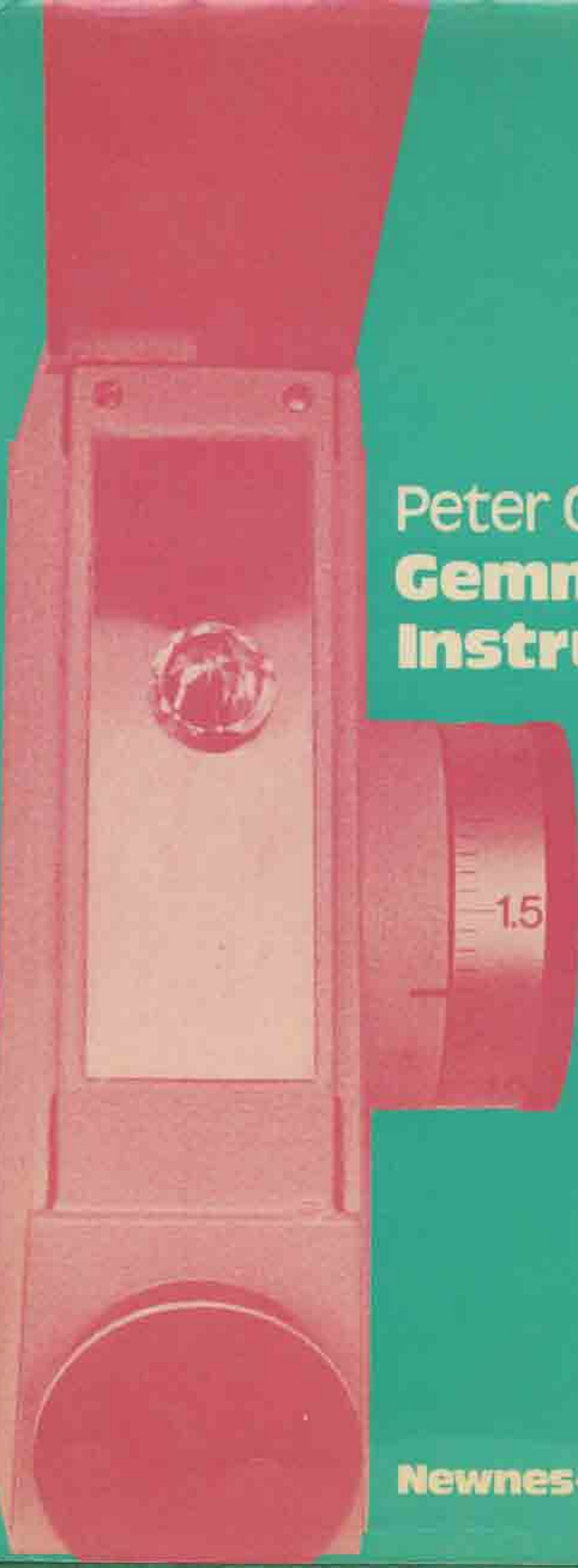

Peter G. Read

Gemmological Instruments

Newnes-Butterworths

Gemmological Instruments

their use and principles of operation

Peter G. Read, CEng, MIEE, MIERE, FGA, FISTC
Former Technical Manager of Diamond Trading Company (Pty) Ltd
(De Beers Central Selling Organisation)

Newnes-Butterworths
London-Boston
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COLOUR COMPARATORS

While the grading of polished gem quality diamonds by colour is a well established art (which is rapidly becoming a science), the classification of coloured gemstones into recognisable divisions of hue, saturation and luminosity is still in its infancy. The reason for this is that the difference in price per carat between diamonds of different shades of colour makes it important that a diamond colour grade is accurately specified. A more detailed appraisal of the various international diamond grading standards is given in chapter 12.

Now that the Diamond Commission of CIBJO[2] has been re-named the Diamond and Coloured Stone Commission, it is probable that grades for coloured stones, similar to the existing CIBJO colour and clarity grades for diamonds, will be formulated. These grades will probably consist of four scales, one for the hue, or colour, of the stone, one for the colour saturation, or shade, one for the luminosity, or brightness, and one for the transparency of the stone.

