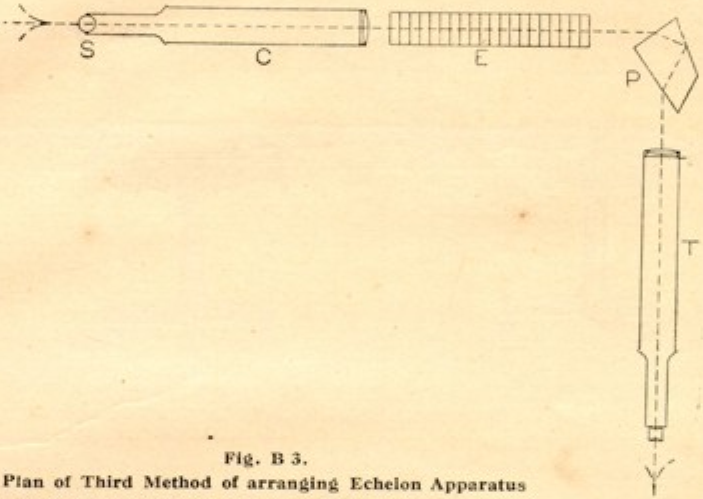

Fig. B 3.
Plan of Third Method of arranging Echelon Apparatus

In this case (Fig. B 3) the auxiliary analysis of the light is obtained by a constant deviation prism, large enough to take the whole beam of light from the Echelon, being placed in the position shown in the figure. Thus the light is subjected first to the analysis of the Echelon, and then to that of the constant deviation prism. The edges of the Echelon are horizontal, and the slit of the Echelon Spectroscope has adjustment in two directions at right angles, consisting, in fact, of two slits superposed with the two pairs of jaws as nearly as possible in one plane.

This arrangement has the advantage over the second method (which it resembles in effect), that the light has to pass through only two object glasses, with the result that there is less loss of light.

This arrangement is shown in Fig. B 10, in No. 3 size.

For very complex spectra of sufficient intensity a ruled diffraction grating may be employed for the auxiliary dispersion in place of the constant deviation prism P in Fig. B 3.

ECHELON SPECTROSCOPES FOR USE IN ARRANGEMENT 1

(*See* p. B 2.)

The five following Echelon Spectroscopes can be supplied suitable for No. 2 Arrangement by placing a prism of special form in front of the slit. The prism spectrum, as seen in the eyepiece, is then dispersed in a vertical direction, while the resolution of the Echelon remains in a horizontal direction.

B 230.—Prism and mount for converting to No. 2 arrangement.

The smaller sizes of Echelon can be adapted to almost any Spectroscope, but owing to the peculiarity of the Echelon, that it is always used at direct vision, special forms of Spectroscopes become more convenient. These special Spectroscopes are supplied in five different sizes, suitable for various sizes of Echelon.

No. 1 is suitable for from 10 to 14 plates 10 mm. thick.

No. 2 is suitable for from 15 to 20 plates 10 mm. thick.

No. 3 is suitable for from 21 to 33 plates 10 mm. thick; or from 20 to 22 plates 15 mm. thick.

No. 4 is suitable for from 34 to 40 plates 10 mm. thick; from 23 to 33 plates 15 mm. thick; or from 20 to 25 plates 20 mm. thick.

No. 5 is suitable for from 41 to 56 plates 10 mm. thick; from 33 to 37 plates 15 mm. thick; or from 26 to 28 plates 20 mm. thick.

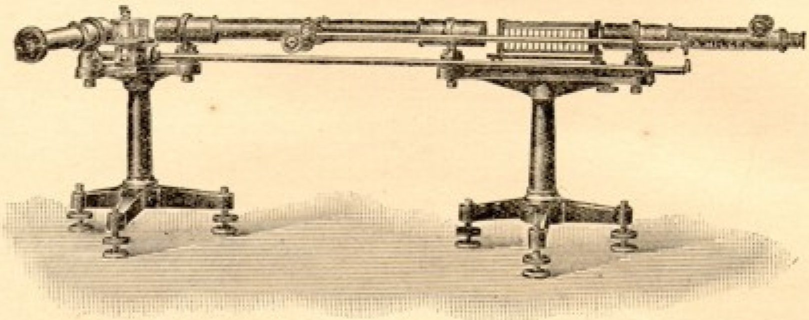

Fig. B 4

B 29.—Echelon Spectroscope No. 1 (as shown, together with Echelon and an auxiliary Spectroscope in position, in Fig. B 4), with slit, collimator, and telescope, means of rotating Echelon and rackwork for the same, and high and low power eyepieces. The slit has non-corrosive jaws, and screw for adjusting width of aperture, with divided drumhead. The object glasses are of $1\frac{1}{4}$ inch clear aperture, and $11\frac{1}{4}$ inches focal length. The whole mounted on strong iron tripod. The price does not include the wavelength spectrometer shown, for which *see* pp. D 1 and D 2.

NOTE.—*Since the preparation of Fig.* B 4 *above, the design of this No.* 1 *Echelon Spectroscope has been improved, the collimator and telescope being supported by double supports, this arrangement greatly adding to the rigidity. The wavelength spectrometer has also been greatly improved.*

B 30.—Slit arranged with rod with milled head to actuate it from the eye end ... ...

B 31.—If supplied with wavelength spectrometer rod for passing through spectrum ... .

B 32.—Echelon Spectroscope No. 2 (Fig. B 5), suitable for 15 to 20 plates. The object glasses are $1\frac{5}{8}$ inch clear aperture, and $14\frac{1}{2}$ inches focal length. This stand has means of moving the Echelon out of the field without taking it off the instrument. Two eyepieces are supplied.

B 33.—Slit arranged with rod with milled head to actuate it from the eye end ... ...

B. 34—If supplied with wavelength spectrometer rod for passing through spectrum ... ...

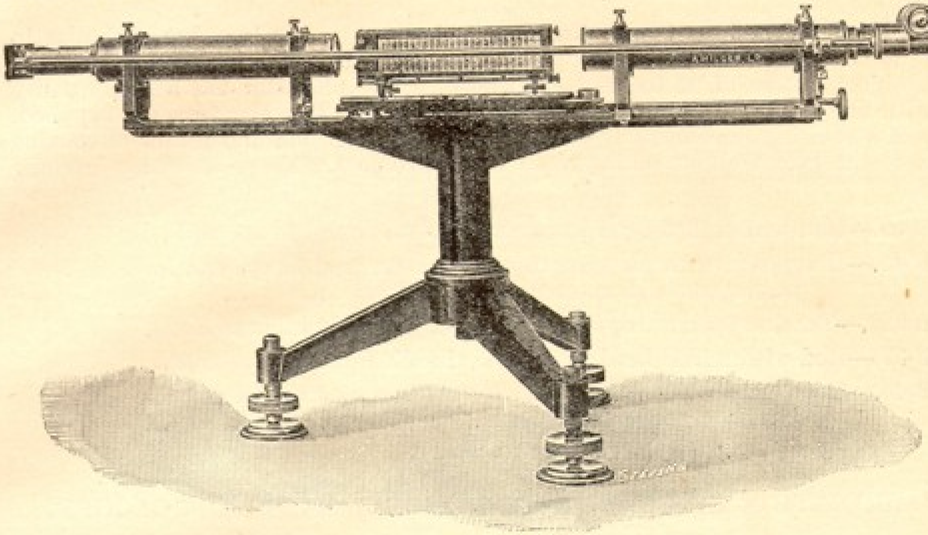

Fig. B 5

B 35.—Echelon Spectroscope No. 3 (as shown, together with Echelon and an auxiliary Spectroscope in position, in Fig. B 6), with 2 inch diameter object glasses, of 22 inches focal length. The collimator has a high quality slit, with fine steel screw and large divided drumhead. Two eyepieces are supplied. There is a rotating movement by rackwork for the Echelon, and means of moving it out of the field without taking it off the instrument. On strong tripod stand, with three levelling screws. The price does not include the wavelength spectrometer shown, for which *see* D 1 and D 2.

NOTE.—*Since the preparation of Fig.* B 6, *the frame of the No.* 3 *Echelon Spectroscope has been remodelled. The wavelength spectrometer has also been greatly improved, see Section* D, pages D 1 and D 2.

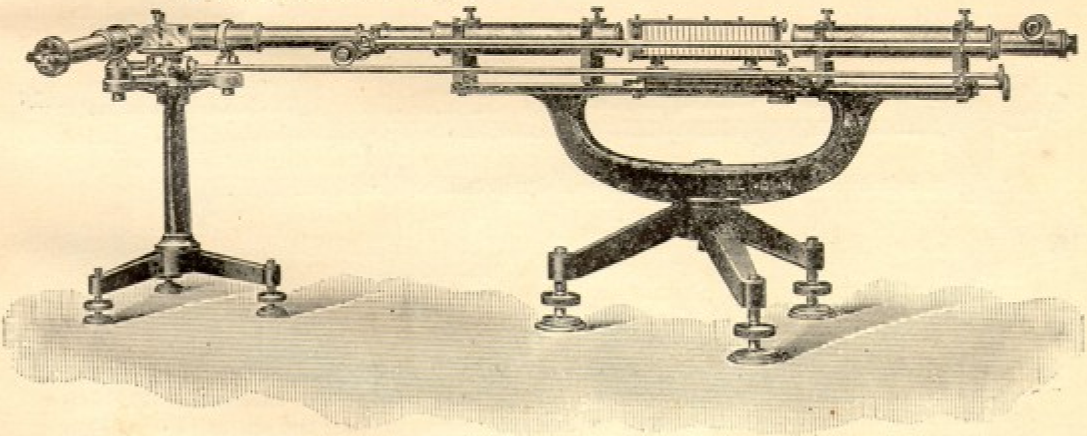

Fig. B 6

B 36.—Slit arranged with rod with milled head to actuate the slit from the eye end ... ...

B 37.—If supplied with wavelength spectrometer, rod for passing through spectrum ... ...

B 38.—Echelon Spectroscope No. 4 is built upon a cast-iron frame similar in character to that of the No. 3 size. The telescope and collimator have 2 inch diameter object glasses of 22 inches focal length. The collimator has a high quality slit, with fine steel screw and large divided drumhead. Two eyepieces are supplied. There is a rotating movement by rackwork for the Echelon, and means of moving it out of the field without taking it off the instrument. There are three levelling screws.

B 39.—Rod with milled head to actuate the slit from the eye end ...

B 40.—If supplied with wavelength spectrometer, rod to eye end for passing through spectrum ... ...

B 229.—Echelon Spectroscope No. 5 is similar in construction to No. 4.

B 39.—Rod with milled head to actuate the slit from the eye end ...

B 40.—If supplied with wavelength spectrometer, rod to eye end for passing through spectrum ... ...

COMBINATION OF ECHELON AND AUXILIARY SPECTROSCOPE,

for Arrangements 1 and 2

The prices below are for No. 1 arrangement.

B 230.—Prism and mount for converting to No. 2 arrangement. *See* pp. B 2 and B 3.

We can supply Echelon Spectroscopes Nos. 1 to 4 above mounted in combination with the wavelength spectrometer above on one substantial cast-iron base.

B 43.—No. 1 size (not including Echelon) ...

B 44.—No. 2 size " " ...

B 45.—No. 3 size, as shown in Fig. B 8 " " ...

B 46.—No. 4 size " " ...

B 231.—No. 5 size ... ... " " ...

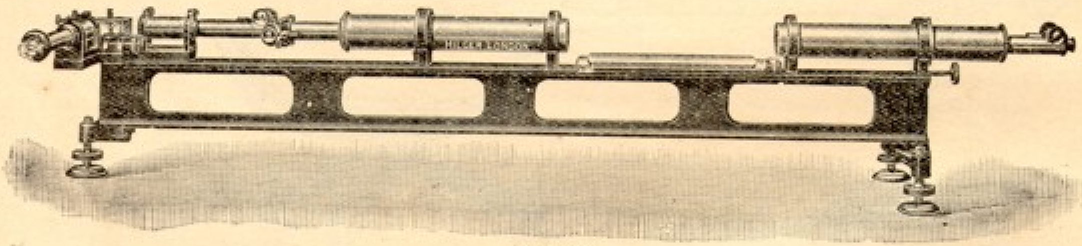

Fig. B 8

The above combinations include the wavelength spectrometer (D 1), with prism of 1·65 refractive index for D, mounted on the long base which carries the Echelon Spectroscope instead of on the usual tripod, rods for actuating the slit of the Echelon Spectroscope and for passing through the spectrum (these rods are not shown in Fig. B 8), and the slit, collimator, telescope, etc., as described in the corresponding No. of Echelon Spectroscope (pp. B 4 to B 6).

Any of the above can be supplied with prism of 1·74 refractive index for D ... ...

THIRD ARRANGEMENT OF ECHELON APPARATUS

(*See* p. B 3.)

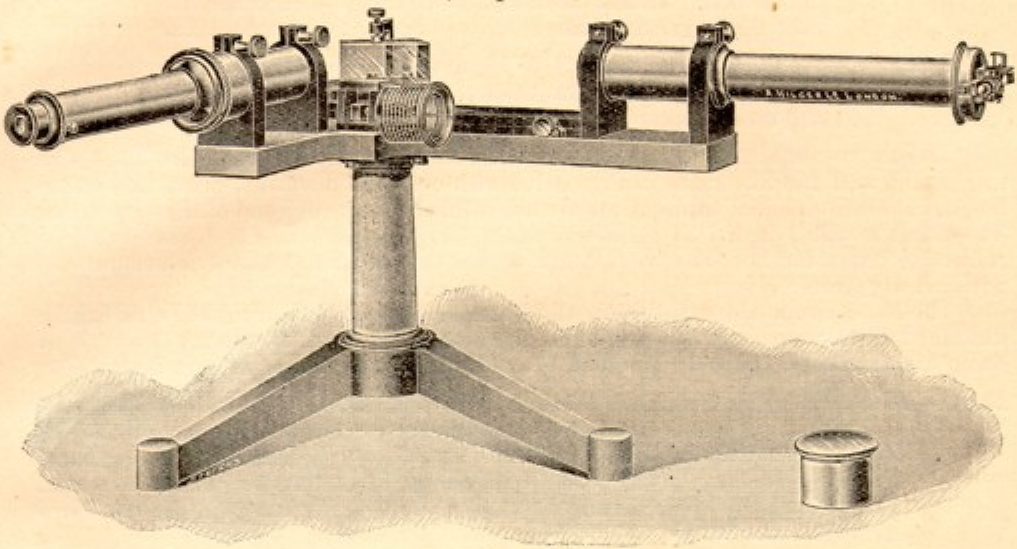

Fig. B 9

B 48.—No. 1 suitable for from 10 to 12 plates 10 mm. thick (Fig. B 9).

B 49.—No. 2 suitable for from 13 to 20 plates 10 mm. thick.

B 50.—No. 3 suitable for from 21 to 33 plates 10 mm. thick (Fig. B 10); or from 20 to 22 plates 15 mm. thick. The price does not include the micrometer eyepiece shown in the figure

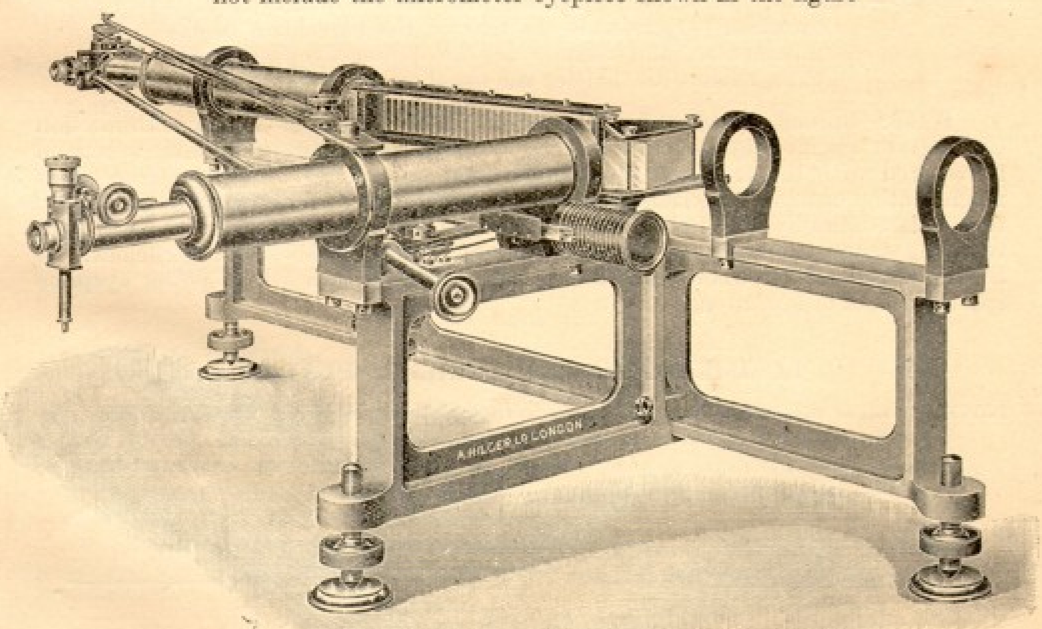

Fig. B 10

B 51.—No. 4 suitable for from 34 to 40 plates 10 mm. thick ; or from 23 to 33 plates 15 mm. thick ; or from 20 to 25 plates 20 mm. thick. Similar to No. 3, but suitably modified to take the larger echelons ... ...

B 232.—No. 5 suitable for from 41 to 56 plates 10 mm. thick; from 33 to 37 plates 15 mm. thick; or from 26 to 28 plates 20 mm. thick ... ...

The above combinations include the whole arrangement (as shown for No. 1 size in Fig. B 9 and for No. 3 size in Fig. B 10) with constant deviation prism and wavelength calibrations. All adjustments are accessible from the eye end of the apparatus. The prism in size 1 is of 1·74 refractive index for D, and in sizes 2, 3, and 4 of 1·65 refractive index for D. The wavelength calibration in sizes 3 and 4 is accurate to within 1 angstrom.

The No. 1 size is also suitable for the Lummer Plate and Fabry and Perot Etalon described in Section O, " Spectroscopic Apparatus for High Resolving Power," it being identical with the O 10 Modified Wavelength Spectrometer therein described.

NOTE.—*In Fig.* B 10 *the Echelon is shown with its edges vertical, but as described on p.* B 3, *for the Third Arrangement the edges of the Echelon are horizontal. It will be noted that the No. 3 and No. 4 sizes can be used as in arrangement No. 1 by removal of the prism, and change of the position of the telescope. The accessibility of the various adjustments is, however, arranged for the Third Arrangement.*

VARIOUS ACCESSORIES FOR USE WITH ECHELON APPARATUS

B 52.—Camera with enlarging lens combination for any of the above Echelon Spectroscopes can be supplied enlarging either twice or three times ... ...

B 53.—Accurate micrometer eyepiece with zero adjustment in a direction perpendicular to that of the movement of the micrometer, and adapter for low-power eyepiece interchangeable with that for the usual eyepiece supplied ...

F 128.—Special eyepiece for Lummer-Gehrcke Plates or Echelon Diffraction Gratings, or wherever in the use of a spectroscope great magnification of the spectrum is required with the retention of as much light as possible. This eyepiece has a magnification of 23 in a horizontal direction, and of only 3·85 in a vertical direction ; thus it is admirably adapted to the examination of spectra produced by such high resolving power elements as Lummer-Gehrcke Plates or Michelson Echelons. It is also of general use wherever it is desired to observe with a high power eyepiece spectrum lines of low intensity.

LUMMER-GEHRCKE PARALLEL PLATES

NOTE.—*Unless otherwise specified in ordering, Lummer-Gehrcke Parallel Plates will always be supplied with a prism cemented on (or, in the case of Quartz Lummer Plates, in optical contact), the prism being of the kind indicated in Fig.* B 12, *whereby the combination becomes a " direct vision " one.*

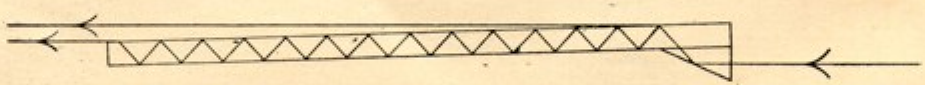

Fig. B 12

SIZES OF LUMMER-GEHRCKE PARALLEL PLATES USUALLY SUPPLIED

	Length.	Width.	Thickness.	Approximate Resolving Power.
B 56.—	130 mm.	15 mm.	4½ mm.	200,000

The above size, which can usually be delivered from stock, is strongly recommended, except in the cases where an even higher resolving power is essential. It will be noted that the resolving power of this size (B 56) is already very great.

	Length.	Width.	Thickness.	Approximate Resolving Power.
B 57.—	130 mm.	25 mm.	10 mm.	200,000
B 58.—	200 mm.	30 mm.	10 mm.	327,000
B 59.—	300 mm.	30 mm.	10 mm.	510,000

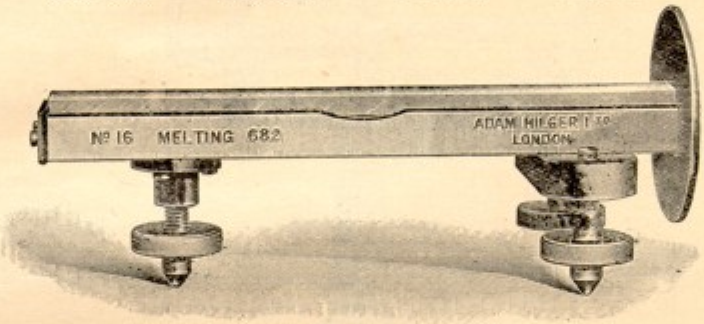

Fig. B 13

A mount of the type shown in Fig. B 13 is supplied with these plates.

We can also supply Lummer-Gehrcke Parallel Plates, of size (B 56), in quartz for work in the ultra-violet.

B 60.—Quartz Lummer-Gehrcke plate in mount (Fig. B 13)... ...

B 61.—Quartz-rocksalt triple or quartz-fluorspar double achromatic lens on the mount described below (Fig. B 14), when the plate is used in front of a quartz spectrograph ...

As quartz-fluorspar makes a better achromatic combination than quartz-rocksalt, the former will always be supplied whenever fluorspar of suitable quality is obtainable.

SPECTROSCOPES, ETC., FOR USE WITH LUMMER-GEHRCKE PARALLEL PLATES

For sizes (B 56) and (B 57) above, the (O 10) Modified Hilger Wavelength Spectrometer shown in Fig. B 9 and described in Section O, "Spectroscopic Apparatus for High Resolving Power," is suitable. As so used, the Lummer-Gehrcke Plate lies almost horizontal and thus diffracts the light in a vertical plane.

The ordinary prism spectrum is seen in the eyepiece, the bright lines being readily identified by the wavelength drum ; and the Lummer-Gehrcke Plate on being introduced effects the resolution of each ray into its minute structure in a vertical sense.

B 62.—Spectroscope for use with plate sizes (B 56) and (B 57) ...
B 63.— „ „ „ (B 58) ... ...
B 64.— „ „ „ (B 59) ... ...

In the case of B 64 the necessary extension makes the spectrometer somewhat unwieldy for ordinary spectroscopic work, though without other detriment to its efficiency.

MOUNT TO TAKE THE ABOVE LUMMER-GEHRCKE PARALLEL PLATES IN FRONT OF AN ORDINARY SPECTROSCOPE

This mount (Fig. B 14) is made to suit the Lummer-Gehrcke Parallel Plates described above.

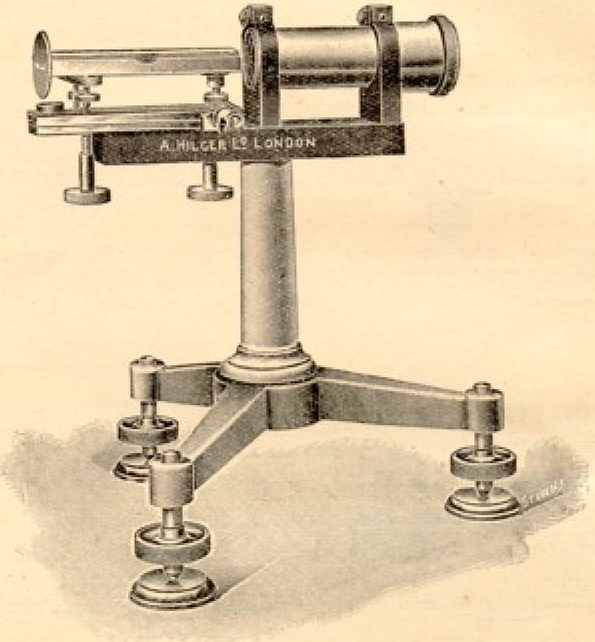

Fig. B 14

The Lummer-Gehrcke Parallel Plate (as in Fig. B 14) stands in its mount on a brass plate which is capable of slight rotation about a vertical axis by means of a milled head screw. This, together with a readily accessible levelling screw, provides the necessary adjustment.

The rays from the source of light should be approximately collimated by a condensing lens. They then traverse the Lummer-Gehrcke Parallel Plate, and an image of the resulting diffraction pattern is formed by an achromatic lens. This image consists, of course, of a number of superimposed images produced by the various monochromatic radiations emanating from the source.

The spectroscope or spectrograph to be used in conjunction with this arrangement is then placed in train with the above apparatus so that the diffraction images fall on the slit. The jaws of the slit should be set vertical; and the dispersion of the spectroscope will then separate out the overlapping diffraction images.

The apparatus is mounted on a substantial cast-iron tripod, with three levelling screws, and is suitable for use with any ordinary spectroscope.

B 65.—Mount for size (B 56) or (B 57) ... ...

B 66.—Mount for size (B 58) ... ...

B 67.—Mount for size (B 59) ... ...

Besides its use with the Lummer-Gehrcke Parallel Plate, this piece of apparatus can also be employed with a Fabry and Perot Etalon. (*See* Section O, "Spectroscopic Apparatus for High Resolving Power.")

USEFUL ACCESSORIES FOR THE DEMONSTRATION OF THE ZEEMAN EFFECT BY MEANS OF THE LUMMER-GEHRCKE PARALLEL PLATE

B 68.—Small electro-magnet on raising and lowering stand, pole pieces adjustable from contact to ½ inch (12½ mm.) apart; suitable for demonstrating the Zeeman effect with these Lummer-Gehrcke Parallel Plates. The current required is about 3 amperes when using an ordinary vacuum tube as the source of light. The lines are separated with these plates into triplets, etc.

B 69.—Shutter eyepiece with bright pointer and double image prism for Zeeman effect observations with the Lummer-Gehrcke Parallel Plate. By means of the shutter eyepiece the line under observation can be isolated, and the double image prism being turned into position, the components of the rays polarised in vertical and horizontal planes can then be observed side by side simultaneously.

The surfaces of the double image prism are protected by glass plates.

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October 1924

SECTION C

SPECTROMETERS AND GONIOMETERS

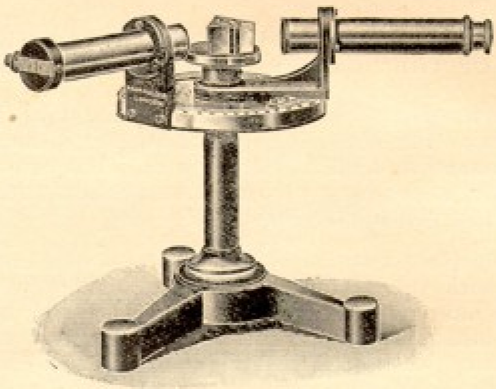


Fig. C 14

C 14.—**Educational Spectrometer.**—This is a very small spectrometer in which the elements have been reduced to their simplest form, the optical and other work being none the less made of good quality.

The focal length of the object glasses is 120 mm., and their aperture 17 mm.

The eyepiece has an equivalent focus of 10 mm., thus giving a satisfactorily high power which is yet suitable for the aperture.

The circle, which is 5½ inches in diameter, reads by vernier to one minute.

The prism, which is large enough to take advantage of the entire aperture of the object glass, is of approximately 1·62 refractive index, and the D lines are easily divided.

C 14.—Educational Spectrometer ... ...

C 15.—Comparison prism ... ...

C 16.—Replica diffraction grating, 14,000 lines per inch ...

C 1.—**Table Spectrometer** (formerly known as No. 1 A).—This instrument is built in a very strong and simple way, and will stand hard use well. The divided circle, vernier, and the jaws of the slit are of platinoid, which is almost untarnishable.

Specification :—

- Slit, No. F 24, p. F 5.
- Object glasses of collimator and telescope, 1¼ inch (31½ mm.) clear aperture, 11¼ inches (285 mm.) focal length.
- The focus of the collimator is accurately set and fixed; the telescope focusses by helical motion.
- Prism, 1$\frac{5}{16}$ inch (33 mm.) high ; 1⅝ inch (41 mm.) length of refracting faces ; refractive index for D 1·65.

Divided circle, 6 inches diameter, divided all round to read by vernier to 1 minute of arc. The division is on platinoid, which is almost untarnishable.

Prism table rotates, has a clamp for the prism, and a division every two degrees.

Eyepiece.—One eyepiece is supplied, with cross webs. The cross webs are capable of a slight lateral movement by means of a milled head screw, whereby one can very readily set the instrument to repeat exactly readings which may have been taken some time before.

Tripod, strong, of enamelled cast iron.

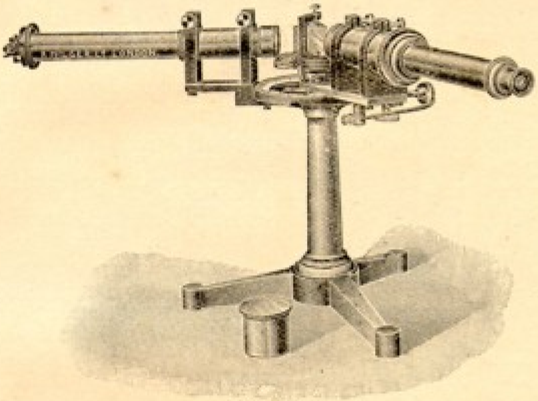


Fig. C 1

C 1.—Table Spectrometer ... ...

C 2.—Protective cover to prism table ... ...

C 3.—Levelling screws ... ...

C 4.—Photographic scale adapted on a third tube, the scale being reflected into the telescope from the second surface of the prism, and being seen in juxtaposition to the spectrum ...

C 5.—Screw adjustment to photographic scale ... ...

C 6.—Well-made case, with lock and key ... ...

Table Spectrometer No. C 7 (formerly known as No. 2).—The divided circle is 8 inches in diameter, the division being on platinoid. The telescope vernier reads to 30 seconds of arc. The prism stands on a separate levelling table, 6 inches in diameter, which is worked optically flat and stands on three levelling screws which fit in radial grooves in the rotating prism table. This latter reads by vernier to 30 seconds. One flint prism is supplied, refractive index for D 1·65. The prism is in a separate mount, and can at once be placed in its correct position on the prism table. The collimator has a well-made adjustable slit (*see* Section F of "Spectroscopic Accessories," Slit No. F 24, p. F 5), with platinoid jaws, wedge for reducing the aperture, comparison prism, and protective cap. The telescope is supplied with high and low power eyepieces, cross spider webs for measurement, and steel tangent screw for slow motion. Both telescope and collimator have helical focussing adjustment. The objectives are of 11¼ inches (285 mm.) focal length, and 1¼ inches (31¼ mm.) clear aperture. The fittings of collimator and telescope are secured by double clamps. The above is mounted on a stable iron tripod stand with three levelling screws.

C 7.—Table Spectrometer ... ...

C 8.—Photographic scale on a third tube uniform in design with telescope and collimator ... ...

C 9.—Screw adjustment to photographic scale ... ...

C 10.—Well-made case, with lock and key ... ...

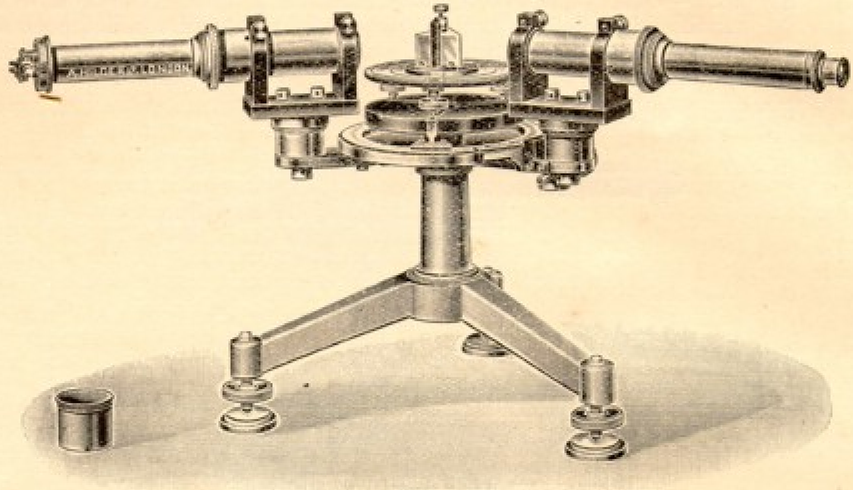


Fig. C 7

C 12.—Table Spectrometer (formerly known as No. 5), designed with special reference to accurate measurement of angles and refractive indices. The divided circle is 10 inches in diameter, and can be rotated to eliminate errors of the division. The circle has two divisions on platinoid, one on the top, on which the prism table

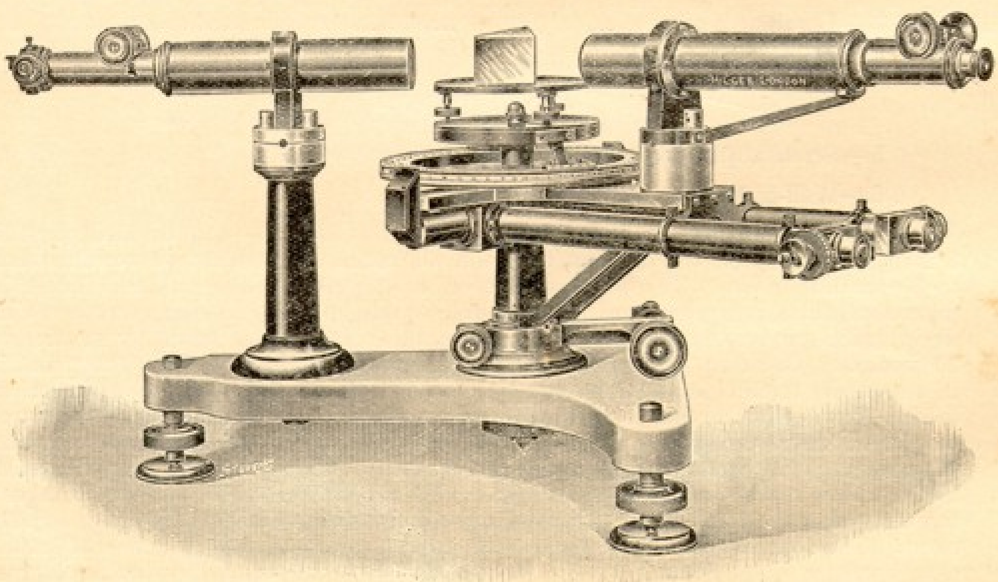


Fig. C 12

reads to 30 seconds of arc by vernier, and one on the edge, on which the telescope reads by two microscopes, each with high quality micrometer eyepiece, to 1 second of arc. By a system of reflecting prisms the micrometers are read from the eye end of the telescope. The levelling table for prisms is worked optically flat, and stands on three levelling screws in three radial grooves in the rotating table. This has a slow motion by rack and pinion. One large dense flint prism is supplied. The collimator has a high quality slit, which is adjustable by a good steel screw with large divided drumhead, wedge for varying the aperture, comparison prism, and screws for correcting any want of parallelism of the jaws which may develop in course of time. The collimator is supported on a separate pillar rising direct from the base. The telescope fitting consists of a 6-inch long sleeve fitting on a fine ground steel spindle, on which are also turned the fittings for the circle and prism table. The greatest care is taken to ensure that the fittings for the telescope circles and prism table are accurately coaxial. The telescope is well stayed, and is exceedingly rigid. Three eyepieces are supplied, each with cross webs. Both collimator and telescope have rack and pinion focussing and divided draw tubes (millimetre division). The objectives are of 1⅝ inches clear aperture and of 14½ inches focal length. The slow motion of the telescope is obtained by the action of a steel screw against a radial arm, which is attached to a split ring fitting on the sleeve carrying the telescope, and it can be put in or out of action by a clamp. The base is of cast-iron, massive and rigid, with levelling screws standing in cups.

For Accessories for the above Spectrometers, see Section F, " Accessories for Spectrometers and Spectrographs."

SECTION D

WAVELENGTH SPECTROMETERS MONOCHROMATORS, AND SPECIALISED SPECTROSCOPES

The constant deviation Wavelength Spectrometer was introduced by us in 1904. The size then made appears in this catalogue in its latest form under the number D 1 or D 2. A number of accessories greatly extending its applications are fully described in Sections D and F of the catalogue. A guide to selections of accessories for various purposes and for chemical or physical laboratories appears in our "Lists of Selected Spectroscopic Accessories," which will be sent post free on demand.

Other types of Wavelength Spectrometer useful for particular purposes are shown, but for general use the instrument recommended is the D 1 or D 2.

THE HILGER WAVELENGTH SPECTROMETER

CONSTANT DEVIATION TYPE

(Standard Model)

The design of this instrument (Fig. D 1, D 2) is based on the use of the now well-known "Constant Deviation Prism." There are a number of different forms of this prism, of which the one used on the Hilger Wavelength Spectrometer is shown in Fig. D 1a. It may be considered as built up of two 30° prisms and one right-angled prism from the hypotenuse of which the light is internally reflected as shown.

The telescope and collimator are both rigidly fixed, since to pass through the spectrum it is only necessary to rotate the prism; and as a result a construction is arrived at which is at once extremely convenient and mechanically sound.

The table on which the prism stands is rotated by means of a fine steel screw, the point of which pushes against a projecting arm on the prism table. To the screw is fixed a drum (*see* Fig. D 1b) on which the wavelength of the line under observation is read off direct as indicated by the index which runs in a helical slot, the index being on the side of the drum towards the eye, so that the wavelengths of lines can be read off without quitting the eyepiece (*see* Fig. D 1, D 2). The point of the micrometer screw is of hardened steel, and is permanently fixed before the screw thread is cut, to avoid the risk of periodic errors, the point forming one of the centres whilst the screw thread is being cut. This hardened steel point presses against a steel plug in the above-mentioned projecting arm of the prism table, itself flint hard and *optically polished*.

The telescope and collimator are both rigidly fixed to the cast-iron base, and the whole is screwed to a strong cast-iron tripod. The object glasses of both telescope and collimator are of 11¼ inches (285 mm.) focal length, and 1¼ inches (31½ mm.) clear aperture.

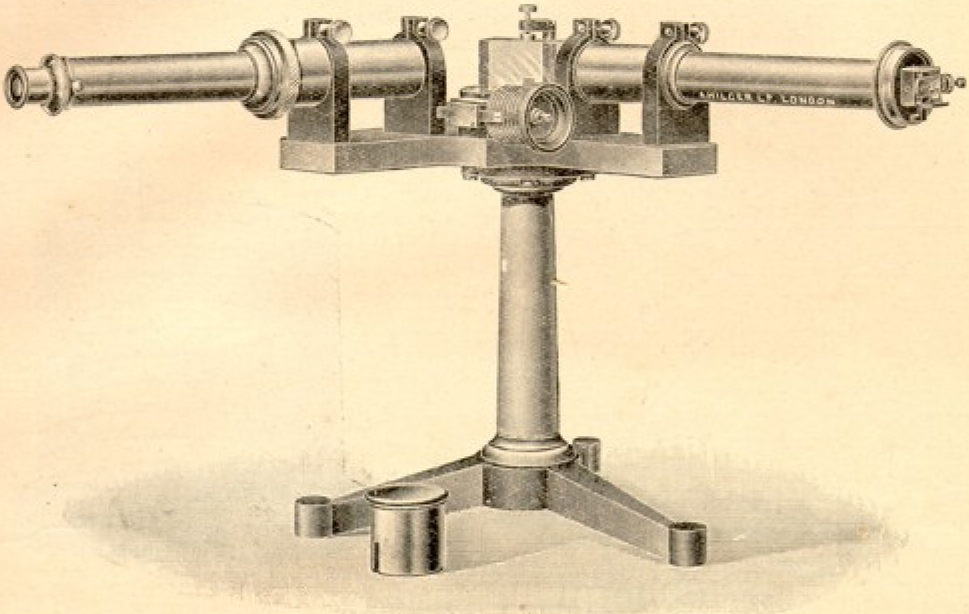


Fig. D 1, D 2

Height to the centre, 320 *mm. without levelling screws ; with levelling screws,* 370 *mm.*

The focussing of the telescope is obtained by the milled ring, which can be seen in the figure on the body of the telescope. By the turning of this ring the object-glass is made to move by a carefully protected helical mechanism, the eyepiece remaining always fixed.

It should be noted that the telescope and collimator can be interchanged on this instrument. The accuracy of calibration is unaffected by the interchange.

It should also be noted that the path of light through the prism may be the reverse of that shown in Fig. D 1a. Indeed, this reverse direction is the one shown in the illustration Fig. D 1, D 2.

Price :—

D 1.—Wavelength spectrometer, prism of 1·65 refractive index for D, accurately calibrated from 3850 A to 8000 A * ... ...

D 2.—With denser prism 1·74 refractive index for D, and correspondingly increased accuracy of calibration, the calibration being from 3900 A to 8000 A * ... ...

D 4.—Protective cover to prism table ... ...

D 5.—Levelling screws ... ...

* With the prism of 1·65 refractive index for D, the Helium line 3888·8 and the Lithium line 8127 can both be seen. With the prism of 1·74 refractive index for D, the Helium line is not visible, but the Calcium lines 3968·6 and 3933·8, and the Aluminium lines 3961·7 and 3944·2 are visible in the light of a carbon arc fed with lime and alumina ; while at the red end the Lithium line is easily visible.

D 6.—Well-made case with lock and key, for either of the above ...

D 7.—Extra high-power eyepiece, with its own zero adjusting cross-webs ... ...

F 40.—Shutter eyepiece with lateral adjustment to bright pointer (*see* Fig. F 40, and description below) ... ...

F 41.—Slide with light filters to the shutter eyepiece for giving the pointer any desired colour, by means of which an increase of accuracy and comfort in reading can be secured, especially in the violet part of the spectrum ... ...

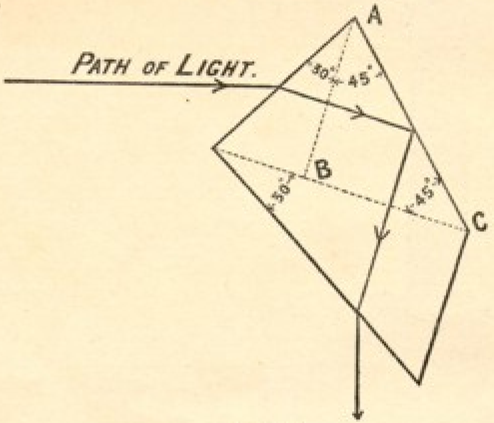


Fig. D 1a

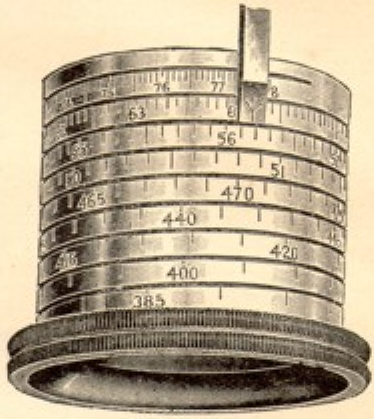


Fig. D 1b

NOTE.—*This eyepiece has two shutters, which can be shifted from either side in the focal plane so as to cover any desired part of the field, thereby obscuring any bright lines which by their proximity prevent the observation of feebler lines. The metal pointer, whose extremity is ground exceedingly fine and polished bright with the greatest care, is illuminated from above by a mirror. This bright pointer is adjustable laterally by the two milled head screws below, so that one can always return to the standard reading by setting the bright pointer on a reference line.*

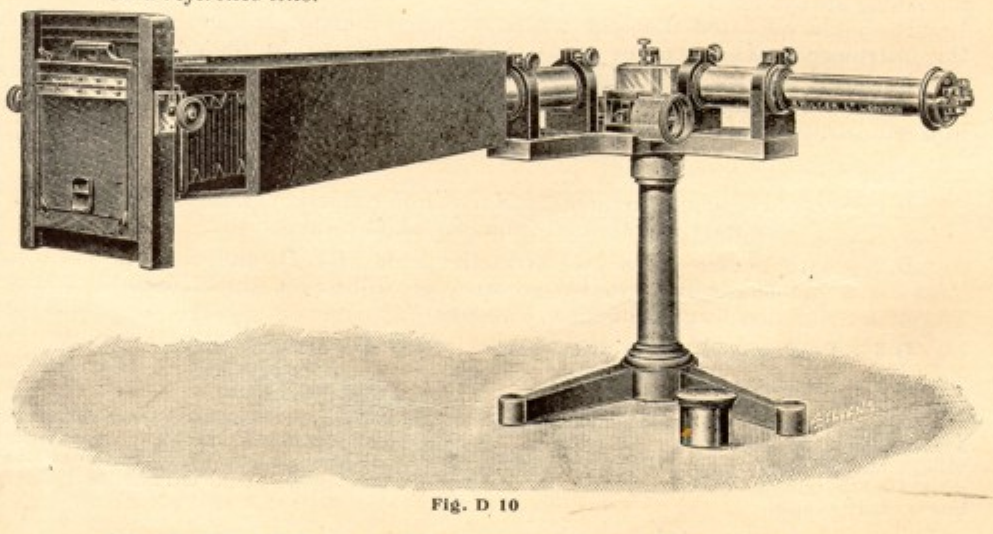


Fig. D 10

D 10.—Camera, with 21-inch focus lens, tilting adjustment for accurately focussing the whole spectrum, and shutter for exposure (shown in position in Fig. D 10)

D 11.—Telescope fixed to side of the camera, and internal mirror with external milled head by means of which the spectrum can be reflected into the telescope at will. In this way the spectrum can be observed immediately before photography. The telescope is on the collimator side of the camera, so that the slit, wavelength drum, and light source are all within reach of the observer ...

D 12.—Replica of Rowland diffraction grating, as described on pp. D 7 and 8, interchangeable with the prism, including calibration in wavelengths for both prism and grating. A wooden case is supplied for holding prism and grating when not in use.

NOTE.—*This can only be supplied if ordered at the same time as the spectrometer.*

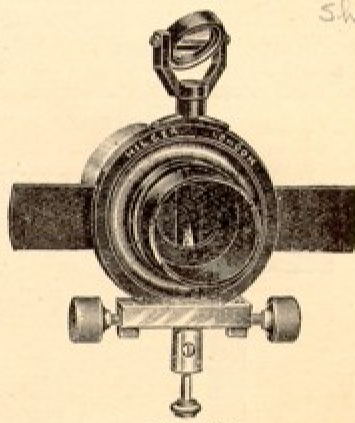


Fig. F 40

We can now supply for these spectrometers apochromatic triple object glasses. The calculations for these lenses and the measurements of the refractive indices of the glasses used have been made by J. W. Gifford, Esq.

Clear aperture ... ... 32 mm. ($1\frac{1}{4}$ in.).
Equivalent focal length ... ... 280 mm. ($11\frac{1}{4}$ in.).

D 13.—Triple object glasses adapted to the Wavelength spectrometer in place of the usual achromatic doublet object glasses ...

Infra-Red Accessories.—The Hilger Wavelength Spectrometers, in common with other spectrometers in which the lenses and prisms are of glass, although not suitable for the extreme infra-red, are nevertheless capable of use considerably beyond the visible spectrum. With the additions described below they can, moreover, be calibrated interferometrically down to W.L. 2·0 μ (20,000 A). This being as far as water transmits, the instrument is quite suitable for measurements of the absorption of aqueous solutions in the infra-red.

The additions required are as follows:

F 77.—**Hilger Thermopile** (*see* pp. F 13-15) sensitive area 20 × 1·5 mm., suitably mounted on tube to fit in place of eyepiece of Hilger Wavelength Spectrometer, with symmetrical slit; symmetrical slit to replace that usually supplied for the collimator, with 20 mm. effective length of jaw; simple shutter attachment clamping to the Spectrometer for exposing and cutting off light; helical drum divided into 100 parts per revolution to replace the wavelength drum for infra-red work.

F 78.—If the additions be ordered at the same time as the Wavelength Spectrometer, then instead of an additional helical drum for infra-red work one extended drum alone will be supplied, calibrated in wavelengths throughout both the visible and infra-red regions, as far as W.L. 2·0 μ.

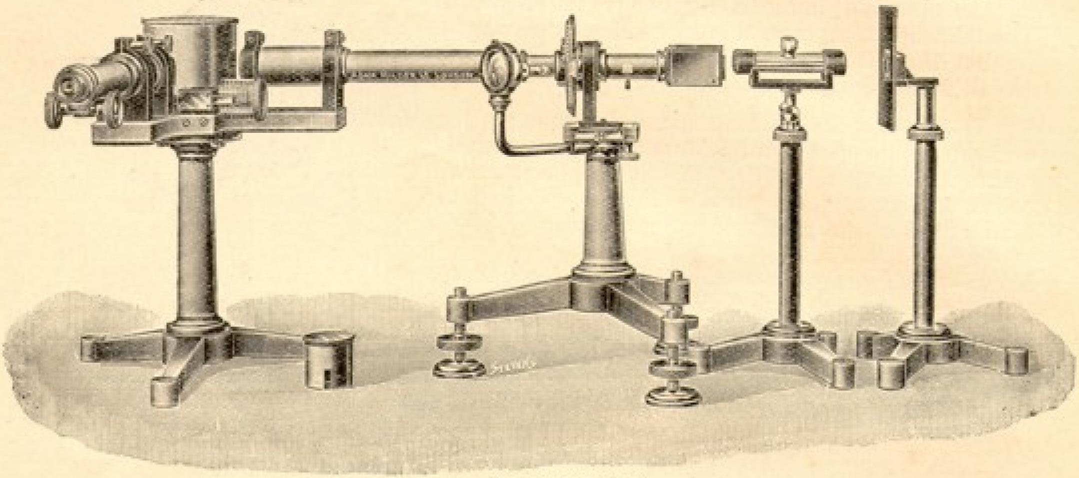
The following table gives the average error of wavelength reading for various regions of the spectrum in the case of the Hilger Wavelength Spectrometer (constant deviation type) with dense prism. The figures have been obtained by readings on actual instruments:—

	VISIBLE.					INFRA-RED.		
Wavelength in A	4000	5000	6000	7000	8000	10,000	17,000	20,000
Average error in A	1	1	1·6	3	5	30	70	80

F 79.—Broca Galvanometer (made by Cambridge Instrument Co., Ltd.), specially selected for use with the above.

F 80.—Scale, on stand, with lamp for use with this Galvanometer (strongly recommended), with flexible lead, holder, and plug adapter (made by Cambridge Instrument Co., Ltd.).

For other accessories, see Section F, "Accessories for Spectrometers and Spectrographs."



D 1 or D 2, H 56

The above figure shows the Hilger Wavelength Spectrometer D 1 *used with the Nutting Photometer H* 56. (*See* pp. H 7-9.)