The microcolorimeter

A colour-comparator microscope, which can be used to establish classifications for coloured gemstones, has been developed by McCrone Research Associates in association with Tintometer.

This instrument enables the sample to be viewed and compared simultaneously with a set of calibrated colour filters, which can be inserted into the field of view to give combinations of hue and colour saturation. When the nearest colour match has been achieved with the filters, their reference numbers can be converted to the three-figure CIE[3] co-ordinates for classification purposes.

Chelsea colour filter (Gemmological Instruments Ltd)

Another colour aid, developed to distinguish between genuine emeralds and their paste and doublet simulants, is the Chelsea colour filter (*Figure 4.3*). This filter was the outcome of research work carried out in the Gem Testing Laboratory of the London Chamber of Commerce and at the Chelsea College of Science and Technology.

The filter is made in the form of a hand loupe, and consists of a combination of two gelatine filters designed to transmit only deep red and yellow-green light. This particular combination was chosen to match the unusual spectral response of emerald, which permits the transmission of light in the deep red, but absorbs it in the yellow-green.

When several green stones are strongly illuminated and are viewed through this filter, the genuine emeralds will appear distinctly red or pinkish in colour (depending on the depth of colour of the emerald), while green faceted glass, doublets and most soudé emeralds will appear green. There are, unfortunately, several exceptions to the filter's ability to identify genuine emeralds and to reveal simulants. Some emeralds, in particular those from South Africa, may not appear red or pink through the filter (fortunately these cases are relatively rare). In addition, synthetic emeralds react in the same way as natural emeralds, but the red colour usually appears more brilliant. Demantoid garnet and green zircon also give a pinkish effect.

On the credit side, however, the filter can be used to identify both natural and synthetic ruby, as these appear as a characteristic brilliant red, (due to the presence of chromium oxide). Synthetic blue spinels can also be tested, as these appear yellowish-orange or pink, which serves to distinguish them from aquamarine or sapphire, which appear green or greyish green.

As no naturally occurring transparent gem minerals contain cobalt, and as cobalt coloured materials appear pink or red through the filter (e.g. synthetic blue spinel and blue cobalt glass), any transparent blue gemstone which shows these colours through the filter should be suspect.

Colorimeters

Although two of the instruments described in this section are diamond grading colorimeters, they have been included in this chapter (rather than in chapter 12, which deals with diamond grading) as they are basically colour measuring devices.

Colorimeters[4] can be divided into two main types:

1. Tristimulus instruments which measure the intensity of the red, green and blue/violet light transmitted by (or reflected from) the sample.
2. Spectrophotometers, which measure the transmission losses (absorption) in the sample at selected wavelengths.

While the tristimulus instrument is capable of measuring any colour in the visible spectrum, it is a relatively complicated device, and for this reason diamond grading colorimeters are usually of the photometer type. As the colour to be measured is limited to a small range in the yellow, the photometer version can be further simplified by reducing the sampling wavelengths or colours to two.

Diamond-Photometer (Eickhorst) *(Figure 4.4)*

This colorimeter is of the spectrophotometer type and uses monochromatic yellow and blue light to measure the absorption of the diamond at these wavelengths, and is therefore only intended for the grading of those diamonds in the Cape series, white to yellow.

As can be seen in the diagram in *Figure 4.5*, yellow and blue light is directed, in turn, into the table facet of the diamond by means of a glass fibre light guide. Use is made of the optics of the brilliant cut stone to achieve total internal reflection of the sampling light, which is then collected as it emerges from the table facet by a second concentric light guide. The output of this second light guide is fed to a photo detector which is connected to a meter to indicate the intensity of the yellow and blue light.

These two intensities are called T1 and T2, and the ratio of these two figures is called the transmission quotient (by taking the ratio of T1 and T2, the effects of path length differences in diamonds of different size are cancelled out). The transmission quotient number is then converted to the appropriate diamond colour grade by means of a graph on the front of the instrument. Before each measurement is made, a white calibration plate is placed under the fibre optic head (in place of the diamond), and the calibration control is adjusted for a 100% transmission reading on the meter.

As previously explained, the photometer is only intended for the measure-

Figure 4.4
The Diamond-Photometer uses the ratio of monochromatic yellow and blue light to measure the colour grade of Cape series diamonds (Eickhorst)

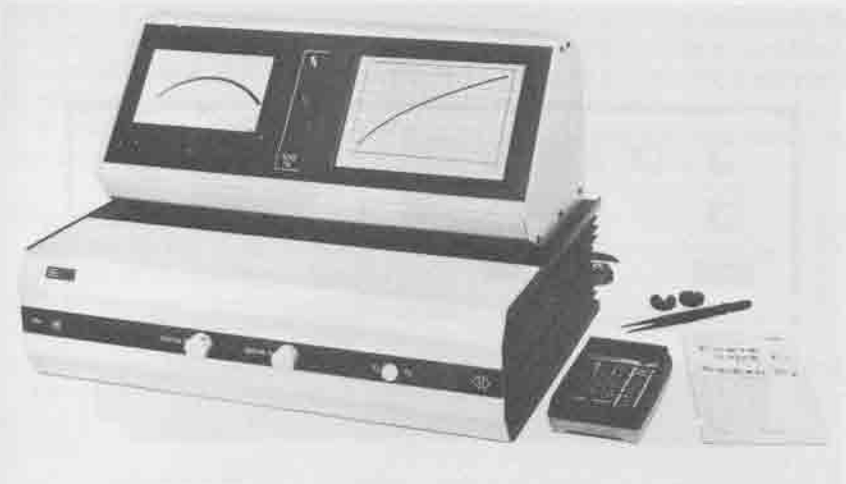


Figure 4.5

Diagramatic representation of the Eckhorst photometer. T 1 is the intensity of the transmitted blue light, and T 2 the intensity of the transmitted yellow light

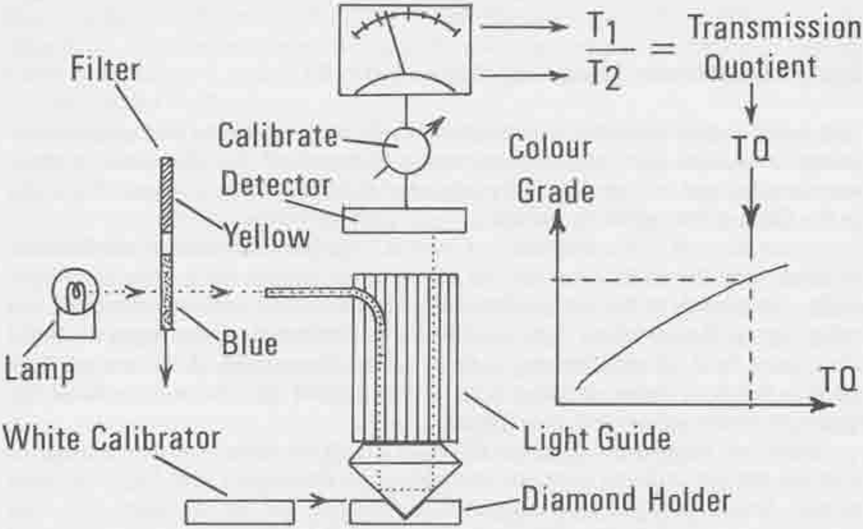
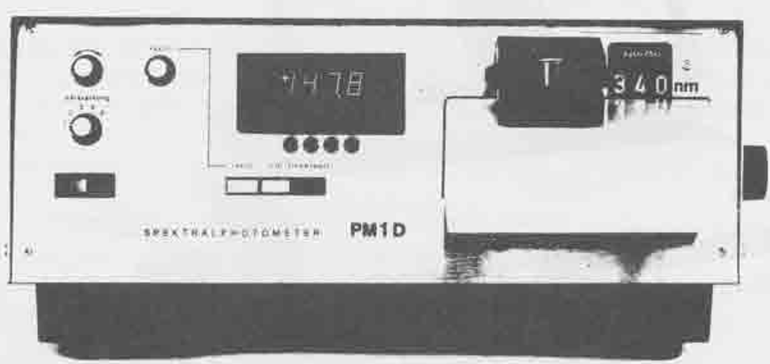