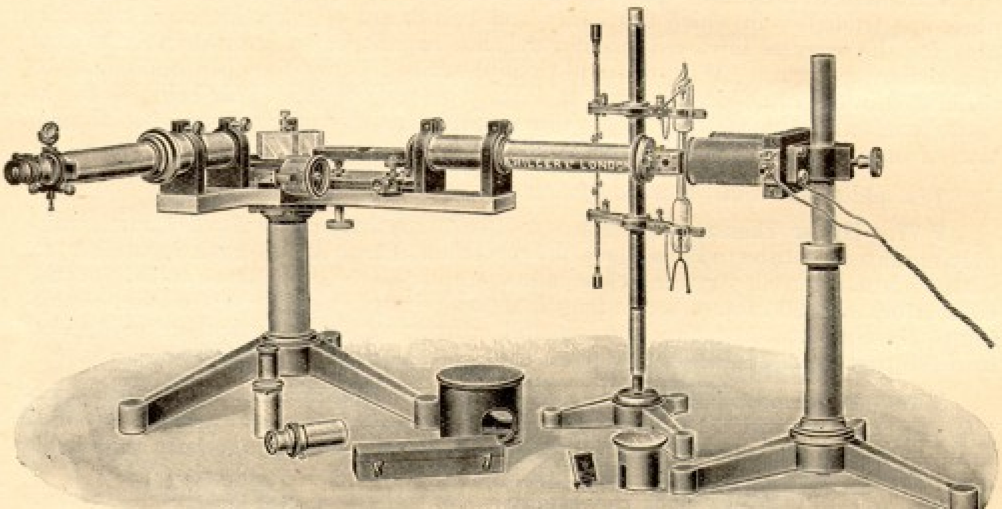


Fig. O 8 or O 10, O 3, F 3 and O 14

The above figure shows the Hilger Wavelength Spectrometer modified for use with Fabry-Perot Etalon, Michelson Echelon diffraction grating, or Lummer-Gehrcke parallel plate; with Lummer-Gehrcke parallel plate in position as set up for observing the Zeeman effect. The complete equipment is described in Section O.

HILGER WAVELENGTH SPECTROMETER

CONSTANT DEVIATION TYPE

(Large Model)

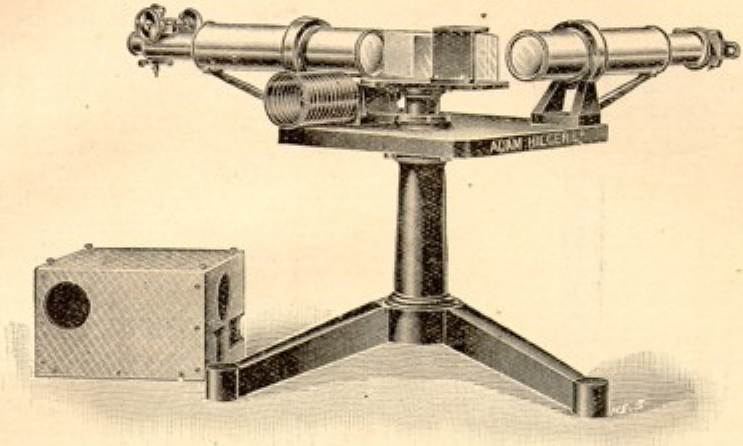


Fig. D 19

Height to the centre 320 mm. without levelling screws ; with levelling screws, 370 mm.

This instrument (Fig. D 19) reads with an average accuracy of about 1 angstrom, from 3888 A to 7950 A in wavelengths direct. The principles of its construction are the same as that of the smaller model, but it is larger and more powerful in every way. The object glasses are of 1⅝ inch (41½ mm.) clear aperture, and of 14½ inches (368 mm.) focal length. The divided scale of wavelengths is engraved on a helical drum, the length of scale division being about 81 inches (205 cm.). The eyepiece has a bright pointer for measuring the wavelengths of bright spectrum lines on a dark field. The instrument is of the constant deviation type—*i.e.* the telescope and collimator are both rigidly fixed, the spectrum being traversed by the fine micrometer screw to which the helical drum is attached. The index is on the side of the drum towards the eye, so that the wavelengths of lines can be read off without quitting the eyepiece.

D 19.—Large model wavelength spectrometer, including shutter eyepiece with bright pointer and lateral adjustment (*see* Fig. F 40), and calibrated complete ... ...

D 21.—Levelling screws to the above ... ...

D 22.—Well made mahogany case, with lock and key ... ...

D 23.—Camera to go in place of the telescope, with 21½-inch focus lens ... ...

For further accessories, see Section F, " Accessories for Spectrometers and Spectrographs."

HILGER WAVELENGTH SPECTROMETER

CONSTANT DEVIATION TYPE

(Small Model for Students)

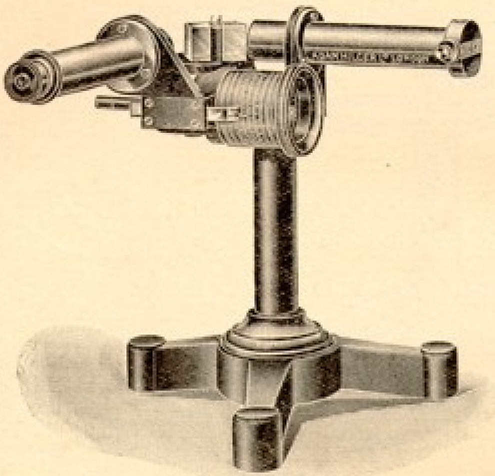


Fig. D 45

This spectrometer is precisely similar in principle to the Hilger Constant Deviation Wavelength Spectrometer, D 1 and D 2 (*see* pp. D 1–2). Although of smaller size and of commensurately lower resolving power than the latter instrument, it is accurately made, with a high quality micrometer screw motion with drum (reading in wavelengths direct) identical with that of the larger instrument.

The object glasses are of $4\frac{3}{4}$ inches (120 mm.) focal length and 0·7 inch (17 mm.) clear aperture; and the eyepiece being of 0·4 inch (10 mm.) equivalent focal length, the sodium lines are distinctly separated, even with the lighter prism.

D 45.—Students' Wavelength Spectrometer, Fig. D 45, prism of 1·62 refractive index for D.

D 50.—Students' Wavelength Spectrometer, with denser prism, 1·74 refractive index for D, and correspondingly increased accuracy of calibration.

D 46.—Protective cover to prism table for either type.

HILGER WAVELENGTH SPECTROMETER

(Constant Deviation Type)

WITH DIFFRACTION GRATING

Resolves the 4 doublets of the E group, and measures wavelengths to 1 angstrom, but is suitable for arc spectra only.

This spectrometer (Fig. D 25) gives a greater accuracy of wavelength measurement than does the D 2, to which it is similar in construction. It is suitable for use in all cases where the amount of light available is great.

Its dispersion is greater than that of the dense prism instrument in the red end of the spectrum, and the readings are accurate to 1 angstrom throughout the spectrum.

Of the prism instrument and this instrument each has its peculiar advantages, the latter on account of its higher accuracy, and the former on account of the brightness of the spectrum.

The diffraction grating, which is a carefully selected film replica of a first quality ruled diffraction grating, is mounted on a right-angle prism from the hypotenuse of which the light is totally reflected. By this means one can pass through the spectrum by rotation of the table on which the prism stands, as in the case of the instrument described on pp. D 1 and D 2. The wavelength drum and index are shown in Fig. D 25a.

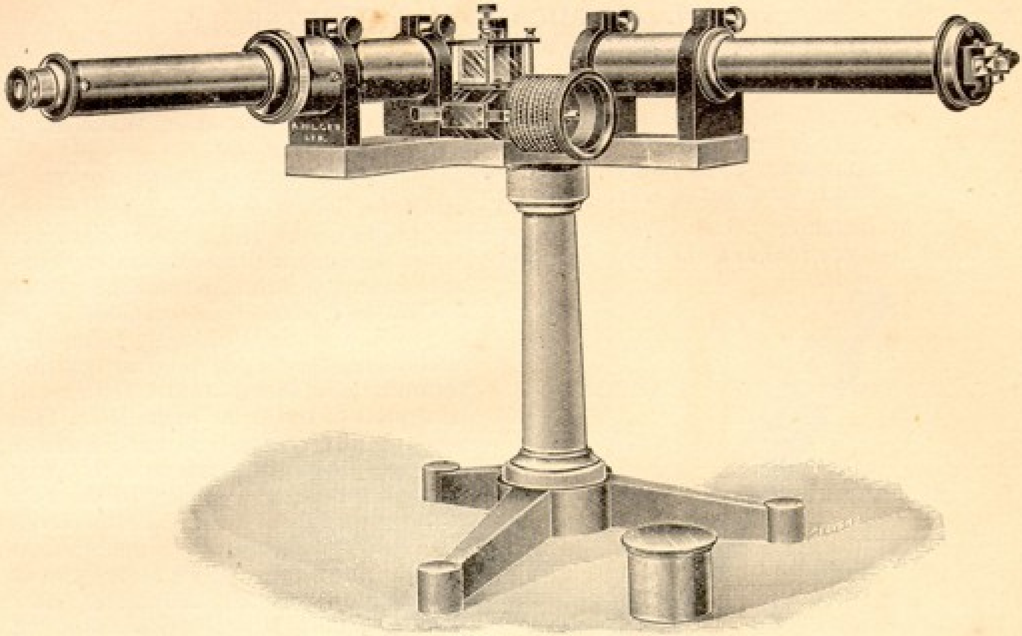


Fig. D 25

Height to centre 320 *mm. without levelling screws ; with levelling screws,* 370 *mm.*

D 25.—Grating Wavelength Spectrometer, accurately calibrated in wavelengths throughout the whole visible spectrum from 3800 A to 8000 A (including cover to prism table)

D 26.—Additions to convert into the prism instrument described on pp. D 1 and 2, with wavelength graduations for both grating and prism scales, and wooden case for keeping prism and grating when not in use. In ordering please state whether a dense or a light prism is required

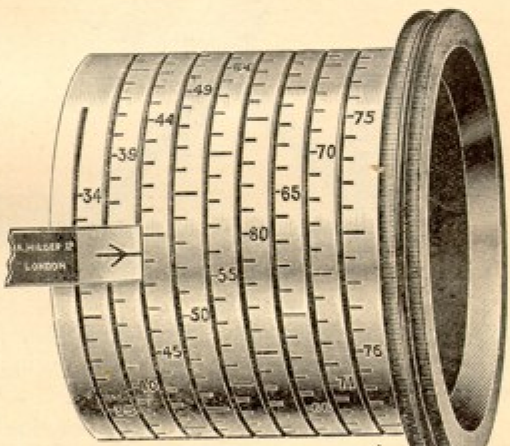


Fig. D 25a

NOTE.—(D 26). *These can only be supplied if ordered at the same time as the spectrometer.*

The following additions can be supplied with this instrument :

Levelling screws, case with lock and key, extra high power eyepieces, shutter eyepiece, and camera. For descriptions, *see* under the prism instrument, pp. D 2 to D 4.

For further accessories, see Section F, " *Accessories for Spectrometer and Spectrographs.*"

D 39. CHEMICAL SPECTROMETER

READING IN WAVELENGTHS DIRECT

The Chemical Spectrometer is distinguished by the following features :—

Very substantially lower cost than The Constant Deviation Wavelength Spectrometers D 1 and D 2.

Compactness, economy of table space, and convenience in manipulation.

Readings direct in wavelengths, to an average accuracy of 1·5 angstroms.

The instrument, as will be seen from Fig. D 39, is of quite novel design. It takes no more room on the table than does a microscope, which in size and appearance it somewhat resembles. The telescope (T) has in its eyepiece a slit and small autocollimating prism for introducing the light. After passing through the object glass (O), the rays of light proceed to the 30° prism (P). This prism is silvered on the back surface, and the light then retraces its path through the object glass (O) to the eyepiece by means of which the spectrum is viewed. The prism (P) is mounted on a table provided with a lever, and is rotated by means of a micrometer screw pressing against the lever, a drum, on which is engraved the scale of wavelengths being attached to the screw. The index moves along a helical slot. An enlarged view of the drum is shown in Fig. D 39a. A cover (C) is provided for the prism for protection and to exclude extraneous light other than that from the slit; and a small mirror with clamp for attaching to the telescope can also be provided (not shown in the illustration).

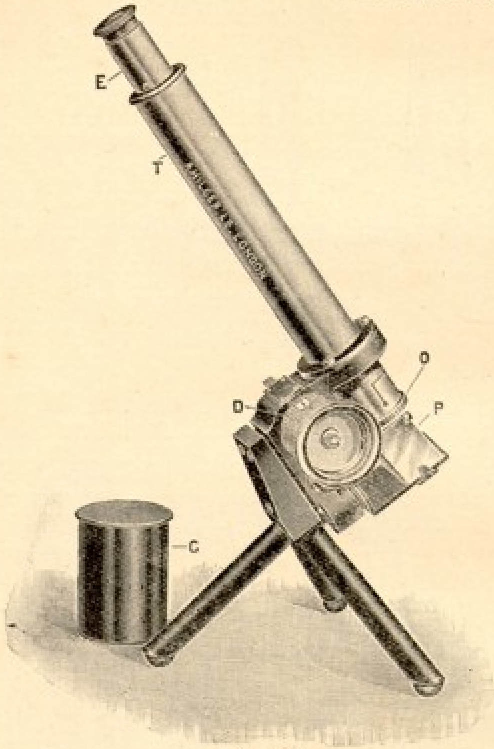


Fig. D 39.

The instrument can be supplied in wooden case with carrying handle, the outside dimensions of the case being $9\frac{1}{2}'' \times 8'' \times 16\frac{1}{2}''$ (24 × 20 × 41 cm.) high. Thus it is very compact for storing and convenient for transport. The instrument may be quickly removed from the case with one hand, and is then ready for use.

Accessories.—These are very few and comparatively simple. For investigation of arc spectra (which we strongly recommend) an arc taking about $2\frac{1}{2}$ amps. is quite sufficient. This will work well on any ordinary D.C. lighting circuit of 150 volts or more. A rough stand capable of carrying the poles of such an arc can easily be made where saving of expense is imperative, and this with a resistance which may conveniently take the form of a board with a few carbon filament lamps connected in parallel, provides all that is necessary even for the most accurate work.

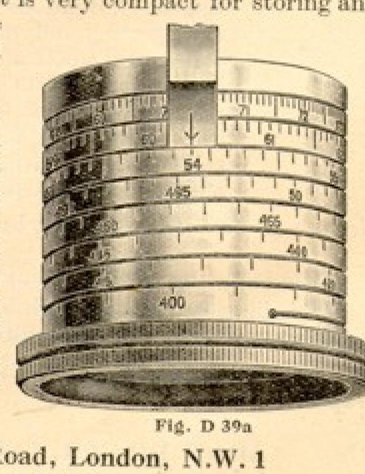


Fig. D 39a

Convenient forms of arc lamp (F 4) and of lamp resistance (F 284) are made by us. When required a small screen can be supplied for mounting on the rod carrying the mirror to protect the eye from too great glare of light; and this screen carries a condensing lens, giving greater illumination.

The following outfit may be recommended:

D 39.—Chemical spectrometer, without case.
D 52.—Adjustable mirror with rod and clamp attachment.
D 53.—Eye-shield with condenser.
D 54.—Polished wooden case with handle.
F 4.—Arc lamp.
F 284.—Resistance.

D 48. THE HILGER "FLAME" WAVELENGTH SPECTROMETER

(Photoscale Type)

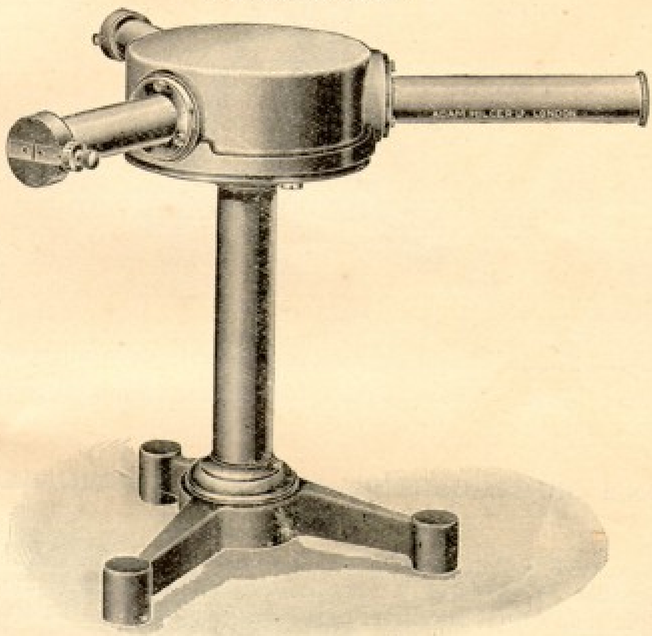


Fig. D 48

The spectrometer whose dispersive system consists of one 60° prism (from the second surface of which is reflected a photographic scale), dates back to the time of Kirchhoff and Bunsen. It is still the best type of instrument for the examination of flame spectra.

The "Flame" wavelength spectrometer is of this kind, small and portable, strong and not easily put out of adjustment, with a fine and accurate scale reading in wavelengths direct.

It is an ideal instrument, not only for chemical students' first instruction in spectrum analysis, but for expert use whenever simple spectra are concerned. The focal length of the object glasses is 120 mm. and their aperture 17 mm.

It is made in two forms, D 48 in which the telescope is horizontal, and D 49 in which the collimator, telescope and photoscale tube all lie in a vertical plane, the telescope sloping downward at a convenient angle for reading. In the latter form, it is convenient to read by an observer standing and working at a laboratory bench.

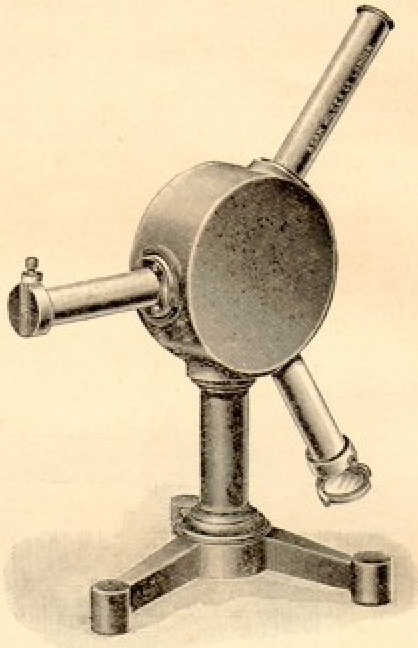


Fig. D 49

D 48.—Hilger " Flame " wavelength spectrometer, horizontal type (see Fig. D 48).

D 49.—Hilger " Flame " wavelength spectrometer, vertical type (see Fig. D 49).

DR. TUTTON'S SPECTROSCOPIC MONOCHROMATIC ILLUMINATOR

APERTURE RATIO F/6

This instrument (Fig. D 32) is described and illustrated in Dr. Tutton's " Crystallography " (Macmillan & Co., 1911). It performs efficiently the same functions as the spectroscopic monochromatic illuminator described by Dr. Tutton to the Royal Society in 1895 (*Phil. Trans. A*, 185, 913), an illustrated account of which is also given in his " Crystalline Structure and Chemical Constitution " (Macmillan & Co., 1910) ; while it has the added advantage that it reads in wavelengths direct. It is similar in construction to the Hilger Wavelength Spectrometer (prism form) described on pp. D 1 to D 2, with the following modifications :—

(1) The addition of a second adjustable and symmetrically opening slit which can be put in the place of the eyepiece, thus converting the instrument into a Monochromatic Illuminator. The first slit is also made symmetrically opening.

(2) The prism (of 1·62 refractive index for D) is of larger size, giving an effective beam of light 30 mm. wide for 5890 A.

(3) The object glasses are 31·5 mm. clear aperture ; but to increase the intensity of the light the focal length is reduced to 185 mm.

(4) The eyepiece may be attached in front of the second slit, for observation of the spectrum lines and regulation of the opening of the slit.

(5) One of two alternative ground glass diffusing screens is mounted on an adjustable tubular fitting in front of the second slit, adequately to diffuse the issuing monochromatic light so as to fill the field of any observing instrument brought in front of it.

The wavelength drum is engraved from 3850 A to 8000 A.

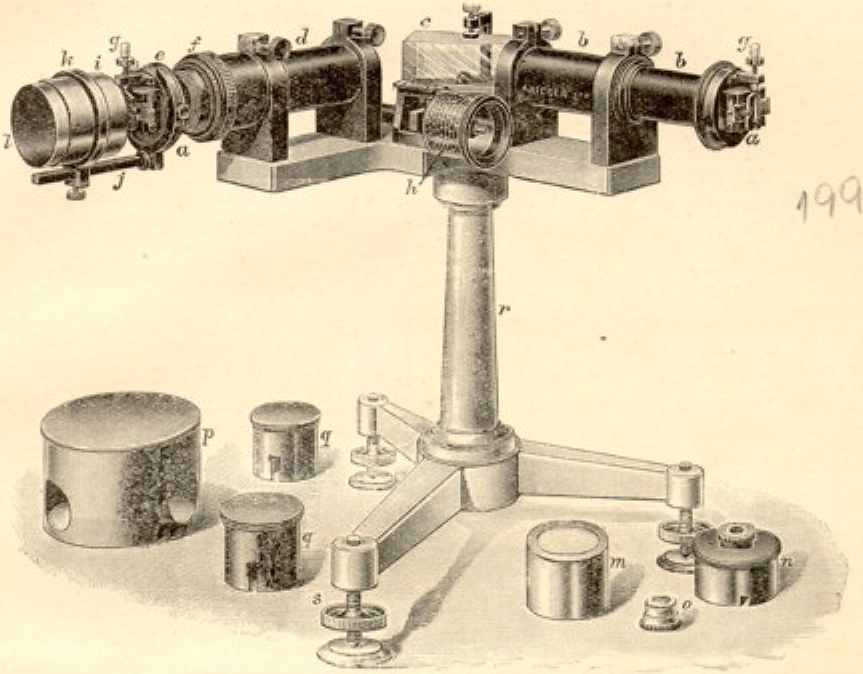


Fig. D 32

Height to centre, 370 mm., with levelling screws.

D 32.—Tutton's monochromatic illuminator, including the usual accurate wavelength calibration and protective cover for the prism table ... ...

In the case of certain classes of work for which this instrument may be used requiring greater intensity of light, a suitable lens may be mounted in place of the ground glass screen ; but for convenience and efficiency in crystallographic observations Dr. Tutton has found the diffusing screens greatly superior.

MONOCHROMATIC ILLUMINATOR for the ULTRA-VIOLET and VISIBLE

READING FROM 1850 A TO 7000 A DIRECT IN WAVELENGTHS

This instrument (Fig. D 33) which is particularly suitable for experiments on the photo-electric effect, etc., is shown in the following illustration.

Levelling screws are always supplied, although not shown in the figure.

The lenses are of 31 mm. aperture and 210 mm. focal length for $\lambda = 3000$ A.

The beam of light from the collimator passes at minimum angle through a cornu prism of quartz (height 32 mm., length of face 42 mm.), and is then reflected from a plane mirror into the telescope. The mirror consists of a plane parallel plate of quartz coated on the back with mercury tinfoil amalgam, which is an excellent reflector in the ultra-violet. The prism and mirror stand on one table, which is rotated by means of a fine steel screw in the same way as the prism table of the

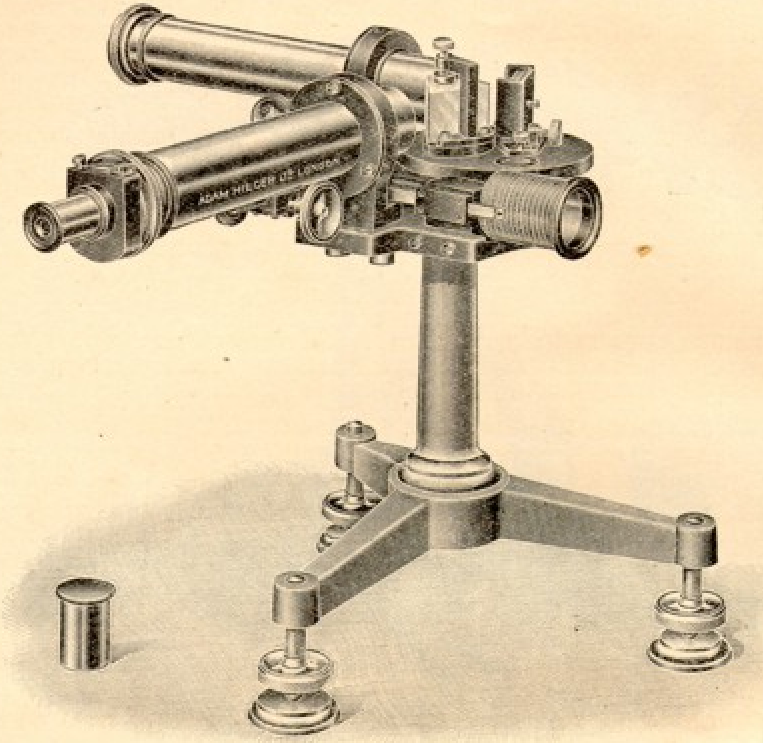


Fig. D 33

wavelength spectrometer, constant deviation type (*see* pp. D 1 to D 2), the wavelength of the portion of the spectrum under observation being read off direct on a helical drum.* The average accuracy of reading throughout the range is about 3 A. The collimator and telescope are rigidly fixed to the cast-iron base. If desired, a

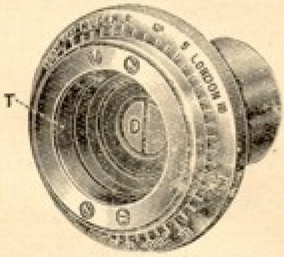


Fig. D 33a

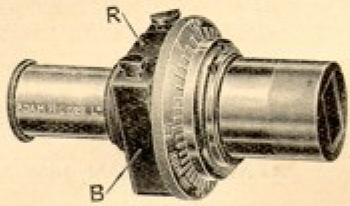


Fig. D 33b

quartz prism on the constant deviation principle can be supplied, but owing to the greater thickness of quartz traversed with such a prism, and the fact that the absorption of quartz begins to be important even at wavelength 2020 A, this form is not recommended.

* See note (†) on p. D 15.

The improved symmetrical slits supplied on these instruments and on the infra-red spectrometer are shown in Figs. D 33a and D 33b.

Slit 33a, for the collimator, is provided with a screw-thread T in front of the slit, into which is screwed a diaphragm of 11 mm. aperture. If it be desired to utilise the entire length of the slit this diaphragm can be removed. The screw thread forms a ready means of adapting an eyepiece to the slit, an arrangement which is often convenient.

Slit 33b for the telescope differs from slit A only in having a block B with recess R for thermopile, and an eyepiece (removed in the illustration) for observation of the slit and thermopile. This block is no hindrance to the use of the slit for the monochromatic illuminator.

Both the above slits are adjustable by large milled ring, with division reading to 1-1000 inch.

D 33.—Monochromatic Illuminator for the ultra-violet ... ...

F 17.—Quartz condenser on raising and lowering stand ... ...

F 43/44.—Fluorescent eyepiece with bright pointer by means of which the ultra-violet lines can be seen as far as the 1850 aluminium group ... ...

D 41.—Large Aperture Monochromatic Illuminator.—This instrument is generally similar in design to the above illuminator (D 33) but the lenses are 22 cms. focus and have an aperture of F/4·5. The prism is 74 mm. face by 45 mm. high.

For such large focal apertures it is desirable to use in front of the slit a special quartz condenser figured to remove spherical aberration.

D 41.—Large Aperture Monochromatic Illuminator ... ...

F 278.—Quartz condenser for same on raising and lowering stand ...

ADDITIONS FOR CONVERTING THE ABOVE INSTRUMENT INTO THE INFRA-RED SPECTROMETER, DESCRIBED ON p. D 15, CONSISTING OF:

Rocksalt prism, concave mirrors of electro-platinum deposited on glass, plane mirror to replace that used for the ultra-violet, thermopile to fit into slit 33b above, extra helical drum calibrated for the infra-red, cast-iron base and mounting for the symmetrical slits and mirrors, and case to take the ultra-violet or infra-red portions of the apparatus when not in use.

When it is desired to use the apparatus for infra-red work, it is only necessary to remove the telescope and collimator, to replace the quartz prism by that of rock-salt, and to attach the cast-iron frame on which the mirrors are mounted with the symmetrical slits in position thereon.

D 34.—Complete infra-red attachments as described ... ...

For suitable galvanometer for use with the above infra-red attachments, see p. F 15 *of our Catalogue.*

INFRA-RED SPECTROMETER

CALIBRATED IN WAVELENGTHS FROM 5,000 TO 100,000 A

For this region of the spectrum the Infra-red Spectrometer shown in Fig. D 35 and described below is suitable.

The optical elements of the Infra-red Spectrometer shown in Fig. D 35 are as follows :—

Two symmetrical slits, each having an effective length of jaws of 20 mm. In the second of these slits is mounted a Hilger thermopile (fully described on pp. F 13 to F 15).

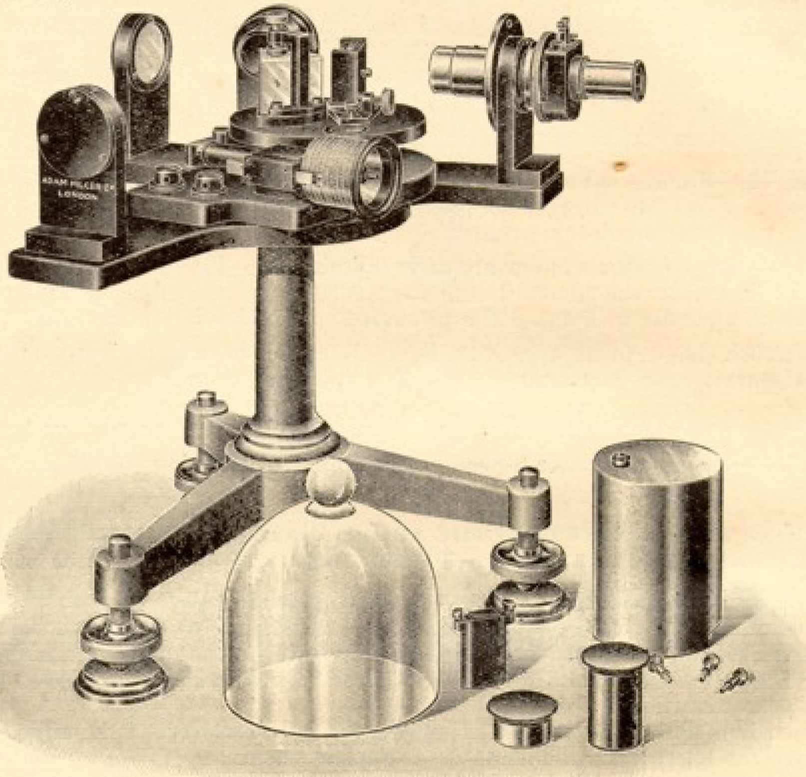


Fig. D 35

Two concave mirrors of platinum deposited on glass, both of 27 cms. focal length and 38 mm. diameter.

Rocksalt prism 32 mm. high, 42 mm. length of face.

Plane mirror, platinum on glass.*

The two slits and the two concave mirrors are rigidly fixed to a cast-iron base.

Levelling screws are supplied to the tripod.

The light entering from the first slit is collimated by the first mirror, and passes through the rocksalt prism to the plane mirror. It is reflected thence to the second concave mirror, by which an image of the spectrum is formed on the second slit.†

* Formerly of gold ; now, as a result of experiment in our laboratories, of platinum.

† An arrangement, in which every ray when in the position of observation passes through the prism at minimum deviation, was first described by Wadsworth, *Phil. Mag.* (5), *38*, 346 (1894). The arrangement used on the D 35 differs however from that of Wadsworth in that the mirror is differently orientated relative to the 60° prism.

The rocksalt prism and plane mirror are mounted on a table which is capable of rotation by a fine screw. To this screw is attached a drum on which the wavelength of the line under observation is read off direct by means of an index running in a helical slot in the same way as in the case of the Wavelength Spectrometer described on pp. D 1–2.

The entire thermopile case is protected from external radiations by a large nickel-plated case.

The thermopile will be supplied with a sensitive area 10 mm. long × 0·5 mm. wide unless otherwise ordered. If desired the 20 mm. long × 1·5 mm. wide size can be supplied, the price being the same. The larger size gives, of course, larger galvanometer deflections (provided the whole length of the slit be filled with light), but owing to the curvature of the spectrum lines a less accurate reading of the wavelength is obtainable.

The rocksalt prism is varnished with a solution of pyroxylin in amyl acetate unless special instructions are given to the contrary. This varnish, while protecting the prism, allows most of the infra-red rays in the region over which this spectrometer is calibrated to pass almost unabsorbed. It has one strongly-marked absorption band, but if necessary it can easily be washed off with amyl acetate.

Outfit recommended :—

D 35.—Infra-red Spectrometer ... ...

F 91.—Broca Galvanometer (made by Cambridge Instrument Co. Limited), selected as being suitable for work with this instrument ... ...

or **F 92.**—Paschen Galvanometer (made by Cambridge Instrument Co. Limited). Much more sensitive than the Broca

F 93.—Scale, on stand, with lamp for use with either of the above galvanometers (made by Cambridge Instrument Co. Ltd.)

If required :—

D 36.—Additions to convert the infra-red spectrometer D 35 into the monochromatic illuminator for the ultra-violet D 33 ; including case for parts not in use ... ...

The sensitivity to be expected from this instrument may be gathered from the following data :—

A D 35 Infra-red Spectrometer taken without special selection from our stock and used with a Broca Galvanometer of 15 seconds period, both slits being ¼ mm. wide, thermopile having a sensitive area of 10 × 0·5 mm., gave a deflection of 20 mm. for the mercury green line (Silica lamp) and 180 mm. for the 44,000 A line given by a Meker burner.

D 42. INFRA-RED SPECTROMETER OF LARGE APERTURE

CALIBRATED IN WAVELENGTHS UP TO 160,000 A

This instrument is of similar design to our standard model, D 35, but so modified as to have a focal aperture of f/4·5. It is provided with a rocksalt prism of about 45 mms. height, and 70 mms. length of face. The concave mirrors are of 23 cms. focal length and 50 mms. diameter. These and the plane mirror are of platinum electro-deposited on glass. Recent experiments with mirrors of stainless steel have led us to believe, however, that this substance is more resistant to atmospheric conditions than metallic films on glass, and of about equal reflecting power. It is probable that this material will be adopted if the tests are confirmed.

The instrument is calibrated in wavelengths from 0·5μ (5000 A) to 16μ (160,000 A), the extension of calibration having been made by Paschen's dispersion formula.

SPECIAL SPECTROSCOPES FOR THE RAPID DETECTION OF NICKEL, CHROMIUM, COBALT, AND OTHER SPECIFIED METALS IN STEELS OR OTHER ALLOYS

A type of spectroscope has been designed by us for the rapid detection of a specified metal in an alloy under workshop conditions.

The instruments consist externally of a substantial casting, with screw focussing eyepiece or eyepieces at the one end, and a stout protective glass plate at the other. The adjustment for observation of the distinctive line or lines is effected once for all in our works, and any intelligent lad can, after a few hours preliminary observation of a range of samples having known percentages of the metal in question, state at once whether that metal is present, and approximately in what amount.

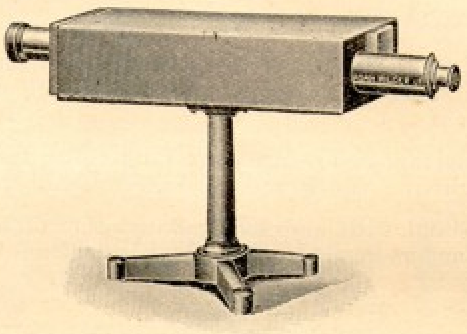


Fig. D 60

The illustration shows an earlier model; the present types are different in external appearance.

The method of use is very simple. To take as an example one form designed for the detection of nickel and chromium, in bars of mixed kinds of steel.

One bar of carbon steel is held in a suitable wooden frame, and the bars to be tested are then placed in position on V-supports one by one as rapidly as possible, connection with the electric mains being automatically provided through a suitable resistance.

The arc is struck by touching both rods simultaneously with a third rod of iron or carbon steel (insulated by pushing over one end of it a piece of ordinary rubber tube). Removal of this rod strikes the arc, and the observer at the Spectroscope is able immediately to state whether the sample contains an important quantity of nickel or chromium or not, and the approximate percentage.

The design of each instrument has to be suited to each case, but on receipt of a statement of any problem of this kind, we shall be pleased to send a report on the subject and quotation for an appropriate instrument.

D 60.—Spectroscope for detecting nickel and chromium (on tripod for warehouse use) ... ...

D 59.—Spectroscope for scrap-yard use ... ...

SECTION E

SPECTROGRAPHS

Specimen photographs taken on any of the Spectrographs mentioned in this Section will be sent post free on application.

QUARTZ SPECTROGRAPHS

Unless a special desire is expressed to the contrary, we now supply on the slits of the spectrographs described on pp. E 1 to E 5, in place of the usual comparison prism, a sliding diaphragm, interchangeable with the wedge of the slit, this diaphragm having three apertures giving three comparison spectra in close juxtaposition.

In addition to those described in this Section, other forms of spectrograph made by us are the "Littrow" spectrographs (either with plane diffraction gratings or with prism systems) of 10 feet focal length (*see* Section G); and quartz spectrographs of large aperture ratio (up to *f*/5); while for work in the visual spectrum not requiring great resolving power, the wavelength spectrometers with cameras described in Section D should also be taken into consideration. Prices, and specimen photographs taken on any of these, will be sent post free on application.

Photographs of Samples.—We are prepared to take photographs of the spectra of samples on one of our quartz (E 3) spectrographs, with wavelength scale, at a charge of 12s. 6d. for each photograph. Also to obtain readings or interpretations of the spectra and otherwise to assist inquiries with reference to the subject.

For micrometers for use with these spectrographs, see *Section L.*

For other accessories for spectrographs, including photographic plates, see *Section F.*

LARGE QUARTZ SPECTROGRAPHS E 1 and E 30

Dispersion from 2294 to 2618 A = 128 mm.

Quartz Spectrograph, E 1 (formerly known as size D), Fig. E 1.—This spectrograph has a dispersion three times that of E 2, being designed for work with complex spectra, such as that of iron. It takes the entire spectrum from 2100 A to 8000 A in three exposures, on 10 × 4 inch photographic plates.

It is of the "Littrow" form, which in so large an instrument presents great advantages owing to its compactness.

The optical train consists of one quartz lens of 70 mm. clear aperture, and 170 cms. focal length; and a 30° prism of quartz 93 to 99 mm. length of refracting face ×54 to 58 mm. high, the second face being coated with tin mercury amalgam,* which is a good reflector throughout both the visual and ultra-violet regions.

The slit is our No. F 31 (*see* p. F 4).

The light enters by the slit, is reflected along the camera tube by a right-angled prism of quartz, is collimated by the lens, enters and is reflected back by the quartz prism, and retraces its path through the lens, an image of the spectrum being formed on the photographic plate.

The prism and lens are mounted on a carriage which moves along a slide, its position being definitely determined by two stops with screw adjustment. The prism can also be rotated to one of three definite positions. These alternative positions correspond with the three portions of the spectrum; the camera being provided with means of varying the inclination of the plate necessary to obtain good definition throughout the spectrum.

The whole is mounted on a substantial cast-iron base.

Overall length of spectrograph 78·7 inches (2000 mm.).
Overall width of spectrograph 13·75 inches (350 mm.).

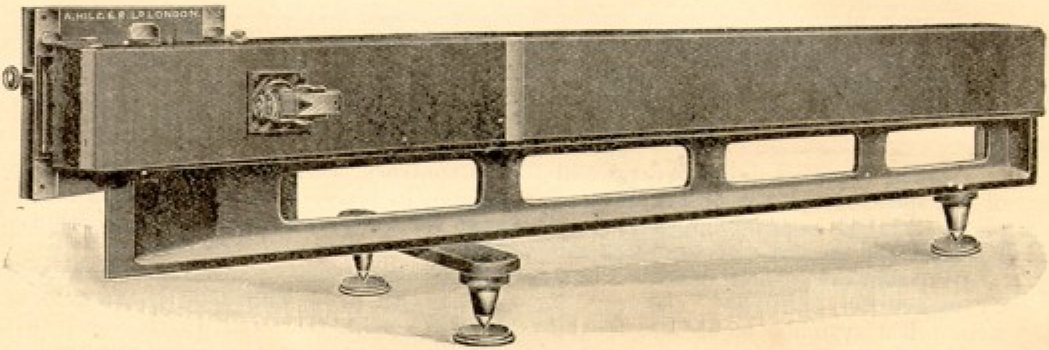


Fig. E 1

E 1.—Quartz spectrograph as above.

E 30.—The same as above but with lenses and prism of smaller aperture.

E 44.—Legs for Quartz Spectrograph, Size E 1 or E 30.—A specially designed carriage can now be supplied for this instrument with castors to enable it to be readily moved about. The construction is such that the instrument may be moved about over an uneven floor without fear of straining the bed or putting the instrument out of adjustment. Height to optical centre of instrument about 48 inches.

Glass Prisms and Lenses for the E 1.—In response to requests for means of converting the E 1 size spectrograph when desired into an instrument giving a larger dispersion in the visible spectrum, we have designed glass systems consisting of lens and prism to replace those in the E 1, whereby increased dispersions can be obtained in the visible and near ultra-violet regions.

E 52.—Dense glass prism and lens to interchange with the quartz prism and lens of the E 1. The spectrum from 8000 to 3800 A is about 35 cms. long, and can be photographed in two settings.

E 56.—Spectrograph as E 1 (above) but with dense glass prism and lens in lieu of quartz.

* Experiments are now in progress with a view to replacement by platinum.

PERMANENT ADJUSTMENT QUARTZ SPECTROGRAPHS

The following spectrographs (pp. E 3 to E 5), *with quartz prisms and lenses, have been very carefully designed with the following objects in view :—*

(1) *To be in permanent adjustment.*
(2) *To give the whole spectrum from* 8000 A *to* 2100 A (*and in the case of the small size to* 1850 A) *on one plate.*
(3) *To give good definition over the whole spectrum on the ordinary photographic plate.*
(4) *To give as large an amount of light as is consistent with the above conditions, thus enabling spectrograms to be taken with relatively short exposures.*

They are sent out completely adjusted, ready for photographs to be taken.

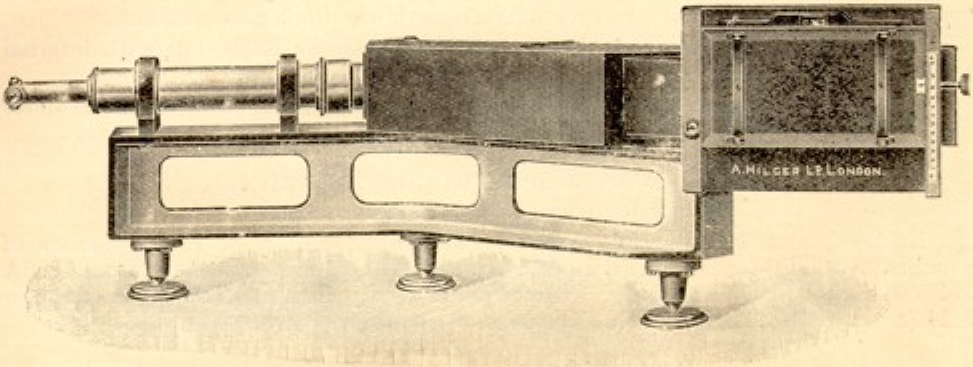


Fig. E 2

MEDIUM QUARTZ SPECTROGRAPHS E 2, E 3, E 36, E 4, E 29, E 34, E 41

Dispersion from 2294 to 2618 A=44 mm.

E 2.—Quartz Spectrograph, E 2 (formerly known as size C) (*see* Fig. E 2).—Lenses of 24 inches (610 mm.) focus, the instrument giving a spectrum from 2100 A to 8000 A of about 200 mm. long. Prism, 41 mm. high × 65 mm. long face. Size of plate, 10 × 4 inches. The slit is our No. F 31 (*see* p. F 4). The dispersing system consists of one Cornu prism. There is a vertical motion by rack and pinion to the dark slide, with scale, whereby a number of exposures can be taken one below the other.

E 3.—Quartz Spectrograph, E 3, being the same as E 2, but with wavelength scale.

In the case of the E 3 instrument, an accurate scale of wavelengths is mounted internally in such a manner as to be brought at will in contact with the photographic plate. Illumination is provided by means of a small electric lamp, and a contact print of the wavelength scale can thus be obtained on the same plate as, and in juxtaposition to, the photograph of the spectrum. A second lamp is supplied as a spare.

The accuracy with which wavelengths can be read on these scales is approximately as follows:—

Wavelength.	Error of Reading.
7000 A	100 A
4000	20
3000	5
2500	2
2200	1

E 36.—Quartz Spectrograph, E 36, being the same as E 2, but with metal slides for plate-holder.

At the request of various customers working in tropical climates or desiring not to rely on woodwork for the slides of the plate-holder, we can now supply the size E 2 and E 3 spectrograph with metal slides for the plate-holder, the said slide being attached to the base of the instrument by a rigid metal bracket. In this construction the wooden cone and bellows of the camera are still retained, but play no part in the support of any essential portions of the apparatus.

E 4.—Quartz Spectrograph, E 4, being the same as E 3, but with metal slides for plate-holder.

E 29.—Quartz Spectrograph, E 29.—Similar to quartz spectrograph E 2 (formerly known as size C) but of smaller aperture. Although this instrument requires a somewhat longer exposure than E 2, it is entirely suitable for practically all purposes for which the E 2 is used, and is of course less expensive. The prism is of the Cornu type, 27 mm. high, 40 mm. long face. The aperture of the lenses is 33 mm.

E 34.—Quartz Spectrograph, E 34, being the same as E 29, but with internal wavelength scale similar to that described under E 3 above.

E 41.—Quartz Spectrograph, E 41, being the same as E 34, but with metal slides for plate-holder.

SMALL QUARTZ SPECTROGRAPHS E 31, E 37

Dispersion from 2294 to 2618 A=14 mm.

E 31.—Quartz Spectrograph (formerly known as size A or E 6).—Lenses of 8 inches (203 mm.) focus, the instrument (*see* Fig. E 31) giving a spectrum from 1850A to 8000 A of about 65 mm. long. Size of plate, $4\frac{1}{4} \times 3\frac{1}{4}$ inches. The slit is our No. F 24 (*see* p. F 4). The dispersing system consists of one Cornu prism.

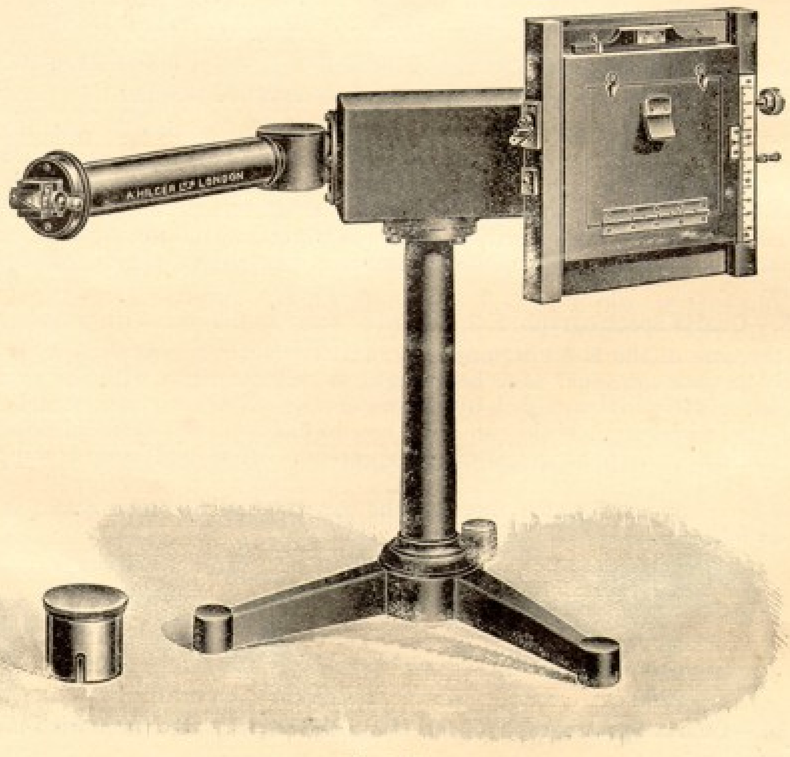


Fig. E 31

E 7.—Accurate scales of wavelengths have been prepared in connection with this spectrograph. These scales are photographed on glass, and can be laid direct on the spectrograms to read off the wavelengths. They are prepared to suit each individual instrument, and are sufficiently accurate to determine the identity of most lines.

E 37.—**Quartz Spectrograph,** being the same as E 32, but with internal wavelength scale similar to that described under E 3 above.

UVIOL GLASS SPECTROGRAPH

E 42.—**The Hilger Uviol Spectrograph.**—This instrument gives on a single plate, $6\frac{1}{2}$ inches × $4\frac{3}{4}$ inches (16·5 cms. × 12 cms.), the spectrum from wavelength 7000 A in the red to 3170 A in the ultra-violet. For this reason it has been used and strongly

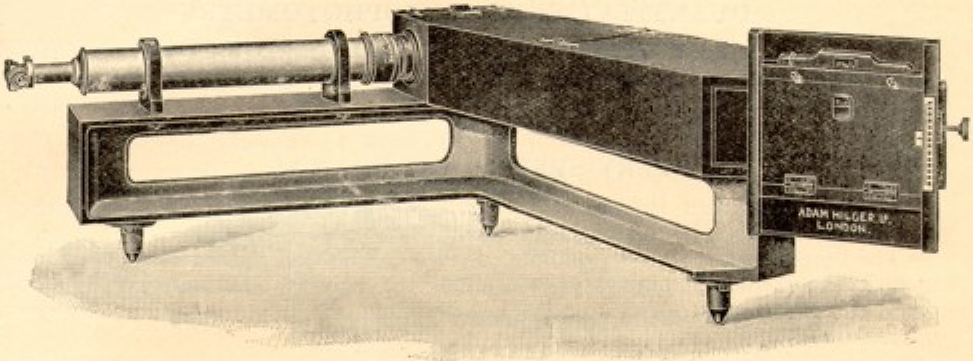


Fig. E 42

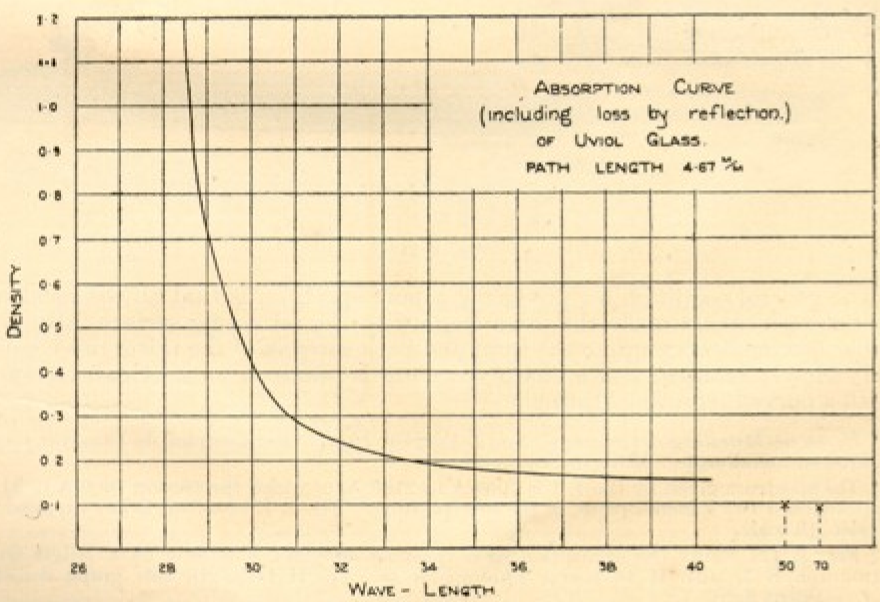


Fig. E 42a

recommended * for metallurgical analysis and particularly for the analysis of steels. Although both in range and dispersion it is exceeded by the more expensive E 1 † it gives a dispersion sufficient for complex spectra such as those of iron, nickel, vanadium, etc., and includes within its range the great majority of the rays classed by Hartley, Pollok, Leonard and Gramont as "persistent" or "sensibles."