Figure 4.6

The Zeiss Spectrophotometer uses a monochromator to measure the absorption of the sample across the visible spectrum (Zeiss)



ment of Cape series diamonds, and those having a brown or green tint will give incorrect readings. Before being tested, diamonds should also be checked for fluorescence, as blue fluorescing stones will also give incorrect readings. The reason for this is that the U-V component in daylight, or in diamond grading lamps, causes the diamonds to appear whiter (because of the blue fluorescence) than the colour indicated by the instrument, whose yellow and blue sampling light does not excite fluorescence.

Shipley electronic colorimeter

This diamond grading colorimeter, now obsolete, is of the two-wavelength (yellow, blue) photometer type. It was designed by Mr. R. Shipley (of the Gemological Institute of America and the American Gem Society), but was only made available to members of the American Gem Society.

The GIA have developed a new photometer for diamond grading, which uses the yellow/blue transmission ratio. This instrument will be commercially available to the trade.

Spectrophotometer PM1D (Carl Zeiss) (*Figure 4.6*)

This instrument, unlike the Eickhorst and the Shipley/GIA, measures the transmission losses in the sample across the whole visible spectrum by means of a monochromator. The spectrum covered also includes LW U-V (320–750 nm; 3200–7500 Å), and the monochromator, which is of the grating type, has a band width of 10 nm.

For each discrete wavelength, transmission values are obtained which, when plotted as a graph against a wavelength base line, show a continuous transmission curve for the sample over the LW U-V and visible spectrum. From this curve, transmission quotients can be calculated for use in diamond grading, or, alternatively, tristimulus measurements can be extracted at the red, green and blue wavelengths and after further computations can be turned into colour grades. For a coloured gemstone the transmission curve represents an objective overall record of that stone's characteristic colour.

A more sophisticated version of this model, covering the U-V, visible and near infra-red spectrum of 185–2500 nm is described in Chapter 13.

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2. Confederation Internationale Bijouterie
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4. Wright, W. D., *The Measurement of Colour*, 4th Edition, Adam Hilger Ltd., London (1969)

ARTIFICIALLY COLOURED DIAMONDS

Perfect diamonds are colourless in that they do not selectively absorb any wavelength in the visible region of the spectrum. Bombardment of a diamond with high energy radiation, whether produced naturally or artificially, causes the stone to become coloured. The artificial production of colour centres in diamond has been studied in detail for three types of radiation, fast neutrons, fast electrons and gamma rays[18]. Neutron irradiated diamonds appear green, while electron or gamma irradiated stones have a blue-green colour.

It is not possible to remove a natural colour from a diamond by this treatment (i.e. to change a yellow stone to a lighter shade) as the colour change is an additive one, and is used commercially to change a yellow stone into a more acceptable, if darker, shade of green or blue.

The production of colour, or colour change, in diamond is the result of the radiation introducing defects into the lattice. The defects, which may be stable up to temperatures of 600° C, can become mobile within the lattice at higher temperatures, and the heat treatment of stones which have been turned green through irradiation can produce a more attractive shade of yellow or amber.

The colour produced by electron or gamma ray bombardment is only skin deep and can be polished off. Colour produced by neutron bombardment, however, penetrates the whole body of the stone. Such irradiation usually produces a cloverleaf or umbrella pattern round the culet.

The detection of diamonds which have been artificially coloured by irradiation and then heat treated, is by means of the spectroscope, which shows a diagnostic line at 594 nm, (together with the original line system at 415.5 nm if the stone was originally a yellow 'Cape').

A blue-green stone can be proved to be artificially coloured if it acts as an electrical insulator, as all naturally occurring blue diamonds are Type IIb and will pass an electric current.