There are two prisms of the most transparent Uviol glass,‡ 32 mm. high × 66 mm. length of face; each of 60° refracting angle. The collimator, camera, slit and lenses exactly correspond with the E 2 Quartz Spectrograph, except that the optical work is of Uviol glass instead of quartz.

E 43.—Uviol Spectrograph with wavelength scale. Similar to the **E 42**, but with wavelength scale like that of the E 3, which is described on p. E 3.

(*Specimen photographs will be sent post free on application.*)

QUANTITATIVE SPECTROPHOTOMETRY

For apparatus for quantitative spectrophotometry in the ultra-violet *see* Section H and the separate descriptive booklet on "Spectrophotometers," which will be sent post free on request.

FÉRY SPECTROGRAPH, E 11

In this instrument the collimator and camera lenses are entirely suppressed, the only optical work being the prism itself.

The employment of the principle of auto-collimation with a 30° prism simultaneously shortens the apparatus, simplifies the lens system, and avoids trouble due to the rotatory properties of the quartz, since the prism is traversed twice in opposite directions.

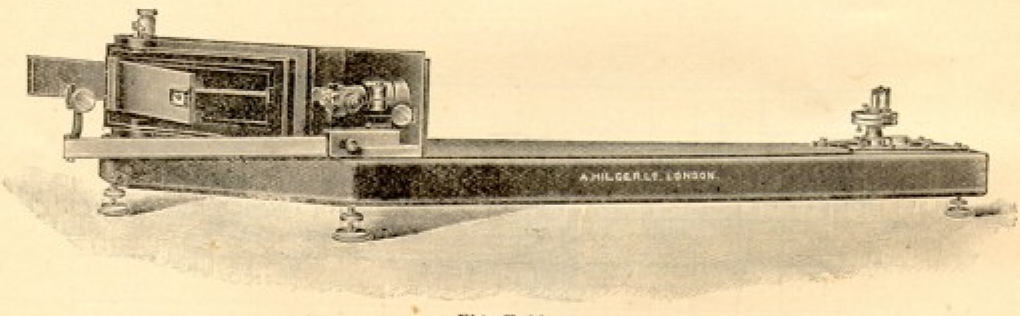


Fig. E 11

The general condition for producing a pure spectrum is that all the incident or refracted rays should make the same angle with the refracting surface. By giving suitable spherical curvature to the front and back surfaces of the prism this condition is very closely realised, and a sharp spectrum is obtained on a cylindrical surface as with a curved reflecting grating.

* *Revue de Metallurgie*, 19e année, No. 2, Février, 1922, "Sur l'emploi de l'analyse spectrographique en métallurgie," M. A. de Gramont.

† The spectrum given by the E 1 is 7000 A to 2100 A, of which the section 7000 A to 3170 A all appears on a 10 × 4 inches plate, in the first position. The E 1, however, is not supplied with a wavelength scale.

‡ Fig. E 42A shows the absorption of a specimen of glass, measured on a Hilger Quartz Spectrograph E 3, with H 16 Sector Photometer (*see* pp. H 1-4). In this graph density = $\log_{10}\left(\frac{\text{incident light}}{\text{transmitted light}}\right)$.

Dimensions :—

Size of prism, 58 mm. ; length of face, 50 mm. high.
Distance from face of prism to centre of photographic plate, 1080 mm.
Size of photographic plate, 10 inches × 2 inches (or if desired 24 cm. × 5 cm.), taking 4 spectra one below the other.

The spectrum extends from W.L. 2100 to W.L. 8000, the length of spectrum between these limits being 224 mm.

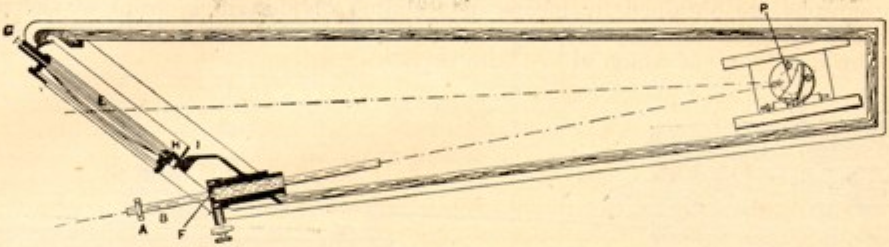


Fig. E 11a

The spectrograph is shown in Fig. E 11 and in diagram in Fig. E 11a.

It is supplied complete with quartz sphero-cylindrical condensing lens.

E 11.—Féry spectrograph as described ... ...

CONCAVE GRATING SPECTROGRAPHS

(EAGLE MOUNTING)

(*See* Paper by A. Eagle " On a New Mounting for a Concave Grating ")
Astrophys. Journ., 31, page 120 (March 1910).

In comparison with the classical Rowland mounting, the Eagle mounting has the following advantages :

(1) It occupies very little space.
(2) No darkened room is necessary.
(3) Spectra on either side of the normal may be used with equal facility ; a point of some value, as it may happen that the best third-order spectrum is on the opposite side to the best first-order spectrum.
(4) Everything being on the same axis, great rigidity is obtained.
(5) It is much easier to ensure uniformity of temperature. This is of capital importance in making long exposures with the larger models.
(6) Higher orders are obtained.

Mr. Eagle has developed in detail in the above-mentioned paper the comparison between the two methods of arranging the diffraction grating.

For stigmatic mountings for concave gratings, according to the system of Meggers and Burns, Bureau of Standards Scientific Paper, No. 441, 1922, see p. E 9.

SIZE E 14. (*See* Fig. E 14.)

(*Suitable for a K 16 Grating of 100 cm. radius and 4·5 cm. diameter ; 14,400 lines per inch.*)

The instrument consists of a cast-iron girder on which are mounted the camera, and the slide for the grating carriage. The grating carriage is movable longitudinally by a screw of $\frac{1}{4}''$ pitch, the motion being sufficient to give the following ranges of spectra, if the grating be of 14,400 lines per inch.

1st order, from the extreme violet to 26,000 A				
2nd	,,	,,	,,	13,000 ,,
3rd	,,	,,	,,	8,800 ,,
4th	,,	,,	,,	6,500 ,,
5th	,,	,,	,,	5,300 ,,

The frame of the camera is of metal, the dark slide of mahogany. Comparison photographs are obtained by means of a sliding diaphragm in front of the plate actuated by screw motion. The slit is our No. F 28 size (*see* p. F 4). The size of the film is $10'' \times 2''$, of which $9\frac{1}{2}'' \times 1''$ are exposed.

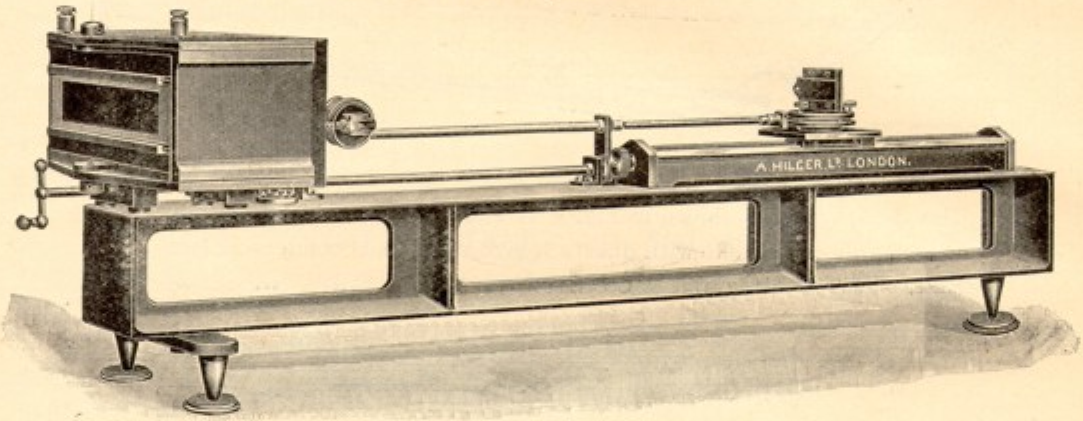


Fig. E 14

We recommend that with this and the next size of instrument films be used. Stiff films are now easily obtainable from photographic plate makers, and they will bend to the full curvature and give perfect definition from end to end. For the use of plates, however, a second dark slide is provided, which has only half the correct curvature, that being the greatest amount of bending to which one can safely submit even the specially thin plates now obtainable.

The grating mount is provided with means of levelling the grating, and of setting the lines of its ruling parallel to its axis of rotation. The slit can also be adjusted to be parallel to the lines of the grating. The instrument is provided with a well-made light-tight cover.

E 14.—Concave Grating Spectrograph including best quality N.P.L. grating of dimensions mentioned above ... ...

E 15.—Rods from camera ends of the instrument to actuate the screw motion and rotate the grating ; also counting mechanism to both for accurately setting the grating to any desired position.

SIZE E 16

(*Suitable for a K* 17 *Grating of* 150 *cm. radius and* 4·5 *cm. diameter ;* 14,400 lines per inch.)

This instrument is of the same design as size E 14, but of increased length.

E 16.—Concave Grating Spectrograph including best quality N.P.L. grating ... ...

The price of the rods and counters is the same as for the size E 14 instrument.

E 44.—Legs for Grating Spectrograph Size E 16.—A specially designed carriage with castors to enable the instrument to be readily moved about. The construction is such that the instrument may be moved about over an uneven floor without fear of straining the bed or putting the instrument out of adjustment. Height to optical centre of instrument about 48 inches.

SIZE E 17

(*Suitable for a K* 22 *Grating of* 300 *cm. radius and* 10·5 *cm. diameter ;* 14,400 lines per inch.)

With gratings of this radius it is usually preferable to mount the camera and the slides with screw motion, etc., on separate concrete or brickwork supports instead of both on one girder, and the camera and slides are designed for this purpose. A drawing of the necessary brickwork is sent in receipt of every order for one of these instruments. The wooden cover is provided as for the smaller size of grating mounting, but in this and in the following case a second inner cover is provided further to retard the temperature variations which with all large grating spectrographs are a source of great inconvenience if not provided against. The camera is arranged to take plates 40 × 4 cm., and all adjustments, as given under specification for size E 14, are provided, together with rods from the camera to actuate the screw motion and rotation of the grating. The slit is our No. F 31 size (*see* p. F 4).

E 17.—Concave Grating Spectrograph including best quality N.P.L. grating ... ...

SIZE E 18

(*Suitable for a grating of* 650 *cm. radius and* 6″ *diameter.*)

This size is of exactly the same design as size E 17 described above, with the exceptions that it is longer to suit the longer radius of curvature, and that the grating mount and carriage are suitably modified for the larger size grating.

E 18.—Concave Grating Spectrograph including best quality grating

(*At the time of printing, gratings of this size are not available.*)

E 49 STIGMATIC CONCAVE GRATING SPECTROGRAPH, SYSTEM OF MEGGERS AND BURNS.*

E 49.—Stigmatic concave grating spectrograph, system of Meggers and Burns (Bur. Standards Sci. Paper No. 441, 1922), with 3 metre concave grating ruled at the National Physical Laboratory (first quality with N.P.L. Certificate), catalogue number K 22.

This instrument takes photographic films 10″ × 2″. The dark slide has vertical movement by rack and pinion, with dividing, for taking several spectra on one plate.

The two chief elements, viz., slit and grating mount, with movable arm and camera, and the mirror mount, with the rails on which the camera arm slides,† are to be supported on three brick or cement piers (drawing of which is supplied by us).

No cover for the apparatus, which is customarily used in a dark room.

All necessary adjustments are provided.

E 49.—Stigmatic Concave Grating Spectrograph, with grating ...

* *Bureau of Standards Scientific Paper*, No. 441, 1922.

† *See* Fig. 2, p. 192 of *Sci. Paper of Bur. Standards*, No. 441, 1922.

VACUUM GRATING SPECTROGRAPH E 50

E 50.—This is a concave grating spectrograph specially designed for the investigation of the Schumann and Lyman regions of the spectrum. The grating supplied is the K 35, which is a circular polished speculum mirror 7 cms. in diameter, and of 100 cms. radius of curvature ruled with about 14,400 lines per inch, but the ruling is specially done to give light in the short wave region. The grating mounting has been specially designed so as to reduce the diameter of the instrument as much as possible, while leaving sufficient room for the requisite motions. Focussing motion is provided by sliding the grating mount in tubular portion of the instrument, and opposing screws allow of its being clamped firmly in position. Readily accessible screws are provided for all other necessary adjustments. No refractive substance, *e.g.* quartz or fluorite, is introduced, but the spectrum from 2100 A to 500 A is obtained with one setting of the grating by the use of two slits, while shorter wavelengths are obtainable by resetting the grating. The slits are disposed in the end plate of the instrument, just below the plate-holder, and, beside extending the range of spectrum obtainable from one setting of the grating, provide a means of measuring wavelengths by Lyman's method. The slits are of the fixed jaw type, but either jaw can be removed for cleaning and replaced without varying the slit width. The plate-holder is cylindrical in form, and provided with a cover which permits of introducing it into and removing it from the instrument in daylight. A shutter is provided so that two exposures can be made on a plate 6×1 cm. A large aperture is provided for pump connection, and a tray for phosphorus pentoxide to dry the residual gas is supplied in a readily accessible position. The 459 A carbon line is obtained with every instrument, while lines as far as 372 A have been obtained.

E 50.—Vacuum Grating Spectrograph ... ...

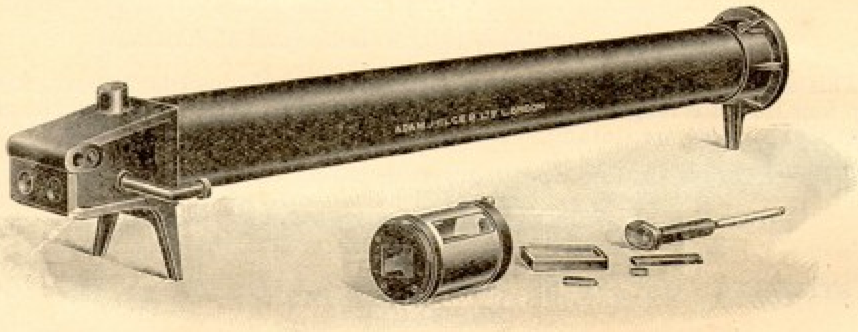


Fig. E 50

Vacuum Arc Lamp for Metals.—This consists of a water-cooled jacket, which can be applied to the slit of the Vacuum Grating Spectrograph. The electrodes are attached to rods which pass through insulated vacuum-tight fitting in the jacket, and designed to allow of motion for adjusting and striking the arc. The position of the electrodes when touching is such that the light produced is sufficiently close to the slit to allow of the maximum aperture being used.

F 280.—Vacuum Arc Lamp for Metals ... ...

Accessories.—We can supply the following accessories for use with the above spectrograph :—

(*a*) Schumann Plates of our own manufacture, specially made for use throughout the whole region. (*See* p. F 17 and special leaflet.)

(b) Vacuum pumps employing oil (not mercury) and mechanically driven, suitable for producing a high vacuum rapidly in large apparatus. (*See* leaflet entitled "The Rapid Production of High Vacua," pp. F 7-8.)

(c) Large bore discharge tube for use as vacuum gauge.

Bibliography.—The following are references to work with this Vacuum Spectrograph :—

McLennan - - - *Proc. Phys. Soc.*, 31, pp. 1-29, 1918.
McLennan and Lang - *Proc. Roy. Soc.* (A.), 95, pp. 258-273, 1919.
Simeon - - - *Proc. Roy. Soc.* (A.), 102, pp. 484-496, 1922.
Fowler - - - *Proc. Roy. Soc.* (A.), 103. pp. 413-429, 1923.
Simeon - - - *Proc. Roy. Soc.* (A.), 104, pp. 368-375, 1923.
Simeon - - - *Phil. Mag.*, 46, pp. 816-819, Nov. 1923.

Other references to work in this region with similar instruments are :—

Lyman - - - *Astrophys. Journal*, 35, pp. 341-353, 1912.
Lyman - - - *Spectroscopy of the Extreme Ultra-Violet*, Longmans, Green & Co., 1914.
Saunders - - - *Astrophys. Journal*, 43, p. 234, 1916.
McLennan - - - *Proc. Roy. Soc.*, 98, p. 114, 1920.
Millikan - - - *Astrophys. Journal*, 52, pp. 47-62, 1920.
Millikan - - - *Astrophys. Journal*, 53, pp. 150-160, 1921.
McLennan and Petrie - *Trans. R.S.C.*, 15, pp. 15-29, 1921.
Wood - - - *Phil. Mag.*, 46, pp. 741-750, Nov., 1923.
Hutchinson - - *Astrophys. Journal*, 58, pp. 280-293, 1923.
Millikan and Bowen - *Phys. Rev.*, 23, pp. 1-34, 1924.

E 45/6. DR. MÜLLER'S X-RAY SPECTROGRAPH

FOR CHEMICAL, CRYSTALLOGRAPHIC AND RADIOGRAPHIC LABORATORIES, AND FOR THE GENERAL STUDY OF X-RAYS

Provision is made for the following work :

(1) Determination of space lattice structure of crystals and powders, and hence
(2) Analysis of Crystals and Powders.
(3) Determination of Wavelengths of characteristic emissions of anti-cathodes with sufficient accuracy for analysis of solids used as anticathodes.
(4) Determination of end radiation from tubes with different excitations.

etc. etc.

DESCRIPTION OF DR. MÜLLER'S X-RAY SPECTROGRAPH E 45/6

To meet the requirements of the various classes of work mentioned above, Dr. Müller has designed an extremely compact form of X-ray Spectrograph. While of sufficient accuracy for this class of work, the instrument is made of simple design and at such moderate cost that it can be put into the hands of advanced students who are capable of profiting by experience of this important class of work.

The instrument consists of a support carrying a rotating table for the crystal mount, and passing through the latter a bar of triangular section upon which slide carriers for slit and plate-holders respectively. This support is mounted on a box containing a spring motor, to the shaft of which is attached a cam. A lever, which can be clamped at any orientation to the axis of the crystal table, is kept in contact with the cam by a spring, and is thus oscillated through a certain angle as the cam rotates. Three cams are supplied giving angles of oscillation of 5°, 10° and 15° respectively.

The crystal mount consists of a vertical plate with lead screen, to which the crystal can be attached with soft adhesive wax and which is provided with tilting

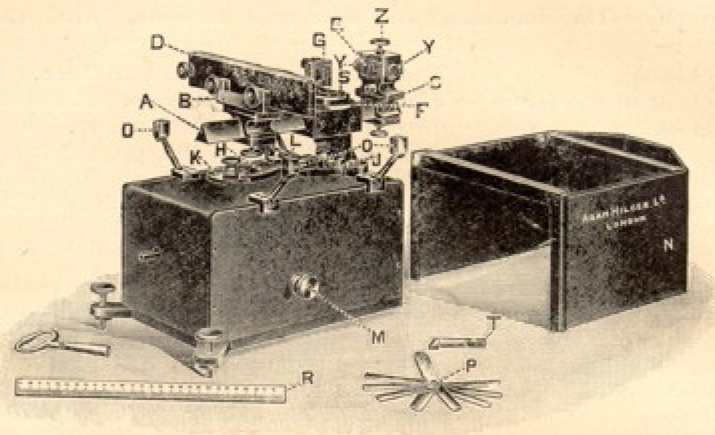


Fig. E 45/6. Arranged for Bragg Method

adjustment about a horizontal axis. The mount can be traversed in a slide across the rotating table so as to bring the face of the crystal up to the axis of rotation. The edge of the table is divided in degrees to facilitate the setting relative to the lever in order to register lines upon each side of the normal to the photographic plate.

The plate-holder, which is attached to its slide by two milled head screws, is designed to take plates $4\frac{3}{4}$ ins. × $\frac{3}{4}$ in. (12 cms. × 1·9 cm.) which can be cut from standard

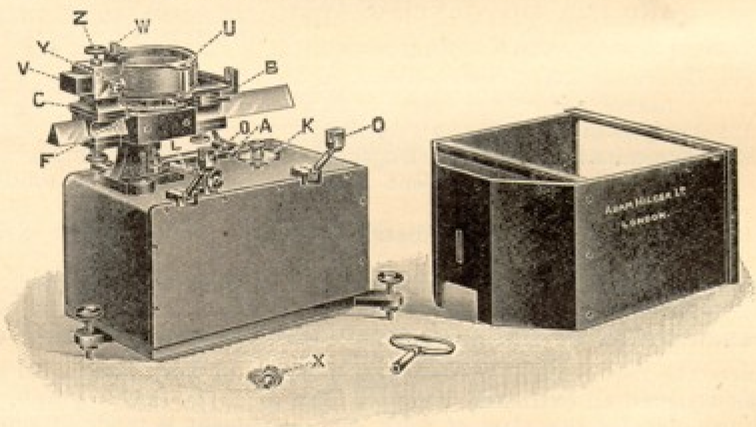


Fig. E 45/6. Arranged for Debye and Scherrer Methods

size plates ($\frac{1}{2}$-plate size). It is provided with a black paper screen, so that the instrument may be used in daylight without risk of fogging the plate, and no special sheath for the plate is necessary.

The instrument is mounted on three levelling screws, the heads of which, as well as those of other adjusting screws, are made of vulcanite to minimise risk of shock in case the instrument is charged by induction from the tube and transformer, etc. A lead screen is also mounted upon the instrument to prevent fogging of the plate by stray X-radiation.

As described, the instrument is available for work with a single crystal by the Bragg method. By a simple interchange of parts which can be effected in about one minute it becomes suitable for the investigation of powders by the Debye method. The slit jaws, crystal mount and plate-holder are removed and the carriers moved up to support a circular camera, 6 cms. in diameter, which carries a photographic film. The camera is so disposed that a powder-holder can be inserted in the centre of the rotating table and advantage taken of the oscillating movement for this work also. In place of the slit is mounted a brass block pierced with an aperture 1 mm. in diameter. The end of this block fits into an aperture of the camera and points directly to the powder-holder in the centre.

The instrument is also available for taking photographs by Hull's powder method, a small spring attached to the slit being supplied. Thus the three standard methods now in use are available in the one instrument.

E 45/6.—Müller X-ray Spectrograph as described, including parts for single crystal and powder methods of analysis. With mahogany case with lock and key, fitted to take instrument and box, into which are fitted the parts not in use when the instrument is being used in either way ...

For full description see separate Leaflet, sent post free on request.

COMPLETE EQUIPMENT FOR THE PRODUCTION OF X-RAYS

SUITABLE FOR USE WITH DR. MÜLLER'S X-RAY SPECTROGRAPH

F 245.—Shearer Tube.—This tube has a water cooled metal anticathode, the rays emerging from a window of thin aluminium foil ($\frac{1}{10}$ mm.) placed immediately in front of the anticathode. The anticathode is detachable, and four interchangeable anticathodes are customarily supplied; iron, copper and molybdenum for the production of the K radiations of these elements, and brass for the attachment of powders when it is desired to analyse by X-ray methods the elements contained in such powders.

The tube possesses very considerable self-rectifying properties, the result being that it can be operated successfully on a closed core high tension transformer running on alternating current without the aid of any subsidiary rectifying devices.

During operations the tube is kept continuously exhausted by a simple type of mercury vapour pump. The pressure in the tube can be controlled so that the rays are of the wavelength required for the investigation. It is well suited for use with the Hilger Müller X-Ray Spectrograph.

F 258.—Transformer.—The transformer is of the closed core shell type and is oil immersed.

The secondary winding is layer wound, each layer being insulated by specially prepared varnish impregnated paper having a very high dielectric strength.

Terminals are arranged so that the milliammeter may be connected in the tube circuit at the "earth" end of the secondary winding. Thus this meter may be installed upon the switchtable and may be handled whilst the apparatus is working without danger.

The rated output of the transformer is 15 milliamperes at 60,000 volts (R.M.S. value) continuously, whilst currents up to 30 milliamperes at the same voltage may be obtained for short periods.

The transformer is contained in a galvanised iron tank fitted with a hard fibre top.

F 259.—Control Board.—The switchgear together with auto-transformer, resistance and their controls are mounted upon a metal switchtable fitted with a black polished slate top.

The auto-transformer is arranged with five tappings so that the correct voltage is applied to the primary winding of the main high tension transformer to give secondary voltages of 20, 30, 40, 50 and 60 kilovolts (R.M.S. value) as required.

A variable resistance can be put in circuit, as not only does the tube run more steadily, but in the event of a short circuit on the secondary side of the transformer the resistance limits the amount of current flowing into the primary winding of the transformer.

The main switch is solidly built and fitted with two pairs of contacts, one pair of the contacts closing first and thereby introducing a resistance into the primary circuit. This limits the initial rush of current into the transformer. When the switch is fully closed the limiting resistance is cut out by means of the second pair of contacts and the transformer is then working normally.

By means of the combination of auto-transformer and resistance controls any value of voltage across the tube may be obtained for any value of milliamperage.

F 260.—Rotary Converter.—In cases where alternating current is not available for use with the transformer it is necessary to convert the direct current into alternating at suitable voltage. This converter is of suitable capacity to work with the transformer described above.

The electrical parts (F 258, F 259, F 260) *are made by Watson & Sons* (*Electro-Medical*) *Ltd.*

(***State voltage of supply in ordering.***)

PUMPS

The system which we recommend for exhausting the Shearer Tube consists of an oil-immersed backing pump (Trimount No. 1) which is motor driven, supporting a mercury diffusion pump set.

The items comprised are :—

F 160.—Oil-immersed backing pump.

F 265.—5-gall. drum of oil for above.

F 266.—½-h.p. motor to drive pump.

F 247.—Mercury diffusion pump on stand with vacuum bottle.

The following will also be required :—

F 248.—Milliammeter reading to 18 m.a. for measuring current in tube.

F 250.—1 doz. Ilford X-Ray Plates 6½″ × 4¾″.

F 251.—1 doz. Kodak Duplitized Film 10″ × 8″.

SECTION F

ACCESSORIES FOR SPECTROMETERS AND SPECTROGRAPHS

CONDENSERS, ABSORPTION TUBES, ETC.

Rod for attachment of Condenser, etc., to any Collimator.—This simple device can be quickly and easily attached to the collimator of any spectroscope without in any way interfering with the adjustments. The figures below show the slit rod in position clamped to a collimator, in Fig. F 6, F 10, a condensing lens being carried, and in Fig. F 6, F 12 a Baly adjustable absorption tube. The absorption tube, condenser, etc., are readily interchangeable and are adjustable for height. A very considerable gain in convenience results from being able to attach such accessories to the collimator in this way.

The following parts are supplied :—

F 6.—**Rod Carrier** for attachment to any collimator tube, with rod and clamp for same.

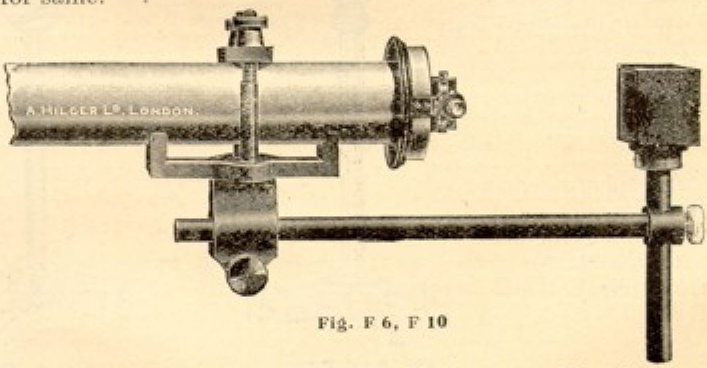


Fig. F 6, F 10

F 7.—**Rod Carrier** with two clamps, suitable for use with mirror and condenser simultaneously.

F 8.—**Condensing Lens** of glass, with spherical surfaces in mount with stem for the above rod carrier.

F 9.—**Condensing Lens** of quartz, do., do.

F 10.—Sphero-cylindrical Condenser of glass (as in Fig. F 6, F 10) similarly mounted for the above rod carrier.

F 11.—Sphero-cylindrical Condenser of quartz.

F 12.—Carrier for Baly absorption tube, described on the next page, with stem for the above rod carrier (as in Fig. F 6, F 12).

(The absorption tube is held securely in place on its mount by means of a rubber band which passes under four projecting pins, the ends being looped over the tube.)

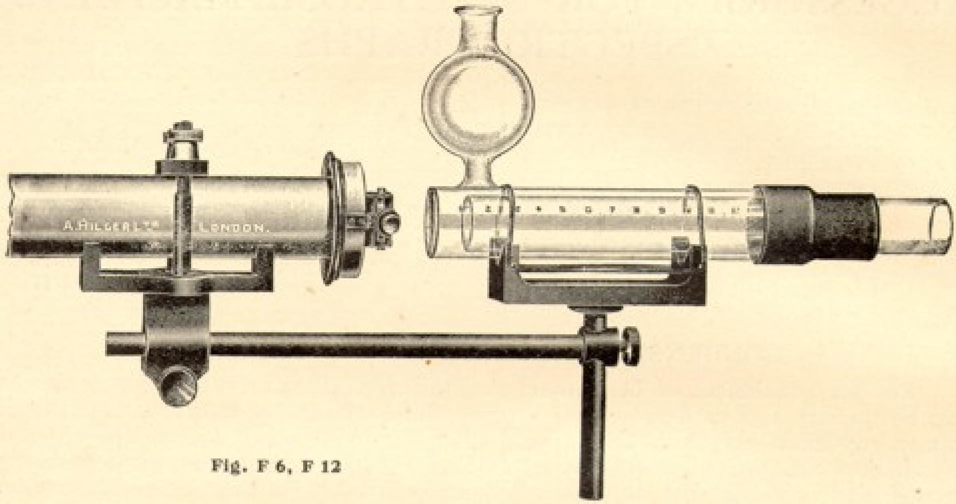


Fig. F 6, F 12

F 13.—Mirror in tilting mount, with stem for the above rod carrier.

Sphero-cylindrical condensers on raising and lowering stand, giving a line of light on the slit from a point source.

F 14.—Glass sphero-cylindrical condenser.

F 15.—Quartz sphero-cylindrical condenser.

F 292.—Quartz sphero-cylindrical condenser of longer focus for use with Quartz Spectrographs E 1 and E 2 to E 41.

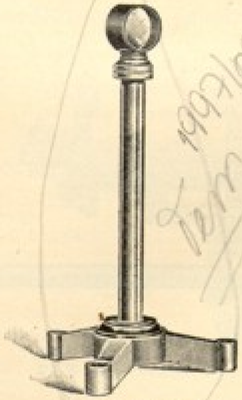


Fig. F 16, F 17

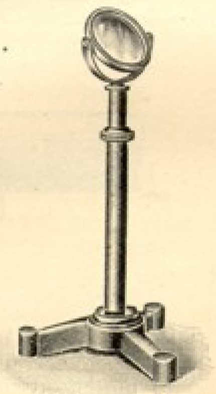


Fig. F 279

Condensers (spherical surfaces) (Fig. F 16, F 17) on raising and lowering stand.

F 16.—Glass condenser, spherical.

F 17.—Quartz condenser, spherical.

F 288.—Glass condenser working at F/4·5, figured to remove spherical aberration.

F 278.—Quartz condenser working at F/4·5, figured to remove spherical aberration.

F 279.—**Mirror**, worked, of colourless optical glass, mounted adjustably on gymbals, on raising and lowering stand (see Fig. 279).

PLANO-CONVEX LENSES OF QUARTZ (SECOND QUALITY) SUITABLE FOR CONDENSING LENSES

	Diameter.		*Focal Length.*	
	in.	mm.	in.	mm.
F 68.—	1	25·4	3	76
F 69.—	1¼	32	3¾	95
F 70.—	1½	38	4½	114
F 71.—	1¾	44	5¼	133
F 72.—	2	51	6	152
F 73.—	2¼	57	6¾	174

F 18.—Adjustable absorption tube for examination of the light absorption of liquids (*see* Baly's "Spectroscopy," First Edition, p. 414). The thickness of liquid can be read off on the scale in millimetres. With quartz end plates, 19 mm. clear aperture, as shown in Fig. F 18.

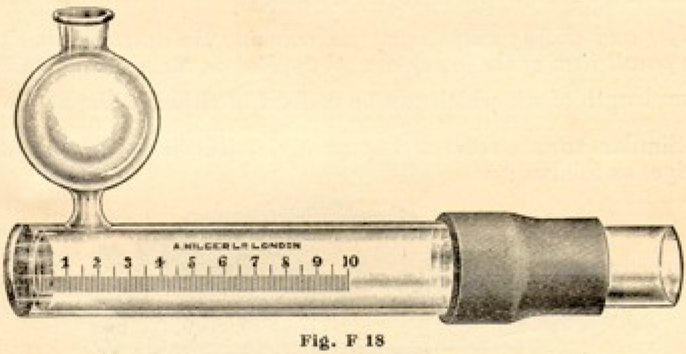


Fig. F 18

Unless instructions are given to the contrary, the quartz end plates for the Baly Tubes will be cemented in position with Khotinsky laboratory cement. The properties of this cement are widely known in scientific laboratories, but it should be mentioned that Khotinsky cement dissolves in alcohol and ether.

F 115.—Baly Tubes can be supplied of special form to stand any solvent at an increased charge of 10/-. In that case the quartz end plate on the inner tube is cemented with special resistant cement, while the outer quartz tube is clamped into position by a metal cap.

F 254.—**Fused silica cell for absorption experiments.**—For rapid examination of the absorption of liquids in the ultra-violet, thickness of liquid about 6 mm., thickness of cell wall about 1½ mm.

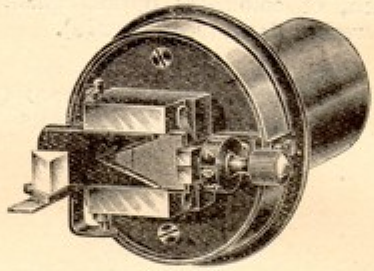
The cell is not optically worked, but is of clear fused silica. It can be held in any ordinary wooden clamp, and is very convenient for filling and cleaning.

It has no cover, and the quantity of liquid required is about 3 cc.

SPECTROSCOPIC ACCESSORIES

SPECTROSCOPE SLITS

Note.—All Spectroscope Slits made by us have jaws of untarnishable metal.



0·6 × *actual size.*

Fig. F 24

F 24.—Slit (Fig. F 24), with fine screw adjustment ; having divided drumhead, comparison prism, wedge for reducing the aperture, screws for correcting want of parallelism of the jaws, should this become at any time necessary, and protective cap.

Instead of the wedge a sliding diaphragm with three apertures for spectrum photography, giving the spectra in close juxtaposition, can be supplied with this slit.

F 25.—Diaphragm supplied instead of wedge.

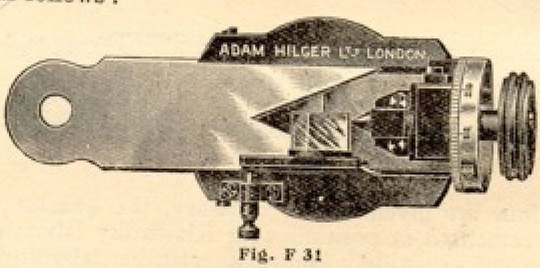
F 26.—Diaphragm supplied in addition to wedge.

F 27.—Slit (Fig. F 24), opening symmetrically.

The wedges and sliding diaphragms for reducing the aperture, and the screws for correcting the parallelism of the jaws are not supplied on the above symmetrical slits.

Maximum length of slit which can be utilised in either of the above = 7 mm.

F 28.—Similar to above slits but giving a length of slit = 14 mm. (without reducing wedge) as follows :



0·6 × *actual size.*

Fig. F 31

F 31.—Slit (Fig. F 31), with adjustment by fine steel micrometer screw, and large divided drumhead, comparison prism, wedge for reducing the aperture, and screws for correcting want of parallelism of the jaws. (Maximum length of slit which can be utilised = 18 mm.)

Instead of the wedge a sliding diaphragm with three apertures for spectrum photography giving three comparison spectra in close juxtaposition can be supplied with this slit.

F 32.—Diaphragm supplied instead of wedge.

F 33.—Diaphragm supplied in addition to wedge.

F 34.—Covered case for No. F 31.

F 111.—Symmetrical Slit, adjustable by large milled ring, with division reading to 1/1000 inch. This slit is provided with a screw-thread **T** into which an eyepiece may be screwed. Maximum length of slit which can be utilised is 11 mm., which can be increased to 20 mm., by removal of a diaphragm attached by the thread **T.**

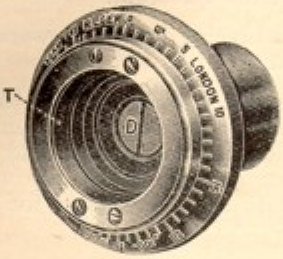


Fig. F 111

CROSSED SLIT

For many purposes it is desirable to have two slits superposed at right angles, both adjustable (*see*, for instance, our Wavelength Spectrometer modified for use with high resolving power accessories, Section O, for one use of such slits).

F 35.—Crossed slit with main slit of the same size as slit No. F 28.

In the above the secondary slit can be readily rotated out of the field, or entirely removed if desired. No comparison prism or wedge is supplied.

EYEPIECES, ETC.

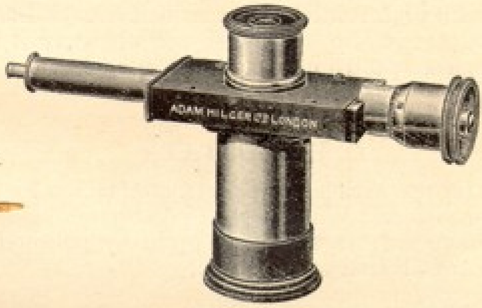


Fig. F 39

F 39.—**Micrometer Eyepiece,** pitch of screw = ½ mm.

F 40.—**Shutter Eyepiece** (Fig. F 40), including one positive eyepiece, bright pointer with lateral adjustment and mirror with universal motion for illumination of the same to render it visible in a dark field, and two sliding shutters in the focal plane.

Note.—This eyepiece has two shutters, which can be shifted in from either side at will in the focal plane to cover any desired part of the field, thereby obscuring any bright spectral lines which by their proximity hinder the observation of feebler lines. The metal pointer, whose point is ground exceedingly fine and polished bright with the greatest care, is illuminated from above by a mirror. This bright pointer is adjustable laterally by the two milled head screws below, so that one can always return to the standard reading by setting the bright pointer on a reference line.

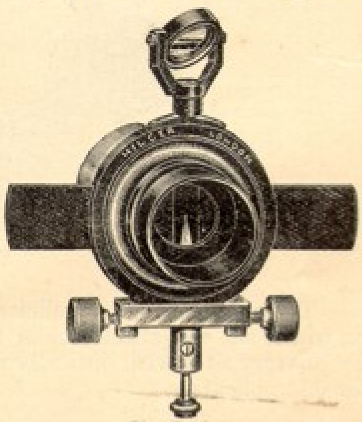


Fig. F 40

F 40/1.—Shutter Eyepiece (as F. 40) with slide with light filters for giving the pointer any desired colour, by means of which an increase of accuracy and comfort in reading can be secured—especially in the violet part of the spectrum.

F 43/4.—Fluorescent Eyepiece, as designed by Prof. Liveing for visual work in the ultra-violet, with illumination of the pointer by mirror.

F 45.—Gauss Eyepieces.—This is a positive, or Ramsden, eyepiece with a plane glass inclined at 45° to the optical axis, placed between the two lenses. Light entering through an aperture in the side of the tube is thrown by the mirror on to the webs. A clear space is left in the middle of the mirror through which the webs can be observed. This forms a very useful accessory to a spectrometer for the accurate adjustment of the optical axis, etc.

F 46.—Autocollimating Eyepiece, having slit with adjusting screw with divided drumhead (the jaws being in the focal plane of the eyepiece), and reflecting prism.

F 128.—Astigmatic Eyepiece for Lummer-Gehrcke Plates or Echelon Diffraction Gratings, or wherever in the use of a spectroscope great magnification of the spectrum is required with the retention of as much light as possible.

This eyepiece has a magnification of 23 in a horizontal direction, and of only 3·85 in a vertical direction; thus it is admirably adapted to the examination of spectra produced by such high resolving power elements as Lummer-Gehrcke Plates or Michelson Echelons. It is also of general use wherever it is desired to observe with a high power eyepiece spectrum lines of low intensity.

HELIOSTAT

F 257.—Heliostat for use with Table Spectrometers, see Fig. F 257; which shows the heliostat in position before a Wavelength Spectrometer.

These heliostats have mirrors which are optically polished, but are not of first quality. The mirrors are silvered on the back.

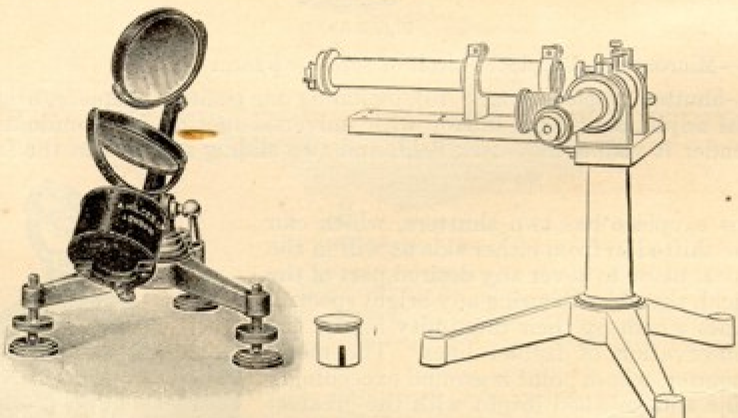


Fig. F 257

The clock motion is sufficiently good to ensure light from the sun being reflected on to the slit of a spectrometer for many hours without readjustment.

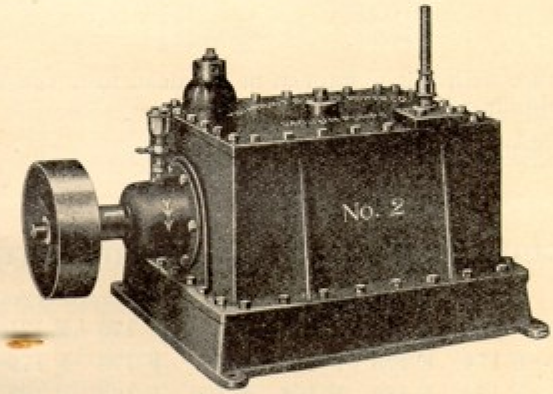
Larger sizes with optically plane silvered glass or speculum metal mirrors quoted for on application.

PUMPS FOR THE RAPID PRODUCTION OF HIGH VACUA

In every modern laboratory the need of a means of easily producing a high vacuum is felt, and for spectroscopic research an efficient vacuum-pump is a necessity, the application including the electric discharge in gases at low pressure, mercury and cadmium arcs in vacuo, the use of photo-electric photometer cells, the examination of light produced in gases (*e.g.* helium) by cathode and positive rays, evacuation of Schumann vacuum spectrograph, experimental X-ray tubes, etc. Within the last few years diffusion pumps of the Langmuir type have become available which permit of the attainment of higher vacua than have hitherto been known and whose speed increases with the exhaustion. As, however, this type of pump does not begin to function until the pressure has been reduced to a fraction of a millimetre of mercury, an efficient pump for attaining this pressure is still required, more especially in such cases as that of a vacuum spectrograph in which the volume to be exhausted is considerable. We have confidence, therefore, in recommending a pump which is (*a*) of strong mechanical construction; (*b*) power-driven, thus requiring no attention while working; (*c*) capable of rapidly exhausting a large container; and (*d*) free from the objection some such instruments are liable to, viz. vapour of mercury.

This pump, which is capable of exhausting to a pressure of ·000025 mm. (1/1,000,000 in.) is immersed in oil in an air-tight case, the driving shaft being provided with an oil-sealed bearing to prevent air from entering the case.

Actual photographs taken in our laboratories with the use of this pump and a vacuum spectrograph have been obtained up to 370 A; and the pump has been used by most workers in this spectral region.



These pumps are made in four sizes :—

F 160.—No. 1, intended as a backing pump for one No. 2.

F 161.—No. 1½, ,, ,, ,, a number of No. 2 pumps.

F 162.—No. 2, the high vacuum-pump described above.

F 163.—No. 3, a combination of Nos. 1 and 2 in one case.

The dimensions of the No. 2 pump are as follows :—

Length, 24 in.; width, 17 in.; height, 14 in.; and weight, 190 lb. It requires a driving power of ¼ h.p.

There is no possibility of injuring the pump by breaking the vacuum, either by design or accident.

We advise a combination of pumps, Nos. 1½ and 2 for high vacuum work, No. 1½ being useful for all exhaustions up to 1/50 in.

TYPICAL TEST OF A NO. 2 PUMP

It contains two rotary pumps connected in series. Both pumps are immersed in oil in an air-tight case. The gases, after leaving the last pump, are ejected into the case above the oil level. A vacuum is maintained on the case by a third pump. For this purpose a single rotary pump was used. This pump was at the same time employed in supporting four other pumps of the same type as that tested.

The pressures were measured, as is customary, by means of a M'Leod Gauge. Pressures could be estimated with a reasonable degree of accuracy as low as ·00005 mm. of mercury. The pump was first connected to a glass container of 3·6 litres capacity, and the following pressures were observed in the container :—

Time elapsed in Minutes.*	Pressure in mm. of Mercury.	Time elapsed in Minutes.*	Pressure in mm of Mercury.
0	760·0	4	0.0005
2	0·006	6	0·0001

The pump was next connected to a container of 15 litres (4-gal.) capacity. Operating with the other conditions the same as in the previous test, the following pressure readings were obtained :—

Time elapsed in Minutes.*	Pressure in mm. of Mercury.	Time elapsed in Minutes.*	Pressure in mm. of Mercury.
0	760·0	7¾	0·0015
1¾	0·500	9¾	0·0004
3¾	0·030	11¾	0·00015
5¾	0·006	13¾	0.00005

Suitable oil for use with this pump can be obtained from the Vacuum Oil Company, and may be obtained through us.

F 164.—10-gal. drum Vacuum Oil.

VACUUM TUBES OF GUARANTEED PURITY

Glass Tubes—	Empty	Neon	Helium	Argon	Mercury	Oxygen	Nitrogen	Hydrogen
Straight Form	F 166	F 167	F 168	F169	F 170	F 171	F 172	F 173
End-on Form	F 174	F 175	F 176	F177	F 178	F 179	F 180	F 181
Guild Form (see below)	F 182	F 183	F 184	F 185	F 186	F 187	F 188	F 189

F 287.—Cadmium end-on vacuum tubes.

Fused Silica—								
Secure Lead Seals	F 190	F 191	F 192	F 193	F 194	F 195	F 196	F 197
Extern. Electrodes	F 198	F 199	F 200	F 201	F 202	F 203	F 204	F 205
End-on Secure Lead Seals	F 218	F 219	F 220	F 221	F 222	F 223	F 224	F 225
End-on External Electrodes	F 226	F 227	F 228	F 229	F 230	F 231	F 232	F 233

* The time is the time elapsed since starting the pump, both pump and container being filled with air at atmospheric pressure at the start. The pump ran at 251 rev. per min.

GUILD FORM VACUUM TUBES

(See *Proc. Phys. Soc.*, vol. xxviii. p. 69.)

It was pointed out by Guild in the above paper that the life of a vacuum could be greatly extended by attaching to the discharge tube a large auxiliary volume. Vacuum tubes of this kind (see Fig. F 182) can be supplied by us as above.

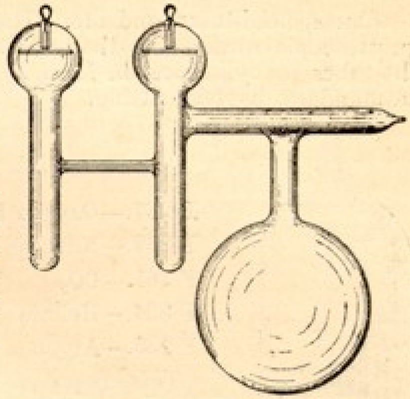


Fig. F 182

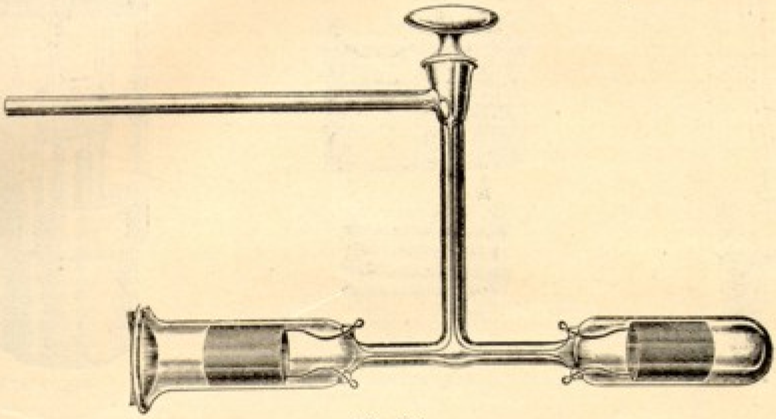


Fig. F 1

F 1 AND F 2 VACUUM TUBES FOR EXPERIMENTAL WORK

The tube is, as will be seen from the sketch (Fig. F 1), of the end-on type. It is supplied with a tap, and the light is concentrated into a line focus by a sphero-cylindrical condenser, of which the spherical portion fits accurately the cup at the end of the vacuum tube.

F 1.—With glass condenser.

F 2.—With quartz condenser.

GAS DISCHARGE LAMPS

FOR SPECTROSCOPIC AND INTERFEROMETRIC WORK

(Made by the General Electric Co., England)

Further details of these lamps will be found on a separate leaflet, which will be sent post free on request.

We can now offer gas discharge lamps which, on a direct current supply of suitable voltage, give a steady glow suitable for spectrum work. These lamps (Fig. F 267) are superior to most ordinary vacuum tubes on the grounds of convenience, steadiness, brightness, and life. The radiating area is small, the necessity in most spectroscopic work being that the source should have great intrinsic brightness. The tubes are cylindrical in form, 1 in. diameter and 3½ ins. long over all, and have the standard bayonet fitting.

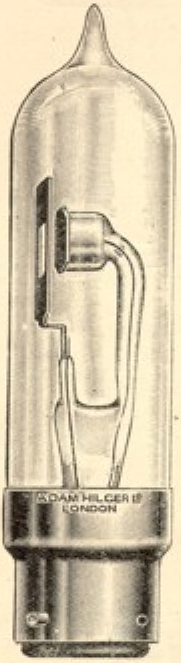


Fig. F 267

			D.C. Voltage
F 267.—Oxygen Discharge Lamps			300
F 262.—Nitrogen	,,	,,	320
F 261.—CO_2	,,	,,	300
F 234.—Helium	,,	,,	220
F 235.—Argon	,,	,,	220

This lamp gives the "blue" spectrum.

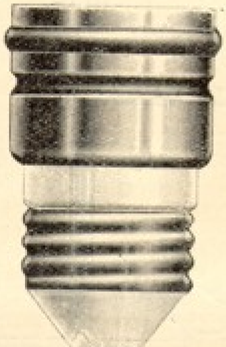


Fig. F 253

Fig. F 273

F 156.—**Neon Discharge Lamps,** supplied in two voltage ranges 200 to 220 volts, or 220 to 250 volts.