Diamonds can of course be coloured by other means than irradiation[19]. To make a diamond appear more white, a translucent coating may be applied to its pavilion, the colour of the coating being the compliment of the body colour of the diamond. Such coatings can be removed by solvents such as alcohol or acetone.

A more scientific coating is the anti-reflection fluoride composition that is applied to camera lenses. A bluish fluoride coating applied to a yellow diamond will, by the mixing of the two complimentary colours, make the diamond appear less yellow. The coating can be detected as it kills the adamantine lustre of the surface to which it is applied. It can be removed by treatment in hot acid.

INFORMATION SOURCES ON SYNTHETICS AND SIMULANTS

For further information on the detection of synthetics and simulants, reference should be made to B.W. Anderson's 'Gem Testing' and to its French translation by C. A. Schiffmann 'Identification des Pierres Precieuses'. In order to keep abreast of new materials and testing techniques it is also advisable to read the

Each machine can size up to 3000 carats at one loading, and is capable of weighing each diamond in the batch to an accuracy of ± 0.005 carats at the rate of one every two seconds. The 'heart' of the machine consists of a Mettler KM102 electronic tablet balance, around which the CSO have designed their own feeding and sorting mechanisms and control circuits.

THE GRADING OF POLISHED DIAMONDS

We now move from the world of rough gem diamonds to that of the polished end product. Polished diamonds are graded to what is known as the 'Four C's' of colour, clarity, carat and cut. Over the years, various nationally accepted standards for the grading of diamonds for colour, clarity (or purity) and cut (or proportion) have become established.

Although the diamond dealer may evaluate a given diamond directly in terms of its buying or selling price, descriptive and acceptable grading classifications are necessary for the international trading in polished diamonds. For many years, the various national grading standards and descriptions tended to increase rather than reduce the confusion in the communication of diamond classifications on an international level.

The establishment of a Diamond Commission (now renamed the Diamond and Coloured Stone Commission) by the international jewellery organisation CIBJO[6] has resulted in a common set of colour and clarity grades being established in eleven countries. The CIBJO grades, and their relationship to the various national grades, will be described in detail later in this chapter.

The following description of the grading of polished diamonds for colour, clarity and cut is intended only as an introduction to the associated equipment. For a more detailed appraisal of grading techniques, reference should be made to Mr. E. Bruton's book 'Diamonds' (NAG Press Ltd, 1st edn, 1974) and Varena Pagel-Theisen's 'Handbook of diamond grading' (Druckerei Haus, Hanau, 4th edn 1973).

Colour grading

For the colour grading of polished diamonds, two essentials are required. One of these is the correct illumination, and traditionally this is a neutral (i.e. white) north light (or, in the sourthern hemisphere, such as South Africa, a south light). The second requirement is for a colourless background so that the eye is not biased by its attempts to compensate for surrounding colours (e.g. the eye will eventually adapt itself to seeing a slightly tinted background as white).

The colour grading of a polished diamond depends upon the ability of the grader to both see and appraise the body colour of the stone. As a brilliant cut diamond is fashioned so that as much as possible of the light entering its crown facets is reflected back, it follows that it can be quite difficult to look into the stone and form an appreciation of its body colour.

Experience has shown that one of the best methods of appraising a diamond's colour is to lay it, table facet down, in the crease of a piece of folded white paper, or card, and to inspect the diamond through the side of the pavilion.

Until fairly recently, no attempt was made to continue with the colour grading of diamonds once the natural daylight had faded. These days, there are several colour corrected fluorescent lamps available which enable the colour grading of diamonds to be continued successfully under artificial daylight conditions. In fact, having spent many hours in the colour sorting/grading of both rough and polished diamonds, the writer believes that once experience has been gained in the use of a colour-corrected lamp, the most consistent results (certainly in the absence of comparison stones) are achieved by using the same light source full time.

The colour grading of diamonds is greatly assisted by the use of a master set of comparison stones. These stones should be correctly proportioned, but need not be flawless, although any flaws present should not be visible without the aid of a loupe, and should not affect the colour or transparency of the stone. For the grading of diamonds up to half a carat, the master stones should not be smaller than 20 points (0.2 carat).