F 236.—**Hydrogen Discharge Lamps** with standard bayonet fitting, to run on 300 to 400 volts D.C. (best voltage is stated with each lamp).

The Balmer series is fainter in this lamp than in the ordinary vacuum tube.

						D.C. Voltage
F 239.—Krypton Discharge Lamps			...	...	...	300
F 238.—Xenon	,,	,,	...	...	...	360

GAS DISCHARGE LAMPS WITH QUARTZ WINDOWS, FOR THE ULTRA-VIOLET. (Fig. F 273)

						D.C. Voltage
F 273.—Nitrogen Discharge Lamps			...	...	...	320
F 269.—CO_2	,,	,,	...	...	...	300
F 270.—Helium	,,	,,	...	...	...	220
F 268.—Argon	,,	,,	...	...	...	220

This lamp gives the "blue" spectrum.

		D.C. Voltage
F 272.—Neon Discharge Lamps	... ...	200 to 220 or 220 to 250
F 275.—Krypton ,, ,,	... ...	300
F 276.—Xenon ,, ,,	... ...	360

ACCESSORIES FOR DISCHARGE LAMPS

F 133.—Stand with Lamp Holder, 4 ft. of flex, and bayonet connector for ordinary lamp socket ... ...

F 253.—Adapter to suit Edison screw socket ... ...

F 237.—Direct Current Generator for use with these tubes. This small generator can be driven by a $\frac{1}{10}$ or $\frac{1}{8}$ H.P. motor, and is capable of giving voltages up to 1000 volts according to the speed of rotation. The current is amply sufficient for this type of lamp, and the generator will be found useful for lamps containing gases which will not light on 220 volts, and for use with other gases when a supply at 220 volts is not available. Curve connecting speed and voltage is supplied with each generator

ARC LAMPS AND SPARK ELECTRODE HOLDERS

F 3.—Combined Vacuum Tube Holder and Spark Apparatus, readily interchangeable (Fig. F 3).

F 4.—Arc Lamp (Fig. F 4) suitable for the arc spectra of metals. Rods of the metal (of $\frac{1}{8}$ in. to $\frac{1}{4}$ in. diameter) are held in the screw clips. A direct current is employed, which should be off a circuit of 100 volts or more, with suitable resistance to give about 3 amps.

F 5.—Attachment for using the arc horizontal.

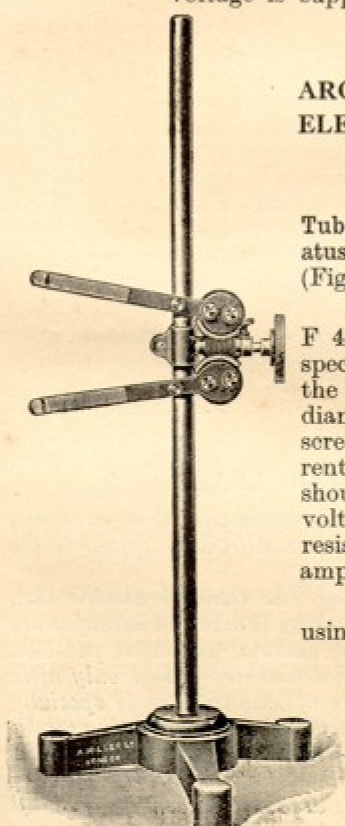


Fig. F 4

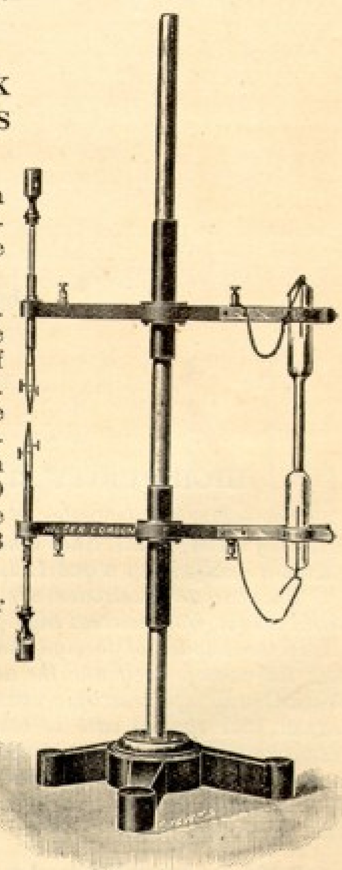


Fig. F 3

F 277.—Gramont Spark Electrode Holder (Fig. F 277). A very convenient form for spark spectrography. Both the spark length and the height of the spark from the table can be adjusted by rack and pinion while the spark is running.

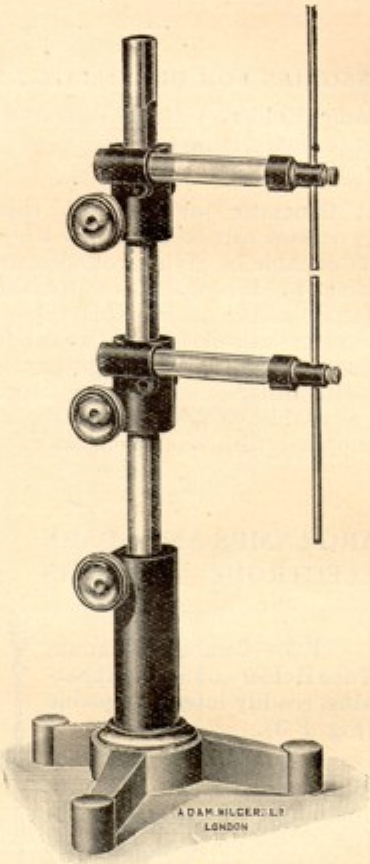


Fig. F 277

HIGH PURITY ELECTRODES FOR ARC OR SPARK

The following electrodes of copper, iron and carbon are accompanied by a report, including a list of the lines other than those of the substance itself which appear in the spectrum analysis on a quartz spectrograph.

The carbon electrodes are specially made for us by The General Electric Co., Birmingham, from selected high purity carbon. The utmost care is taken in manufacture to keep the amount of foreign, and particularly of metallic, material as low as possible. Both the carbon itself and the adhesive are selected material and are passed only after chemical and spectroscopic examination. The machinery of manufacture is specially cleaned, and special care is taken to exclude dust while the carbons are being made. Tests are made of the proportion of ash and of its constituents, and a spectroscopic analysis is made of the carbons themselves. A report of these tests, including a list of the lines which become evident in the arc during a month's exposure, is sent out with all these electrodes.

F 127.—Copper Electrodes, 5 mm. dia., 15 cm. long.

F 138.—Iron Electrodes, 5 mm. dia., 15 cm. long.

F 129.—Carbon Electrodes, 7 mm. dia., 15 cm. long.

F 214.—Nickel Electrodes, 5 mm. dia., 15 cm. long.

(Other high purity electrodes are in course of preparation.)

F 165.—Ilmenite Electrodes.—The titanium ore known as Ilmenite has the interesting property that an arc can be sustained between electrodes of the substance with a very small current. We can supply pieces of Ilmenite, suitably gripped in copper rods for use on our small hand-feed Arc Lamps. The spectrum includes the numerous lines of titanium. With these electrodes an arc will run as long as three hours or more on 220 volts with sufficient resistance in the circuit to allow one ampere only to pass.

HILGER THERMOPILES

(LINEAR THERMOPILES OF GREAT SENSITIVENESS)

The following thermopiles are the result of experiments in our laboratories, undertaken with a view to putting on the market a thermopile of great sensitiveness for spectrum work. Our experiments during 1912 convinced us of the soundness of the principles of construction laid down by Johansen in his very valuable paper in the *Annalen der Physik* (4), 33, p. 517, 1910, and it is on the general principles enunciated in that paper that our thermopiles are constructed. The distinctive design is our own.

We supplemented the work of Johansen by experiments in our own laboratory on the distribution by convection, conduction, and radiation of the energy received by the thermopile; and from the data thus obtained we were able to calculate very closely for each size of thermopile the number of elements, dimensions of lead wires, etc., to produce the maximum sensitiveness. It should be noted that there is in each case a particular number of elements giving maximum sensitiveness, and thermopiles having more than this number are *less* sensitive.

To obtain greatest sensitiveness the galvanometer should have a resistance not greatly different from that of the thermopile.

The couple chosen was Bismuth-Silver, a combination which produces a thermopile superior in sensitiveness to any other couple which had been tried for this purpose, with the exception of Bismuth-Iron.* Although the latter is somewhat more sensitive, the iron is very subject under ordinary working conditions to rust, which may render the thermopile useless in a few weeks. The receiving plates are of silver foil.

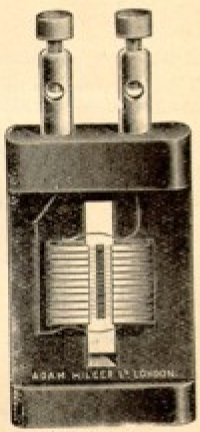


Fig. F 109

Our more recent experiments, however, have resulted in a still further improved design, which, while having a sensitiveness nearly 50 per cent. greater than our previous model, is almost entirely free from "creep." It is thus much better adapted for use with very sensitive galvanometers for energy measurements in the ultra-violet, etc. In this improved form the Hutchins alloys are used (bismuth-tin and bismuth-antimony).

During the last few years we have adopted an improvement whereby "creep" of the zero has been greatly lessened. The "creep" of Thermopiles of this type is chiefly due to the cold junctions becoming of a temperature different from that of the envelope. We have, therefore, in our modern Thermopiles, attached the cold junction to wings of silver which are bent round so as themselves to form an almost complete envelope round the cold junction.

*A further exception is Bismuth-Tellurium. We have made thermopiles of Bismuth-Tellurium, a couple which gives, for equal rise of temperature, an E.M.F. about eight times as great as Bismuth-Silver; but have not yet been able to produce them of sufficient permanence, mechanical soundness, or rapidity of action to justify our placing them on the market.

The thermopile for use in air is shown in Fig. F 109. It can be supplied either in a simple mount or in a symmetrical slit.

The simple mount (Fig. F 83) has a tube with eyepiece and a protecting tube which can be screwed on over this eyepiece tube without disarranging the eyepiece. It also has a tube with the standard fitting for the telescopes of our spectrometers.

The symmetrical slit mount is also provided with these same tubes.

Both the above mounts are arranged for attachment to a raising and lowering stand.

DETERMINATIONS MADE AT THE NATIONAL PHYSICAL LABORATORY (25th August, 1923, Cons. No. H 245) ON THREE UNSELECTED HILGER LINEAR THERMOPILES, Nos. 19, 27, and 29, SHOW THE SENSITIVITY TO BE AS FOLLOWS :—

For the purpose of determining the sensitivity a Hefner lamp was used as a standard of radiation. A screen with an aperture 14 × 50 mm. was fixed between the thermopile and the flame, and at a distance of 10 cms. from the latter. The smaller sides of the aperture were horizontal, the lower edge being level with the top of the wick tube of the lamp. Under these conditions the intensity of radiation at a distance of 1 metre is stated by Coblentz (*Bulletin of the Bureau of Standards*, vol. xi. 1915, p. 89) to be 97 microwatts per sq. cm.

Slit—Width.		E.M.F. (microvolts).		
Inches.	mm.	No. 19.	No. 27.	No. 29.
0·00	0·0	0·0	0·0	0·0
0·02	0·5	2·9	2·6	2·5
0·04	1·0	5·1	5·0	4·9
0·06	1·3	6·0	6·5	5·9
0·08	2·0	6·5	7·4	6·4
0·10	2·5	6·6	7·6	6·6
0·15	3·8	6·6	7·7	6·7
0·20	5·1	6·6	7·7	6·7

Quickness of response.

The thermopiles were connected in turn to a critically damped galvanometer with a period of about 1 second, and slit-width was adjusted to 2·5 mm. (0·1 inch). The times taken to reach 90 per cent. of the full deflections were found to be as follows :—

No. 19 - - 2 seconds.
No. 27 - - 2·5 „
No. 29 - - 2 „

The figures are given to the nearest 0·5 second.

Effect of radiation on the back of the case.

The back of the case was exposed to the radiation from a gas-filled lamp of 100 watts capacity at a distance of 2 metres, but no measurable effect was produced on the readings of the instrument.

The following Thermopile, designed for use in air, can usually be delivered from stock :—

Dimensions of sensitive area—20 mm. long ; 1·5 mm. wide.

Number of junctions—20.

Resistance (*approximate*)—10 ohms.

F 83.—Price of the thermopile described above, mounted in simple mount

F 84.— „ „ „ symmetrical slit

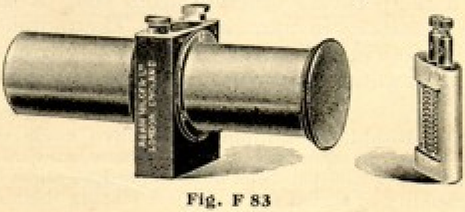


Fig. F 83

F 85.—Raising and lowering stand to take either of the above, extra.

F 86.—Sensitive portion of above thermopile alone, in brass case.

We can also supply thermopiles having sensitive areas as follows :—

Length.	*Width.*	*In Simple Mount.*	*In Symmetrical Slit.*	*In Brass Case.*
10 mm.	1 mm.	(F 87)	(F 89)	(F 109)
10 mm.	0·5 mm.	(F 88)	(F 90)	(F 110)

These are interchangeable in the mounts described above. We can further supply thermopiles designed to have maximum sensitiveness when used *in vacuo.*

F 91.—**Broca Galvanometer** (made by the Cambridge Instrument Co. Ltd., Cambridge), selected as being suitable for general work with the thermopile.

F 92.—**Paschen Galvanometer** (made by the Cambridge Instrument Co. Ltd., Cambridge).—This is a modified form of the Thomson Galvanometer, and was specially designed by Professor Paschen for radiometric measurements. The magnet system consists of two groups of thirteen magnets arranged alternately on opposite sides of a fine glass stem. The coils are elliptical in shape, and are wound with six different sizes of wire, with the object of producing a maximum field for a given resistance of copper. The sensitivity is about forty times as great as that of the Broca Galvanometer. The period can be varied by means of a control magnet. The galvanometer has a resistance of about 12 ohms.

F 151.—Magnetic shielding for the Paschen Galvanometer, made by the Cambridge Instrument Co. Ltd., Cambridge (strongly recommended for this sensitive instrument).

F 93.—Scale, on stand, with lamp for use with the above galvanometers (made by the Cambridge Instrument Co. Ltd.).

SPARKING APPARATUS FOR SPECTRUM WORK

Whenever a high voltage is required for spectrum work, *i.e.* lighting a vacuum tube or sparking between metal electrodes, a transformer specially wound to our specification has been found most convenient and efficient.

For vacuum tubes we recommend the insertion of a lamp resistance, for control, in the primary circuit of the transformer. In general, one 50 c.p. carbon filament lamp is suitable, but for tubes with large electrodes, such as are used with the Pulfrich Refractometer (F 189 or M 56), two such lamps in parallel with each other are not too much. For small tubes a lower c.p. lamp should be used.

For sparking between electrodes a condenser should be connected in parallel with the spark gap.

Where alternating current is available, such a transformer with lamp resistance, etc., can be run straight off the mains. Where only direct current is to be had the following is the necessary outfit shown in Fig. F 281-3, which, however, does not show the present type of outfit.

F 281.—¼ **K.W. Rotary Converter** 110 volts or 220 volts D.C.; giving 75 volts or 150 volts respectively, 60 cycles, A.C. (state voltage of supply in ordering).

F 282.—¼ **K.W. Transformer** specially wound for spectrum work, including auto-transformer, so that transformer will run on anything from 75 to 220 volts A.C.

F 283.—¼ **K.W. Condenser**, capacity approximately 0·03 m.f.

F 284.—Lamp Resistance Board, consisting of polished teak base with six lamp holders arranged in parallel, wired with 3 feet of flexible connection, and adapter for plugging on to electric supply; including six 50 c.p. carbon filament lamps, each giving about 1 ampere on a 220 volt circuit.

F 285.—Hemsalech Self-induction Coil for removal of the air lines, self-induction 0·001 henry approximately.

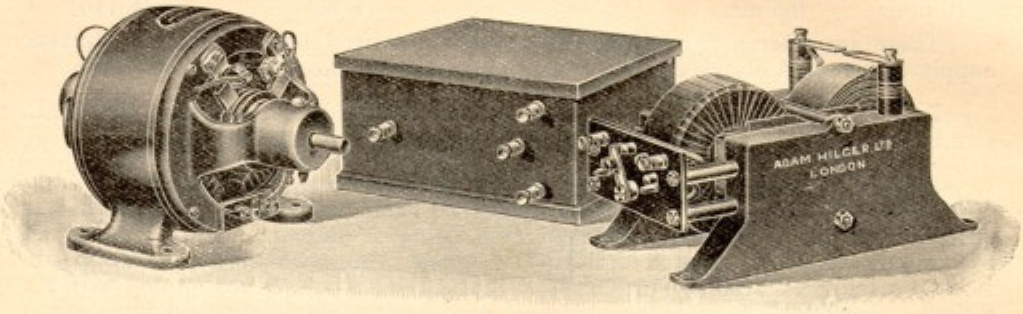


Fig. F 281-3

Careful spectrographic tests have been made in our laboratory with this coil inserted in the circuit in series with the spark. None of the air lines between 5300 A and 2980 A as given in Eder & Valenta's "Atlas Typischer Spektren" were registered when the exposure was adjusted to give the metal lines of the same intensity as when no coil was used.

(The air lines between 2980 A and 2100 A are not registered under the same conditions even without the coil.)

F 132.—Jones' Electrodes.—Specially treated carbon rods as recommended by H. C. Jones, of Baltimore.

F 66.—Sparking Tube with gold electrodes and platinum conducting wires for the spark spectra of metals in solutions (as used by Dr. James H. Pollok in his researches on the quantitative spectra of metals in solution; see *Sci. Proc. Royal Dublin Society*, vol. xi., Nos. 16, 17, 18).

For sparking outfit for X-ray Spectrography, see pp. E 13-14.

SENSITIVE PLATES FOR SPECTROGRAPHIC WORK

The following plates are those which we have found the best for general Spectrographic work.

Ilford Special Rapid Panchromatic	Sensitive from the Ultra-violet up to 7200 A with normal exposures. With prolonged exposures up to 7900 A.
Ilford Rapid Process Panchromatic	Of similar sensitiveness to the Special Rapid Panchromatic but of much finer grain and greater contrast and about one-third the speed.
Wellington Anti-Screen - -	A fast "ordinary" plate of fine grain suitable for Ultra-violet work.

Not only are these plates extremely sensitive, but they keep good for a long time.

Messrs. Kodak, Ltd., make Light Filters, of which upwards of eighty varieties are now stocked, either transmitting narrow bands, or cutting out a specified region of the spectrum. Price Lists on application.

See also the Hilger Schumann Plates described below and on the separate descriptive leaflet sent post free on request.

Photographic Plates for the Region in the Ultra-Violet between Wavelength 2200 A and 130 A, for Positive Rays, and for the very soft Röntgen Rays produced by the Impact of Positive and Slow Cathode Rays (*see* paper by Sir J. J. Thomson, *Proc. Phys. Soc.*, vol. xxvi., Part V., Aug. 1914, p. 288).

The strong absorption of light by gelatine renders the ordinary photographic plate of little value beyond wavelength 2100 A, in fact the general absorption by gelatine extends almost up to the visible region of the spectrum. The first plates used for the extreme ultra-violet were prepared by Schumann,* the gelatine being reduced to the minimum necessary to hold the silver bromide on the plate.

We can now supply plates made to a modification of the Schumann formula and suitable for the purposes mentioned above.

	Size. Inches.	Size. Cms.		Size. Inches.	Size. Cms.
F 94.	$4\frac{1}{4} \times 3\frac{1}{4}$	$10{\cdot}8 \times 8{\cdot}2$	**F 95.**	10×4	$25{\cdot}4 \times 10{\cdot}2$

Other sizes can be supplied, providing that not less than three dozen are ordered, the price in shillings per dozen being determined by the formula $9{\cdot}5 + 2{\cdot}1 \times$ area in inches.

For five dozen and over of one size, reduction of 10 per cent.
For ten dozen do. do. 20 per cent.

The advantage of these plates becomes very apparent after wavelength 2200 A and at wavelength 1850 A they are five times as rapid as the most sensitive commercial plates, while for shorter wavelengths the latter are of no use at all.

These plates will stand handling much better than those made to the original Schumann formula. They increase in sensitiveness for some time after being made, and providing they are kept with the customary care, they have a life of similar length to that of the ordinary dry plate.

Durability.—*As far as our experience goes, under favourable circumstances these plates will last as long as twelve months. If supplied sealed up in canisters they will last probably more than two years.*

A separate leaflet is issued giving full particulars of the range of Schumann plates manufactured by us.

PUBLICATIONS

(Obtainable direct from ourselves or through any bookseller.)

		Nett.	Post free.
F 208.	**Vol. 1, Refractive Indices of Essential Oils** ...	12s. 6d.	13s. 0d.
F 209.	**Vol. 2, Refractive Indices of Oils, Fats and Waxes** † (Compiled by R. Kanthack. Edited by J. N. Goldsmith, Ph.D., M.Sc., F.I.C.)	17s. 6d.	18s. 0d.
F 210.	**Report on Quantum Theory of Spectra.** (Silberstein)	3s. 6d.	3s. 9d.

* *Ann. der Physik*, 5, 349 (1901).

† Prospectus of this work will be sent post free on application.

	Nett.	Post free.
F 211.—Elements of Electromagnetic Theory. (Silberstein)	3s. 6d.	3s. 9d.
F 212.—Elements of Vector Algebra. (Silberstein) ...	3s. 6d.	3s. 9d.
F 213.—Optical Methods in Control and Research Laboratories. 2nd ed.* (Goldsmith, Judd Lewis and Twyman)	1s. 6d.	1s. 8d.
F 145.—Lines in the Arc Spectra of Elements. (Stanley)	7s. 6d.	7s. 9d.
F 146.—Wavelength Tables for Spectrum Analysis * (Twyman)	7s. 6d.	7s. 9d.

F 147.—Enlarged Photograph of the iron arc spectrum marked with over 800 wavelengths, including all those recommended as standards by the International Astronomical Union. In six sections as follows :—About 100 lines from 2130 to 2280, 75 lines from 2280 to 2470, 150 lines from 2470 to 2800, 150 lines from 2800 to 3300, 225 lines from 3300 to 4190, and 100 lines from 4190 to 6680 ; with additional sections showing (*a*) the 20 lines of the neon spectrum from 5852·488 to 7032·412 A ; (*b*) the 19 lines of the helium spectrum from 3613·641 to 7281·349 A, determined interferometrically by P. W. Merrill ...

F 290.—Enlarged Photograph of the Neon Spectrum as (*a*) above.

F 291.—Enlarged Photograph of the Helium Spectrum as (*b*) above.

F 152.—Collotype print of the Spectrum of Copper marked with Wavelengths, for checking the Wavelength Scale of Quartz Spectrographs. ... ...

* Prospectuses of these works will be sent post free on application.

ADAM HILGER, Ltd., 75a Camden Road, London, N.W. 1

Entrance :—24 Rochester Place (adjoining)

Telegraphic Address—" Sphericity, Phone, London."
Telephone—North 1677/8.
Cable Code—Western Union.
Cable Address—" Sphericity, London."

October 1924

SECTION H

SPECTROPHOTOMETERS, COLORIMETERS AND APPARATUS FOR SENSITOMETRY

SPECTROPHOTOMETERS

FOR THE ULTRA-VIOLET, VISIBLE AND INFRA-RED REGIONS

In view of the great interest for the chemist which the measurement of selective absorption has assumed—as will be seen from the bibliography on this subject which we publish—and in view of the great necessity of making such measurements quantitative, we have developed a series of instruments which will enable quantitative measurements of absorption to be made, not only in the visible spectrum, but also in the infra-red and in the ultra-violet.

In the ultra-violet alone a great amount of work has been done in the examination of absorption spectra, but extremely little of it has been of a quantitative character. Professor Kayser, writing in 1908, drew attention to the unsatisfactory nature of the work which had been and was then being done in this direction, owing to its being merely qualitative.* It must not be forgotten that not only the intensity, but the actual position of the maximum of an absorption band is undetermined until quantitative measurements have been made, since any variations throughout the spectrum of intensity of the light source, of sensitiveness of the photographic plate, or of dispersion, may cause the apparent maximum of absorption to be in a position different from that of the actual maximum. All absorption work, therefore, which is done other than quantitatively is subject to this criticism.

Even in the visible region Spectrophotometry has not received in the chemical laboratory the attention it deserves. Yet it is only necessary to remember one or two instances of its application in order to remind oneself of the very great importance of the physical measurement. Such investigations as the determination of CO in blood by Vogel,† and the separation of Neodymium and Praseodymium by Auer v. Welsbach, may be cited in this connection.

Measurements of absorption acquire their chief interest when plotted on a wavelength scale (or, better still, on a frequency scale). With all the instruments described below the necessary readings for doing this are immediately at hand without the necessity of the purchaser carrying out laborious calibration himself.

* *Handbuch der Spectroscopie von H. Kayser*, Band 3, S. 49 : " Aber alle diese Methoden eignen sich doch nicht zu einer genauen Bestimmung der Absorptionsconstanten für viele Substanzen und verschiedene Wellenlängen. Trotz der zahlreichen im Vorhergehenden besprochenen Apparate musste, man bis vor Kurzem sagen, dass es kein brauchbares Instrument für Photometrie im Ultraviolett giebt mit dem man etwa daran hätte denken können, eine ausgedehnte Untersuchung z. B. organischer Substanzen vorzunehmen. Man war ausschliesslich auf die später zu besprechende Methode angewiesen, die namentlich von Hartley ausgebildet und durchgeführt ist, die aber keine Messung der Constanten, höchstens eine Schätzung über die Grösse der Absorption zulässt."

† *Ber. d. deutsch. Chem. Ges. 10*, 792 (1877) and *11*, 235 (1878).

The infra-red, in which region far less work has been done, is also of interest for the chemist, and a suitable instrument for the region up to 9 μ is described below.

APPARATUS FOR SPECTROPHOTOMETRY IN THE ULTRA-VIOLET

The apparatus recommended by us for this purpose consists of our Quartz Spectrograph, size E 31 or 37 (formerly known as size A), or size E 3 (formerly known as size C), with an auxiliary apparatus enabling quantitative photometric measurements to be made. Our Quartz Spectrograph, E 3, has been very widely used for work on absorption spectra, for which class of work it is particularly well suited. But the cheaper instrument has ample dispersion for most absorption work, and can now also be supplied with a wavelength scale. The auxiliary apparatus is as follows (*see*

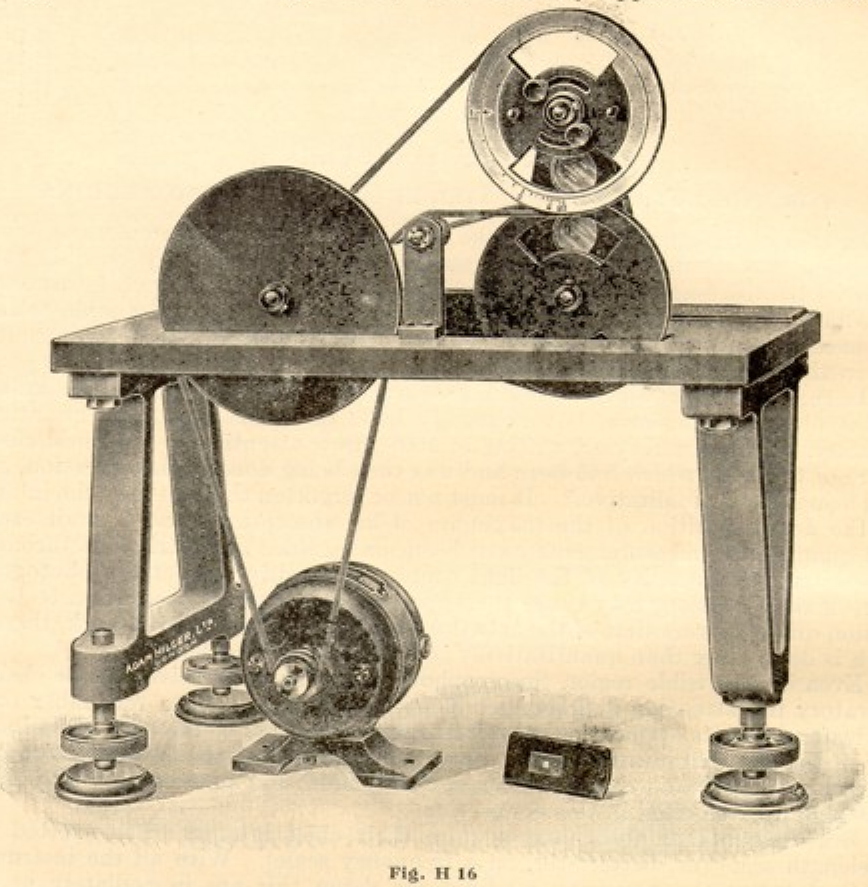


Fig. H 16

diagram, Fig. H 16 a, and general view, Fig. H 16): Immediately in front of the slit and attached to it is a bi-prism, B, which receives the light from the source in the following manner. The light emanates from the source, L, and may reach the slit by two alternative paths. An upper beam passes through a rotating sector, S, the aperture of which can be varied. The beam then passes through the wedge prism, P, and, falling on the bi-prism, is deviated by the lower half of that prism to pass axially along the collimator of the spectrograph. The second beam traverses first the absorbing liquid under examination contained in a suitable cell, A, then through a rotating sector, S′, of fixed aperture, and a wedge prism, P′, similar to P but so arranged as to divert the light upwards instead of downwards. The beam is then diverted by the upper half of the bi-prism, B, and passes axially along the collimator of the spectrograph like the first. We thus have the spectrograph fed by two beams, the one capable of being varied in intensity at will by varying the aperture of the

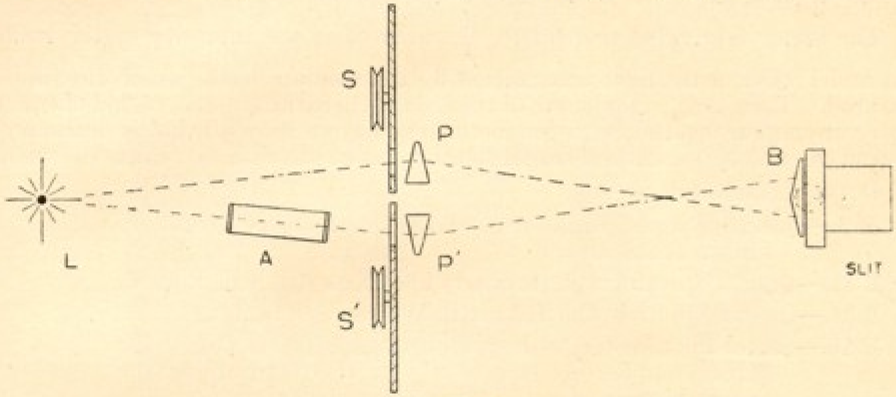


Fig. H 16a

rotating sector, the other subject to the absorption of a known thickness of the liquid under examination. A series of photographs is taken with the sector S set to different apertures. If we consider one of these photographs we shall see that it consists of a pair of spectrum photographs in close juxtaposition, one of which is

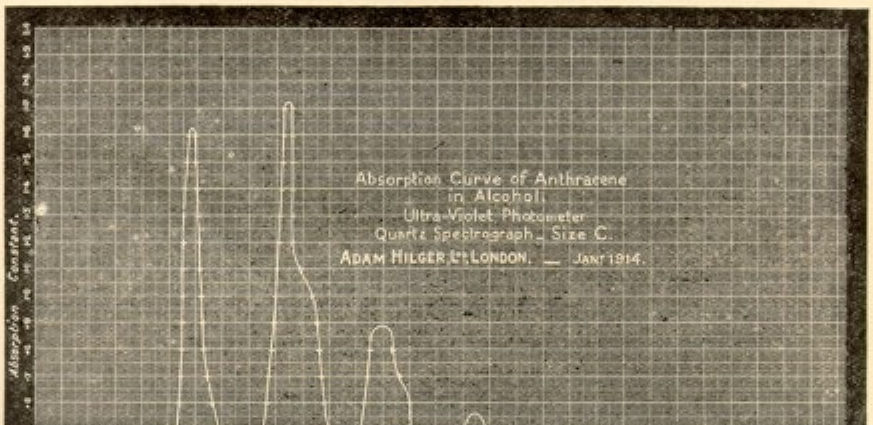


Fig. 16b

of reduced density throughout its whole length, the other—that, namely, which has passed through the material under test—being more dense than the first in certain parts and less so in others, there being certain wavelengths where the density of the two is equal.

It is found that the wavelength at which the densities of the two spectra are equal is, within wide limits, independent of the exposure, of the intensity of illumination, and of the speed of rotation of the sectors.*

Furthermore, the photographs are taken simultaneously, and there are, therefore, no errors arising from fluctuations in the light source.

The sector is divided to read log $\frac{I}{I'}$, where I is the intensity of the incident light and I′ that of the light transmitted by the medium whose absorption is being measured. Thus, if the wavelength of the points where the two spectra are of equal intensity are noted, together with the sector reading, we have all that is necessary for drawing the absorption curve. Fig. 16b shows an absorption curve thus determined.

Outfit recommended :—

E 3.—Quartz Spectrograph with Wavelength Scale (formerly known as size C)... ... ...

or **E 31.**—Quartz Spectrograph (formerly known as size A or E 6) ...

or **E 37.**—Quartz Spectrograph E 32 with Wavelength Scale ...

H 16.—Sector Photometer, with motor arranged for 12, 110, or 220 volts, complete as shown in Fig. H 16, including the quartz bi-prism for the slit of the Spectrograph ...

When ordering, the voltage of supply should be stated.

H 17.—Tubes with quartz ends for solutions, length of liquid, 10, 20, or 40 mm., price each ... ...

Light source :—

F 3.—Combined Vacuum Tube holder and Spark electrode holder

F 132.—Jones electrodes, per pair ... ...

For photographic plates see section F and separate leaflet.

Sparking apparatus (fully described in section F).

F 281.—½ K.W. Rotary converter 110 volts or 220 volts D.C.; 75 volts or 150 volts respectively, 60 cycles, A.C. ...

F 282.—¼ Kilowatt transformer specially wound for spectrum work, including auto-transformer to give 8000, 10,000, 12,500 or 15,000 volts ... ...

F 283.—¼ Kilowatt condenser, capacity approx. 0·03 M.F. ...

Where alternating current is available the converter S 2 is not required.

When ordering, the voltage of supply should be stated.

THE JUDD LEWIS SECTOR PHOTOMETER

FOR SPECTROPHOTOMETRY IN THE ULTRA-VIOLET

Catalogue No. H 40

To the original form of sector photometer H 16, made by them since 1913, and described above, Adam Hilger, Ltd., have now added the manufacture of the new sector spectrophotometer H 40, invented by Dr. S. Judd Lewis, the first model of which was described in the *Transactions of the Chemical Society*, 1919, pp. 312-319. This instrument has now been improved by Dr. Judd Lewis as described in his Cantor Lecture (*Journ. Roy. Soc. of Arts*, 1921, 806-808), and brought by him to such a state of efficiency and ease of adjustment to the spectrograph in conjunction with which it is used, that he finds it possible to map an absorption spectrum in the

* The speed selected by us is 120 revolutions per minute.

ultra-violet region with as much confidence and precision, and almost as readily, as can a series of observations be made with the polarimeter and plotted on a curve. The importance of this new facility in its bearing on the progress of chemical and physical science, both pure and applied, can scarcely be exaggerated. The new model can moreover be worked with great rapidity, and with it it is possible to photograph twenty or thirty absorption spectra in a minute. Owing to this rapidity of working, a new means of studying the progress of a chemical reaction or controlling a process becomes accessible.

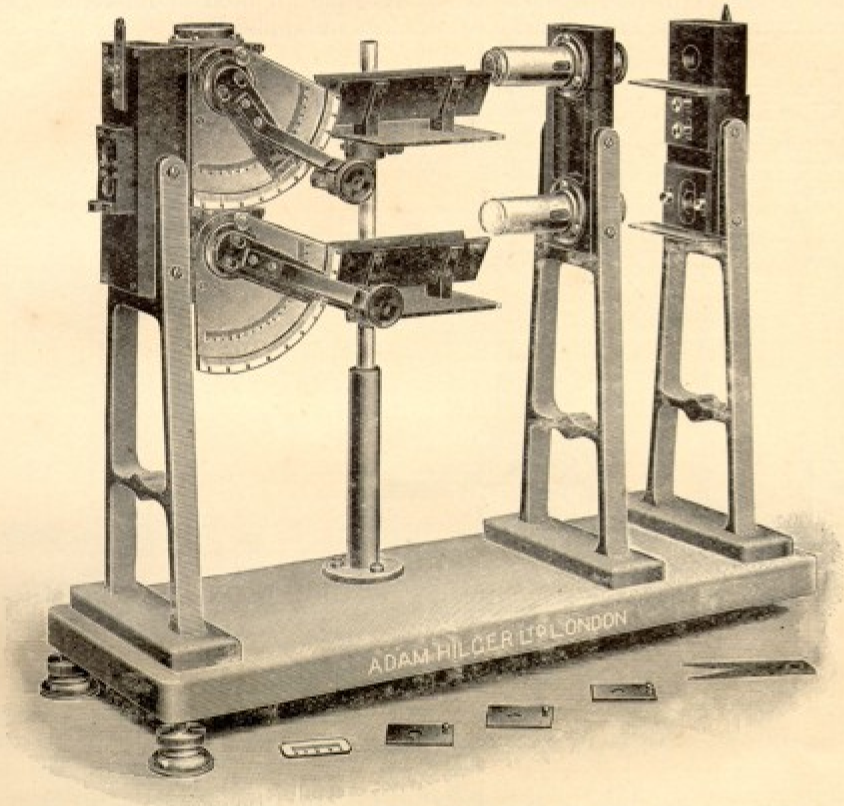
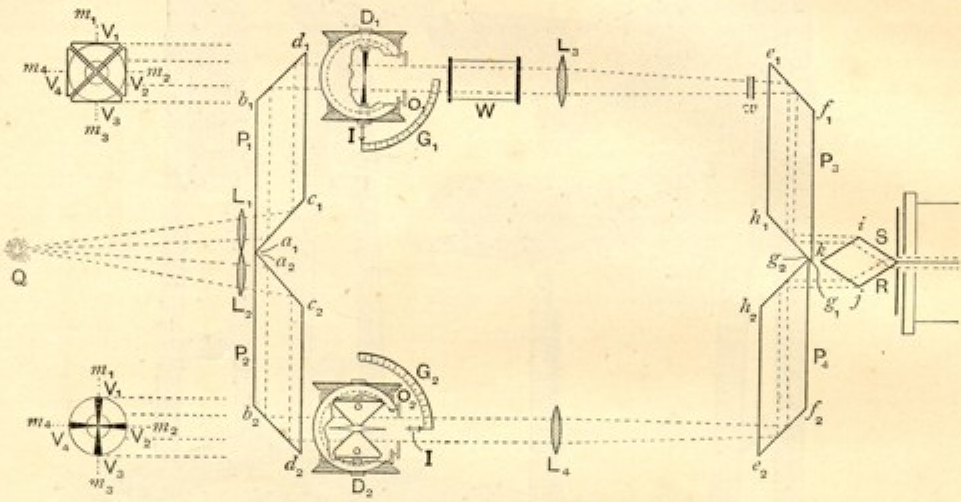


Fig. H 40

The chief features of the new instrument are displayed in the accompanying figure and diagram. Light from the lamp Q passes through the fluorite-quartz combination L_1, and as a parallel beam it falls on the reflecting face, a_1c_1, and then on the face b_1d_1, whence it is reflected as a parallel beam through the sector D_1, and the observation cell, W, to the lens L_3, which focusses the light on the slit, the light passing through the reflecting rhomb P_3 and the Albrecht rhomb R. The lens L_3 moves in a graduated sleeve for focussing the light accurately for any region of the spectrum it is desired to study critically, although for ordinary work this adjustment is quite unnecessary. Another beam of light is treated in exactly the same way in the lower path. Hence, with both sectors fully open, two spectra identically similar in all respects may be photographed in juxtaposition. The cell W contains the substance under examination, by which the spectrum is absorbed in a way peculiar to the substance in question. By adjustment of the lower sector D_2, the light passing through it may be cut down to any desired intensity, and the normal spectrum so produced used for determining the points equal to it in the absorption spectrum. The wavelength at which the two members of each pair are equal is marked by a dot; whence the unknown intensity in the absorption spectrum becomes known by reference to the known intensity of the normal spectrum. The absorption spectra are then plotted with extinction coefficients for ordinates and wavelengths for abscissae. The extinction coefficient may be read directly from a table correlating the angle θ on the graduated quadrant (by which the known intensities are determined) with the extinction coefficients, but the quadrant is also graduated so as to read directly in terms of the extinction coefficients, so avoiding all need of reference. Photogravures exemplifying the work may be obtained on application.



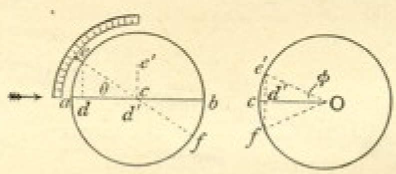


Fig. H 40a

The open construction of the stand enables the instrument to be used with observation cells of any shape or size, a convenience which adds greatly to the scope and possibility of the operations.

The instrument is also fitted with an index (not shown in the figure) for adjusting precisely the position of the spark from time to time, and it is to this feature that the speed of the instrument in use is in great part due.

The instrument is fitted with two sector systems, which is desirable for its wider applications, and for making the instrument complete and self-calibrating when desired for certain work. The instrument fitted with only one sector is fully sufficient for most practical purposes, and can be supplied at a lower price.

The sectors with graduated quadrant can be supplied separately.

H 40.—Judd Lewis Sector Photometer with two sector system.

H 41.—Judd Lewis Sector Photometer with one sector system.

(Detailed description post free on application.)

APPARATUS FOR SPECTROPHOTOMETRY IN THE VISIBLE

SUITABLE FOR WORK ON DYES, ETC.

The instrument which we recommend for this purpose is as follows: Hilger Wavelength Spectrometer with light prism (pp. D 1-2), with Nutting Photometer and equipment as described below.

The form of Hüfner Spectrophotometer made by us since 1904 was designed for research on photographic plates, and for this purpose it has given general satisfaction. While it has also been very serviceable in general chemical work it presents for such purposes several disadvantages. When, therefore, we turned our attention to the development of a Spectrophotometer which should be as convenient and accurate as possible for general chemical work, we adopted as the basis of such an instrument—after a careful survey of the main types of photometer available—the form of

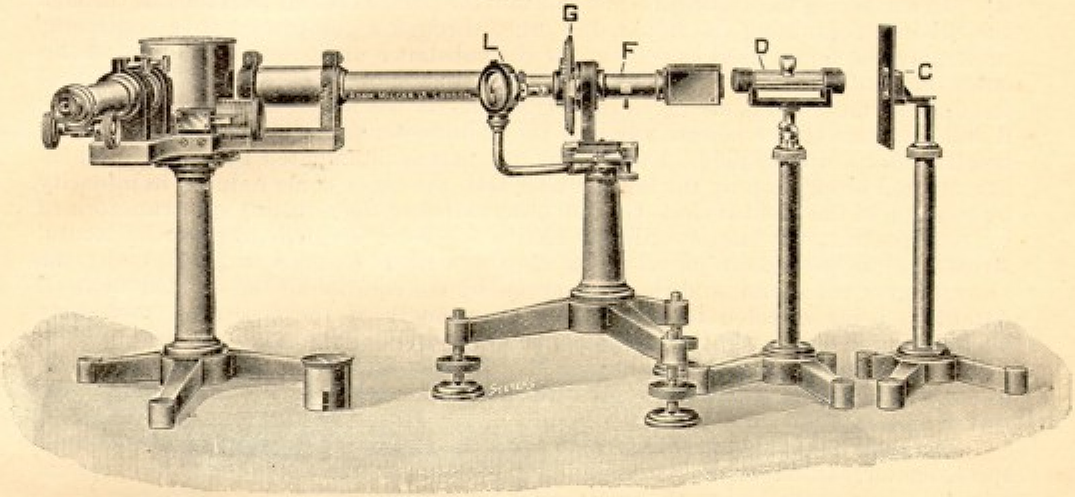


Fig. D 1, H 56

polarisation photometer described by P. G. Nutting (*see* reprint No. 155, *Bulletin of the Bureau of Standards*), using it in conjunction with our Constant Deviation Wavelength Spectrometer.

Considerable alterations were made in the design of the photometer to fit it for the purpose in view, but certain essentials remain; while every modification has been the subject of careful consideration.

The features of chief interest to the user are as follow:

(1) One light source is used for both beams of light.
(2) Tubes for liquids or gases of any desired length can be used.
(3) There is ample separation between the two beams (the distance between the centres of the beams being 38 mm.).
(4) The circle is divided both in "densities" and degrees.
(5) The photometer can be used with any ordinary spectroscope, although the Wavelength Spectrometer is to be preferred on account of its convenience, accuracy, and robust design.

In the more recent instruments (those namely issued during 1921 and subsequently) both fields are varied in intensity by the rotation of the divided circle, the one increasing while the other decreases in illumination, until the match is achieved. Thus the later instruments follow a "$\tan^2$" law instead of, as in the earlier ones, a "$\sin^2$" law. The object of this modification is to get rid of systematic errors which occur when, as is often the case, there is a certain amount of polarised light coming from the source. With the latest model such an occurrence causes no error in measurements of absorption.

It has not been found possible to combine this improvement with the same perfect juxtaposition of the two fields as existed in the older instrument, but the nett result is a gain in reliable accuracy.

An additional point of importance is that great care has been taken to work out thoroughly the correct conditions of illumination, a point of the utmost importance for accurate spectrophotometry.

Our latest model of Nutting Photometer in combination with the Wavelength Spectrometer is shown in Fig. D 1, H 56.

Referring to the figure, the two beams of light from the light source are made parallel by the device C (whose correct distance from the light source is engraved upon it). In measuring the absorption of a solution the parallel beams pass the one through the tube D, containing the liquid, the other through a companion tube containing preferably the liquid used as solvent for the substance under test. The two beams enter the photometer by the apertures A and B (not shown in the figure). Details of the optical construction are given in instructions for use issued with the instrument; it will therefore suffice here to say that the photometer projects upon the slit of the spectrometer a double field, of which the one part is illuminated by the light which has suffered absorption by the liquid under test, the other being reduced in intensity by rotation of the divided circle G. On observation of the resulting spectrum formed by the spectrometer one accordingly sees a spectrum divided into two horizontal strips in close juxtaposition, of which the top strip is reduced in intensity by the absorption of the liquid, and the bottom one by the rotation of the divided circle G. Attention being directed to a particular wavelength of the spectrum (preferably by isolating it with a shutter eyepiece) the two parts of the spectrum are made to match in intensity, and the reading on the divided circle (divided by the length of the tube of liquid in centimetres) gives the extinction coefficient of the liquid for the wavelength in question.

The scale of the divided circle, alike with the measuring drum of the wavelength spectrometer, can be conveniently read by the observer without quitting the eyepiece, a lens, L, being attached to the photometer for the purpose.

Outfit recommended :—

D 1.—Wavelength spectrometer with prism of 1·65 refractive index for D, accurately calibrated in wavelengths ...

D 4.—Protective cover to prism table of Wavelength Spectrometer ... ...

F 40.—Shutter eyepiece for Wavelength Spectrometer, with lateral adjustment to bright pointer ... ...

H 56 formerly known as **F 119**.—Nutting Photometer as described above, with levelling screws, and including beam parallelising device and small electric lamp for illumination of the divided circle ... ...

H 57 formerly known as **F** 22.—Raising and lowering stand for holding tubes of absorbing liquids, taking tubes 10 cm. long and upwards ... ...

H 58 formerly known as **F** 23.—10 cm. tubes, accurate to ±0·01 cm., with screwed end caps, and side tube for filling ...

F 215.—Pointolite Lamp, 100 c.p. (can only be supplied for direct current) ... ...

F 216.—Universal resistance for Pointolite Lamp ... ...

F 217.—Wooden Light-tight Box for 100 c.p. Pointolite Lamp ...

The box is made carefully light-tight, with a small hole only for the emergence of the beam to be utilised. Designed for use with the Nutting Photometer, the height of the light and aperture is suitable for that instrument, but there is a rising and falling panel which bears both lamp and aperture, so that the height can be exactly adjusted within a range of 1¾ ins. The position of the radiant ball of the Pointolite Lamp is indicated by a white spot on the top of the box. The box is lined with asbestos to prevent over-heating. The stand is provided with holes for screwing to the bench if desired.

For measuring very high densities, *i.e.* high absorptions, or for making measurements in the extreme red or violet; also for measuring reflective power of fabrics, papers, etc., a 500 c.p. Pointolite Lamp is recommended.

F 242.—500 c.p. Pointolite Lamp ... ...

F 243.—Low voltage resistance for above lamp for direct current

F 244.—High voltage resistance for above lamp for direct current

A 150 c.p. Pointolite Lamp can now be supplied for alternating current, prices on request.

H 32.—**Nutting Direct Vision Spectrophotometer,** a simple form of spectrophotometer, consisting of a direct vision spectroscope and Nutting photometer combined in one direct vision direct reading instrument.

OUTFIT FOR SPECTROPHOTOMETRY IN THE INFRA-RED

D 35.—**Infra-red Spectrometer,** calibrated in wavelengths from 5000 A to 100,000 A (for complete description see pp. D 15-16)

A complete outfit consists of :—

D 35.—Infra-red Spectrometer ... ...

F 91.—Broca Galvanometer (made by the Cambridge Instrument Co. Limited), selected as being suitable for work with this instrument ... ...

or **F 92.**—Paschen Galvanometer (made by the Cambridge Instrument Co. Limited). Much more sensitive than the Broca (for fuller particulars see p. F 15) ... ...

F 151.—Magnetic shield for the Paschen Galvanometer (strongly recommended) made by the Cambridge Instrument Co. Ltd. ... ...

F 93.—Scale, on stand, with lamp for use with either of the above galvanometers (made by the Cambridge Instrument Co. Ltd.) ... ...

The sensitivity to be expected from this instrument may be gathered from the following data :—

A D 35 Infra-red Spectrometer taken without special selection from our stock and used with a Broca Galvanometer of 15 seconds period, both slits being ¼ mm.

wide, thermopile having a sensitive area of 10 × 0·5 mm., gave a deflection of 20 mm. for the mercury green line (Silica lamp) and 180 mm. for the 44,000 A line given by a Meker burner.

If greater intensity be required, the larger instrument D 42 can be substituted for the D 35, see below.

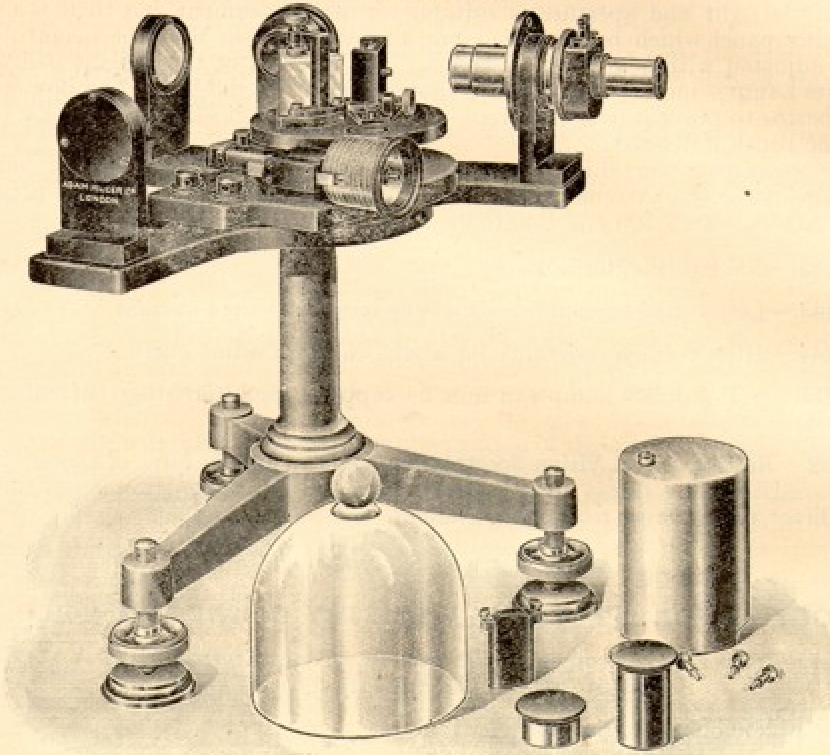


Fig. D 35

D 42.—Infra-Red Spectrometer of large aperture, calibrated in wavelengths from 5000 to 160,000 A.—This instrument is of similar design to our standard model, D 35, but so modified as to have a focal aperture of f/4·5. It is provided with a rocksalt prism of about 45 mms. height, and 70 mms. length of face. The concave mirrors are of 23 cms. focal length and 50 mms. diameter. These and the plane mirror are of platinum electro-deposited on glass. Recent experiments with mirrors of stainless steel have led us to believe, however, that this substance is more resistant to atmospheric conditions than metallic films on glass, and of about equal reflecting power. It is probable that this material will be adopted if the tests are confirmed.

The instrument is calibrated in wavelengths from 0·5μ (5000 A) to 160,000 A, the extension of calibration having been made by Paschen's dispersion formula.

HÜFNER TYPE SPECTROPHOTOMETER

FOR PHOTOGRAPHIC PLATE AND FILTER FACTORIES

The above form of spectrophotometer (Fig. H 1) is designed for the accurate measurement of absorption of liquids, etc., for light of any desired wavelength ; but it can be equally well used for the determination of the densities of photographic plates or films, for which purpose it is extremely accurate and convenient.

It was for this combination of purposes that it was first designed to the requirements of Dr. C. E. K. Mees.*

It is in use in many of the most important photographic plate works of the world.

The instrument consists of the following essentials :—

It is desired to compare the intensities of two beams of light, one of which has undergone absorption (by passage through a known thickness of a liquid, for instance). In the path of the beam which has not undergone absorption is interposed a Nicol prism, which polarises the light perpendicularly. The two beams of light are then thrown on the slit of the spectroscopic portion of the apparatus, being brought into close juxtaposition with a sharp dividing line by a prism of special design. The light after passing through the slit undergoes collimation, and is dispersed into a spectrum by a prism, and after passing through a second Nicol prism is brought to a focus, and observed by an eyepiece. Two spectra are then seen one above the other, with a very sharp dividing line between ; the one being an

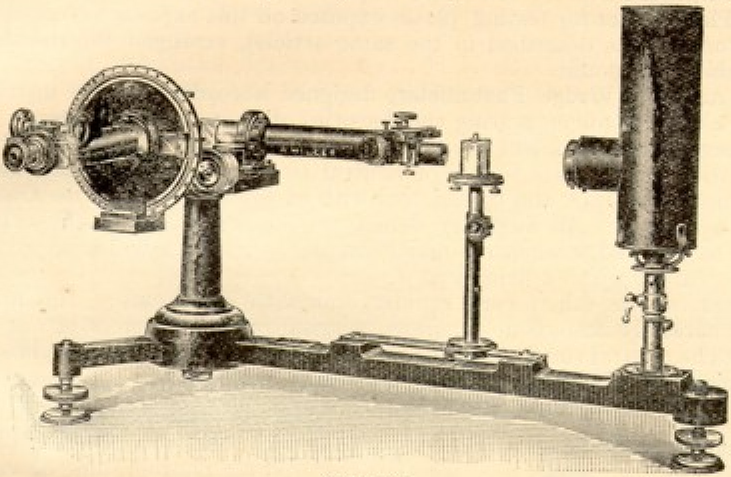


Fig. H 1

absorption spectrum of the substance under observation, the other spectrum being reducible by rotation of the second Nicol prism to any desired intensity. The intensity of this latter spectrum can be simply deduced from the rotation of the second Nicol, and thus, by exact matching of any desired part of the two spectra, an exceedingly accurate measurement of the amount of absorption by the material under observation can be obtained. One can pass through the spectrum by a screw motion, with a large drumhead on which the part of the spectrum under observation is marked in wavelengths. Owing to the special form of prism used the telescope is rigidly fixed.

The rotation of the second Nicol is read off by a vernier. The eyepiece has two shutters pushing in from right and left, by means of which any part of the spectrum can be isolated.

The illuminating system is a metal filament lamp of the type having all the radiating section in one plane. If preferred we are prepared to supply a "Pointolite" lamp at an additional charge of £3 10s. When ordering, state voltage of electric supply.

H 1.—Hüfner Spectrophotometer (not including Schulz's Cell and mount, shown in Fig. H 1) ... ...

H 2.—Division in densities in addition to the division in degrees ...

* See *Photographic Journal*, July 1904.

H 3-H 4.—Reading microscope, attached to the telescope, for reading the circle without quitting the eyepiece, with 4-volt electric lamp for illumination, and mirror for reading the drum from the eyepiece. ... ...

H 5.—Schulz's Cell, for absorption measurements, on raising and lowering stand, with rack and pinion ... ...

H 6.—Reflectors of plaster of Paris, for comparison of two light sources ; to go on same stand as Schulz's Cell ... ...

H 7.—**Exposure Box,** for plate testing work, as designed by C. E. Kenneth Mees, Esq., and described in the *Photographic Journal*, July 1904 ; with accurate Hurter & Driffield rotating sector ; glass cells for use as colour screens, and two dark slides as described in the above paper ; ready for running ... ...

H 8.—Exposure Box for use in the tropics ... ...

H 9.—**Plate-holder** for testing plates exposed on this exposure box on the above spectrophotometer (as described in the same article), arranged for the same stand as the Schulz's Cell mount.

H 10—**Accurate Wedge Photometer,** designed according to the instructions of F. F. Renwick, Esq., for measuring the densities of photographic plates.

The density measurement is effected by comparing the photographic plate under test with an accurate wedge of neutral tint glass, which is provided with a traversing motion by rack and pinion, and with an accurate scale of densities (Hurter & Driffield notation). An auxiliary density of known amount can be introduced in addition to the wedge when required, and the instrument will then give readings with great accuracy up to a density of 4.

Readings can be taken very rapidly and with great ease. The neutral tint wedges are carefully tested on accurate polarisation micrometers of our own construction. The neutral tint glass of which the wedges are made is Jena glass, specially free from selective absorption. Supplied complete with lamp.

(*When ordering state voltage of electric supply.*)

H 11.—**Rotating Sector** (Fig. H 11) for photometric work. In ordering please state whether required for photographic or visual use.

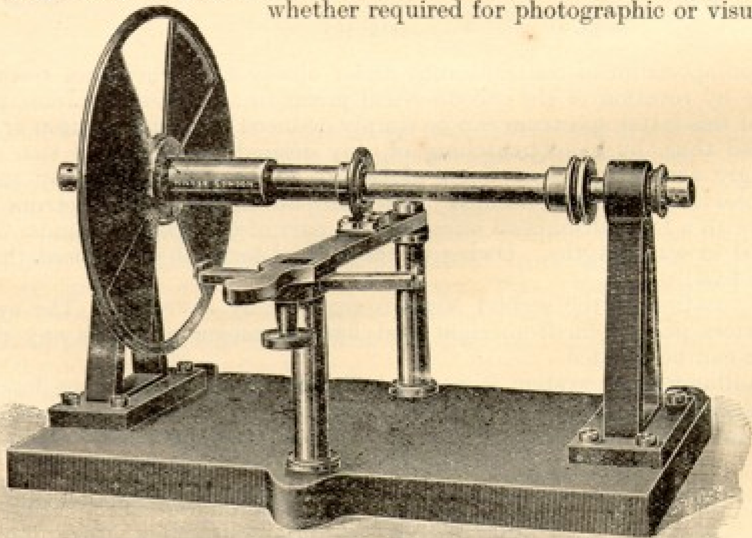


Fig H 11

WEDGE SPECTROGRAPH FOR TECHNICAL USE (COLOUR SENSITOMETRY), WITH NEUTRAL TINT WEDGE AND WAVELENGTH SCALE

Designed by Dr. C. E. Kenneth Mees for rapidly obtaining a permanent record of the absorption curves of dyes, colour filters, or the curves of sensitiveness of photographic plates.

BIBLIOGRAPHY

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"Plates Sensitised with Dicyanin" and "The Photography of the Infra-Red," by C. E. Kenneth Mees and S. H. Wratten, *Phot. Jour.*, Jan., 1908.

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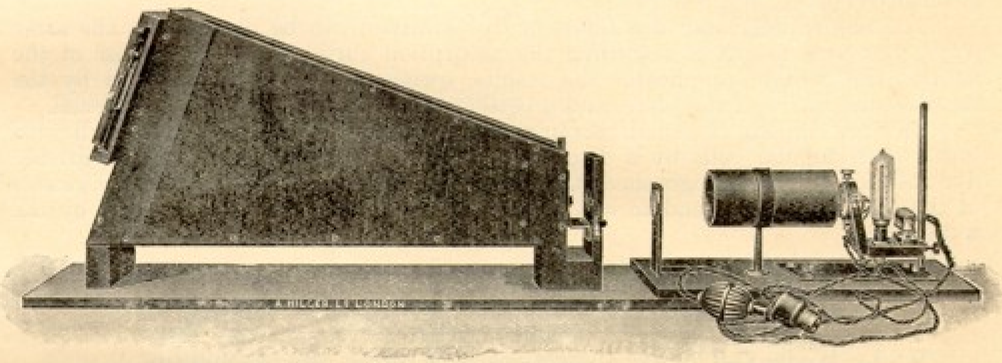


Fig. H 12

The instrument (Fig. H 12) consists of a baseboard carrying a Spectrograph, condensing lens, and 12 v. ½ Watt lamp, the filament being focussed on the slit of the Spectrograph. The Spectrograph consists of a slit, collimating lens, diffraction grating (a film replica of a Rowland's diffraction grating), and camera lens, all enclosed in the same box.

The first order spectrum is thrown on to a quarter-plate dark slide, which contains the photographic plate. In the dark slide is fixed a transparent scale of wavelengths, which is photographed at the same time as the spectrum. The red end of this scale is covered by a yellow screen, by which the overlapping ultra-violet of the second order is absorbed, the first order ultra-violet passing through the undyed portion of the screen. Three spectra can be recorded on each plate by moving the dark slide. Although not primarily designed for the examination of line spectra, the greatest care has been taken to render the scale as accurate as possible, with the result that a most efficient instrument of excellent definition is provided.

In order to use the instrument for recording the sensitiveness curve of a plate, a small wedge of neutral tint glass, equal in length to the length of the slit, is fitted in front of the slit of the Spectrograph, and produces a graduation of intensity across the spectrum. The neutral tint glass has been most carefully selected, and has no transmission or absorption band in the visible spectrum. It is of a neutral grey, with only a very slightly less absorption in the red than in the blue, though the extreme violet and ultra-violet are more strongly absorbed. The density of the wedge is so arranged that the light end transmits 10,000 times the light transmitted by the dark end, the extinction coefficient (or, in photographic terminology, "the density") varying from 0·2 to 4·2. The wavelength scale is also provided with a scale at right angles to it (Fig. H 12 B), the divisions indicating that those points correspond to the densities of 0 (on the zero line), 1, 2, 3, and 4. If the light passing the thinnest end of the wedge be represented by unity, the light passing through the portions of the wedge corresponding with the divisions of this scale will be given by 1 (on the zero line), 1/10, 1/100, 1/1,000, and 1/10,000.

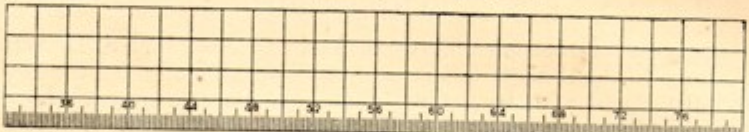


Fig. H 12 B

If, then, a plate is exposed in the Spectrograph, with the wedge in position, its sensitiveness is represented by a graphic curve showing the maxima and minima of sensitiveness.

The absorption band of a filter, or dye solution, can be obtained in the same way; but as a means of recording the absorption curve of a dye, the use of the neutral tint wedge complicates the results, owing to the effect produced by the sensitiveness curve of the plate, and a better method is the use of the wedge cell.

This cell consists of a small rectangular box of glass, open at the top, and divided into two triangular cells by a diagonal partition. One of these is filled with the dye solution to be photographed, the other with water. In this way the thickness of the dye varies from end to end of the slit, while deviation is prevented by the water cell.

H 12.—Wedge Spectrograph, with neutral tint wedge and wavelength scale, including 12 v. ½ Watt Lamp, instead of Nernst lamp, as illustrated in Fig. H 12 ... ...

H 13.—Wedge Cell for dye absorptions, with carrier fitted to Spectrograph ... ...

DR. EDRIDGE-GREEN'S COLOUR PERCEPTION SPECTROMETER

(*See* Paper by Dr. F. W. Edridge-Green, *Trans. of Ophth. Soc.*, 1907, and "Colour Blindness and Colour Perception," *Int. Scient. Series.*)

DESCRIPTION OF APPARATUS

This instrument (*see* Fig. H 14) is a spectrometer so arranged as to make it possible to expose to view in the eyepiece the portion of a spectrum between any two desired wavelengths. It consists of the usual parts of a prism spectroscope, *i.e*, a collimator with adjustable slit, prism, and telescope with eyepiece, of the following dimensions :—

Focal length of collimator and telescope object glasses = 7⅛" (180 mm.).

Clear aperture of collimator and telescope object glasses = ⅞" (22 mm.).

Slit, 7 mm. effective length of jaw, with wedge for reducing the length of the slit, protective cap, comparison prism, and screw adjustment for the slit width with divided head (*see* Fig. H 14 A).

The prism is of flint glass, 1·65 refractive index for D.

Eyepiece, Ramsden form, focussing on to the shutters described below.

In the focal plane of the telescope are two adjustable shutters with vertical edges; the shutters being carried by levers which rotate about centres near the object glass of the telescope. The shutters can be moved into the field from right and left respectively, each by its own micrometer screw, and to each screw is attached

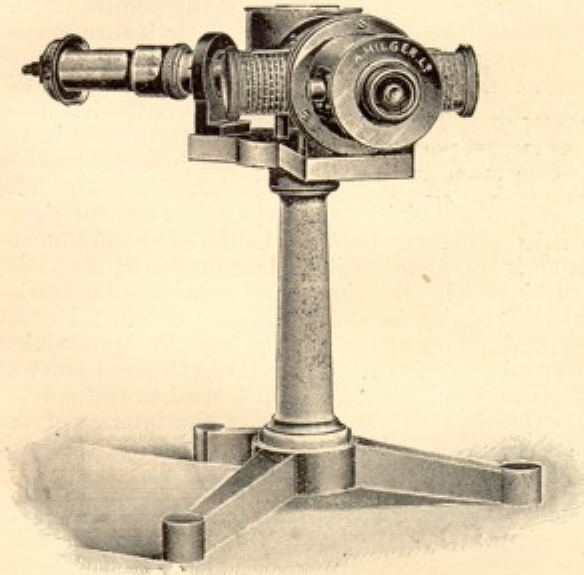


Fig. H 14

0·6 × *actual size.*

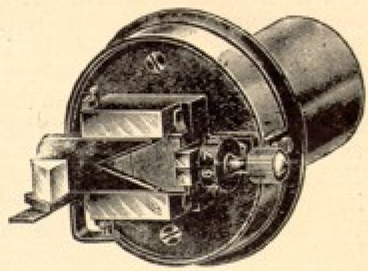


Fig. H 14a

a drum, the one being on the right and the other on the left of the telescope. On each of these drums is cut a helical slot in which runs an index, and the drum is engraved (*see* Fig. H 14 B) in such a manner that the reading of the index gives the position in the spectrum of the corresponding shutter in wavelengths direct.

Thus it will be seen that if, for instance, the reading on the left drumhead is 5320 and that on the right drumhead is 5950, the region of the spectrum from Wavelength 5320 to Wavelength 5950 is exposed to view in the eyepiece.

Fig. H 14b

An adjustment for the shutters is provided in case of possible zero alterations in course of time. These adjustments (which are provided for each shutter independently) are reached by unscrewing the small screw caps on the right and left of the eyepiece end of the telescope. This exposes a screw with a square head, on to which head fits a key which is provided. To adjust the shutter the corresponding drumhead is set to the wavelength of one of the sodium lines. The slit is illuminated by a sodium flame, and the key is turned till the edge of the shutter exactly coincides with that line. The key is then removed and the reading checked. The drum will then read correctly throughout the entire spectrum.

Care should of course be taken to avoid pressing inward with the key, to which only a turning force should be applied.

H 14.—Price ... ...
H 15.—Well-made case, with lock and key, extra ... ...

The instrument is used as follows :—The instrument should be used as far as possible with a known quality and intensity of light. A small oil-lamp is quite suitable for the purpose. The observer should first ascertain the exact position of the termination of the red end of the spectrum, the left-hand shutter being moved across until every trace of red just disappears. The position of the pointer on the left-hand drum is noted, and the wavelength recorded. The left drum is then moved so that the shutter is more towards the middle of the spectrum. The right-hand drum is then moved, until the pointer indicates the wavelength recorded as the termination of the red end of the spectrum. The observer then moves the left-hand shutter in and out until he obtains the largest portion of red, which appears absolutely monochromatic to him, no notice being taken of variations in brightness, but only in hue. The position of the index on the left-hand drum is recorded. The left-hand shutter is then moved more towards the violet end of the spectrum, the right-hand shutter being placed at the position previously occupied by the left-hand shutter. In this way the whole of the spectrum is traversed until the termination of the violet end of the spectrum is finally ascertained with the right-hand shutter. The variation of the size of the patches and the terminations of the spectrum with different intensities of light can be noted. The instrument can also be used for ascertaining the exact position and size of the neutral patch in dichromics, the position of greatest luminosity, and the size and extent of pure colours. When it is used to test colour-blindness, the examinee should first be shown some portion of the interior of the spectrum, and then asked to name the various colours which he sees. In this way he will have no clue to the colours which are being shown him.

H 42.—Hilger Colour Perception Spectrometer.—This instrument is similar in principle to Dr. Edridge-Green's apparatus, but consists of a Hilger constant deviation wavelength spectrometer, Catalogue No. D 1, with a special micrometer slit with one fixed and one movable jaw arranged in the focal plane of the telescopic eyepiece.

The fixed jaw of the micrometer slit is set to correspond with the readings on the wavelength drum, and the movable slit jaw measures (by reference to tables) the extent to which that part of the spectrum under observation appears to the observer to be monochromatic. The collimator slit is provided with a divided drum indicating the width of opening.

Tables are provided for conversion of the micrometer slit readings into wavelength differences.

H 43.—Polished white wood case for H 42 with lock and key ...

H 44.—Hilger Colour Perception Spectrometer Diffraction Grating Model.—This consists of a Hilger diffraction grating spectrometer, Catalogue No. D 25, with micrometer eyepiece. The drum of the micrometer eyepiece is divided to read wavelengths.

The method of use is similar to that of H 42, with the advantage that it is not necessary to refer to tables to obtain the wavelength reading of the movable micrometer eyepiece jaw, the result being obtained by adding the reading on the micrometer drum to the reading on the grating drum.

H 45.—Polished white wood case for H 44 with lock and key ...

THE NUTTING COLORIMETER

(U.S. Patent 1026878, May, 1912)

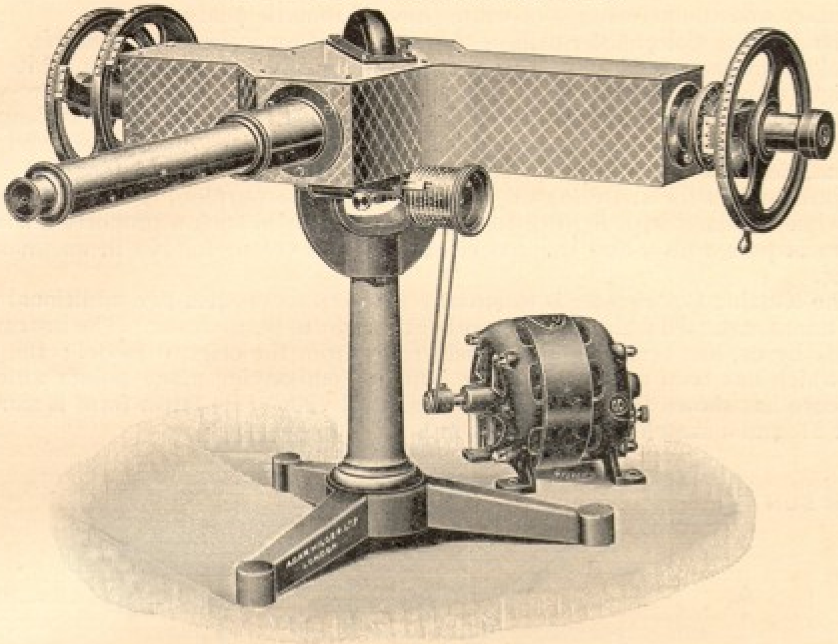


Fig. H 21

BIBLIOGRAPHY

1. P. G. Nutting, *Bull. Bureau of Standards*, 9, 1913, pp. 1-5.
2. L. A. Jones, *Physical Review*, 4, 2nd Ser., pp. 454-466.

PURPOSES OF THE INSTRUMENT

The main purpose for which the Nutting Colorimeter has been designed is the analysis and specification of colours, for instance, those of papers, powders, liquids, textile fabrics, colour screens, or light sources.

It is also an efficient instrument for—

Photometry (including Spectrophotometry).
Visual sensibility determinations.
Hue sensibility determinations.
Purity sensibility determinations.

With this instrument, then, it is possible to measure and record numerically a colour so that at any future time, and with a different instrument if desired, it can be accurately reproduced from the record.

Obviously, too, determinations of colour blindness and lesser abnormalities of colour sensibility come within its scope.

There are clearly a great number of special applications in Art, Science and Industry. For instance, the colours of natural objects (plumage of birds, flowers, etc.) can be specified, the fading or darkening with time of coloured objects or pigments measured, the accuracy of colour reproductions checked, colour matching carried out by correspondence, trials of colour harmony schemes effected, and so forth.

It is well known that any colour may be analysed and specified in either of two different ways: (1) In terms of three primary components, red, green, and blue (trichromatic analysis); or (2) in terms of wavelength of dominant hue or its complementary and the percentage of white (monochromatic analysis).

The Nutting Colorimeter utilises the method of *monochromatic analysis*.

Colour measurement with this instrument is effected by mixing white light with light of a pure spectral hue. The hue, and the proportion of white are varied until the mixture matches the colour to be analysed. Finally the wavelength of the dominant hue and the percentage of white admixed are determined, and these two qualities (*hue* and *purity*) recorded as specifying the colour determined. This procedure suffices for analysing all colours, except the purples. For these, light of a pure hue is mixed with light of the unknown colour in such a proportion that the mixture is pure white, and the specification of the colour follows in an analogous manner.

The Nutting Colorimeter is essentially a spectroscope with two additional arms, one to admit standard white light, the other the light to be analysed. The instrument, as made by us, has been modified considerably from the original model; the latest form, which has been approved by Dr. Nutting, embodying many points which his experience has shown to be desirable. A general view of its latest form is shown in Fig. H 21, and a sketch plan in Fig. H 21A.

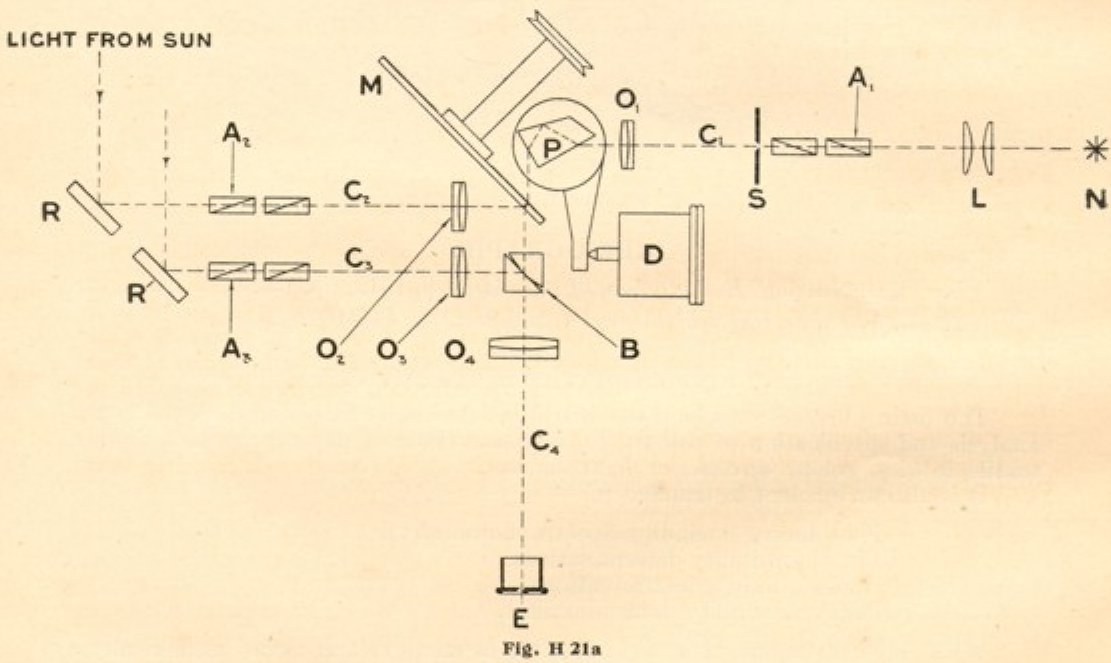


Fig. H 21a

C_1 is the spectral collimator to admit light to be spread into a spectrum. The dispersing prism P is of the constant deviation type, thus permitting a fixed arm form of spectroscope to be used.

The prism is rotated by a fine screw motion actuated by the drum D, on which the wavelength of the line under observation is read off directly in wavelengths.

The intensity of the spectrum is variable at will by adjustment of the bi-lateral slit S, or by rotation of one of the polarising prisms A. In this way a great range of intensity can be obtained in the spectral beam. In making measurements the rotation of the polarising prism should be adopted, the relative brightness, I', being determined in the usual way from the formula—

$$\frac{I'}{I} = \cos^2 A$$

A being the reading on the circular scale attached to the outer polarising prism, and I being the intensity when $A = 0$. In what follows the brightness of the spectral component, as thus determined, is represented by I_r.

C_2 is the white light collimator to admit the standard white light. This beam can also be altered in intensity by means of the polarising prisms A_2.

C_3 is a collimator to admit the light to be analysed, also with polarising prisms A_2 for altering the intensity.

C_4 is the observing tube.

M is a plate of glass, of which two sectors of 90° are silvered on the back, thus forming mirrors, the remaining two sectors of 90° being clear glass.

The mirror axle has a pulley by means of which the mirror can be rotated, in its own plane, by a small motor provided with the instrument.

The light beams from collimators C_1 and C_2 are brought by the Lummer-Brodhun cube B into favourable juxtaposition with that from the collimator C_3, so that an accurate judgment of match can be made.

When a purple or magenta is to be analysed, the arrangements outside C_2 and C_3 are simply interchanged.

The colour is expressed in the following terms :—

$$x\%\text{white} \pm y\%\lambda$$

where λ is the wavelength of the dominant or complementary hue, as given by the wavelength drum, and x the % white obtained, as detailed in the instructions provided.

Of course the definition of the colour is not complete until we have included a factor defining the luminosity, which is obtained by comparing the intensity of light proceeding from the object with that of light from some object of standard or unit brightness. If the intensity of the reference standard be known in terms of some absolute unit, the intensity factor thus found will naturally also be in terms of that unit. Should this, however, not be the case, the reference standard is accepted as the unit to which the coloured light under test is referred.

Full instructions are provided with the instrument.

In ordering, the voltage of the electrical supply should be stated, in order that a suitable motor may be supplied.

H 21.—Nutting Colorimeter as described above.

(Fuller description post free on application.)

SECTION K

DIFFRACTION GRATINGS

K 0.—Rowland Diffraction Gratings.—A stock of diffraction gratings, ruled at the Johns Hopkins University, both plane and concave, is usually kept. The best quality only are stocked. Price lists and particulars of gratings in our stock will be sent post free on application. In recent years there has been a shortage in the supply of these gratings.

For Concave Grating Spectrographs, *see* Section E.

K 1.—Infra-red Diffraction Gratings.—Plane gratings, ruled on brass, 946 lines per cm., specially cut to give maximum intensity for wavelength 4·40 μ, in the first order spectrum on one side.

The polished surface is $6\frac{1}{2} \times 5$ cms.
The ruled surface is 5×4 cms.

For Wavelength Spectrometer, Constant Deviation Type, with Diffraction Grating, see *Section D, " Wavelength Spectrometers."*

Film Replicas of Rowland's Diffraction Gratings. (14,438 lines per inch.)

K 3.—Mounted on best plane parallel worked glass, for use with table spectroscope, specially selected gratings, in case.

The K 3 Film Replicas referred to above are made in our own Laboratories, and are of first quality. In the course of the manufacture of these, a certain number are occasionally produced which are not quite of the first quality. These can be supplied, when in stock, at about one-half the price of the K 3 grating.

K 2.—Hilger Film Replica of second quality (as described above), mounted on plane parallel glass.

K 4.—Mounting with three levelling screws for replica gratings K 2 or K 3.

K 5.—Mounted in $5\frac{1}{2}$ inch long direct vision pocket spectroscope, with adjustable slit in brass case. *Visible spectrum over* 20°.

K 8.—Photographed Gratings, 3,610 lines per inch, for demonstration purposes.

We can also supply the Thorp Film Replicas as follows :—

K 33.—Thorp Film Replica mounted on selected plate glass.

K 34.—Thorp Film Replica mounted on worked glass.

For gratings ruled at the National Physical Laboratory, see p. K 2.

Replicas of interest in connection with the ruling of Diffraction Gratings.—A set of replicas of three gratings ruled in the following way :—

K 9.—Uniform ruling. Spacing $\frac{1}{1800}$ inch.

K 10.—Alternate ruling. Spacing $\frac{1}{3600}$ inch.

K 11.—Ratio of spacing $\frac{1}{7200} : \frac{3}{7200}$.

In the first, all spectra are present and bright ; in the second, alternative spectra are weak or absent ; in the third every fourth spectrum is missing.

Owing to the coarseness of ruling a considerable number of spectra are visible on each side of the central image.

Each replica is mounted on plane parallel glass and is of good definition for demonstration work.

Sold only in sets of three (limited number only available).

K 12.—**Students' Hand Diffraction Grating Replica.**—This grating replica consists of a small patch, about ½ inch square, cast in celluloid from an original Rowland Grating, and mounted between two protecting plates of glass. The number of lines per inch is printed on each grating. The gratings are not intended for use in a spectroscope, for which they are insufficiently accurate, but for use in the hand.

(*For fuller particulars, see separate leaflet.*)

DIFFRACTION GRATINGS RULED AT THE NATIONAL PHYSICAL LABORATORY

We are now in a position to offer both plane and concave gratings ruled at the National Physical Laboratory, of the sizes stated in the table below. These gratings are of first quality, and can be examined by appointment at our Works and Laboratories.

The dimensions of the ruled area are approximate, and subject to small variations. The grating plates are square, the polished area being circular, and the ruling approximately 14,400 lines to the inch.

The price of these gratings, which are of first quality, includes a certificate from the National Physical Laboratory.

We can supply these gratings specially ruled and tested for the Lyman region, an extra charge being made for the test (see below).

Grating mountings of the " Eagle " type will be found in Section E.

Stigmatic mountings for concave gratings, according to the system of Meggers and Burns, Bureau of Standards Scientific Paper, No. 441, 1922, will also be found in Section E.

PLANE GRATINGS

Symbol.	Diameter of Polished Circle. Cms.	Ruled Area. Cms.	Radii of Curvature. Metres.
K 13	4·5	3 × 2·0	Flat
K 14	7·0	5 × 3·5	Flat
K 15	10·5	8 × 5·0	Flat

CONCAVE GRATINGS

Symbol.	Diameter of Polished Circle. Cms.	Ruled Area. Cms.	Radii of Curvature. Metres.
K 16	4·5	3 × 2·0	1·0
K 17	4·5	3 × 2·0	1·5
K 18	7·0	5 × 3·5	1·0
K 19	7·0	5 × 3·5	1·5
K 20	7·0	5 × 3·5	2·0
K 21	10·5	8 × 5·0	2·0
K 22	10·5	8 × 5·0	3·0

K 35.—Concave Diffraction Gratings specially ruled at the National Physical Laboratory for the Schumann and Lyman Regions. On circular speculum plates 7 cm. diameter, area for ruling 5 × 3·5 cm., 1 metre radius.

Delivery sometimes from stock ; otherwise about four weeks.

K 36.—We can undertake the test of these gratings in a vacuum spectrograph in our own laboratory for the Lyman region up to 459 A (carbon). Fee for test, including spectrogram showing that line.

The length of spectrum when mounted on an E 50 Hilger Vacuum Spectrograph is about 50 mm. from 2100 to 1200 A, and the same from 1200 to 300 A.

This test customarily retards delivery by from 3 to 8 weeks.

Second quality gratings can occasionally be offered at a reduced price, and are supplied without certificate. Prices of any in stock will be sent on application.

For Michelson Echelon Diffraction Gratings, see *Section B.*

ADAM HILGER, Ltd., 75a Camden Road, London, N.W. 1

Entrance :—24 Rochester Place (adjoining)

Telegraphic Address—" Sphericity, Phone, London."
Telephone—North 1677/8.
Cable Code—Western Union.
Cable Address—" Sphericity, London."

October 1924

SECTION L

MICROMETERS, Etc.

PHOTOMEASURING MICROMETERS

NOTE.—*The words "Micrometer screw" are often applied indiscriminately to any screws of fine pitch, sometimes even to screws cut with dies. When used by us they connote a screw well cut between dead centres on a special lathe with tested screw, and fitted and ground into its nut with due care and skill.*

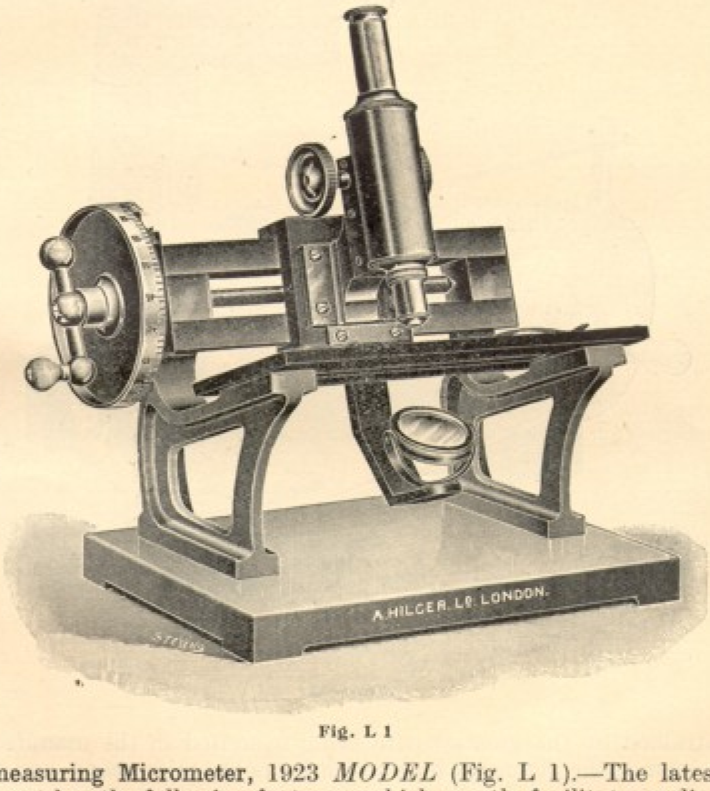


Fig. L 1

Photomeasuring Micrometer, 1923 *MODEL* (Fig. L 1).—The latest model of this instrument has the following features, which greatly facilitate readings :—

The mirror moves with the travelling microscope.
The milled head for turning the screw has been replaced by a handle.
The standards which support the slide and substage are so designed that the axis of the microscope is sloped towards the observer.
A vernier has been added, reading to 0·001 mm.

The scale on which the whole revolutions are read is engraved in a position convenient for the eye of the observer.

Though specially designed for accurate and rapid measurements of spectrum photographs, this instrument can be used with equal advantage for any accurate length measurements.

The objects aimed at in its construction are :—

i. Accuracy.
ii. Long life under frequent use.
iii. Rapidity and convenience of working.

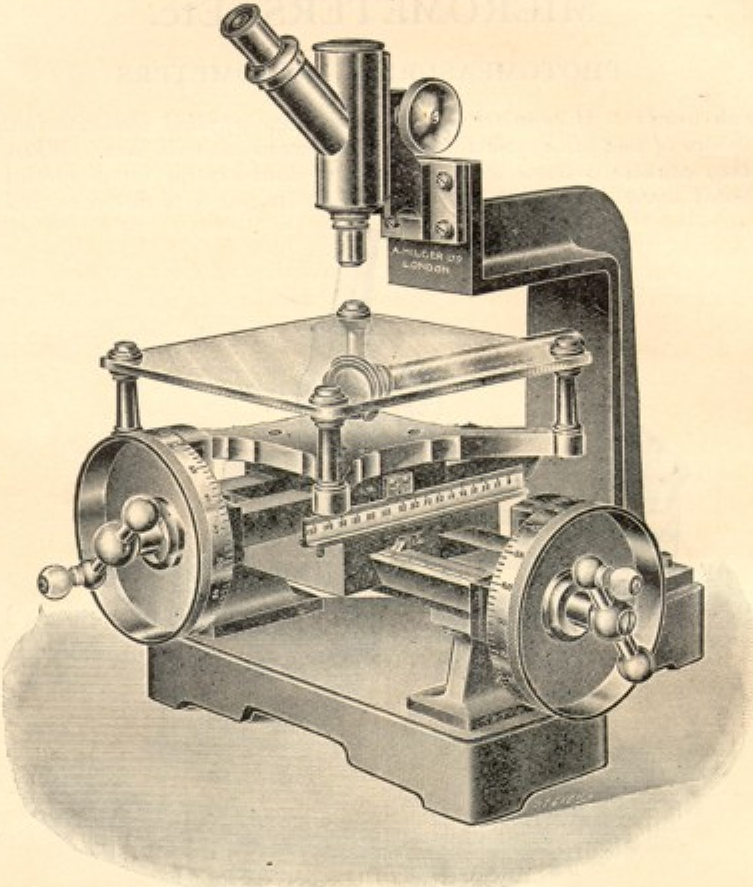


Fig. L 12

I. Is attained by the greatest care being exercised in the manufacture of the steel screw, its nut, the gunmetal slide which bears the microscope, and the shoulder fitting of the screw.

II. Is attained by simplicity of design, and by the provision of adequate bearing surfaces in screw and microscope slide. The deep thread of the screw and its substantial diameter are the main points to be noted in this respect.

III. Is attained by making the screw of fairly large pitch, *i.e.*, 1 mm., and putting on a specially large divided drumhead and vernier. With the aid of the handle now provided, one can pass rapidly over the whole range of motion, while at the same time the large drumhead enables measurements to be taken to 0·001 mm.

The base is of cast-iron, and the microscope slide is mounted on two cast-iron standards, of such a shape as to form convenient handles for moving the instrument.

Relative Pitch.—The accuracy of the L 1, L 2 and L 12 is such that measurements made on an instrument are consistent with each other to 0·002 mm.

Absolute Pitch.—Each instrument is accompanied by a test sheet. The absolute pitch of the screws is given on the test sheet to 1 part in 10,000, and no greater error of absolute pitch than 0·1% is permitted.

L 1.—Photomeasuring Micrometer with 6-inch (152 mm.) travel ...

L 2.— ,, ,, with 3-inch (76 mm.) travel ...

L 12.—Cross-Slide Photomeasuring Micrometer. New Model, with inclined observation tube (Fig. L 12).—In this instrument the photographic plate moves, the microscope being rigidly fixed. Six inches (152 mm.) of motion is provided in two directions at right angles to each other, the distance being measured by accurate screws similar to those of the instrument described above, massively and rigidly mounted, and of the highest accuracy. Where long series of readings have to be taken, observation in a vertical direction is fatiguing. We have therefore adopted the inclined observation tube on our standard model.

L 6, L 8.—"Standard" Spherometer (Ring Form).

This form of spherometer (Fig. L 6, L 8) has a ring instead of the usual three legs. The ring is ground so as to have two truly circular edges, one of which makes contact with concave surfaces, and the other with convex surfaces. The inside and outside diameter are accurately measured. With this instrument readings can be obtained as reliable as those of the most elaborate instruments.

Fig. L 6. L 8

L 6.—Spherometer, in case, 1 inch, radius ... ...

L 8.— ,, ,, 2 ,, ...

SECTION M

POLARIMETERS AND REFRACTOMETERS

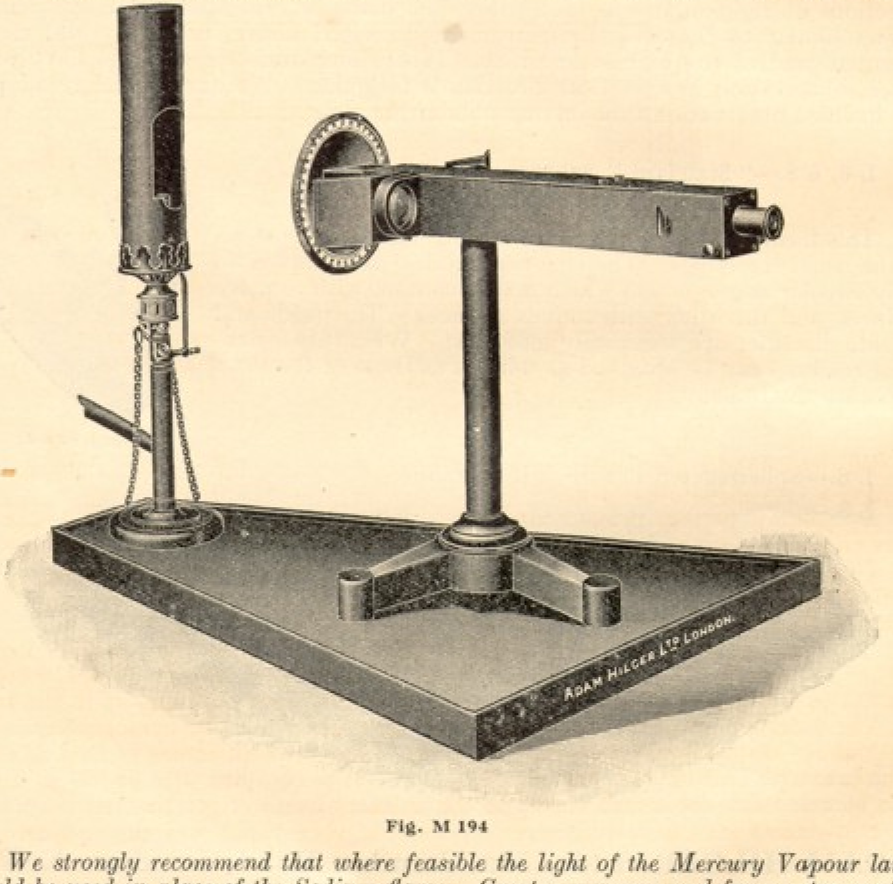


Fig. M 194

We strongly recommend that where feasible the light of the Mercury Vapour lamp should be used in place of the Sodium flame. Greater accuracy and far greater comfort and convenience of reading are thus obtained (see *Lowry*, "*The Rotatory Dispersive Power of Organic Compounds*," Trans. Chem. Soc., 1913, *vol.* 103, *p.* 1064). *Commercial Mercury Vapours lamps are now easily to be purchased from various sources.*

M 191.—Industrial, Medical, and Students' Polarimeter (Patent 166842/20 and Application 2104/23).—This polarimeter has been specially designed for any polarimetric work which does not demand a greater accuracy in angular rotation than 0·05 degree. When used for sugar work this corresponds with 0·035 grams sugar in 100 cc. measured in a 2 decimetre tube. The scale is divided to read by vernier to 0·05 degree.

The graduations of scale and vernier are very distinct. By means of two lenses the observer takes readings without quitting the eyepiece. By means of suitable reflectors the light source itself (*e.g.* Sodium flame) is used to illuminate the scale; the observer's eye being, however, protected from the light by the circle of the instrument.

The main aluminium body is extremely rigid and carries the analyser, polariser and reading glasses.

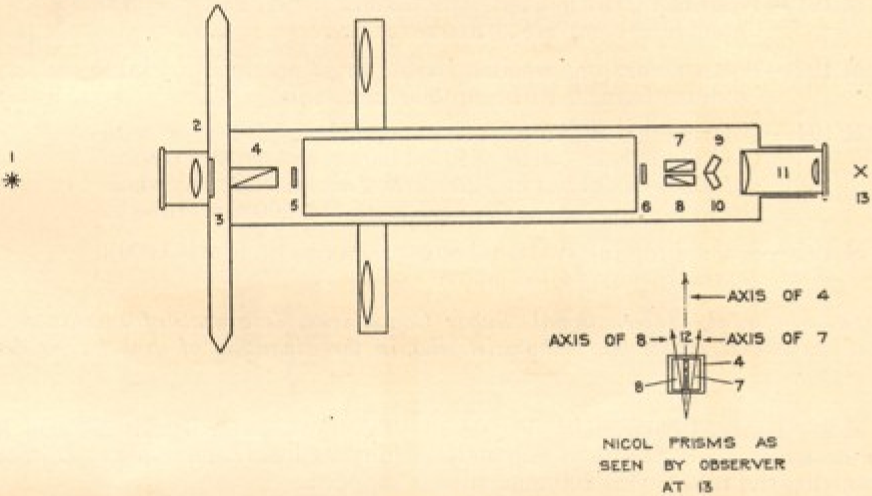


Fig. M 194 A

Efficient splash glasses are provided, very accessible for wiping, thus making cleaning a very rapid operation.

No window fittings project into the trough, so that the harmful corrosion, so likely to occur at such places, is avoided.

The trough accommodates standard diameter 200 mm. and 100 mm. tubes, ordinary form glass or metal. Two apertures are provided at the bottom of the trough to facilitate cleaning.

The dividing line is formed by the edge of one of two glass plates (Patent 16,6842/20), and is in constant focus whether the tube is in position or not, whether it is full or empty, and whatever may be the refractive index of the liquid in the tube.

The definition of the dividing line is not affected by want of homogeneity in the liquid under examination; neither will the line disintegrate in course of time as often is the case with Iceland spar prisms. Readings can be obtained with liquids so turbid as to be unsuitable for measurement on the ordinary forms of polarimeter.

Convenient zero adjusting screws providing very rapid and easy adjustment are mounted below the observing eyepiece.

For spectropolarimetry the instrument can, without any modification, be used very conveniently in conjunction with a Students' Wavelength Spectroscope D. 45, which enables the whole of the polarimeter field of view to be illuminated with any particular radiation.

A filter is provided spectroscopically equivalent in absorption to the standard potassium bichromate filter.

The half shadow angle is fixed at 14°.

The optical design is indicated in Fig. M 194A. The source of light (1) is placed at the focus of a condensing lens (2), which allows parallel rays to pass through the filter (3), a Nicol prism (4), two splash glasses (5) and (6), two Nicol prisms (7) and (8), two equally inclined plates (9) and (10), and a low power positive eyepiece (11). The condensing lens (2), filter (3) and Nicol prism (4) first mentioned are so mounted that they can be rotated, and the two last mentioned Nicol prisms (7) and (8) are so constructed and mounted that their planes of polarisation make a fixed half shadow angle (12) between each other. The equally inclined plates (9) and (10) are arranged so that a sharp dividing line between the two halves of the field is maintained at the focus of the eyepiece (11).

M 191.—Polarimeter with fixed half shadow angle, and one 200 mm. tube complete as above .. .. ..

M 192.—Polarimeter, on wooden base large enough to take sodium burner, with one 200 mm. tube .. ..

M 194.—Polarimeter, mounted on wooden base, together with sodium burner, bottle of fused borax, and copy of *Optical Methods in Control and Research Laboratories*; the whole in well-made mahogany case, with one 200 mm. tube ..

M 195.—Scale of the International Sugar Commission (Paris 1900), extra to any of the above .. .. ..

The scale of the International Sugar Commission is a scale of sucrose content; thus it has no interest for the pathologist who, in the diagnosis of diabetes, is dealing with glucose.

M 2.—**Standard Polarimeter** (Fig. M 2).—Taking tubes for liquids 220 mm. long; with screws for raising and lowering and levelling, and slides for sideway adjustment for centring the tube. One 200 mm. tube is supplied.

For polarimeter tubes, *see* pp. M 6-8.

The polarising system is of the Lippich form, in which the field of view is as shown in Fig. M 2 A.

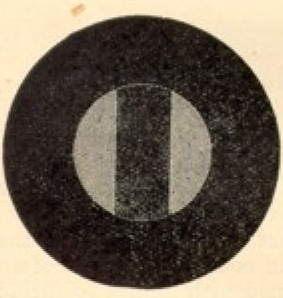


Fig. M 2a

The illumination of the middle strip decreases in intensity when the outer increases, and *vice versa*. The brightness of the illumination can be varied by rotation of the polarising prism; and an index and clamp are provided for the setting of this adjustment.

The divided circle is 7 in. diameter, and the division is on platinoid, which does not readily tarnish. There are double verniers, reading to 0·01 degree, and readers and illuminating lamps for the same. There is a good screw slow motion with clamp for fine adjustment of the analyser; and the screw is made of platinoid, which on account of its resistance to corrosion is preferable to steel where use in a chemical laboratory is in question.

M 4.—Well-made case, with lock and key ... ...

M 5.—**Standard Polarimeter,** as above, but taking tubes 400 mm. long, the construction being otherwise identical, with tube for liquids. ... ...

M 110.—Well-made case, with lock and key ... ...

M 3.—International Sugar Scale in addition to the ordinary division to either of the above ... ...

100° on the sugar scale of this instrument equals 34·617 circular degrees, which is the rotation of the normal solution for wavelength 5892·5 Å, according to the latest measurements (Bates & Jackson, *Bull. Bur. Standards*, Vol. 13, p. 118, 1916).

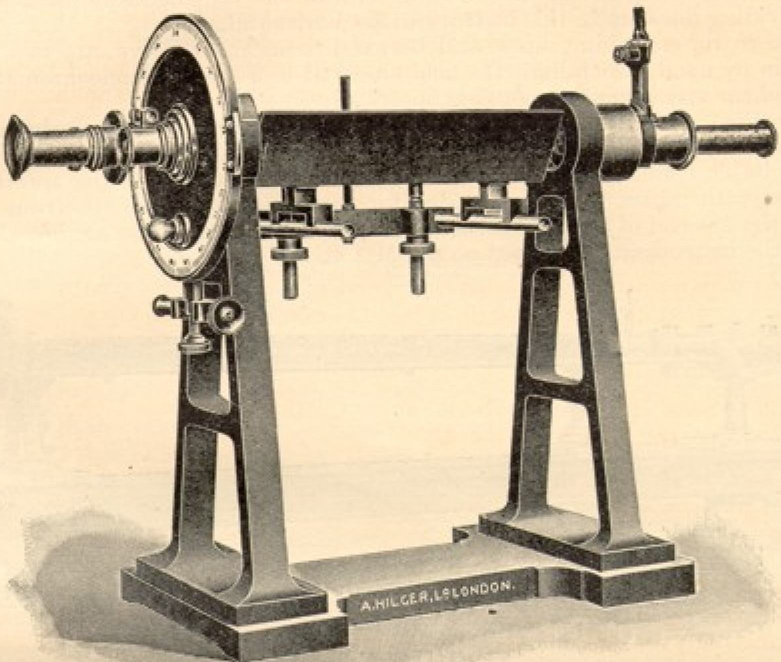


Fig. M 2

M 6.—Addition of Direct Vision Spectroscope attachments to either of the above, consisting of slit at polariser end (formed by shutters pushing in by hand in front of Lippich polariser), and one high dispersion direct vision prism in mount screwing on in front of the eyepiece ... ...

The above direct vision prism can be supplied direct for the red, green, or violet, as desired.

M 7.—Extra prisms mounted, price each ... ...

F 289.—Sodium burner, with bottle of fused borax ... ...

For complete description of the M 2 and M 5 Polarimeters, see *separate Booklet, post free. For Polarimeter Tubes*, see pp. M 6-8.

SPECTRO-POLARIMETER

(*For measurements on the rotatory power for radiations of any desired wavelength in the visible region.*)

This instrument (Fig. M 8-M 10) consists of a wavelength spectrometer, as described on pp. D 1 to D 2, reading in wavelengths direct, a polariser, and an analyser—all mounted on an accurate cast-iron bed. An image of the spectrum is projected on to the plane of the dividing lines of the Lippich triple field polariser, which dividing lines are in this instrument set horizontal.

Close to these dividing lines, and between them and the eye, are two shutters pushing in by hand, which limit the field observed to a strip of monochromatic light. The slit of the spectrometer opens symmetrically

The three standards carrying the spectrometer, polariser, and analyser can be clamped in any desired position on the bed.

A suitable condensing lens is mounted on the collimator of the spectrometer, and a rod with milled head is provided for passing through the spectrum without quitting the eye end of the apparatus. The polariser and analyser are identical with those in the instruments described on pp. M 3 and M 4.

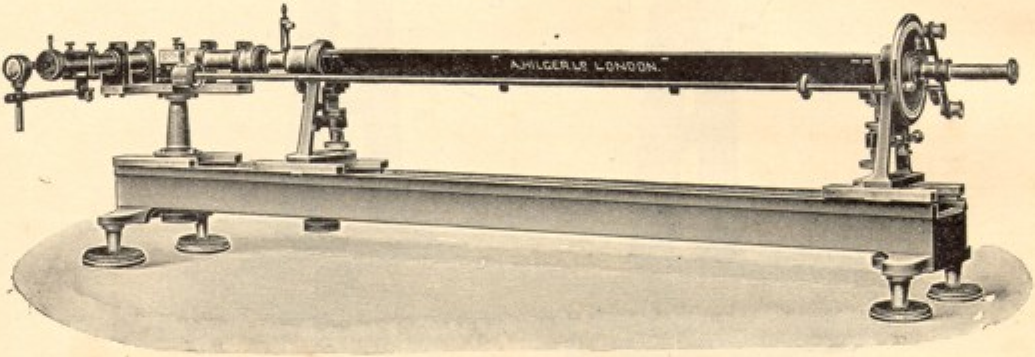


Fig. M 8-M 10

M 8.—Spectro-Polarimeter, taking tubes up to 200 mm. long ...

M 9.—Spectro-Polarimeter, taking tubes up to 400 mm. long ...

M 10.—Spectro-Polarimeter, taking tubes up to 1000 mm. long ...

Owing to the impossibility of entirely avoiding faint diffused light of mixed wavelengths it is highly desirable to use in conjunction with this apparatus the direct vision spectroscope attachments described at the bottom of p. M 4.

M 11.—Complete set of three prisms ... ...

For Polarimeter Tubes, see pp. M 6-8.

SACCHARIMETERS

M 41.—220 mm. Saccharimeter complete, with one enlarged end tube ... ...

M 42.—400 mm. Saccharimeter complete, with one enlarged end tube ... ...

M 149.—Quartz control plate for checking the 100° point, together with *Bureau of Standards* certificate for same ... ...

M 000.—Quartz control plate for checking intermediate points on the scale, together with the *Bureau of Standards* certificate (state approximate sugar value required) ... ...

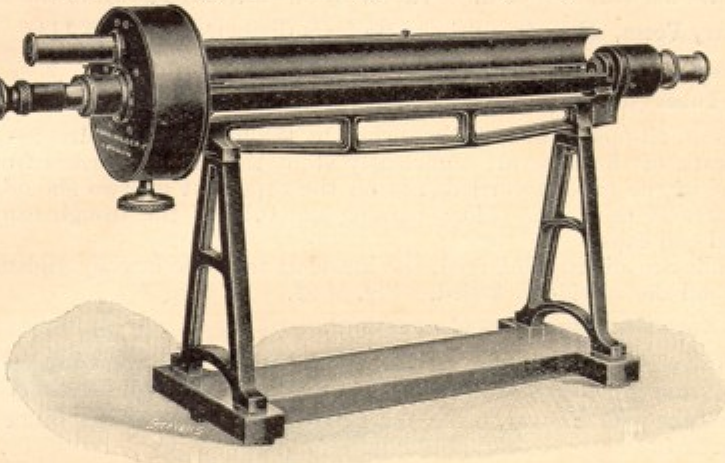


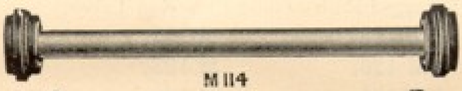
Fig. M 42

M 157.—Pointolite lamp on stand, complete ... ...
M 162.—High voltage half-watt lamp on stand ... ...
M 163.—6 volt half-watt lamp on stand ... ...

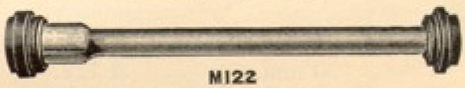
For Saccharimeter Tubes, see pp. M 6-8.

(*For full description, with historical notes, etc.,* see *separate* 11-*page Booklet, post free on request.*)

POLARIMETER AND SACCHARIMETER TUBES

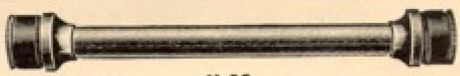


M114

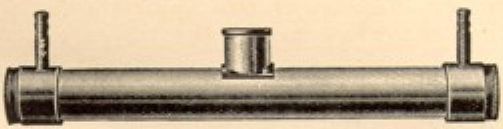


M122

M98

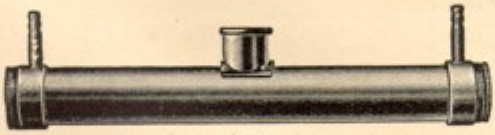


M 92

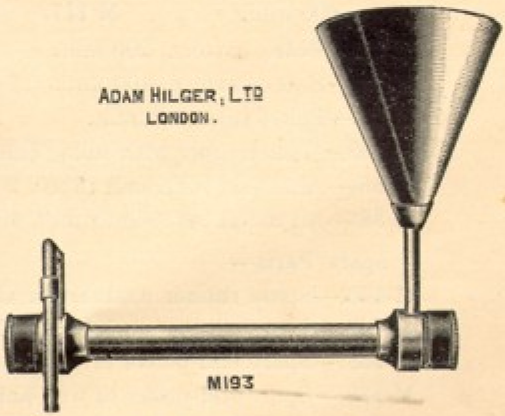


M130

ADAM HILGER, LTD
LONDON.



M86



M193

Lengths correct to ± 0·025 mm. at 20° C.
The end plates of all tubes are of well annealed optical glass.

We make six varieties of these tubes, all of which are shown in the figure.

Ordinary Form, with glass tube of uniform diameter. Fig. M 114.

Ordinary Form, with enlarged end. Fig. M 122.

Bates Tubes (see *Circular Bur. Standards No.* 44, 2nd edition, 1918, p. 44).

This is an all-metal tube, distinguished by the following features :—

The walls of the tube are sufficiently stout to eliminate errors from bending. The weight of the tube is carried, not on the caps, but on two shoulders forming integral parts of the tube. Thus, turning the tube in the trough cannot disturb the screwed end caps.

The ends are slightly enlarged, the inside of the tube heavily gilded to prevent corrosion, and the outside nickelled. Fig. M 92.

Pellet Tube (for continuous observation).

The design is similar to that of the Bates pattern with the addition of two side tubes, to permit of continuous circulation of the liquid through the tube. Fig. M 98.

Pellet Tube with Funnel, being the Pellet Tube with a filling funnel and overflow. Fig. M 193.

Inversion (Water-Jacketed) Tubes with Glass Inner Tube, the outer tube being brightly nickelled to reduce radiation. Fig. M 130.

All Metal Inversion Tubes.—These tubes are similar to the ordinary water-jacketed tubes, but with the central tube made of metal. This eliminates expansion difficulties, and the substitution of solder for cement makes it possible to work at much higher temperatures than with glass tubes. The inner tube is heavily gilded to prevent corrosion. Fig. M 86.

The following are the sizes which can be delivered from stock :—

Length.	Catalogue Symbol Ordinary.	Catalogue Symbol Enlarged End.	Catalogue Symbol Glass Inversion Tubes.
25 mm.	M 111.	M 119.	M 127.
50 mm.	M 112.	M 120.	M 128.
100 mm.	M 113.	M 121.	M 129.
200 mm.	M 114.	M 122.	M 130.
220 mm.	M 115.	M 123.	M 131.
400 mm.	M 116.	M 124.	M 132.
600 mm.	M 117.	M 125.	M 133.

M 92.—Bates pattern, 200 mm.

M 94.—Bates pattern, 400 mm.

M 98.—Pellet tube, 200 mm.

M 193.—Pellet tube, with filling funnel and overflow.

M 86.—All metal inversion tubes, 200 mm.

M 88.—All metal inversion tubes, 400 mm.

Spare Parts—

M 140.—Spare rubber washers for above tubes, small.

M 141.—Spare rubber washers for above tubes, large, for enlarged ends.

M 138.—Spare end-plates of well-annealed optical glass.

M 139.—Spare end-plates of well-annealed optical glass, large.

M 242.—End plates for glass inversion tubes.

M 142.—Spare end-plates of well-annealed optical glass, for water-jacketed tubes.

M 243.—Thermometer for inversion tubes. These thermometers are graduated in one-half degrees centigrade from 0° to 100° and the total length of the scale is about 140 mm.; with N.P.L. certificate.

For other Tubes suitable for absorption, &c., see p. H 4.

BABINET COMPENSATOR

(JAMIN'S MODIFICATION)

(*See Wood's* "*Physical Optics*," 1911 *edition, pp.* 333-5, *or Preston's* "*Theory of Light*," 4*th edition, pp.* 421-6.)

Jamin's Modification of Babinet's Compensator consists of two acute prisms or wedges of quartz, which are mounted as shown in Fig. M 238A.

In the prism ABC the optic axis is parallel to the face AB and to the plane of the paper, while in the prism DEF the axis is parallel to the face EF, but perpendicular to the plane of the paper.

The fringes seen between Nicol prisms are about 0·7 mm. apart (angle of each wedge being about $2\frac{1}{2}$°). The quartz wedges are mounted with one wedge fixed, and on this is engraved a diamond line serving as a datum point. The other wedge is moved by a micrometer screw of $\frac{1}{2}$ mm. pitch, with divided drumhead, each division of the head corresponding to 0·01 mm. The total range of motion of the movable wedge is about 10 mm.

The instrument may be used to determine the characteristics of elliptically polarised light (phase difference, position of the axes, and ratio of the axes); while

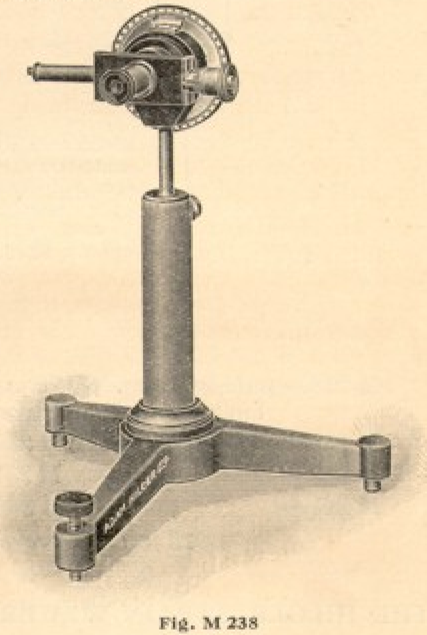


Fig. M 238

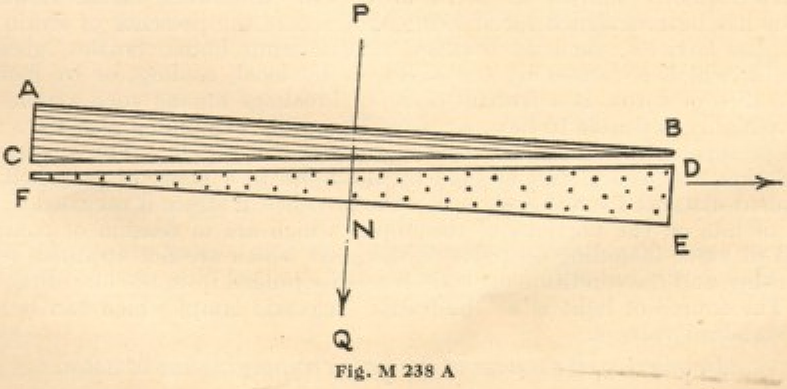


Fig. M 238 A

as a special instance may be mentioned its great value in the measurement of double refraction due to strain in transparent media.

The instrument is shown in diagram in Fig. M 237.

M 236.—Babinet Compensator, with eyepiece but without Nicol Prism ... ...

M 237.—The compensator can also be supplied mounted in a micrometer eyepiece as above, but the whole fitted into a rotating mount with vernier reading to 1-10° (*see* Fig. M 237). The whole supported on steel rod suitable for clamping in laboratory support ; without Nicol Prism

MOUNTING FOR BABINET COMPENSATOR

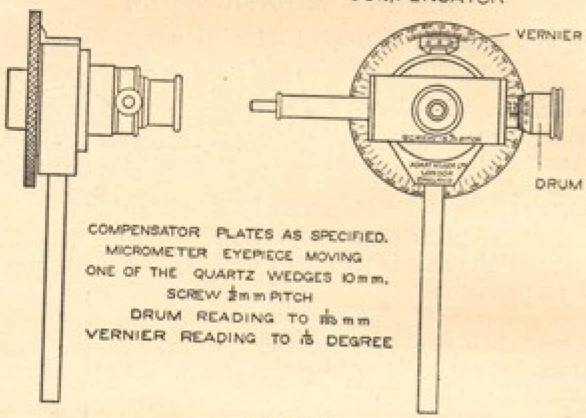


Fig. M 237

M 238.—Babinet Compensator as described under No. M 237 above, but mounted on tripod stand (Fig. M 238) ... ...

M 239.—Being the same as M 236, but with Nicol Prism ...

M 240.— „ M 237, „ „ ... ...

M 241.— „ M 238, „ „ ... ...

(*Full formulæ are given in the instructions for use.*)

THE HILGER STRAIN-VIEWERS (POLARISCOPES) FOR GLASSWARE

M 219 (formerly known as S 13 or S 43).—**Glassware Strain-Viewer.**—This apparatus has been designed for showing at a glance the presence of strain in commercial glass articles, such as beakers, electric-lamp bulbs, bottles, glasses, etc. This strain, which is caused by too rapid, or by local, cooling, or by inclusion of foreign bodies or cords, is a fruitful cause of breakage among such articles. It is, therefore, highly desirable to have a means of rapidly examining glassware to ascertain the presence of strain in any part of the finished article. The apparatus is so arranged that any article can be held by the hand in a beam of polarised light at a convenient distance from the eye, when the presence of strain is revealed by distinct changes of hue on the portions of the object which are in tension or compression. The field of view, including all parts of the glass which are not strained, remains a magenta tint, and the condition of strain is readily judged from the hue of the strained parts. The source of light is a " half-watt " electric lamp, which can be supplied for any standard voltage.

In ordering, the voltage of the electric supply should be stated.

In the side of the case of the instrument, towards the observer's left hand, a large hole is provided which makes it possible easily to examine considerable lengths of tube or other long objects.

The instrument is substantially built in well-seasoned and polished mahogany.

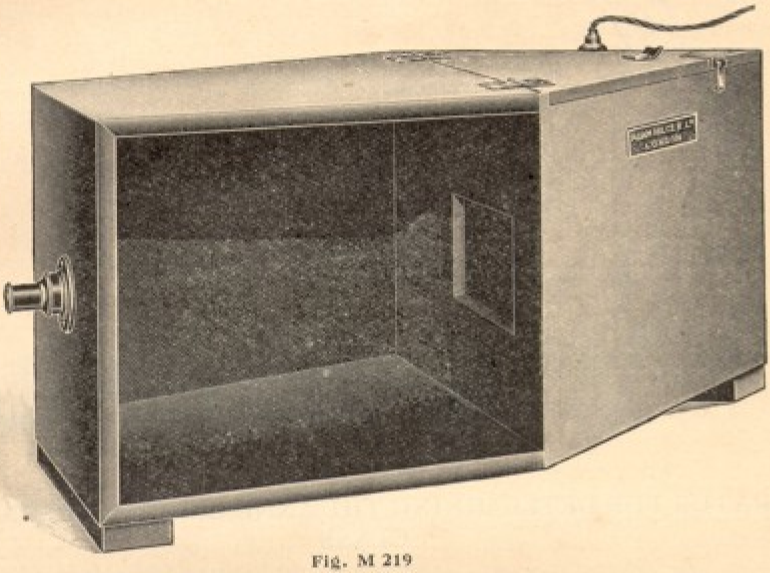


Fig. M 219

M 226 (formerly known as S 31).—**Factory Strain-Viewer.**—A simplified form, in which the illumination is provided by a sheet of diffusing glass at suitable angle, which sheet can be illuminated by any fairly powerful artificial source of light, or

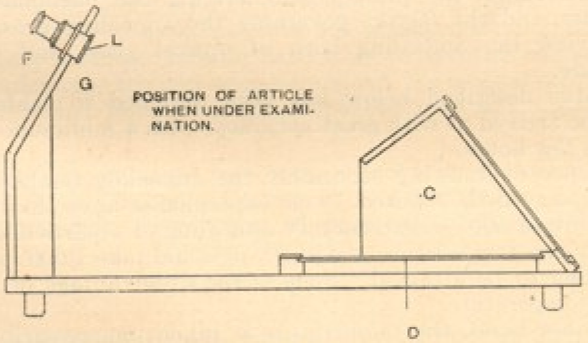


Fig. M 226

by daylight from a window. Light from the diffusing screen is reflected from a horizontal polarising sheet, and observation is made from an analyser identical with that of the standard M 219 instrument.

M 227 (formerly known as S 32).—**Simple Factory Strain-Viewer.**—A simplified form, suitable for use with daylight, being similar to M 226, but without the diffusing screen.

M 223 (formerly known as S 20).—**Portable Factory Strain-Viewer.**—This is very similar to M 226 but is arranged with hinges and wing nuts so as to admit of folding flat for ease in carrying. Very convenient for use by commercial travellers, or where for any reason portability is a consideration. A canvas carrying case is supplied with this instrument.

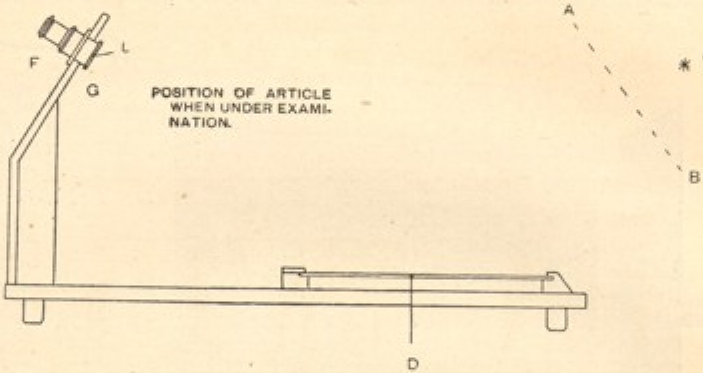


Fig. M 227

Full printed instructions with examples are sent out with each instrument.

APPARATUS FOR DETERMINING THE ANNEALING TEMPERATURE OF GLASS

(*We have also applied this apparatus in our own works to determine the annealing temperature of some metals.*)

M 220 (formerly called S 14).—This apparatus is the outcome of a series of researches that were carried out in 1915 and the beginning of 1916, the object of which was to determine the principles underlying the phenomenon of defective annealing of glass, and the factors governing the annealing process. The experiments had in view the annealing both of optical glass, and of domestic and chemical glassware.

The apparatus described below has been designed to enable the annealing temperature to be arrived at with great accuracy, with a minimum of skill, and with a delay of only a few hours.

The importance of knowing accurately the annealing temperature for a glass seems still to be very little realized. Our experiments have shown, however, that if, at a temperature of 500° C. satisfactory annealing of a particular glass will occur in one hour, then at a temperature of 420° C. it would take 1,000 hours for the same degree of annealing to be attained. Such is the disadvantage of not heating to a sufficiently high temperature.

If, on the other hand, the temperature is taken unnecessarily high, there are great drawbacks. First, the glass may get too soft, so that the articles go out of shape. Secondly, there is a loss of time consequent on raising the temperature unnecessarily high and allowing it to fall again to the lower temperature which would suffice.

To these must be added a third great drawback. It is very necessary not only to anneal the glass, but to secure that faulty annealing is not reintroduced as the temperature is taken down. If the temperature is raised only just sufficiently high for annealing to take place, the temperature will naturally fall slowly through the range within which faulty annealing may occur. When the temperature has got below that range, it is impossible to reintroduce want of annealing by means of cooling, however rapid ; the cooling may even be so fast that the articles are fractured without any permanent strain being introduced. If, however, the temperature is taken unnecessarily high, it will naturally be falling rapidly throughout the very range where slow cooling is essential.

These considerations show how important it is that the annealing temperature of every glass used by a manufacturer should be accurately known to him. Even the variations of glass from the same furnace week by week are important, and should be followed by corresponding variations in the annealing lehr if the best and quickest annealing is to be attained.

The apparatus is shown in the figure and consists of an electric furnace (C); a pyrometer (D) and temperature indicator (E); an optical system—lamp (A), lens (B), lens (F), telescope (G), and a jig for holding the strip of glass under observation.

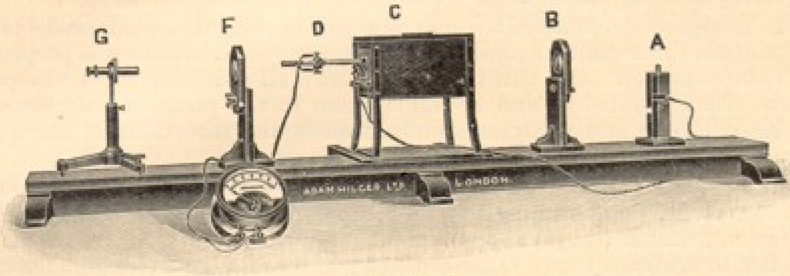


Fig. M 220

The electric furnace is of tube pattern wound with nichrome wire, and is fitted with mica windows. A switchboard and regulating resistance are supplied. The voltage available should be stated in ordering.

The pyrometer and indicator consist of a Pt. Pt-Ir thermocouple and millivoltmeter reading direct in degrees centigrade.

The optical system is substantially mounted on an oak base, and consists of a small metal filament lamp which can be run from a 4-volt accumulator, a condensing lens (F), another lens (B), and a reading telescope (G) with a divided circle.

The jig is of nickel or of nichrome, and is so constructed that one end of a small strip of the glass may be slipped into the base, while to the other end is fixed a weighted arm. A nickel or nichrome straight-edge is provided, the inclination of which measures the bending of the strip; and this inclination is observed and measured by the telescope (G).

The apparatus is accompanied by a detailed and fully worked out example of the routine elaborated in the Research Laboratory of Adam Hilger, Ltd., for the determination of the annealing temperature of glass, with full specification of size of glass strip, etc.

PROFESSOR COKER'S PHOTO-ELASTIC APPARATUS

(For Determination of Stresses in Structural and Machine Members.)

Uses.—The apparatus was devised by Prof. E. G. Coker, F.R.S., and has been used by him for many years to determine the stress distribution in parts of machines and structures by observations on models constructed of transparent materials. By this means it is possible to measure, to an accuracy of ± 2 per cent., the stress distribution under any system of loads, in any body which can be represented by a plate model stressed in its own plane.

Description of the Apparatus.—The examination is carried out on models cut from transparent celluloid. Suitable sheets of selected celluloid are stocked, and the preparation of the models presents no difficulty. The apparatus is susceptible of various arrangements, of which the most important are as follows :

(*a*) The model is illuminated with circularly polarised light, and an image of it projected through a polarising system on to the screen. The mere inspection of the projected image generally reveals the places under greatest stress, and where failure will occur.

(*b*) Simultaneously with the image of the model as in (*a*) one can project the image of a bar of the same thickness of celluloid, which is loaded by a measurable amount in the "Calibration Member." By varying the load till the colour in the calibration bar matches that at any point along an unloaded edge of the model, the stress at that point can immediately be stated.

(*c*) The model can be illuminated by plane polarised light, and an image of it projected on the screen through an analyser, whose plane of polarisation is perpendicular to that of the polariser. One can then see at once all points at which the principal stresses are either parallel to and at right angles to the plane of polarisation, and by rotating polariser and analyser simultaneously the directions of the principal stresses can thus be found at every point of the specimen.

The difference $P-Q$ between the principal stresses P and Q can be found by the colour shown at the point in question, as compared with that on a standard bar in the calibration member (*see* (*b*) above).

In order to evaluate P and Q an accessory known as the extensometer can now be brought into play. This affords an extremely delicate means of measuring the difference of thickness due to loading, and by employing it first on a standard bar with known load one can calibrate it in such a manner that its indications give the value of $P+Q$ at any point. By measurement at a number of points the complete distribution of stress in a specimen can be found, as fully detailed in the illustrated booklet which will be sent post free on request.

M 169.—Optical Apparatus.

M 170.—Iron Legs.

M 171.—Optical Calibration Frame, without stand, arranged to go on stand supplied with M 169.

M 217.—Stand for M 171.

M 172.—Tension Frame.

M 215.—Carriage for M 172.

M 216.—Cross Slide for M 215.

M 173.—Recording Device.

M 174.—Tension and Recording Set mounted together on one iron base.

M 175.—Camera.

M 180.—Simple Tension Frame.

M 181.—Bending Frame.

M 182.—Stand for M 180/1.

M 198.—Lateral Extensometer, with simple mount.

M 197.—Lateral Extensometer, with universal mount and stand.

Full illustrated description, with bibliography, post free on application.

REFRACTOMETERS

ABBE REFRACTOMETER

(WITH WATER JACKETED PRISMS)

Description.—The Abbe Refractometer is shown in Fig. M 46. A very complete description of its principles, applications, treatment, adjustment, and use is given in our booklet, "Instructions for Use of the Abbe Refractometer," a copy of which will be sent post free for 1s. 8d. on application.

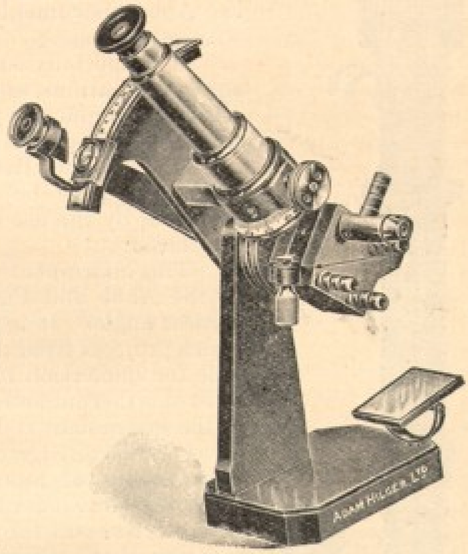


Fig. M 46

The range of refractive indices measurable by the instrument is from 1·3°°° to 1·7°°°, and the accuracy of reading is 0·0001. Measurements may be made using either daylight or artificial light; very little liquid (one or two drops only) is required to make a determination; and the refractive index is read directly on the scale. In addition to the scale of refractive indices, a scale of percentage of "dry substance" can be supplied, if desired, for sugar work. The liquid to be investigated is enclosed as a film between two prisms of dense flint glass. The upper prism has a polished face in contact with the liquid, and it is the ray which grazes this face which is utilised in making measurements. Each prism is enclosed in a hollow jacket through which water at constant temperature can be circulated. The interior faces of the water jackets are heavily gilded to prevent corrosion. The use of daylight is made possible by employing a compensator to neutralise the dispersion of the liquid and thus to give an achromatic field. The compensator consists of two direct vision prisms, which are rotated at equal rates in opposite directions by turning a milled head, and together form a system of variable dispersion. The compensator is provided with a scale, readings on which give *dispersions* by reference to a printed table provided with the instrument.

Further printed information concerning Abbe Refractometers may be obtained on application to Adam Hilger, Limited, 75a Camden Road, London, N.W.1., as follows :—

Full descriptive leaflet of the Abbe Refractometer, with bibliography, post free.

"Instructions for Use of the Abbe Refractometer," containing description of the principles of construction, use, bibliography, etc. Free with every instrument; otherwise 1s. 8d. post free to any part of the world.

"Refractive Indices of Essential Oils," price 12s. 6d. net; or post free 13s. 0d.

"Refractive Indices of Oils, Fats, and Waxes," price 17s. 6d. net; or post free 18s. 0d.

"Optical Methods in Control and Research Laboratories," price 1s. 8d. post free.

M 46.—Abbe Refractometer described above, complete with thermometer, and in case with lock and key ... ...

M 135.—Additional scale for percentage of "dry substance" for sugar work, for temperature of 20° C., extra ... ...

M 136.—Ditto, for temperature of 28° C., extra ... ...

M 45 THE DIPPING REFRACTOMETER

Fig. M 45

In cases where comparatively large quantities of liquids are available, a higher accuracy is required and a limited range is permissible, the Dipping or Immersion Refractometer may replace the Abbe instrument for examination of such substances as fall within its range.

It is specially suitable for the investigation of alcoholic and aqueous solutions, and the extensive percentage tables of aqueous solutions prepared by B. Wagner have been made available by careful design of the instrument.

The Dipping Refractometer is also available for substances which can only be obtained in small quantity or are highly coloured, by the use of an auxiliary prism which can be supplied if ordered.

This instrument works upon the same principle as is employed in the Abbe and Pulfrich Refractometers, namely, that of the critical angle. It is provided with a prism of hard crown glass, which projects from the metal part of the instrument, and is available for immersion in liquids in a similar manner to that of the bulb of a thermometer, and it is from this property that the name of the instrument is derived. Although there is much less colour on the critical edge of the field than is the case in instruments with prisms of more dispersive glass, a direct vision prism, accurately direct for the D lines, is included between the refractometer prism and the object-glass of the observing telescope, and rotation of the direct vision prism by means of a divided collar, conveniently placed upon the body of the instrument, allows of a sharp colourless field being obtained. The position of the edge is at once read off upon a scale placed in the eye-piece of the instrument, which, as stated above, has been designed to fit accurately in with Wagner's tables, and another divided collar is provided for setting to $\frac{1}{10}$th of a scale division.

The range of the instrument is from 1·325 to 1·365, and readings may be made with an average accuracy of ·000035.

In view of the large variation of refractive index with temperature of all liquids (even of those whose index falls within the above range), it is necessary to pay careful attention to temperature control in order that the refractometer readings may be significant. We are in a position to supply a water bath to contain 12 beakers, and provided with substantial mounting for the refractometer and an adjustable lamp.

M 45.—Dipping Refractometer in wooden case, including attachable beaker for investigation of volatile liquids.

ACCESSORIES FOR DIPPING REFRACTOMETER

M 53.—Auxiliary Prism.—This is a prism made of the same glass and angle as the refractometer prism itself and of such a size as to fit into the attachable beaker. The face which goes into contact with the refractometer prism is polished and has a depression with ground surface to take the drop of liquid under examination.

M 144.—Water Bath.—In view of the importance of temperature control, which is imperative in all measurements, special attention has been given to the design of the water bath. The stout circular copper bath is supported on three legs and provided with a central pillar which projects both above and below the bath. The part projecting above carries a substantial clamp for the refractometer, the clamp being hinged so that the refractometer will clear the top of the bath by merely tilting, thus allowing easily for cleaning of the prism and removal to another beaker. A stop screw allows of fine adjustment of the depth to which the refractometer is immersed in a beaker. The lower part of pillar carries (*a*) an adjustable mirror, (*b*) an electric lamp, so that either daylight or artificial light may be available in ample quantity to obtain accurate readings. The voltage for the electric lamp should be stated when ordering. A ground glass window is mounted in the base of the bath.

Inside the bath is a rotating frame to carry 12 beakers, which are of a standard commercial size. A spring stop is provided so that each beaker in turn may be brought to a definite position above the ground glass window. Provision is also made for efficient water circulation.

M 147.—Glass Beakers.—These are supplied by the dozen, and as stated above are of a standard commercial size.

M 178.—Thermometer divided in 1/5° C, and graduated from 15° C to 25° C, with red line at 17·5° C. This small thermometer is intended for insertion in the beaker under examination. With the most careful temperature control by water circulation it cannot be taken for granted that the temperature of the contents of a beaker is identical with that of the water of the bath. It is advised, therefore, that both this thermometer and also M 179 be ordered for use with a water bath.

M 179.—Thermometer divided in 1/10° C and graduated from 15° C to 25° C with protecting metal case and N.P.L. Certificate. This is an accurate standard thermometer for taking the temperature of the water bath and is protected against accident during such use. In view of the rapid variation of refractive index with temperature of most liquids an accurate knowledge of temperature is essential to give significance to readings with the Dipping Refractometer, and it is usually necessary to know the temperature to 1/10° C. The Thermometer previously described (M 178) should be used in conjunction with this one and periodically checked against it to ensure the identity of their indications.

PULFRICH REFRACTOMETER

This instrument is designed for the measurement of the refractive indices of both solids and liquids with an accuracy of about ·0001 ; and also the dispersion (*i.e.* the difference of refractive index for two spectral lines) to about ·00002.

A very efficient water jacket forms an integral part of the instrument, and not only allows of the temperature being effectively controlled, but also permits of measurements being made upon some substances in the liquid state which are not liquid at atmospheric temperature.

Description of the Apparatus.—A glass prism of high refractive index has two plane polished faces which are perpendicular to one another, and is so placed that one of these is vertical and the other horizontal. The substance whose refractive index is required is placed upon the horizontal surface, and in the case of a liquid is contained in a glass cell cemented to the prism so as to contain that face. A beam of monochromatic light is directed almost horizontally through the substance so that it meets the prism face at grazing incidence. The emergent beam is bounded sharply by that ray which actually grazes the prism surface, and the sharp boundary is observed with a telescope attached to a divided circle. On this circle, whose axis of rotation is horizontal, the angle of emergence of the beam from the vertical prism face can be read to one minute with the aid of a vernier. For making measurements of dispersion a clamp and micrometer screw are provided, the smallest division on the drum head of the micrometer screw corresponding to 6 seconds of arc. A condensing lens and supporting rod for vacuum tube form part of the apparatus.

A small reflecting prism is also provided so that another source of light, *e.g.* a sodium flame, is easily interchangeable with the vacuum tube.

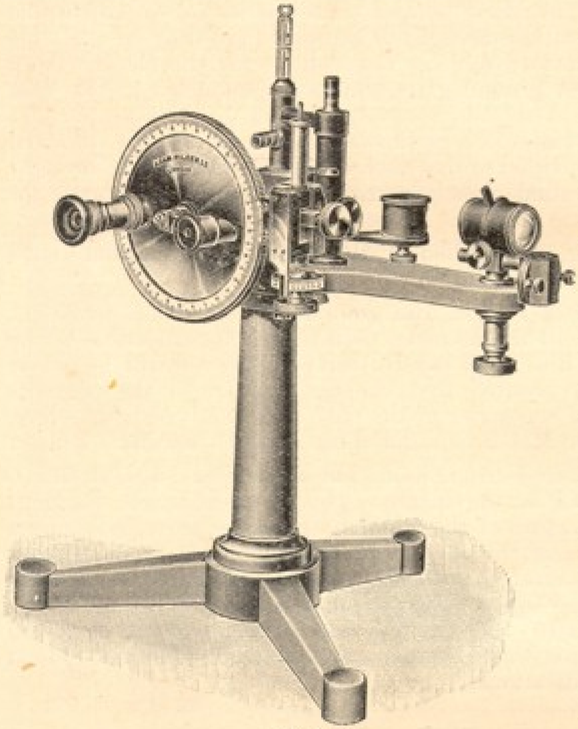


Fig. M 48

A special feature of the instrument is the increased effectiveness in the temperature control as compared with that to be found in previous designs. The hollow metal water jacket surrounding the prism is provided with a top cover which is itself of hollow metal. These two are connected in train with the thermometer jacket which dips into the cell for liquids. The prism and substance experimented upon are thus completely jacketed with the exception of the vertical prism face from which the light emerges, and a small rectangular aperture by which the light enters the prism. The temperature can thus be maintained very constant by pumping a stream of water at constant temperature through the system described.

We recommend a Lowry Thermostat for this purpose.

Tables giving corresponding values of μ and the angle i are supplied with every prism; and for the following lines of the spectrum —D_1, H_α or C, H_β or F, H_γ or G^1.

The thermometer provided is sufficiently sensitive to attain its final temperature in less than 30 seconds.

It is to be noticed that the refractive index to be measured must be less than that of the glass of the prism. For this reason two prisms are advised, one suitable for measurement on liquids, and the other for measurements on solids, such as samples of glass, etc. In the case of solids also the specimen to be investigated must have two perpendicular faces meeting in an unbroken line, while one of them (viz. that which comes in contact with the prism face) must be plane and fairly well polished.

Optical contact is made with the prism by means of a drop of some liquid of higher refractive index than that of the solid to be investigated (*e.g.* monobromonaphthalene).

M 48.—**Pulfrich Refractometer** with prism of refractive index D of 1·74 for substances of refractive indices for D. between 1·47 and 1·73, with mount and carrier and improved water jacketing attachments. Complete in case with lock and key ... ...

F 189.—Hydrogen End-on Vacuum Tube, Guild form (see p. F 9)

M 57.—Prism of refractive index for D. of 1·62, for liquids of refractive indices for D. between 1·33 and 1·61, with mount and carrier and with glass cell for liquids ... ...

M 58.—Thermometer ... ...

M 73.—60° Prism for Pulfrich Refractometer.—A prism of this angle was suggested by Mr. J. Guild of the National Physical Laboratory in place of the usual prism of 90° angle. With the smaller angle refractive index from that of air to that of the prism itself can be measured. It is thus possible to check the refractive index of the prism on the Pulfrich Refractometer without reference to any secondary standard such as quartz. Further, one prism only is required for the measurements on both solids and liquids. The corresponding decrease in length of scale does not materially affect the accuracy of the results obtained.

A full description of the instrument and its use, with notes and bibliography, post free 1s. 8d. *A copy of this is sent free with each instrument. For tables of refractive indices, etc.*, see p. F 18.

JAMIN REFRACTOMETER

(*Full description, abstracted from Jamin's original paper in the* Ann. de Chim. et de Phys., *3rd series,* tome lii. p. 163, 1858, *sent out with each instrument or post free on application.*)

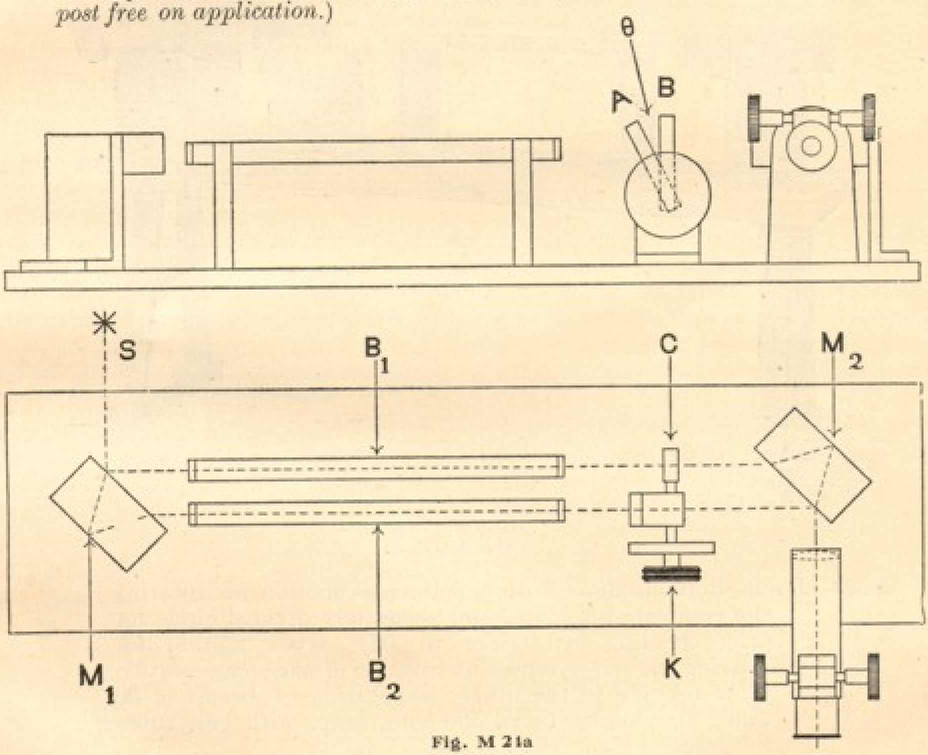


Fig. M 21a

The Jamin Refractometer, as supplied by us, is shown in Fig. M 24 and in diagram in Fig. M 24 A.

Light from any convenient source S is divided by the mirror M_1 (silvered on the back) into two beams; the first is reflected from the exterior face and passes along the tube B_1, the second is reflected from the interior silver face and passes along the tube B_2.

After traversing the two tubes (which contain respectively the gas under test and that with which it is to be compared), the two beams pass through the plates of the compensator C. Falling on the mirror M_2, which is identically the same as M_1, and parallel to it, the beams experience reflections inverse to those to which they were primarily subjected, with the result that they are superimposed under conditions suitable for interference.

M 24.—Jamin Refractometer (*see* Fig. M 24) giving a separation between the centres of the beams of 18 mm., and taking tubes 250 mm. long. The observation telescope has rack and pinion for focussing and cross-webs in the eyepiece. Two tubes for gases are provided. Means are provided for altering the angle between the compensator plates, and the rotation of the plates is read by vernier to 0·1°. All optical work is of the highest quality ... ...

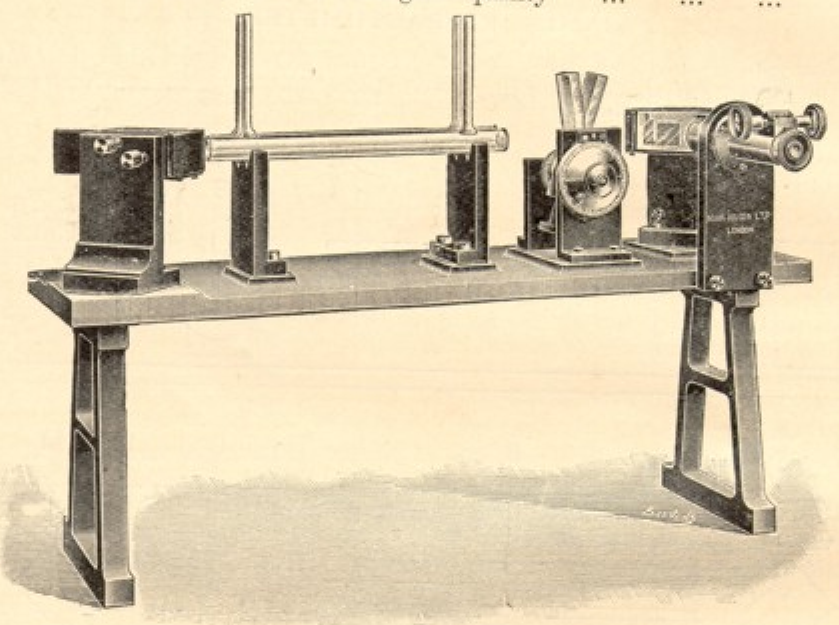


Fig. M 24

M 26.—Jamin Refractometer with worm-wheel motion for rotating the compensator plates and accurately divided circle for same, reading by vernier to ·02°; screw motion for altering the sensitiveness by rotation of one compensation plate relative to the other; separation of beams of 30 mm., and taking tubes 500 mm. long, with two tubes for gases ... ...

RAYLEIGH INTERFERENCE REFRACTOMETER

This instrument is designed for work on the refractometry of gases, of which the refractive indices differ so little from unity that a very high degree of sensitivity is required in any refractometer to be used with them. Some idea will be obtained as to the sensitivity of the instrument when it is stated that it is possible by means of it to detect the presence of ·01% of hydrogen in air, a quantity which causes a change of refractive index of only ·000,000,015.

The principle underlying the design of the instrument is that of the interference bands formed by two adjacent slits in collimated light, and observed by means of a telescope. The arrangement is, in fact, a diffraction grating with only two openings. The means whereby the system of bands thus obtained is made to indicate the refractive index of a substance is provided by the sideway shift of the whole band system when any change is made in the optical path of one of the interfering beams; part of the optical path being, of course, the substance under examination.

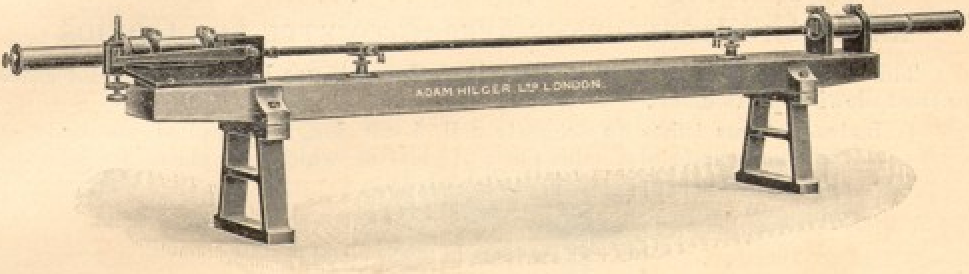


Fig. M 75

The relative refractivity of two gases can be measured with considerable accuracy by means of this instrument. Rayleigh * in measuring the refractivity of argon, using his early experimental model, which had only 12-inch tubes, and in which the sensitivity was limited by the accuracy of reading a mercury manometer with only 8 inch total pressure, succeeded in obtaining an accuracy of one part in a thousand.

With the present instrument, wherein the accuracy of reading exceeds that of setting, the error is probably less than one part in twenty thousand, corresponding to an error in refractive index of ·000,000,015. The instrument is consequently well adapted to determining the quantity of a known impurity in a gas of otherwise fixed composition.

Appended will be found a list of gases and the percentage which would be detectable (as an impurity in air) assuming an accuracy of setting of one-fortieth band. Even greater accuracy than this can be attained with a little experience.

In each case it is, of course, necessary to calibrate the instrument for the particular work for which it is required. Thus, if we are estimating hydrogen as an impurity in air, a shift of one-fortieth band corresponds to about ·01%. If, however, we are estimating the quantity of helium in argon, the same shift corresponds to only ·006%.

It may be found preferable for some work to read directly in difference of refractivity of the two tubes independently of what gases they may contain. This may be done by making a small correction to each reading r, of the form $r^1 = r - ar^2$ where a is a constant; r^1 is then directly proportional to the difference of refractivity of the gases in the two tubes.

M 75.—Rayleigh Interference Refractometer, including tubes, as illustrated (length of tubes = 1000 mm.)

Additions to convert the above into Liquid Refractometers, *see* p. M 22.
Sources of Illumination for these Refractometers, *see* p. M 22.

* *Proc. Roy. Soc.*, LIX., p. 201, January 1896.

Quantities of Gases in Air detectable by Rayleigh Refractometer.

Minimum observable shift assumed to be one-fortieth band.

Hydrogen	·01%	Water	·04%
Nitrogen	·3%	Hydrogen sulphide	·0045%
Nitric oxygen	·0065%	Chlorine	·003%
Argon	·15%	Carbon monoxide	·03%
Helium	·006%	Carbon dioxide	·0095%
Sulphur dioxide	·034%	Ammonia	·017%

Full description, with bibliography, post free on application.

RAYLEIGH INTERFERENCE REFRACTOMETER FOR LIQUIDS

This instrument differs from the Rayleigh Interference Refractometer for gases in the following particulars :—

1. Instead of gas tubes an accurate cell, 1 cm. long, is supplied, the body of which is made of a solid piece of glass on which end plates are adhesed by our patent process (No. 103233/1916).

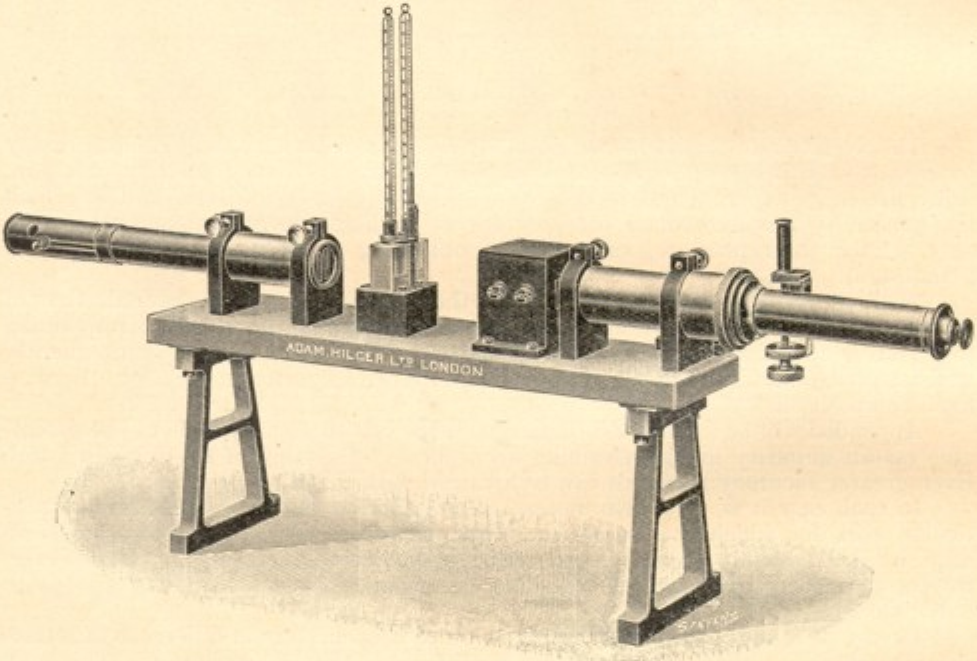


Fig. M 154

2. The instrument is much shorter, since the length for the gas tubes is not required. A suitable stand for the cell replaces the supports for the gas tubes.
3. The plates of glass in the movable beam, the thickness of which determines the range of the apparatus, is 4·7 mm. thick, instead of 1 mm., so that the instrument has a range of ·008 instead of ·000017.
4. Two thermometers (tested at the National Physical Laboratory) are supplied, with suitable holder.

M 154.—Rayleigh Interference Refractometer, with double one-piece liquid cell 1 cm. thick, having both the interior and exterior surfaces accurately parallel to 1/50,000 inch (1/2000 mm.) ... ...

M 161.—Extra liquid cell, 1 cm. thick ... ...

M 160—Additions to convert the gas refractometer into a liquid refractometer, including seat for the liquid cell, holder for thermometers, accurate liquid cell, two tested thermometers, and compensating plates suitable for liquids, readily interchanged with those for gases ... ...

Illuminating sources for the Rayleigh Interference Refractometer. Any sufficiently intense light source is satisfactory for these instruments. The following may be recommended :—

M 157.—Illuminating lamp, consisting of Pointolite lamp with resistance, lamp in case with raising and lowering motion, exactly as supplied with our Saccharimeters ... ...

(*State voltage of supply in ordering.*)

M 156.—Cheaper form of lamp, consisting of stand with ordinary metal filament lamp without shade ... ...

(*State voltage of supply in ordering.*)

APPARATUS FOR THE MEASUREMENT OF REFRACTIVE INDEX IN THE ULTRA-VIOLET

The apparatus consists of a horizontal slit (S 1) on which the rays of condensed spark between suitable electrodes are gathered by a quartz condenser. The pencil of rays is collimated by the concave mirror (M 1), and fall normally upon the quartz

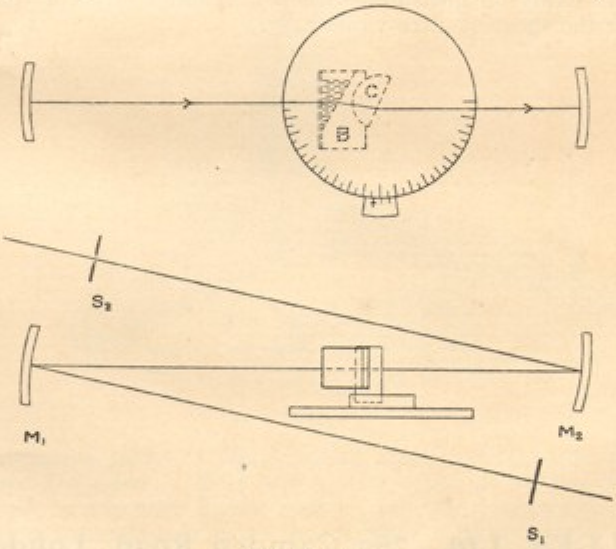


Fig. M 148

plate of the prism arrangement BC. This consists of a quartz prism (B), which, together with a quartz plate, forms a wedge cell into which is placed the liquid under examination. A hemi-cylindrical cavity (B) serves to receive a hemi-cylindrical block of quartz (C), which is capable of rotation, this rotation being measured on a divided circle.

If the zero of the instrument is in the position where the plane face of C is parallel to the quartz plate (which, with the block (B), forms the liquid cell), and if A be the angle of its rotation required to bring rays of wavelength λ_1 deviated by the liquid prism to a direction once more parallel to the incident direction, then the other rays are deviated either upwards or downwards. A small spectrum is thus obtained, of which an image is formed on the slit (S 2) of a quartz spectrograph such as the Hilger size E 2 (formerly known as size C), or size E 31 (formerly known as size A).

When, therefore, a spectrogram is taken, a slanting spectrum results, which intersects the standard spectrum, which is first taken with the liquid prism not in position.

The two spectra cross at a point, for which it is true that the total deviation caused by liquid and quartz is zero. The refractive index (μ) of the liquid for this wavelength is calculated from the formula—

$$\mu \sin \theta = \sin (\theta - i) \sqrt{\mu_o^2 - \sin^2 i} + \cos (\theta - i) \sin i.$$

where μ_o is the refractive index of quartz for the wavelength in question,

θ is the angle of the wedge cell (about 30°),

and i is the angle of emergence from the hemi-cylinder, or, what is the same thing, the angle of rotation of the circle.

Fifteen to twenty different spectra are taken on the same plate for different values of the angle, and one only has to measure the wavelengths for which there is an intersection of spectra.

This very rapid method gives a most satisfactory precision ; the errors only reach three to four units of the fourth decimal place, and the value of the point of intersection λ can easily be measured with a maximum error of ten A for $\lambda > 3000$ and of five A for the shortest ultra-violet rays.

ADAM HILGER, Ltd., 75a Camden Road, London, N.W. 1

Entrance :—24 Rochester Place (adjoining)

Telegraphic Address—" Sphericity, Phone, London."
Telephone—North—1677/8.
Cable Code—Western Union.
Cable Address—" Sphericity, London."

October 1924

SECTION N

MICHELSON, FABRY & PEROT, AND HILGER INTERFEROMETERS

See also for Fabry & Perot Etalons—pp. O 2–3, *Fabry & Perot Etalon ; pp.* O 5–6, *Mount for taking the above in front of any ordinary Spectroscope.*

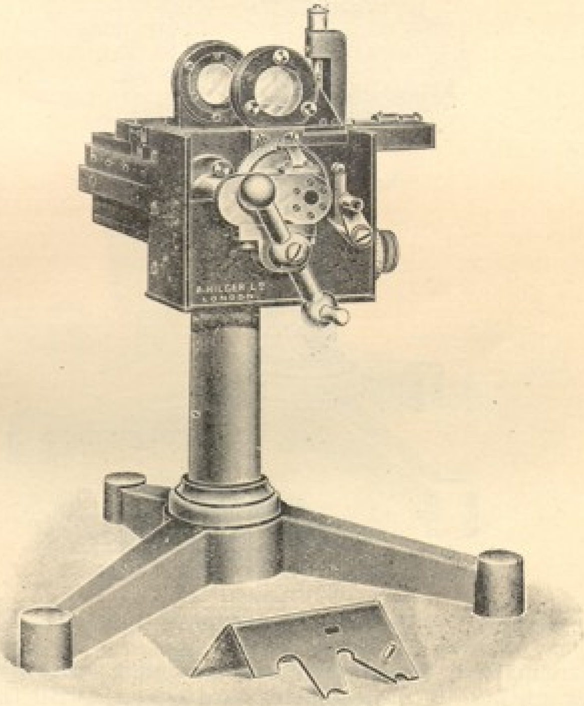


Fig. N 1

The transmission plates in the following interferometers are silvered by cathodic deposition from fine silver. With silver films deposited in this manner the loss of light is less than by any other known method, and the necessary condition for sharply defined and bright intensity maxima is thus fulfilled. In the case of the Fabry & Perot Interferometers the plates are made slightly wedge-shaped in the usual manner to avoid the secondary interference systems caused by reflection at the unsilvered outer surfaces.

Our latest models of **Michelson** and **Fabry & Perot Interferometers**—those, namely, sent out during or after August 1912—are in every case so arranged that either the Fabry & Perot or the Michelson system of mirrors can be supplied at any subsequent time and attached without any alteration of the apparatus.

Three sizes are made, having respectively 75 mm., 120 mm., and 200 mm. travel of the movable mirror. The 200 mm. size is supported on a tripod of special form (*see* Fig. N 8). Otherwise, except as regards the lengths of the slides and of the micrometer screws, all three sizes are of identically the same construction, both as to accuracy of workmanship and dimensions. Thus a set of mirrors suitable for any one size is also suitable for any other.

The micrometer screws have 1 mm. pitch. The divided head attached to the screw has 100 divisions, and one turn of the slow motion screw, whose head is also divided into 100 parts, corresponds to one division on the main drumhead. Thus one division on the drumhead of the slow motion screw corresponds to $\frac{1}{10.000}$ mm. (one ten thousandth of a millimetre).

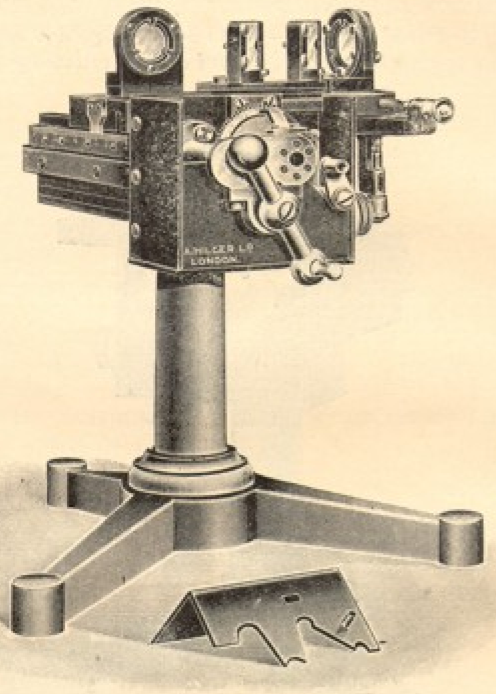


Fig. N 4

The slides are massive, and of steel,* and the sliding surfaces are worked *optically flat*. The slides are heavily protected by hard enamel, with the exception of the actual sliding surfaces. Only these sliding surfaces, therefore, require care to avoid rust. A bottle of suitable oil is provided, which it is well to use freely on the slides, and occasionally on the screw. The most recent construction of the slides is the result of many experiments, and is such that we are able to make them flat to a high optical precision, thus securing the desired accuracy in maintaining the parallelism of the movable mirror in its progress from one end of the slide to the other.

* The slides are made from forgings of specially selected steel, the preparation and treatment of which to avoid subsequent deformations are carried out for us by Sir W. G. Armstrong, Whitworth & Co., whose experience in the construction of standard screw gauges has enabled them to supply us with a material excellently well adapted for the purpose in view.

The slow motion mechanism has a carefully made cover, which can be readily removed, if desired, for inspection.

The micrometer screws are cut between dead centres and ground at constant temperature, and are made throughout with the very greatest care. Their position is determined longitudinally by a plate of polished quartz at the end towards the observer, which end takes the thrust when the mirror is moving in the direction of increasing optical path. A system of opposing screws enables this plate to be set up perpendicular to the axis of rotation of the micrometer screw, whose end is polished to an approximately flat surface. Thus by reflecting light in the direction of the axis of the screw through the thickness of the quartz block (which is polished on both surfaces to enable the end of the screw to be thus observed), one can observe the interference fringes produced between the light reflected from the thrust-taking surface of the quartz and the polished end of the micrometer screw. Observation in this manner enables the adjustment of the plate of quartz perpendicular to the

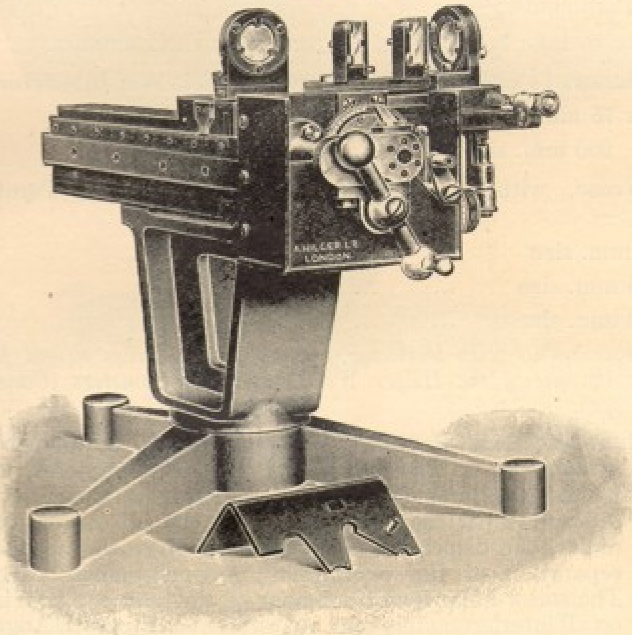


Fig. N 8

axis of rotation of the screw to be made with great and ascertainable precision. The other end of the micrometer screw thrusts against the polished end of a fixed screw, by means of which one is enabled to reduce the longitudinal play of the micrometer screw to a minimum, without introducing any longitudinal compression. The carriage can be removed by lifting it off its slide, and can be as easily replaced. The two thrust blocks under the carriage, which engage with the nut of the micrometer screw, are so adjusted as to allow a small amount of lost time. A convenient spring adjustment is provided for one mirror, which, while enabling the delicate final adjustment for parallelism to be made with great precision, is nevertheless so substantial as to introduce no trouble from vibration.

Fabry & Perot Interferometer, latest design as described above :—

N 1.—With 75 mm. motion of the carriage (Fig. N 1) ... ...

N 2.—With 120 mm. motion of the carriage ... ...

N 3.— „ 200 mm. „ „ ... ...

N 4.—Set of Michelson mirrors, with mounts and spring adjustments complete, as shown in Fig. N 4, suitable for immediate attachment to any of the above instruments :—

N 5.—Case to take both sets of mirrors, with their mounts.

Michelson Interferometer :—

N 6.—With 75 mm. motion of the carriage ... ...

N 7.— „ 120 mm. „ „ ... ...

N 8.— „ 200 mm. „ „ ... ...

N 9.—Set of Fabry & Perot mirrors suitable for immediate attachment to any of the above instruments :—

N 10.—Case to take both sets of mirrors, with their mounts.

Levelling Screws to either Fabry & Perot or Michelson Interferometers :—

N 11.—For 75 mm. or 120 mm. sizes ... ...

N 12.— „ 200 mm. size ... ...

Well-made case, with lock and key, for either Fabry & Perot or Michelson Interferometer :—

N 13.—75 mm. size ... ...

N 14.—120 mm. size ... ...

N 15.—200 mm. size ... ...

The instruments with levelling screws are of suitable height for use in front of the slit of the Hilger Wavelength Spectrometers (Constant Deviation Type).

N 16.—**Achromatic Lens** 6″ (150 mm.) focal length, in mount for attachment to the Fabry & Perot Interferometer, with focussing adjustment. This lens enables an image of the diffraction pattern to be thrown on the slit of a spectrometer, the dispersion of which then gives the necessary separation of the overlapping monochromatic fringes. The screw-holes for attachment of this lens are provided on all interferometers sent out subsequent to 30th August, 1912 ... ...

FABRY-PEROT INTERFEROMETER AND ETALON

for the illustration of

FRINGES OF SUPER-POSITION WITH WHITE LIGHT

(See "*Méthode Interférentielles pour la mésure des grandes Epaisseurs, et la Comparaison des Longueurs d'Onde*," par Messrs. A. Perot et Ch. Fabry, *Ann. Chim. et Phys.*, 7, XVI., March 1899, Ch. III. § iii.)

When a beam of white light traverses successively two plates of air, each with silvered faces, one can obtain a system of fringes whenever the differences of path occasioned by each of the plates bear to each other a simple relation. If, then, a Fabry-Perot etalon be placed in series with a Fabry-Perot interferometer (the air plate in the etalon having a constant thickness and that in the interferometer a variable thickness) a system of white light bands is seen every time that the distance between the silvered surfaces of the interferometer mirrors is either a multiple or a sub-multiple of the distance between the plates of the etalon.

The apparatus is shown in the illustration, where the etalon is mounted on the Fabry-Perot Interferometer of our standard form, as described on pp. N 1–3. Full means are provided for all the adjustments which are necessary to secure the bands.

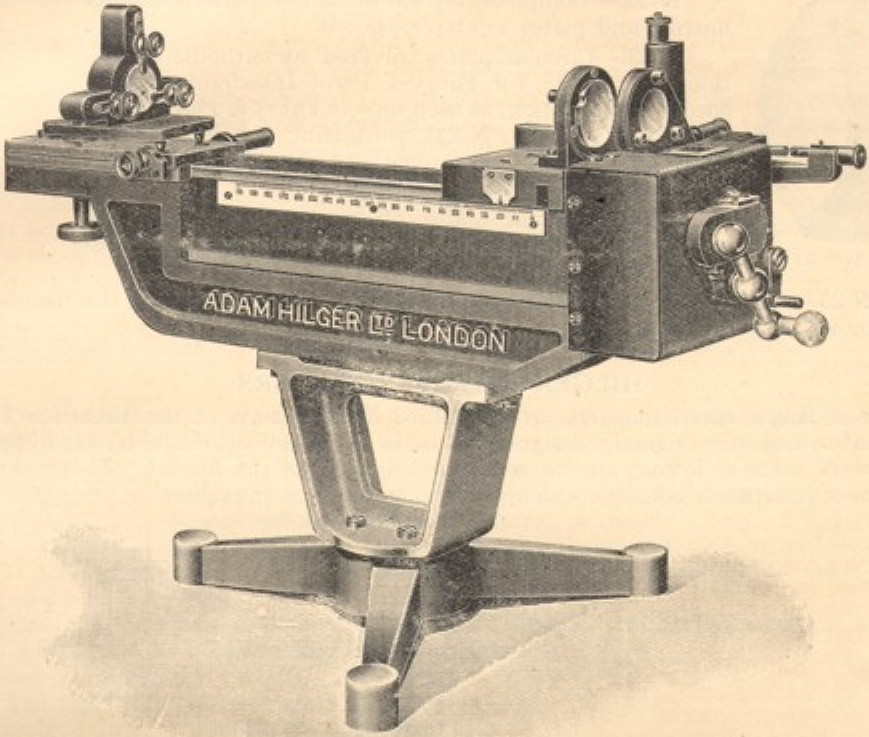


Fig. N 34

N 32.—Fabry-Perot Interferometer, 75 mm. (as N 1), with Etalon (O 6) complete on base ... ...

N 33.—Fabry-Perot Interferometer, 120 mm. (as N 2) with Etalon (O 6) complete on base ... ...

N 34.—Fabry-Perot Interferometer, 200 mm. (as N 3), with Etalon (O 6) complete on base ... ...

Special Mercury Green Line Filters cemented in optically-worked glass :—

N 17.—Transmitting only ½ per cent. of the yellow lines and 72 per cent. of λ 5461 ; 2″ (51 mm.) square—

N 18.—Transmitting 0·0025 per cent of the yellow lines and 50 per cent. of λ 5461, 2″ (51 mm.) square—

N 19.—Filters (N 18) above can also be supplied 16 mm. clear aperture, mounted in brass tube, 30 mm. long—

(These screens are made for us by Messrs. Kodak, Ltd., from glass prepared by ourselves.)

Plates for Interferometers :—

N 20.—Circular mirrors for Michelson Interferometers, 25 mm. dia., each ... ...

N 21.—Transmission and compensation plates for Michelson Interferometers, 40 mm. long × 25 mm. high, each ... ...

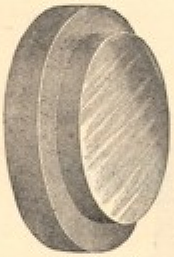


Fig. N 23

N 22.—Complete set of Michelson Interferometer mirrors and plates as above, the set ... ...

N 23.—Circular plates, silvered by cathodic deposition (*see* p. N 1), for Fabry & Perot Interferometers, of special construction, as used on our Fabry & Perot Interferometers (*see* Fig. N 23), permitting the interior surfaces to be brought close together. The diameter of the silvered surfaces is 25 mm., per pair ... ...

N 24.—Circular plates, of quartz, the plates being coated with platinum by cathodic deposition, for ultraviolet work, per pair ... ...

N 25.—**Small Observation Telescope**, with cross webs for viewing the fringes, on raising and lowering stand.

HILGER INTERFEROMETERS

The Hilger Interferometers are specialised developments of the Michelson Interferometer, and were originally designed for use in the manufacture and testing of optical glasswork. The following are the forms already put on the market. They are fully described in separate booklets, which will be sent post free on request.

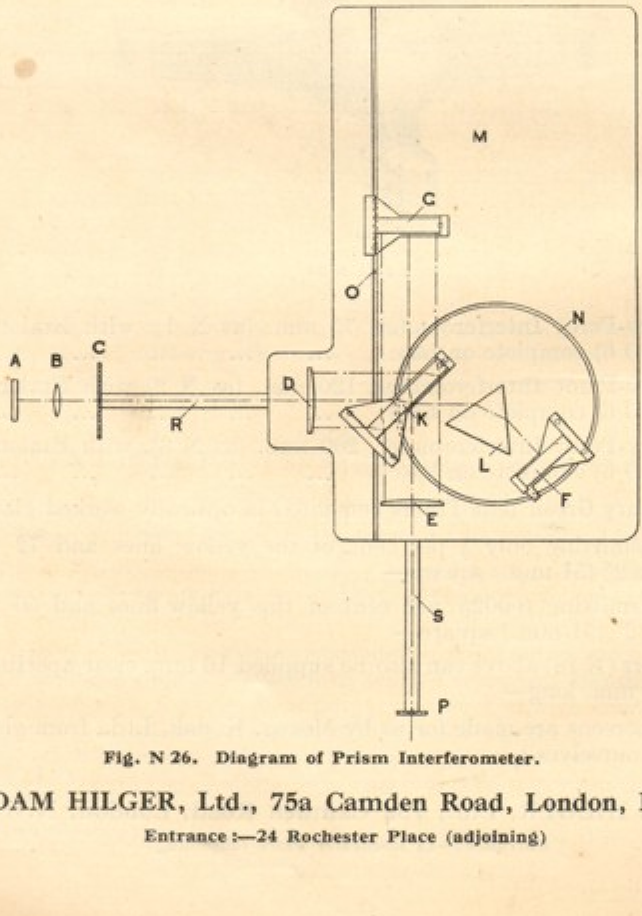


Fig. N 26. Diagram of Prism Interferometer.

		Patent Nos.
N 26.—The Hilger Prism Interferometer, No. 1	-	103,832/16, and corresponding foreign patents.
N 27.—The Hilger Lens Interferometer, No. 1	-	103,832/16, ,,
N 48.—The Hilger Prism Interferometer, No. 2	-	103,832/16, ,,
N 30.—The Hilger Camera Lens Interferometer	-	130,224/18 ,,
N 47.—The Hilger Microscope Objective Interferometer		103,832/16, ,, and patent applied for.

These instruments are supplied to manufacturers of glasswork under licence. For State standardising, testing, and other institutions, brief forms of licence are issued appropriate to the use of the apparatus otherwise than in connection with the manufacture of optical work for sale. This brief form of licence is engraved on the instrument (see p. N 10).

The lens interferometers will only be briefly mentioned in this section, but the No. 1 Prism Interferometer has proved to have so many applications in a physical laboratory that a short description and a statement of some of its uses will not be out of place here.

N 26.—THE HILGER PRISM INTERFEROMETER, No. 1
See Reference 3

This instrument in its simplest form is a development of the well-known Michelson interferometer, the main essential optical differences being that the light is collimated and the two interfering beams of light are brought to a focus at the eye of the observer.

Within its limits of size (a clear aperture of 2¾ inches—70 mm.) it permits the examination of all those optical systems which are required to receive a beam of light which has a plane wave front and deliver it again after transmission with a plane wave front.

It is shown in diagram (Fig. N 26) as arranged for the correction of a 60° prism, such as is used for spectroscopy.

The light used must consist of a limited number of very homogeneous radiations. Such a light may be obtained from a Cooper-Hewitt Mercury Vapour Lamp.

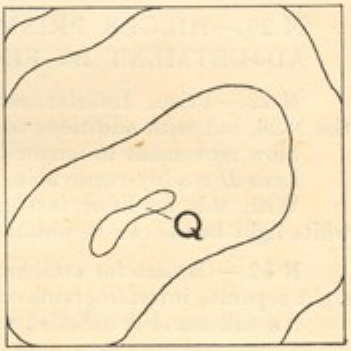


Fig. N 26a

The light from the source is reflected by the adjustable mirror *A* through the condensing lens *B*, by means of which it is condensed on the aperture of the diaphragm *C*.

The diverging beam of light is collimated by a lens *D*, and falls as a parallel beam on a plane parallel plate *K*, the second surface of which is silvered lightly so that a part of the light is transmitted and part reflected. The major part should be reflected. One part passes through the prism *L* in the same way as in actual use, and being reflected by the mirror *F* passes back through the prism to the plate *K*. The other part of the light is reflected to the mirror *G* and back again to the plate *K*. Here the separated beams recombine, and passing through the lens *E* they form on the eye placed somewhat beyond the aperture in the diaphragm *P* an image of the hole in the diaphragm *C*.

When the mirrors are adjusted as described in the booklet, interference bands are seen which form a contour map of the aberrations of wave front caused by the prism or other optical system under test.

Fig. N 26A represents in diagram a typical map, where *Q* represents the highest point of a "hill."

Applications to Physical Investigations

The use of the instrument is by no means restricted to the testing of optical systems. The following are a few among many of the applications to Physical Research which have already been made.

Measurements of small differences of refractive index.*

Observations of diffusion of liquids (the liquids, in a cell with optical glass sides, are placed under observation between mirrors *K* and *F*, Fig. N 26).

Observation of the air-heating effect in hot-wire microphones (the hot wire is placed longitudinally between mirrors *K* and *F*, and the instrument illuminated intermittently with a period equal to that of the note to which the wire is responding. For this, and for instantaneous photography of all such rapidly fluctuating effects, the white light bands are used ; see below, symbol N 45.)

Observation of the time required for thermal equilibrium to be established between, say, a thermometer bulb and the liquid in which it is immersed.

Measurements of the movements of microphone diaphragms.

ACCESSORIES

N 45.—Compensating Plate for use where the white light fringes are required.

This consists of a plate identical with *K* in Fig. N 26 (but not silvered), suitably mounted between *K* and *F*, so that the optical paths of the two beams of light in the interferometer can be made the same for all wavelengths.

N 27.—Additions to convert into the Hilger Lens Interferometer, No. 1. Additions (N 27) can be supplied to the Prism Interferometer whereby lenses can be tested for axial pencils (for details see booklet, *The Hilger Interferometer, No.* 1, *for the Correction of Prisms and Lenses*).

N 29.—HILGER PRISM INTERFEROMETER No. 1, WITH SLOW ADJUSTMENT BY FINE SCREW MOTION TO THE MIRROR G

N 29.—Prism Interferometer, answering generally to the same specification as the N 26, but with additions to facilitate the obtaining of the white light bands, viz. :

Slow movement to mirror *G* at will.

Lens *D* readily removable, and Lens *E* readily interchangeable with a second lens.

With this modified instrument, and the diagonal compensating plate N 45, the white light bands can be obtained in a few minutes.

N 52.—Camera for attaching to prism interferometers, N 26, N 26/27 or N 29 taking eight separate interferograms on one plate.

An oak stand is included with both the N 26 and N 29.

* " *Variation in Refractive Index near the Surfaces of Glass Melts,*" F. Twyman and A. J. Dalladay, *Trans. of Optical Society*, Vol. XXIII., 1921-22, No. 2, p. 131.

" *The determination of Poisson's ratio and of the absolute stress variation of refractive index,*" F. Twyman and J. Perry, *Proc. Phys. Soc.* XXXIV., 151, 1922.

N 48.—THE HILGER PRISM INTERFEROMETER No. 2

This instrument is in principle the same as the Hilger Prism Interferometer No. 1, but is smaller, having a working aperture of $1\frac{1}{8}''$ inch (28 mm.).

Full adjustments are provided, and the instrument is suitable, within range of its aperture, for the same kind of work as the No. 1 model; but additions to convert into a lens interferometer are not supplied.

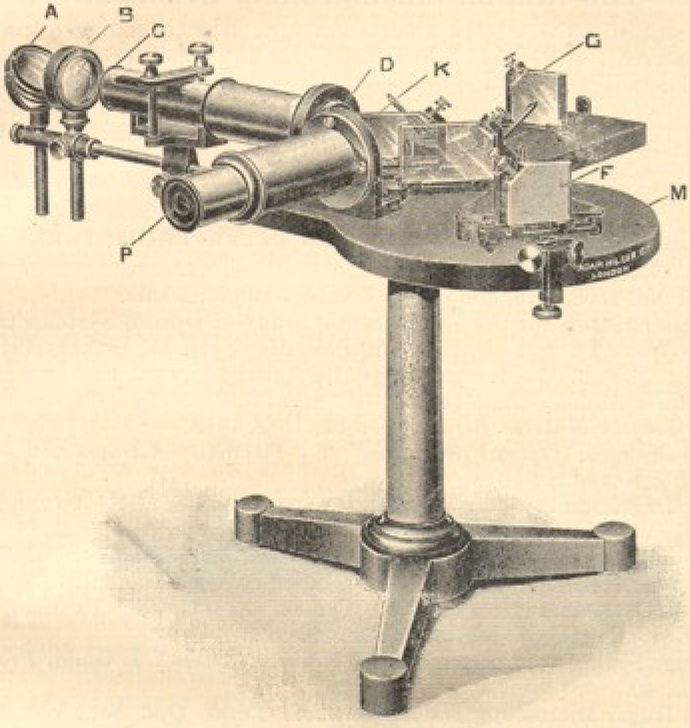


Fig. N 48

N 48.—Hilger Prism Interferometer No. 2.

F 7, F 8, F 13.—Mirror, condensing lens, and rod with clamp for attaching them to the collimator.

N 53.—Fine screw adjustment to mirror *G*.

N 50 and 54.—Compensating Plate for use where the white light fringes are required, in mount, and additional objective for the telescope to facilitate finding the white light bands.

N 58.—Set of 12 defective achromatic objectives, and attachments for interferometric examination of the same.

N 47.—THE HILGER MICROSCOPE OBJECTIVE INTERFEROMETER

By means of this instrument the aberrations of axial beams (including chromatic aberration) can be measured quantitatively. The instrument can also (with the addition of a camera) be used as a micrograph for use with ultra-violet microscope objectives. The exceptional accuracy with which the position of the objective relative to the mechanical stage can be measurably controlled makes the instrument unique in its suitability for this purpose. Illuminating systems for the ultra-violet can also be supplied in this connection.

N 30.—THE HILGER CAMERA LENS INTERFEROMETER

With this instrument all the aberrations of a lens (including distortion) can be accurately measured, as well as its focal length for any zone, for either axial or oblique pencils. Full details will be found in the booklet, *The Hilger Interferometer for Measuring the Aberrations of Camera Lenses*. The instrument was also described in the paper reference 6. The standard model takes lenses from 4″ (101 mm.) up to 27″ (686 mm.) focal length.

The wave surface aberrations can be photographed.

BIBLIOGRAPHY OF HILGER INTERFEROMETERS

1. Patent No. 103832/16, and corresponding foreign patents.

2. Patent No. 130224/18, and corresponding foreign patents.

3. "Interferometers for the Experimental Study of Optical Systems from the point of view of the Wave Theory," F. Twyman, *Phil. Mag.*, vol. 35, January 1918, p. 49.

4. "On the Use of the Interferometer for Testing Optical Systems," F. Twyman. The Twenty-First Annual Traill-Taylor Memorial Lecture. Delivered before The Royal Photographic Society of Great Britain, October 15th, 1918.

5. "Correction of Optical Surfaces," F. Twyman, *Astrophysical Journal*, Vol. XLVIII., No. 4, November 1918.

6. "An Interferometer for Testing Camera Lenses," F. Twyman, *Trans. of Optical Society*, Vol. XXII., No. 4, 1920-21.

7. "The Testing of Microscope Objectives and Microscopes by Interferometry," F. Twyman, *Trans. Faraday Soc.*, Vol. XVI., Part I., September 1920.

8. "An Interferometer for Testing Camera Lenses," F. Twyman, *Phil. Mag.*, Vol. XLII., November, 1921 (reprint of reference 6).

9. "Fringe Systems in Uncompensated Interferometers," J. Guild, *Proc. Phys. Soc.*, Vol. XXXIII., 40.

10. "The Hilger Microscope Interferometer," *Trans. Opt. Soc.*, Vol. XXIV., No. 4, 1922-23.

11. "The Hilger Microscope Interferometer," *Jnl. of Opt. Soc. of America*, Vol. VII., No. 8, August, 1923.

Hilger Interferometers supplied to State standardising, testing, and other institutions are engraved with the following brief form of licence :

> "This apparatus is licensed by Adam Hilger Ltd. to ....
> for use by any of its Departments, but not for use by any other Corporation or person without the written consent of Adam Hilger Ltd."

N 46.—INTERFEROSCOPE

Apparatus of this kind has been used in the workshops of Adam Hilger, Ltd., since 1909. It is primarily designed for assistance in the manufacture of plane and plane parallel glass.

Plane parallel glass is placed upon the velvet-covered shelf of the instrument, and is seen by looking through an aperture in the side about 24 inches above this shelf. When monochromatic light is projected through the instrument, a number of bands of the same colour as that of the light source are seen superimposed upon the object. There is a simple relation between the angle that one surface makes with the other which is dependent upon the wavelength of the monochromatic light employed, the refractive index of the part under test, and the number of bands seen per inch; and tables embodying this relation are issued with the instrument.

The best source of illumination is the well-known Cooper-Hewitt Mercury Vapour Lamp, which can be used for lighting the laboratory or workshop at the same time. The bands seen are so bright that it is not necessary to prevent extraneous light from entering the instrument. It is possible to estimate with a reasonable accuracy the want of parallelism to about 1/10 of a second.

When one or both surfaces are not flat, the light-giving bands follow the lines of equal thickness, forming contour lines which can, if desired, be traced upon the surface of the glass under examination.

It is possible in this way to test the degree of parallelism of the surfaces of transparent plates at a glance, with more ease and rapidity, and with much greater accuracy than by micrometer measurements. The accuracy attainable is about one-millionth of an inch.

The apparatus can also be used for measuring minute differences in the thicknesses of opaque parts, such as steel thickness gauges, plug gauges, outside diameters of screw gauges, balls for bearings, etc., by placing three of the parts between two glass surface plates, and the whole on the shelf of the instrument, when by counting the number of bands seen the difference in thickness can be measured.

Glass surface plates are not supplied with the instrument, but we shall be pleased to quote for any size of plate required. We also recommend our special Mercury Green Line Filters (Catalogue No. N 19) for use with this instrument.

We shall be pleased to advise as to the applicability of this instrument to the measuring of small differences of thickness in any cases placed before us.

Fig. N 46

As working limits become smaller, the methods of testing must become more accurate, and this instrument can be recommended with the confidence derived from its use in our own workshops for more than twelve years.

N 31.—THE HILGER INTERFERENCE GAUGE-TESTING OUTFIT FOR ENGINEERS

This appliance shows with certainty differences of 0·000,01 inch, and with care differences of 0·000,001 inch can be estimated. An illustrated descriptive booklet will be sent post free on request.

SPECIAL APPARATUS

We are prepared to design and supply any form of Interferometric apparatus, including apparatus for the determination of standards of length in wavelengths of light.

INTERFERENCE ACCESSORY FOR TESTING MICROSCOPE STANDS AND FINE ADJUSTMENTS (N 49)

This apparatus was first designed for use in the Dept. of Applied Optics, National Institute for Medical Research, Hampstead, London, N.W.3.

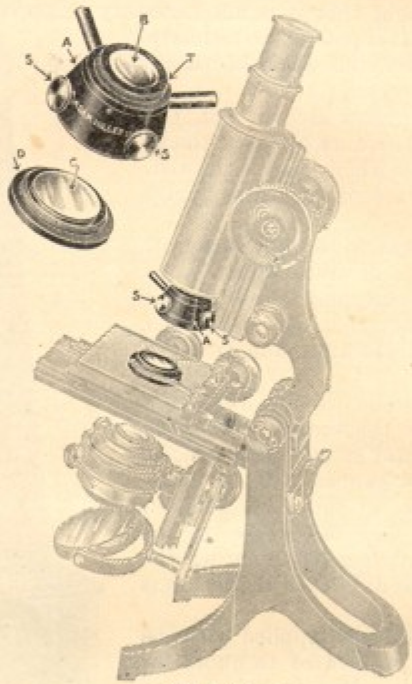


Fig. N 49

Not only does this apparatus enable microscope stands to be tested for rigidity, and slow movements for accuracy, but it forms a very simple means of demonstrating the principle of interferometry to students of physics, since practically every laboratory possesses a microscope.

Full description post free on application.

ADAM HILGER, Ltd., 75a Camden Road, London, N.W.1.

Entrance :—24 Rochester Place (adjoining)

Telegraphic Address—" Sphericity, Phone, London."
Telephone—North—1677/8.
Cable Code—Western Union.
Cable Address—" Sphericity, London."

October 1924

SECTION O

SPECTROSCOPIC APPARATUS FOR HIGH RESOLVING POWER

(See *also Section B for larger Echelons, and Lummer-Gehrcke Parallel Plates, and Section N for Interferometers.*

The instruments described on this and the six following pages are :

O 2.—A Michelson Echelon Diffraction Grating,

O 3.—A Lummer-Gehrcke Parallel Plate,

O 6.—A Fabry & Perot Etalon,

together with apparatus specially designed for use with the above.

Although designed primarily for demonstration work, they are all optically as perfect as our larger apparatus of the same kinds (for which see the lists cited above). They are of a size and design suitable for use on most ordinary Spectroscopes, but are especially useful in conjunction with the modified form of Hilger Wavelength

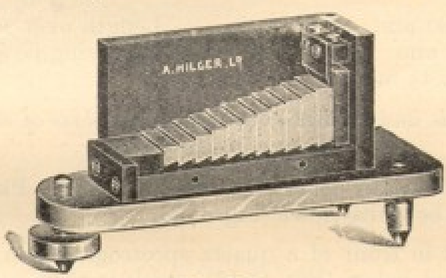


Fig. O 2

Spectrometer (Constant Deviation Type) described below. Thus applied, the Fabry & Perot Etalon affords a means of determining wavelengths to a very high accuracy; while either the Echelon or the Lummer-Gehrcke Plate will demonstrate the Zeeman effect, the effect of pressure on the lines of the spectrum, or the minute structure of any desired lines with a minimum of trouble and with the great intensity of light which distinguishes these powerful devices for high resolving power. At the same time the approximate wavelengths of the lines under observation can be read off direct from the drum of the Wavelength Spectroscope (*see* descriptive leaflet of the Hilger Wavelength Spectrometer, Constant Deviation Type).

The mode of application to the Wavelength Spectrometer has the further great advantage that a large number of lines of the spectrum can be examined at one and the same time, all the lines which are visible in the eyepiece being simultaneously subjected to the analysis of the Echelon, or of the Lummer Plate, or of the Fabry & Perot Etalon, as the case may be.

O 2.—Echelon (*see* Fig. O 2) of highest quality, in mount complete. Suitable for use on any ordinary Spectroscope (in which case an auxiliary analysis of the light is necessary) or on the modified form of wavelength spectrometer described below, in which case the combined apparatus is complete in itself.

Number of plates, 12.	Effective aperture, 29 mm. × 13 mm.
Thickness of plates, 10 mm.	Resolving power, 100,000, for W.L. 5461.
Width of step, 1 mm.	

The accurate thickness of the plates and the optical properties of the glass are in every case engraved on the mount.

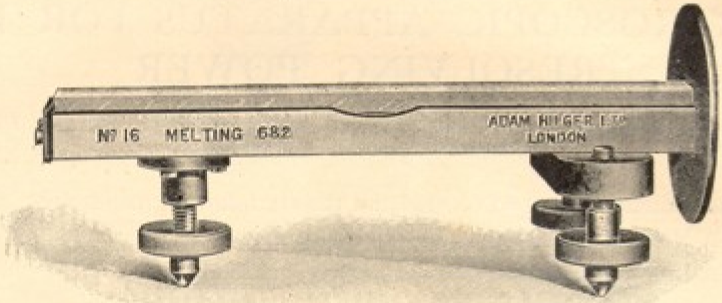


Fig. O 3

O 3.—Lummer-Gehrcke Plate (*see* Fig. O 3), in mount complete. Like the Echelon above, this can be used on any ordinary Spectroscope, or preferably on the modified form of Spectrometer described below.

Length of plate, 130 mm.	Length over all of mount, 135 mm.
Width of plate, 15 mm.	Resolving power, about 200,000.
Thickness of plate, 4½ mm.	

The thickness of the plate and optical properties of the glass of which it is made are engraved on the mount.

O 4.—We can also supply Lummer-Gehrcke Parallel Plates, of the same size, in quartz, for work in the ultra-violet (Fig. O 3).

These can be used in front of a quartz spectrograph on the mount described below (Fig. O 12) which is then supplied with a quartz-fluorspar double (O 5), or a quartz-rocksalt triple (O 18) achromatic lens at an extra charge ... ...

As quartz-fluorspar makes a better achromatic combination than quartz-rocksalt, the former will always be supplied whenever fluorspar of suitable quality is obtainable.

(For the theory of the Lummer-Gehrcke parallel plate, *see Annalen der Physik*, Band 10, 1903, p. 457.)

O 6.—Fabry & Perot Etalon (*see* Fig. O 6). The Etalon is constructed with a distance piece consisting of a hollow cylinder of fused silica between the plates (as described by H. C. Rentschler, *Astrophysical Journal*, December 1908).

The co-efficient of expansion of fused silica being less than that of any other known material (0·000,000,59 per 1C°.—about one-seventeenth part of that of platinum) temperature alterations can be entirely avoided quite easily.

The plates are silvered by cathodic deposition from fine silver. With silver films deposited in this manner the loss of light is less than by any other known method, and the necessary condition for sharply defined and bright intensity maxima is thus fulfilled. The plates are made slightly wedge-shaped in the usual manner to avoid the secondary interference systems caused by reflection at the unsilvered outer surfaces; but the angles of the wedges are the same in each plate, and they are so mounted that the total deviation caused by the Etalon is zero.

The appearance seen in the eyepiece when the Etalon is in position and correctly adjusted is as follows :—

(*a*) The lines of the spectrum are visible in the same positions as they would occupy were the Etalon removed; but of course far less bright.

(*b*) Each spectrum line is a diametrical strip of the ring system which would be produced by the Etalon if the field of view were filled with light of the wavelength of the line in question. The diameter of the ring system for each line can then be measured with a micrometer eyepiece.

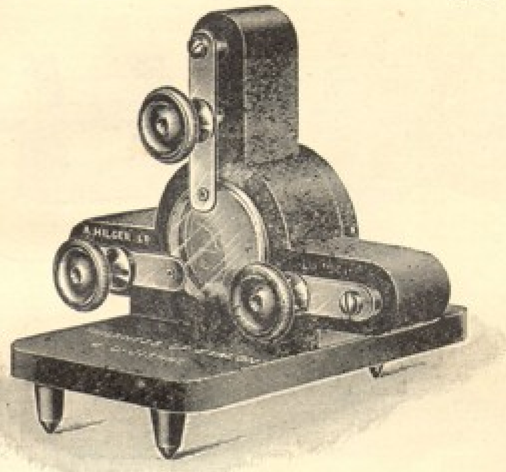


Fig. O 6

The distance between the plates is about 10 mm., this distance producing a convenient ring system for measurement.

The thickness of the Etalon correct to 0·005 mm. is in each case engraved on the mount.

Length over all of Etalon and mount, 105 mm.

O 7.—**Fabry & Perot Etalon** with plates of quartz, platinized by cathodic discharge, for ultra-violet work.

For the method of working to obtain standard wavelengths by comparison with lines of accurately known wavelengths, see papers by Lord Rayleigh, Phil. Mag. (6), *May* 1906, *p.* 685; *and* (15) *April* 1908, *p.* 548.

NOTE.—*The height to the centre of the aperture in each of the above accessories is 35 mm.*

THE HILGER WAVELENGTH SPECTROMETER (CONSTANT DEVIATION TYPE) MODIFIED FOR USE WITH THE ABOVE ACCESSORIES

(*See also separate leaflet describing the normal form.*)

The modifications are as follows :—

(1) The arm carrying the collimator is extended to make room for any one of the above accessories to be placed in position between the collimator and prism. A protective cover for the prism table is also supplied.

(2) The accessories stand on a brass plate capable of slight rotation by means of a milled head screw. This, together with a readily accessible levelling screw, provides the necessary adjustment for each of the accessories.

(3) The aperture of the slit of the collimator is longer than that of the slit generally supplied with the Wavelength Spectrometer, this being desirable for use with the Etalon. A second slit is attached to the main slit, the jaws running at right angles to it. This second slit can be rotated into or out of position as desired, and is necessary for use with the Echelon. The Echelon is mounted with the edges horizontal in the manner employed by Professor Michelson.

(4) An extra low-power eyepiece is supplied for use with the Etalon or Lummer-Gehrcke Plate.

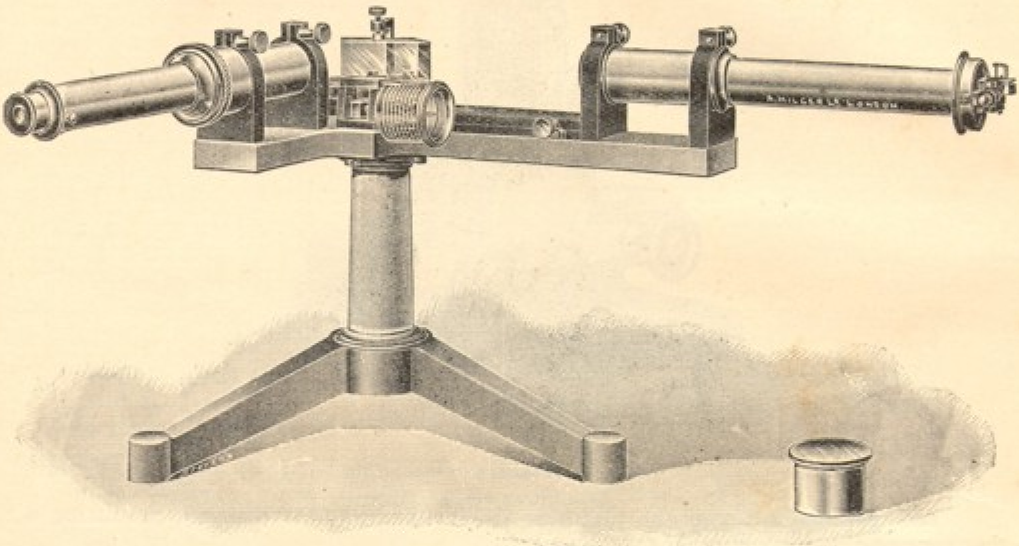


Fig. O 8

O 8.—Modified Wavelength Spectrometer, with extra dense prism, refractive index for D = 1·74, suitable for use with Lummer-Gehrcke Plate or Fabry & Perot Etalon ... ...

O 9.—Well-made case with lock and key ... ...

O 10.—Modified Wavelength Spectrometer extended to suit Echelon of 12 plates (O 2), and suitable also for use with Lummer-Gehrcke plate, or Fabry & Perot Etalon ... ...

O 19.—Well-made case, with lock and key ... ...

O 11.—Accurate micrometer eyepiece for measurement of the diameter of the ring system produced by the Etalon, or for employment with the Echelon and Lummer-Gehrcke Plate, with adapter for low-power eyepiece interchangeable with that for the usual eyepiece supplied. ... ...

(For sundry other accessories for the Wavelength Spectrometer, *see* Sections D and F.)

MOUNT TO TAKE THE ABOVE FABRY & PEROT ETALON, OR LUMMER-GEHRCKE PARALLEL PLATE, IN FRONT OF AN ORDINARY SPECTROSCOPE

O 12.—This mount (Fig. O 12) is made to suit the Fabry & Perot Etalons and Lummer-Gehrcke Parallel Plates described above.

The Etalon (as in the upper figure) or the Lummer-Gehrcke Parallel Plate (as in the lower figure) stands on a brass plate which is capable of slight rotation about a vertical axis by means of a milled head screw. This, together with a readily accessible levelling screw, provides the necessary adjustment for either of the accessories.

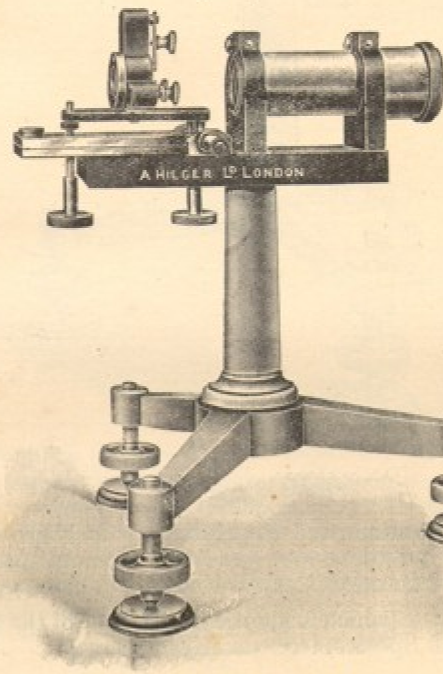


Fig. O 12 with O 6

The rays from the source of light should be approximately collimated by a condensing lens. They then traverse the Lummer-Gehrcke Parallel Plate or Etalon, as the case may be; and an image of the resulting diffraction pattern is formed by an achromatic lens of about 5″ (130 mm.) focal length. This image consists, of course, of a number of superposed images produced by the various monochromatic radiations emanating from the source.

The spectroscope to be used in conjunction with this arrangement is then placed in train with the above apparatus so that the diffraction image falls on the slit. The jaws of the slit should be set vertical; and the dispersion of the spectroscope will then give the necessary separation of the overlapping diffraction images.

The apparatus is mounted on a substantial cast-iron tripod, with three levelling screws, and is suitable for use with any ordinary spectroscope.

O 5, O 18.—Quartz-fluorspar double or quartz rocksalt triple achromatic lens, for use with the quartz Lummer Plate described on page O 2, fitted to the above mount.

Besides its use with the Lummer-Gehrcke Parallel Plate and Etalon, this piece of apparatus can also be employed, with the addition of a special collimator, to utilise the Echelon, described above, in combination with any ordinary spectroscope. The short tube with achromatic lens shown in Fig. O 12 must then be replaced by

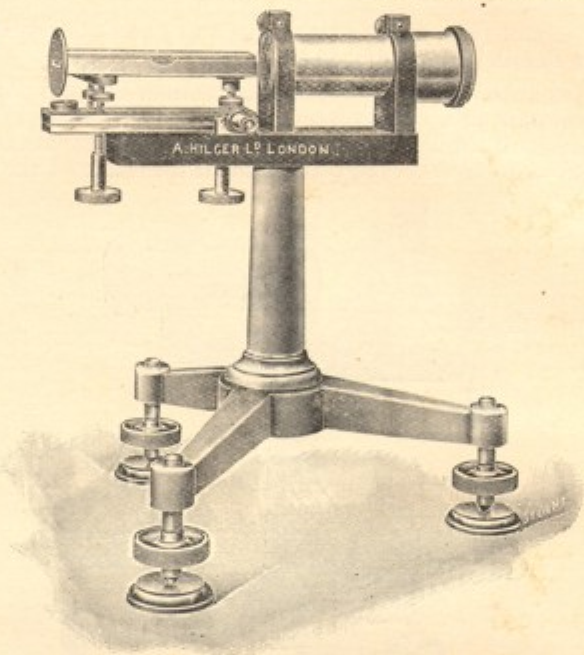


Fig. O 12 with O 3.

the special collimator in question, and the collimator of the ordinary spectroscope removed. The light from the source first passes through the special collimator, then through the Echelon, and then on to the prism of the spectroscope.

O 13.—Special collimator (which is identical with that of the Modified Wavelength Spectrometer described above) ... ...

USEFUL ACCESSORIES FOR THE DEMONSTRATION OF THE ZEEMAN EFFECT BY MEANS OF THE LUMMER-GEHRCKE PARALLEL PLATE

O 14.—Small electro-magnet on raising and lowering stand, pole pieces adjustable from contact to $\frac{1}{2}''$ ($12\frac{1}{2}$ mm.) apart ; suitable for demonstrating the Zeeman effect with these Lummer-Gehrcke Parallel Plates. The current required is about 3 amperes when using an ordinary vacuum tube as the source of light. The lines are distinctly separated with these plates into triplets, etc.

O 15.—Shutter eyepiece with bright pointer and double image prism, for Zeeman effect observations with the Lummer-Gehrcke Parallel Plate. By means of the shutter eyepiece the line under observation can be isolated, and the double image prism being turned into position, the components of the rays polarised in vertical and horizontal planes can then be observed side by side simultaneously.

The surfaces of the double image prism are protected by glass plates.

SECTION P

OPTICAL WORK

Achromatic Object Glasses made from ordinary silicate glasses. Supplied mounted either in flanged, or in screwed cells. In ordering, please state type of cell required.

Catalogue No.	Effective Aperture.		Types I. and II.			Type III.	
			Focal Length.		Relative Aperture.	Focal Length.	
	inches.	mm.	inches.	mm.		inches.	cm.
P 1	0·5	12·7	4·1	104	f/8	4·5	11·3
P 2	0·8	20·3	5·7	145	f/8	6·2	15·8
P 3	1·0	25·4	8·0	203	f/8	8·7	22·1
P 4	1·25	31·7	11·2	284	f/9	12·2	30·9
P 5	1·5	38·1	15·7	400	f/10	17·1	43·6
P 6	1·9	48·2	21·9	556	f/11	23·8	60·6
P 7	2·5	63·5	30·6	777	f/12	33·3	84·6
P 8	3·3	83·8	42·8	1,087	f/13	46·6	118·0
P 9	4·3	109·2	60·0	1,524	f/14	65·4	166·0

The lenses are made in three types.

Type I., for visual spectrum work, corrected for spherical aberration in axis, and achromatised for the extreme visible red and violet.

Type II., for spectrum photography from wavelength 800 $\mu\mu$ to wavelength 350 $\mu\mu$, achromatised for the violet.

Type III., for ordinary telescope work, achromatised for C and F.

The above focal lengths may vary from time to time by as much as 3 per cent.

Ordinary doublet Lenses to other specified sizes, focal lengths, or other special specifications, price 30 per cent. extra.

PRISMS FOR SPECTROSCOPIC WORK

The following expressions give the prices of single prisms of 60° angle made to order :—

h is the height of the prism in centimetres.

l is the length of the refracting face in centimetres.

Refractive Index for D.	Price in Shillings.	The Expressions may be used up to (centimetres)		Glass always in stock to cut Prisms of (centimetres)	
		h	l	h	l
1·58 to 1·62	$0{\cdot}33hl^2+17$	13	18·5	10	13
1·65	$0{\cdot}36hl^2+17$	10·5	16	8	11
1·74	$0{\cdot}62hl^2+17$	8	10·5	6	8

The above prisms have rectangular refracting surfaces.

NOTE (*March* 1920).—*The above prices must be increased by* 140 *per cent.*

Prisms of refractive indices below 1·58 are supplied at the same price as those of 1·58. Higher refractive indices than 1·74 are not recommended except for special purposes. The expressions may be employed up to the sizes given in the third column, and prisms exceeding the dimensions there given will be quoted for on application.

Glass is *always* kept in stock to cut prisms of about the sizes given in the fourth column, and *usually* to cut prisms of the sizes given in the third column.

The prices are for prisms of the highest quality. The angles are made accurate to within 10′. If a greater accuracy be required, for an accuracy of ±15″ add 25 per cent., with a minimum charge for the increased accuracy of 10s.; for an accuracy of ±5″ add 75 per cent., with a minimum charge for the increased accuracy of 25s.

NOTE (*March* 1920).—*All the above prices are increased by approximately* 140 *per cent.*

The following sizes are stocked in refractive indices from 1·58 to 1·65, and are supplied, as will be seen, at a considerable reduction on the above scale of prices. They are in all respects equal in quality to the above prisms, but are only supplied in the sizes and of the refractive indices as stated. The surfaces are rectangular.

Light Flint. ref. ind. for D = 1·58 to 1·62 about.							**Dense Flint.** ref. ind. for D = 1·63 to 1·65 about.				
Length of Face.		Height of Prism.		Catalogue No.			Length of Face.		Height of Prism.		Catalogue No.
in.	mm.	in.	mm.				in.	mm.	in.	mm.	
1¼	32	1	25	P 10			1⅜	35	1	25	P 14
1⅝	42	1¼	32	P 11			1¾	44	1¼	32	P 15
2	51	1½	38	P 12			2⅛	54	1½	38	P 16
2⅜	60	1¾	44	P 13			2½	64	1¾	44	P 17

It will be noted that the lengths of the surfaces in the above prisms are greater than the heights, and that the ratio of length of surface to height becomes greater with the refractive index. By this means a more satisfactory effective aperture is obtained.

RIGHT-ANGLED PRISMS

Length of Square Cathetus Surface.	Catalogue No.
10 mm.	P 18
15 ,,	P 19
20 ,,	P 20
25 ,,	P 21
30 ,,	P 22
35 ,,	P 23
40 ,,	P 24
45 ,,	P 25
50 ,,	P 26
55 ,,	P 27
60 ,,	P 28

Larger sizes quoted on application.

The above right-angled prisms are of the very finest quality; of white, clear, and thoroughly annealed crown. The definition is guaranteed, and all the angles are accurate to within 5′. If a greater accuracy of angles be required, for an accuracy of ±10″ add 25 per cent., for an accuracy of ±5″ add 75 per cent. to the above prices.

Diagonal Planes, of guaranteed quality, silvered. (These planes are so edged as to reflect a circular beam of light when set at an angle of 45°.)

Diameter of minor axis of surface.	Catalogue No.	Diameter of minor axis of surface.	Catalogue No.
$1\frac{1}{8}$ inches.	P 29	2 inches.	P 33
$1\frac{1}{4}$,,	P 30	$2\frac{1}{2}$,,	P 34
$1\frac{1}{2}$,,	P 31	3 ,,	P 35
$1\frac{3}{4}$,,	P 32	$3\frac{1}{2}$,,	P 36

Diagonal planes can be made to fit existing mounts at the same scale of prices.

Plane Mirrors, of guaranteed quality, for Siderostats, Heliostats, and general purposes. The prices includes silvering. The price for speculum metal mirrors is 50 per cent. higher.

Diameter in inches.	Catalogue No.	Diameter in inches.	Catalogue No.
1	P 37	8	P 45
$1\frac{1}{2}$	P 38	9	P 46
2	P 39	10	P 47
3	P 40	11	P 48
4	P 41	12	P 49
5	P 42	13	P 50
6	P 43	14	P 51
7	P 44	15	P 52

For concave mirrors (if of radius not less than 15 times the diameter), add 25 per cent. to the above prices. Concave mirrors of larger sizes, or with radii less than 15 times the diameter, quoted for on application.

Galvanometer Mirrors, of the highest optical perfection, to the following dimensions :—

Diameter.	Thickness.	Radius of Curvature.
10 mm. (or anything smaller)	0·5 mm.	36 inches, or 1,000 mm.

P 53.—(1) Of glass, palladinised on the front. ... ...

P 54.—(2) Of fused silica, platinised on the front. (These can be soldered without damage.) ... ...

Plane Mirrors, up to 10 mm. dia., at the same prices as above.

Concave Mirrors, up to 10 mm. dia., of other radii than those given, can be supplied at double the above prices.

Larger sizes quoted for if required.

CORNU PRISMS OF QUARTZ—REFRACTING ANGLE 60°

These prisms are accurately cut with respect to the axis. They are composed of two prisms of right and left rotation quartz respectively, each of 30° angle.

We have introduced an important improvement in the construction of these prisms, viz., the setting of the two component prisms into optical contact at the interface. This procedure results in

(1) Greater optical perfection.
(2) Removal of double image caused by reflection between the two inside surfaces, without the necessity of any liquid between the two surfaces.
(3) A gain in light transmitted.
(4) Greater convenience of handling.

Following our usual procedure with 60° prisms we quote for a length of face greater than the height of prisms. We cannot, however, in the case of quartz prisms always adhere quite rigidly to the sizes stated.

Length of external faces.		Height of prism.		Catalogue No.
mm.	in.	mm	in.	
25	1	19	$\frac{3}{4}$	P 55
32	$1\frac{1}{4}$	25	1	P 56
42	$1\frac{5}{8}$	32	$1\frac{1}{4}$	P 57
50	2	38	$1\frac{1}{2}$	P 58
57	$2\frac{1}{4}$	44	$1\frac{3}{4}$	P 59
65	$2\frac{5}{8}$	41	$1\frac{5}{8}$	P 60
65	$2\frac{5}{8}$	50	2	P 61
82	$3\frac{1}{4}$	52	$2\frac{1}{8}$	P 62
98	4	59	$2\frac{3}{8}$	P 63
110	$4\frac{3}{8}$	70	$2\frac{3}{4}$	P 64

QUARTZ LENSES

Price of Quartz Lenses, unmounted, accurately cut with the crystallographic and optical axes coincident.

	Clear Aperture.		
Catalogue No.	IN.	MM.	
P 65	1	25·4	... ...
P 66	$1\frac{1}{4}$	32	... ...
P 67	$1\frac{1}{2}$	38	... ...
P 68	$1\frac{3}{4}$	44	... ...
P 69	2	51	... ...
P 70	$2\frac{1}{4}$	57	... ...
P 71	$2\frac{1}{2}$	64	... ...

The above prices are for Lenses of the finest definition, with carefully selected curves, the focal length for W.L. 400 $\mu\mu$ being not less than 10 times the diameter.

Lenses of larger angular aperture up to F/4·5 can be supplied figured to correct the axial spherical aberration at the prices obtained by multiplying the prices in the above table by the factor

$$\frac{8}{N-2}$$

where N is the focal length divided by the aperture.

Condensing Lenses of Quartz, see *Section F*.

PLANE PARALLEL GLASS

(*First quality surfaces only supplied.*)

This is stocked in the following thicknesses :—

1 mm., 2 mm., 3 mm., $4\frac{3}{4}$ mm., $7\frac{1}{2}$ mm., 10 mm.

1 mm. thick Plane Parallel Glass, accuracy of parallelism about 10 seconds.

P 91 Price in shillings = × area in square cms. + .
up to 25 mm. in the longest dimension.

2 mm. thick Plane Parallel Glass, accuracy of parallelism about 6 seconds.

P 91 Price in shillings = × area in square cms. + .
up to 40 mm. in the longest dimension.

3 mm. thick Plane Parallel Glass, accuracy of parallelism about 3 seconds.

P 91 Price in shillings = × area in square cms. + .
up to 50 mm. in the longest dimension.

$4\frac{3}{4}$ mm. thick Plane Parallel Glass, accuracy of parallelism about 3 seconds.

P 91 Price in shillings = × area in square cms. + .
up to 65 mm. in the longest dimension.

$7\frac{1}{2}$ mm. thick Plane Parallel Glass, accuracy of parallelism about 3 seconds.

P 91 Price in shillings = × area in square cms. + .
up to 100 mm. in the longest dimension.

10 mm. thick Plane Parallel Glass, accuracy of parallelism about 3 seconds.

P 91 Price in shillings = × area in square cms. + .
up to 150 mm. in the longest dimension.

Crystalline Quartz of like accuracy cut perpendicular to the axis.
Prices, $2\frac{1}{2}$ times the above.

CONSTANT DEVIATION PRISMS (Fig. P 72), AS USED IN THE HILGER CONSTANT DEVIATION SPECTROMETERS (see p. D 1-2)

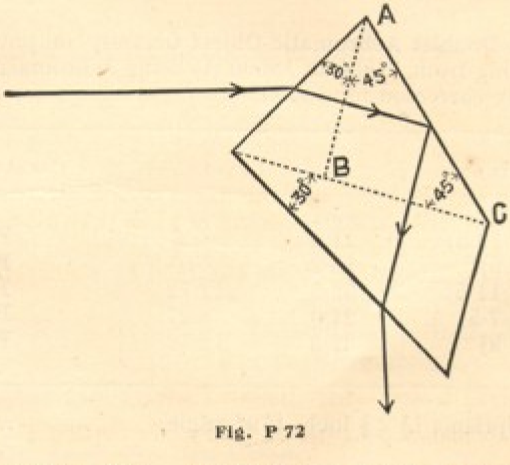


Fig. P 72

Catalogue No.	Refractive Index for D.	Size of Equivalent 60° prism face.			
		Length of Face.		Height.	
		in.	mm.	in.	mm.
P 72	1·65	$1\frac{5}{8}$	42	$1\frac{5}{16}$	34
P 73	1·74	$1\frac{5}{8}$	42	$1\frac{5}{16}$	34
P 74	1·65	$2\frac{5}{8}$	65	$1\frac{3}{4}$	44

Prisms of Rocksalt, up to 6 cm. long face. Can be priced from the following formula :—Price in shillings $=1{\cdot}6\,hl^2+17$ (h and l being the height and the length of face in centimetres).

Lenses of Rocksalt.—Focal length for D not less than five times the diameter, second quality surfaces.

Diameter.		Catalogue No.
inches.	mm.	
1	25	P 80
$1\frac{1}{4}$	31	P 81
$1\frac{1}{2}$	38	P 82
$1\frac{3}{4}$	44	P 83
2	51	P 84
$2\frac{1}{4}$	57	P 85
$2\frac{1}{2}$	63	P 86
$2\frac{3}{4}$	70	P 87
3	76	P 88

First quality lenses of Rocksalt, focal length for D not less than $\frac{1}{4}$ the diameter, curves such as to give minimum spherical aberration for W.L. 10 μ, price $2\frac{1}{2}$ times the above.

Quartz-Fluorspar Doublet Achromatic Object Glasses, computed for use over the spectral range extending from λ1850 to λ8000 A, being achromatised for these wavelengths and spherically corrected for λ3200.

Clear Aperture.		Focal Length.		Catalogue No.
mm.		cms.	in.	
17	(F/12·3)	21·0	8·27	P 94
17	(F/9)	15·3	6·0	P 95
28	(F/11·5)	32·3	12·72	P 96
28	(F/7·5)	21·0	8·27	P 97
36	(F/9)	32·3	12·72	P 98

P 89.—Fresnel biprisms $1\frac{1}{4} \times \frac{3}{4}$ inch, 179° angle, ...

PRECISION GLASS APPARATUS, HAVING THE COMPONENT PARTS UNITED BY HEAT TREATMENT

The information contained in this pamphlet is abridged from a paper "*On a Precision Method of Uniting Optical Glass,*" *etc.* (R. G. Parker and A. J. Dalladay, *Farraday Society Trans.*, Vol. XII. Part I., 1916).

See also *Phil. Mag.*, Vol. XXXIII., March 1917, and "*Nature,*" 21st December, 1916.

The method which we now employ in the manufacture of certain glass apparatus is the result of efforts to obtain glass apparatus suitable for making measurements of the highest precision on liquids.

Method of Construction.—The component parts of the piece of apparatus which is required are designed, and optically worked, so that they can all be put together in optical contact. When this has been done the apparatus may appear completed, but would almost certainly fall to pieces if any attempt were made to use it. If, however, it is gently clamped, so that the components are held in their correct relative positions, and subjected to carefully controlled heating, the surfaces in optical contact will unite; the apparatus may then be used for its proper purpose, as if made of one piece of glass.

The temperature employed is very far below the melting point of glass; it varies with the kind of glass, from about 400° C. to 550° C. Quartz cannot be joined, as it splits up when heated, however slow the rise of temperature may be. With certain limitations, plates of different kinds of glass can be caused to go into complete union.

Advantages offered by the Apparatus:

1. At the low temperature employed, no bending or deformation occurs; the surfaces of the glass work are not injured, so that we have optically-worked surfaces in the *interior* of one integral piece.

2. There is, of course, no cement to contaminate liquids placed in the apparatus, to produce strain in the glass, and to perish eventually.

3. It is wholly of glass, and for this reason will resist very high temperatures (up to 300° C.), always provided it be uniformly heated.

P 90.—Price for a single cell, space for liquid 2 × 2 cms. × 1 cm. thick

M 161.—Double cell, for comparison of two liquids, having two compartments each 14 mm. wide × 29 mm. high × 10 mm. thick ... ...

We shall be pleased to quote for cells to customer's own design upon request.

ADAM HILGER, Ltd., 75a Camden Road, London, N.W.1

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October 1924

SECTION R

THE LOW-HILGER AUDIOMETER

Formerly known as

THE HILGER OPTICAL SONOMETER

(By arrangement with the Low Engineering Co., Ltd.)

Patent Nos. 189, 815/17 and 189, 816/18

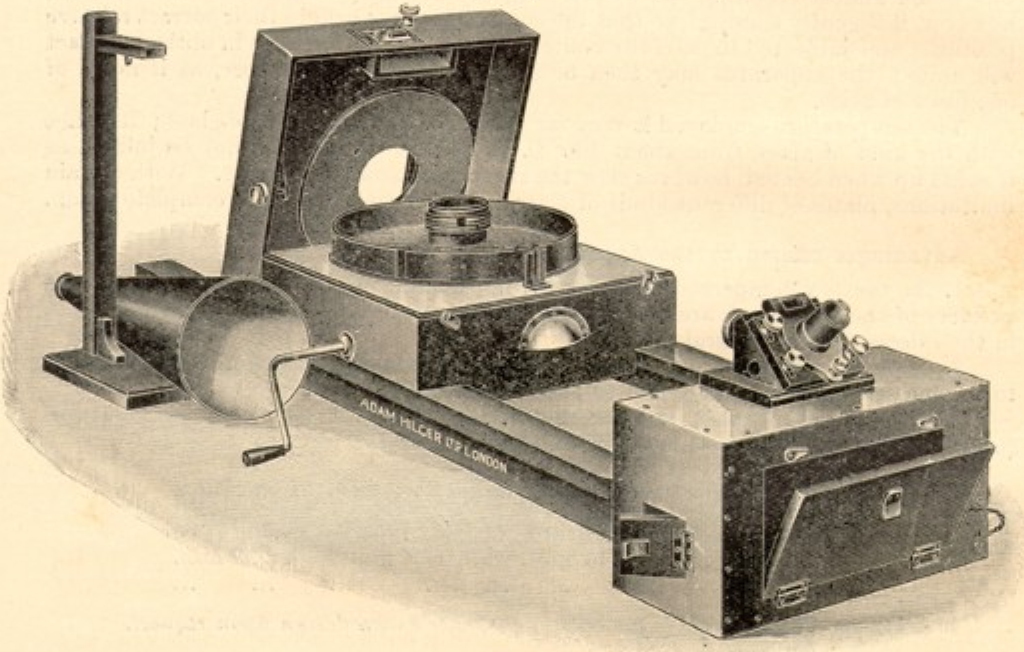

Fig. R 1

The Low-Hilger Audiometer (formerly known as the Hilger Optical Sonometer), of which a general view is shown in Fig. R 1, is an extremely sensitive optical kymograph designed to record the pressure variation caused by sound waves.

The wooden framework is constructed of polished mahogany in the best style of camera work.

On connection of the bayonet plug to a source of electric supply (the voltage of which should be stated in ordering) the instrument is at once ready for use, being entirely self-contained and needing no accessory apparatus whatever.

The length from end to end is 4 ft. (122 cms.), or with the horn 5 ft. 10 in. (178 cms.).

An important feature is that the light-tight camera box which contains the drum J and sensitive film (Fig. R 1 A) is removable without disturbing the rest of the apparatus, and can be taken to the dark room for removal and development of the film and for re-charging. Thus the Audiometer can be used in any room, laboratory, or workshop under ordinary conditions of lighting—no darkening being necessary even during the time of taking a record.

The construction is shown in diagram in Fig. R 1 A.

The sound wave is received by the horn attached to the diaphragm box B.

The horn is of about 12 degrees taper, and 24 in. (60 cm.) long, and it is made of specially selected millboard wound with adhesive rubber tape. This mode of construction has been found by previous investigators favourable to the avoidance of resonance in the horn itself.

In the box B is mounted an extremely light diaphragm of celluloid, rubber, or other material (according to the sensitivity required) of which a small portion is platinized to form a mirror. These diaphragms are manufactured according to a procedure worked out in our Research Department, and are made in thicknesses down

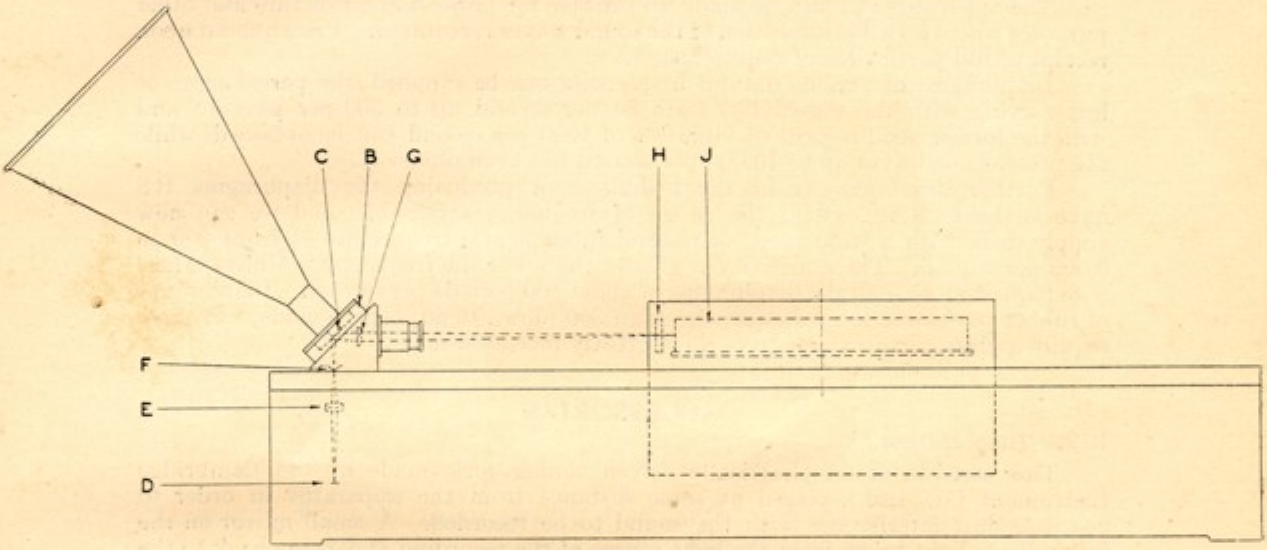

Fig. R 1a

to a fraction of a wavelength of light.* Thus the mass is extremely small, and the air damping very great, both factors making for sensitivity and accurate reproduction of the impressed pressure wave-form.

The diaphragm is mounted so as to be optically flat when it is undeflected, and the small platinized patch which reflects the light remains, even on the deflection of the diaphragm, sufficiently flat to give a very well defined spot of light on the sensitive film.

Light is directed from the light source D by a condenser E through the slit F and brought to a focus on the platinized area of the diaphragm C. Lenses G and H form an image of the slit on the photographic paper (or film) on the drum J. The lens H being cylindrical with its axis parallel to the drum, the beam of light is brought to an intense point image, so that a record of the deflection of the diaphragm is made as the drum rotates. The light source is a 30 candle power Pointolite Lamp, which can be supplied complete with a suitable resistance.

Liberal adjustment is provided so that the spot of light may be focussed on the drum at any distance from 4 to 20 inches according to the amplitude of vibration to be dealt with, while a further great variation of sensitivity (in the proportion of 20 to 1)

* Patent applied for.

may be obtained by selection of a suitable diaphragm. Thus the standard instrument is suitable for recording sounds whose amplitudes differ by more than 100 to 1.

The recording drum is arranged to take standard celluloid or paper film 1⅜ inches wide.

The drum is enclosed in a specially designed camera box which is provided with an automatic shutter arranged to expose from one-sixth to one complete revolution of the drum as desired, thus from 1 to 6 records can be made on one film according to the length it is desired to expose. The drum takes 37 inches of film. It is driven by a spring motor provided with a speed indicator. The speeds shown are however only to be taken as a rough guide, and when accurate timing is required a time marker should be used. As explained above, the camera box is readily removable (two handles being provided for carrying) for charging the films. The camera box is conveniently arranged for loading or unloading with film through a small door in the back.

The apparatus can also be made up suitable for projection for lecture and other purposes where a visible indication of the sound waves is required. Price quoted upon receipt of full particulars of requirements.

Diaphragms of various natural frequencies can be supplied (the period more or less varying with the sensitivity) from 80 per second up to 300 per second; and with the former good records of vibration of 1000 per second can be obtained, while the presence of waves up to 10,000 per second has been observed.

Further developments in the technique of producing the diaphragms R 8 have enabled us to extend the range of frequency attainable, and we can now supply them with a wide range of natural fundamental frequencies of from 300 to 3,000 per second. The sensitivity is greater the lower the frequency. Unless otherwise requested we send the diaphragms of about 800 periods per second. Diaphragms of rubber possessing lower frequencies than 300 (down to 80) can be made, but these require a glass mirror which gives them greatly increased mass.

ACCESSORIES

R 2.—Time Marker.

This consists of an electrically driven tuning fork (made by the Cambridge Instrument Co., Ltd.), placed at some distance from the apparatus in order to guard against interference with the sound to be recorded. A small mirror on the fork reflects light taken from the light source of the recording apparatus back to the drum where it is focussed near the edge of the film; both sets of vibrations are photographed together and thus an accurate time reference is secured.

R 18.—High Frequency Camera.

This contains a drum (on which the film is wound) mounted on the spindle of an electro-motor, the speed of which is variable from 2100 r.p.m. to 700 r.p.m. A speeded shutter exposes the film during one revolution, the length of each record being about 20 inches.

It is sometimes useful for purposes of comparison to record sounds of different frequencies in such a way that one period occupies always the same length of film no matter what the frequency. For this purpose the drum is notched on its upper rim, the distance between the two successive notches being supposed to represent the above wavelength. During rotation a card is held against the notches, and the resultant sound is tuned to the sound to be photographed by varying the speed of the motor.

R 29.—Automatic shutter release for High Frequency Camera.

The above camera can also, if desired, be supplied with an arrangement for automatically releasing the shutter at any desired time up to 15 secs. after the commencement of the sound.

R 27.—Automatic shutter release for Low-Hilger Audiometer R 1.

In the case of sounds of short duration, it is necessary to ensure that the camera shutter opens simultaneously with, or at a short controlled time after, the sound. To enable this to be done we can supply additions to the Low-Hilger Audiometer by means of which an electrical circuit (controlling the means by which the sound is produced) can be broken, at any time up to a second before exposure of the film.

R 26.—Low-Hilger Audiometer for continuous records.

In the case of records which can be made in large numbers before development, it is very convenient to employ a large roll of film. It may also be necessary to record a prolonged sound from start to finish. To fulfil these requirements, we can supply the Low-Hilger Audiometer fitted with means for exposing up to 400 ft. of film at speeds of 60, 40, and 20 inches per sec. The driving arrangements consist of electro-motor, resistance, and countershafting.

CATALOGUE NUMBERS

(*For Prices see Price Sheet.*)

R 1.—Low-Hilger Audiometer, complete with spring motor drive for drum (Lamp not included) ... ...

R 25.—Low-Hilger Audiometer, with electric motor drive instead of spring motor, specially suitable for all purposes where continuous running is required. Complete with resistance adjustable for any voltage from 50 to 250 D.C. or A.C.

R 2.—Time Marker with tuning fork of 50 vibrations per second ...

R 3.—Tuning Fork, 100 vibrations per second (made by the Cambridge Instrument Co., Ltd.) ... ...

R 4.—Tuning Fork, 200 vibrations per second (made by the Cambridge Instrument Co., Ltd.) ... ...

F 215.—Pointolite Lamp, 100 C.P. (can only be supplied for direct current) ... ...

F 216.—Universal resistance for 100 C.P. Pointolite lamp ...

R 7.—Sound box with horn only. Complete with all optical work necessary to project spot of light ... ...

R 8.—Extra Diaphragms in metal case, each ... ...

R 9.—Paper Film 1⅜″ wide, 100 ft. roll ... ...

R 10.—Cinematograph Film (not perforated) 100 ft. roll ... ...

R 11.—Negative Paper. A special fast paper giving a black line print of maximum contrast, speed about 300 H & D. Made up in boxes of 50 lengths of 37″ each. We can highly recommend this new paper ... ...

R 17.—Demonstration Strip. A black band with white lines for visual observation of wave forms. Set of four with different spacings ... ...

R 18.—High frequency camera ... ...

R 29.—Automatic shutter release for R 18 ... ...

R 27.—Automatic shutter release for Low-Hilger Audiometer R 1

R 26.—Low-Hilger Audiometer for continuous records ... ...

R 30.—Cinematograph film (perforated) in 400 ft. rolls ... ...

R 31.—Negative paper (perforated) in 400 ft. rolls ... ...

ALTERNATIVE LIGHT SOURCE

Suitable for use with either Alternating or Direct Current.

R 19.—Focuslite Lamp (20 to 30 Volt, 250 to 400 C.P.) ...

R 20.—Lamp holder and flex with bayonet adapter ... ...

R 21.—Universal Resistance adjustable to suit any voltage from 20 to 250 Volts, A.C. or D.C. ... ...

Alternative Light Source where Accumulators only are available.

R 22.—Focuslite Lamp suitable for use with accumulators (12 Volt, 400 C.P.) ... ...

R 23.—Lamp holder and flex ... ...

R 24.—Accumulator, 12 Volt, 96 amp. hours ... ...

Full description, with reproductions of 25 records, post free on application. A set of 14 lantern slides are available for hire, terms on application.

SUNDRY INSTRUMENTS

(not described in this Catalogue)

Full descriptions will be sent post free on application.

T 5.—The Wilson Projection Comparator.—A rapid and accurate gauging machine for repetition machined parts.

T 8.—The Hilger Optical Gauge.—A specialised and simple development of the T 5.

M 189.—The Michell Viscometer.—An accurate and rapid means of measuring viscosity.

The following are not of our manufacture :—

Dr. Moll's Registering Microphotometer, for measuring the intensity of photographed spectrum lines.

The Chevenard Thermic Analyser.—For determining temperature variations of expansion co-efficients. The temperatures at which the rate of such variations changes rapidly have important technical significance.

Prof. Miers' Student's Goniometer, a useful goniometer, of simple design, for crystallographic work.

The Fereday Palmer Stress Recorder, for accurately recording rapidly varying strains in structures such as those produced by a train travelling at high speed over a bridge, or those taking place in the hull or other parts of a ship at sea.

The Vickers Diamond Hardness Testing Machine, a Brinell machine with many important novel features.

LANTERN SLIDES

We have a large number of lantern slides illustrating our instruments and their performance and uses, and these can be loaned for lectures free of charge on payment of postage.

Lists of those available will be sent on application.

October 1924

ADAM HILGER, Ltd., 75a Camden Road, London, N.W. 1

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Cable Code—Western Union
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October 1924

PRINTED IN GREAT BRITAIN.

MONTHLY PRICE SHEET

NOVEMBER, 1924.

Catalogue Numbers:—We recommend our customers to make use of the Catalogue Numbers when making enquiries or sending orders. They will be found particularly useful when cabling.

Prices :—Prices are for delivery at our Works, and packing is extra. Where no price is given this indicates that the apparatus in question will be the subject of a special quotation.

We shall be very pleased at any time to quote prices, including packing and delivery f.o.b. London, or delivery to any foreign port or railway station.

ADAM HILGER LIMITED

75A CAMDEN ROAD · LONDON · N.W. 1

Entrance :—24 Rochester Place (*adjoining*)

CURRENT PRICES for the Month of NOVEMBER, 1924.

Catalogue Number.	Price.			Catalogue Number.	Price.			Catalogue Number.	Price.		
	£	s.	d.		£	s.	d.		£	s.	d.
B 1	35	0	0	B 35	147	2	6	C 1	35	0	0
B 2	35	0	0	B 36	8	5	0	C 2	1	9	6
B 3	35	0	0	B 37	5	10	0	C 3	2	16	3
B 4	50	17	6	B 38	177	7	6	C 4 }	14	6	9
B 5	56	7	6	B 39	8	5	0	C 5 }			
B 6	63	5	0	B 40	6	3	9	C 6	3	15	0
B 7	68	15	0	B 43	137	10	0	C 7	59	0	0
B 8	74	18	6	B 44	174	12	6	C 8			
B 9	81	2	6	B 45	258	10	0	C 9			
B 10	88	0	0	B 46	290	2	6	C 10	4	5	0
B 11	96	2	6	B 48	98	0	0	C 12	427	0	0
B 12	103	2	6	B 49	187	0	0	C 14	12	10	0
B 13	110	0	0	B 50	405	12	6	C 15	0	17	6
B 14	116	17	6	B 51	459	5	0	C 16	3	10	0
B 15	123	15	0	B 52	9	17	6				
B 16	132	0	0	B 53	18	4	6	D 1	61	0	0
B 17	140	0	0	B 54	4	5	0	D 2	61	0	0
B 18	148	10	0	B 55	5	0	0	D 4	1	8	0
B 19	158	2	6	B 56	26	0	0	D 5	2	5	6
B 20	167	15	0	B 57	38	10	0	D 6	3	18	6
B 21	178	15	0	B 58	66	0	0	D 7	3	10	0
B 22	189	15	0	B 59	107	5	0	D 10	13	15	0
B 23	200	15	0	B 60	52	15	9	D 11	11	15	0
B 24	211	15	0	B 61	13	0	0	D 12	30	10	0
B 25	247	10	0	B 62	98	0	0	D 13	18	1	3
B 26	330	0	0	B 63	103	2	6	D 19	181	0	0
B 27	783	15	0	B 64	108	7	6	D 21	2	15	0
B 29	45	7	6	B 65	29	0	0	D 22	7	7	0
B 30	6	17	6	B 66	35	1	3	D 23	18	0	0
B 31	4	2	6	B 67	39	17	6	D 25	72	10	0
B 32	96	5	0	B 68	13	10	0	D 26	19	0	0
B 33	7	11	3	B 69	13	10	0	D 32	106	0	0
B 34	4	16	3					D 33	138	0	0

Catalogue Number	Price. £	s.	d.
D 34 ..	56	0	0
D 35 ..	117	0	0
D 36 ..	77	0	0
D 39 ..	40	0	0
D 41 ..	250	0	0
D 42 ..	180	0	0
D 45 ..	33	0	0
D 46 ..	0	17	6
D 48 ..	26	10	0
D 49 ..	28	10	0
D 50 ..	34	5	0
D 52 ..	1	0	0
D 53 ..	0	18	0
D 54 ..	1	10	0
D 59 ..	120	0	0
D 60 ..	110	0	0
E 1 ..	292	0	0
E 2 ..	132	0	0
E 3 ..	165	0	0
E 4 ..	227	0	0
E 6 ..	39	0	0
E 7 ..	3	10	6
E 11 ..	185	0	0
E 14 ..	230	0	0
E 15 ..	17	0	0
E 16 ..	266	0	0
E 17 ..	475	0	0
E 18 ..	585	0	0
E 26 ..	57	0	0
E 27 ..	See	E 50	
E 28 ..	290	0	0
E 29 ..	122	0	0
E 30 ..	273	0	0
E 31 ..	39	0	0
E 32 ..	39	0	0
E 34 ..	155	0	0
E 36 ..	197	0	0
E 37 ..	57	0	0
E 38 ..	57	0	0
E 41 ..	217	0	0
E 42 ..	163	0	0
E 43 ..	200	10	0
E 44 ..	20	0	0
E 45/6 ..	47	0	0
E 49 ..	475	0	0
E 50 ..	250	0	0
E 52 ..	40	0	0
E 56 ..	262	0	0
F 1 ..	4	5	0
F 2 ..	5	0	0
F 3 ..	9	10	0
F 4 ..	8	15	0
F 5 ..	1	5	0
F 6 ..	2	18	6
F 7 ..	3	16	6
F 8 ..	1	12	0
F 9 ..	2	10	0
F 10 ..	3	10	3
F 11 ..	3	18	0
F 12 ..	0	16	6
F 13 ..	1	5	0
F 14 ..	6	15	0
F 15 ..	7	15	0
F 16 ..	3	8	0
F 17 ..	4	8	0
F 18 ..	2	15	0
F 22 ..	5	7	6
F 23 ..	1	19	6
F 24 ..	6	5	0
F 25 ..	0	4	3
F 26 ..	0	14	6

Catalogue Number.	Price. £	s.	d.
F 27 ..	12	10	0
F 28 ..	9	10	0
F 29 ..	11	15	0
F 30 ..	0	6	9
F 31 ..	12	10	0
F 32 ..	0	5	0
F 33 ..	1	4	0
F 34 ..	1	0	0
F 35 ..	13	0	0
F 36 ..	26	8	0
F 39 ..	17	16	0
F 40 ..	8	8	0
F 40/1 ..	9	12	0
F 43/4 ..	8	5	0
F 45 ..	3	0	6
F 46 ..	11	10	0
F 66 ..	1	5	0
F 68 ..	0	18	6
F 69 ..	1	5	6
F 70 ..	1	16	0
F 71 ..	2	7	6
F 72 ..	3	0	6
F 73 ..	3	14	6
F 77 ..	48	0	0
F 78 ..	9	0	0
F 79 ..	18	10	0
F 80 ..	4	0	0
F 83 ..	23	8	0
F 84 ..	28	17	6
F 85 ..	3	1	6
F 86 ..	15	3	0
F 87 ..	20	12	6
F 88 ..	19	17	6
F 89 ..	26	2	0
F 90 ..	25	7	0
F 91 ..	18	10	0
F 92 ..	60	0	0
F 93 ..	4	0	0
F 94 ..	1	11	9
F 95 ..	4	1	0
F 109 ..	12	7	6
F 110 ..	11	12	6
F 111 ..	9	15	0
F 114 ..	0	14	0
F 119 ..	77	0	0
F 127 pair	0	2	6
doz. pair	1	5	0
F 128 ..	10	15	0
F 129 pair	0	7	6
doz. pair	3	0	0
F 130 ..	1	15	0
F 131 ..	5	0	0
F 132 ..	0	1	6
F 133 ..	0	15	0
F 134-7	0	3	9
F 138 pair	0	2	6
doz. pair	1	5	0
F 139 ..	0	3	6
F 140 ..	0	13	9
F 141 ..	0	3	6
F 142 ..	0	13	9
F 143 ..	0	2	9
F 144 ..	0	10	0
F 145 ..	0	7	6
F 146 ..	0	7	6
F 147 ..	5	10	0
per sect.	0	17	6
F 148 ..	8	10	0
F 149 ..	2	2	0
F 151 ..	37	0	0
F 152 ..	0	5	0
F 153 ..	2	2	0
F 156 ..	1	8	6

Catalogue Number.	Price. £	s.	d.
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F 160 ..	39	10	0
F 161 ..	51	0	0
F 162 ..	67	10	0
F 163 ..	84	10	0
F 165 ..	0	10	0
F 166 ..	0	12	6
F 167 ..	2	17	6
F 168 ..	1	10	0
F 169 ..	1	10	0
F 170 ..	1	7	6
F 171 ..	1	7	6
F 172 ..	1	7	6
F 173 ..	1	7	6
F 174 ..	0	15	0
F 175 ..	3	0	0
F 176 ..	1	12	6
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F 179 ..	1	10	0
F 180 ..	1	10	0
F 181 ..	1	10	0
F 182 ..	1	15	0
F 183 ..	5	0	0
F 184 ..	3	12	6
F 185 ..	3	12	6
F 186 ..	3	0	0
F 187 ..	2	16	6
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F 190 ..	4	10	0
F 191 ..	7	0	0
F 192 ..	6	0	0
F 193 ..	6	0	0
F 194 ..	5	15	0
F 195 ..	5	10	0
F 196 ..	5	10	0
F 197 ..	5	10	0
F 198 ..	2	10	0
F 199 ..	5	0	0
F 200 ..	4	0	0
F 201 ..	4	0	0
F 202 ..	3	15	0
F 203 ..	3	10	0
F 204 ..	3	10	0
F 205 ..	3	10	0
F 214 ..	0	2	6
F 215 ..	1	10	0
F 216 ..	5	0	0
F 217 ..	3	3	0
F 234 ..	1	8	6
F 235 ..	1	8	6
F 236 ..	1	8	6
F 237 ..	11	0	0
F 238 ..	6	6	0
F 239 ..	6	6	0
F 242 ..	2	10	0
F 243 ..	9	10	0
F 244 ..	12	10	0
F 245 ..	15	0	0
F 246 ..	69	0	0
F 247 ..	6	12	0
F 248 ..	8	0	0
F 249 ..	10	10	0
F 250 ..	0	7	0
F 251 ..	1	1	0
F 252 ..	90	0	0
F 253 ..	0	2	0
F 254 ..	1	0	0
F 257 ..	53	0	0
F 258 ..	45	0	6
F 259 ..	7	10	0
F 260 ..	40	0	0

Catalogue Number.	Price. £	s.	d.
F **261**	1	8	6
F **262**	1	8	6
F **265**	1	5	0
F **266**	20	0	0
F **267**	1	8	6
F **268**	2	10	0
F **269**	2	10	0
F **270**	2	10	0
F **272**	2	10	0
F **273**	2	10	0
F **275**	7	10	0
F **276**	7	10	0
F **277**	9	10	0
F **278**	7	8	0
F **279**	4	18	0
F **280**	20	0	0
F **281**	18	14	9
F **282**	22	10	0
F **283**	7	0	0
F **284**	3	0	0
F **285**	2	17	6
F **287**	1	12	0
F **288**	5	8	0
F **289**	1	7	0
F **290**	0	7	6
F **291**	0	7	6
F **292**	7	15	0
G **1**	3	17	0
G **2**	5	12	0
G **3**	7	5	0
G **4**	17	12	9
G **5**	23	3	0
G **6**	35	5	6
G **7**	56	4	6
G **8**	82	13	9
G **9**	152	3	0
G **10**	23	3	0
G **11**	31	19	6
G **12**	55	2	6
G **13**	88	4	0
G **14**	130	2	0
G **15**	253	11	6
G **19**	12	15	0
G **24**	97	0	0
G **25**	12	10	0
G **29**	150	0	0
G **30**	15	5	9
G **31**	5	4	3
G **37**	323	0	0
G **38**	147	5	0
G **40**	336	0	0
G **41**			
H **1**	182	0	0
H **2**	5	7	6
H **3/4**	12	0	0
H **5**	8	15	0
H **6**	4	13	6
H **7**	41	0	0
H **8**	48	10	0
H **9**	16	5	0
H **10**	63	15	0
H **11**	51	8	3
H **12**	45	0	0
H **13**	3	0	0
H **14**	97	0	0
H **15**	3	18	9
H **16**	47	0	0
H **17**	2	1	3
H **21**	228	0	0
H **32**	35	0	0
H **40**	190	0	0

Catalogue Number.	Price. £	s.	d.
H **41**	100	0	0
H **42**	95	0	0
H **56**	77	0	0
H **57**	5	7	6
H **58**	1	19	6
J **3**	1	9	0
J **4**	1	7	6
J **5**	0	2	9
J **6**	2	16	3
J **7**	3	15	0
J **8**	4	13	9
J **9**	10	2	6
J **10**	20	12	6
J **11**	1	3	3
J **12**	0	13	6
J **13**	2	16	3
J **14**	1	13	9
J **15**	8	12	6
J **16**	4	13	9
J **17**	1	19	0
J **18**	2	7	6
J **19**	2	10	9
K **1**	35	0	0
K **2**	3	7	6
K **3**	6	15	0
K **4**	1	17	6
K **5**	8	12	6
K **8**	1	1	0
K **9**	1	9	0
K **10**	1	9	0
K **11**	1	9	0
K **12**	0	3	3
K **13**	15	0	0
K **14**	22	10	0
K **15**	37	10	0
K **16**	15	0	0
K **17**	15	0	0
K **18**	22	10	0
K **19**	22	10	0
K **20**	22	10	0
K **21**	37	10	0
K **22**	37	10	0
K **33**	1	10	0
K **34**	2	0	0
K **35**	22	10	0
K **36**	15	15	0
L **1**	103	0	0
L **2**	97	0	0
L **3**	225	0	0
L **6**	16	15	0
L **7**	53	0	0
L **8**	31	10	0
L **12**	225	0	0
M **2**	79	0	0
M **3**	6	5	0
M **4**	3	15	0
M **5**	86	0	0
M **6**	8	10	0
M **7**	3	17	0
M **8**	195	0	0
M **9**	207	16	0
M **10**	267	14	6
M **11**	23	12	6
M **24**	83	12	0
M **25**	8	6	9
M **26**	115	5	9
M **27**	8	6	9
M **41**	105	0	0
M **42**	110	0	0

Catalogue Number.	Price. £	s.	d.
M **45**	40	0	0
M **46**	50	0	0
M **48**	105	0	0
M **53**	1	9	6
M **56**	2	16	6
M **57**	7	10	6
M **58**	0	15	3
M **73**	9	10	6
M **75**	93	0	0
M **84**	4	5	0
M **85**	6	0	0
M **86**	7	10	0
M **88**	8	10	0
M **92**	4	12	0
M **94**	5	0	0
M **98**	6	10	0
M **106**	7	5	0
M **110**	5	18	0
M **111**			
M **112**	1	4	0
M **113**	1	7	9
M **114**	1	11	6
M **115**	1	12	9
M **116**	1	17	6
M **117**	2	0	6
M **118**			
M **119**	1	17	6
M **120**	1	11	0
M **121**	1	11	0
M **122**	1	14	3
M **123**	1	15	0
M **124**	2	0	0
M **125**	2	3	0
M **126**			
M **127**			
M **128**	4	18	0
M **129**	5	7	0
M **130**	5	16	0
M **131**	6	5	0
M **132**	6	14	0
M **133**	7	3	0
M **135**	3	0	0
M **136**	3	0	0
M **138**	0	3	6
M **139**	0	4	6
M **140**	0	0	1
M **141**	0	0	1
M **142**	0	3	6
M **144**	11	10	0
M **147**	0	10	0
M **148**	182	0	0
M **149**	14	6	9
M **154**	99	0	0
M **156**	1	10	0
M **157**	12	7	0
M **158**	44	0	0
M **159**	6	15	0
M **160**	23	0	0
M **161**	18	0	0
M **162**	11	0	0
M **163**	10	10	0
M **169**	680	0	0
M **170**	13	0	0
M **171**	80	0	0
M **172**	74	10	0
M **173**	25	10	0
M **174**	97	0	0
M **178**	0	3	9
M **179**	1	1	0
M **180**	13	15	0
M **181**	13	15	0
M **182**	9	0	0
M **184**	9	5	0

Catalogue Number.	Price. £	s.	d.
M 189	6	6	0
M 191	27	10	0
M 192	28	5	0
M 193	7	5	0
M 194	32	10	0
M 195	0	10	0
M 197	161	0	0
M 198	125	0	0
M 217	30	0	0
M 219	36	0	0
M 220	127	0	0
M 223	25	0	0
M 226	19	10	0
M 227	17	0	0
M 234	1	5	0
M 236	27	10	0
M 237	39	10	0
M 238	44	0	0
M 239	30	10	0
M 240	42	10	0
M 241	47	0	0
M 243	0	12	6
N 1	113	0	0
N 2	129	0	0
N 3	157	0	0
N 4	20	0	0
N 5	1	15	0
N 6	121	0	0
N 7	137	0	0
N 8	165	0	0
N 9	12	0	0
N 10	1	9	3
N 11	2	11	6
N 12	3	9	6
N 13	3	1	3
N 14	3	4	0
N 15	3	9	6
N 16	14	5	0
N 17	4	19	0
N 18	6	15	0
N 19	3	10	0
N 20	1	12	0
N 21	3	2	6
N 22	9	9	0
N 23	5	0	0
N 24	10	16	0
N 25	7	15	0
N 31	20	0	0
N 32	143	0	0
N 33	159	0	0
N 34	187	0	0
N 46	30	0	0
N 47	620	0	0
N 48	45	0	0
N 49	7	0	0
N 50 } N 54 }	12	10	0
N 52	12	0	0
N 53	2	0	0
N 58	16	10	6
O 2	35	0	0
O 3	26	0	0
O 4	52	15	9
O 5	13	0	0
O 6	16	0	0
O 7	21	0	0
O 8	87	0	0
O 9	4	15	0
O 10	98	0	0
O 11	21	5	0
O 12	29	0	0

Catalogue Number.	Price. £	s.	d.
O 13	13	4	0
O 14	13	10	0
O 15	13	10	0
O 19	5	17	6
P 1	5	6	0
P 2	7	8	0
P 3	8	13	0
P 4	11	0	0
P 5	13	8	0
P 6	17	0	0
P 7	23	8	0
P 8	33	5	0
P 9	50	13	0
P 10	3	1	3
P 11	4	3	3
P 12	5	18	0
P 13	8	6	9
P 14	4	3	3
P 15	4	14	6
P 16	6	13	3
P 17	9	6	3
P 18	2	4	0
P 19	3	9	6
P 20	4	17	6
P 21	6	5	3
P 22	7	12	9
P 23	9	6	3
P 24	11	2	3
P 25	12	16	0
P 26	14	15	0
P 27	16	13	9
P 28	19	9	3
P 29	6	0	0
P 30	6	17	6
P 31	8	1	0
P 32	9	6	0
P 33	10	12	0
P 34	13	6	0
P 35	16	4	0
P 36	19	15	0
P 37	2	4	3
P 38	3	5	3
P 39	4	14	6
P 40	9	0	3
P 41	14	15	6
P 42	22	5	6
P 43	31	8	6
P 44	43	1	3
P 45	55	11	6
P 46	68	15	6
P 47	84	15	0
P 48	102	16	9
P 49	121	17	9
P 50	141	14	0
P 51	178	10	3
P 52	216	14	3
P 53	0	19	0
P 54	1	4	6
P 55	9	14	6
P 56	13	7	0
P 57	24	0	0
P 58	33	6	9
P 59	55	0	6
P 60	63	10	0
P 61	72	9	0
P 62	113	10	0
P 63	220	0	6
P 64	340	0	0
P 65	4	12	0
P 66	6	5	3
P 67	8	0	6

Catalogue Number.	Price. £	s.	d.
P 68	10	1	0
P 69	12	15	6
P 70	16	13	0
P 71	22	10	0
P 72	10	8	6
P 73	15	5	9
P 74	41	13	6
P 80	2	13	0
P 81	2	18	3
P 82	3	6	9
P 83	3	17	9
P 84	4	14	6
P 85	5	8	6
P 86	6	5	3
P 87	7	18	6
P 88	9	12	0
P 89	3	10	9
P 90	10	10	0
R 1	75	0	0
R 2	17	10	0
R 3	6	8	0
R 4	6	8	0
R 5	1	10	0
R 6	3	12	0
R 7	49	0	0
R 8	5	10	0
R 9	0	10	6
R 10	1	12	6
R 11	1	15	0
R 17	1	5	0
R 18	33	0	0
R 19	0	7	0
R 20	0	8	6
R 21	1	17	6
R 22	0	7	6
R 23	0	8	0
R 24	11	11	0
R 25	84	0	0
R 26	168	0	0
R 27	15	0	0
R 29	12	10	0
R 30	6	0	0
R 31	3	10	6
S 2	18	14	9
S 3	22	10	0
S 4	7	0	0
S 5	5	15	0
S 6	1	7	0
S 13	36	0	0
S 14	127	0	0
S 16	27	10	0
S 17	39	10	0
S 18	44	0	0
S 19	3	0	0
S 20	25	0	0
S 31	19	10	0
S 32	17	0	0
S 39	10	0	0
S 40	10	0	0
S 43	36	0	0
S 44	30	10	0
S 45	42	10	0
S 46	47	0	0
S 47	2	17	6
T 1	172	0	0
T 5	220	0	0
T 8	21	0	0
T 9	19	0	0

M. 5000/10/24. A. H. 3270.