While most diamond grading laboratories use comparison stones, use is also made of electronic colorimeters to measure the colour of diamonds. A description of some of these commercial instruments is given in Chapter 4, which deals in a general way with the appearance of gemstones in terms of their colour.

Another good argument for the use of a 'daylight' type diamond grading lamp is that the 'north' light varies considerably in the different hemispheres. There is also a marked difference in the colour balance between daylight in the early morning, light from an overcast sky, and that from a clear north sky. These variables have been clearly illustrated in a graph contained in an article on diamond colour measurement by Mr. M. Eickhorst[7].

A large proportion of diamonds fluoresce under ultra-violet light, and because daylight (and 'daylight' fluorescent lamps) contains a proportion of ultra-violet rays, such stones can appear to be 'whiter' than they actually are because of their blue fluorescence. For this reason, most lamps have a diffusing cover over their fluorescent tubes which absorbs ultra-violet rays, and, in addition, have a separate LW ultra-violet lamp which can be used independently to check diamonds for fluorescence.

DIAMOND GRADING LAMPS

The following paragraphs describe a selection of lamps and accessories designed specially for the colour grading of diamonds.

Diamondlite (GIA/Gem Instruments Corp.) *(Figure 12.5)*

This unit not only provides a diffused illumination similar to that of north daylight, but also encloses the area adjacent to the test position with a neutral white background.

The diamonds to be graded can either be placed on the large display pad, together with comparison stones, or if a more subdued lighting is required,

Figure 12.5
The GIA 'Diamond-Lite', provides a daylight illumination and a neutral background for the colour grading of diamonds (Gem Instruments Corp.)

they can be placed in the translucent adjustable tray and inserted in the recessed compartment at the top of the unit. This allows the light to be filtered through the translucent tray before entering the diamond.

The unit is fitted with a separately-controlled LW ultra-violet light source to test diamonds for fluorescence.

Colour grader (GIA/Gem Instruments Corp)

This is an adjustable translucent white diamond grading tray for use with the GIA Gemolite microscopes and the Diamond Grader microscope.

Overhead light source (GIA/Gem Instruments Corp)

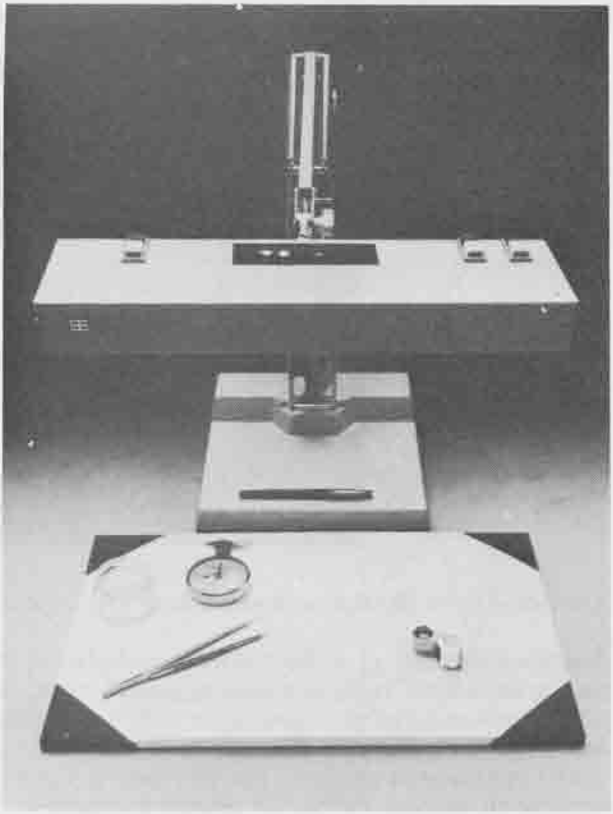
An incident light source designed for general and diamond grading use with the GIA Gemolite microscopes and the Diamond Grader microscope. It is fitted with two 4 W fluorescent tubes which are covered with an opalescent diffuser.

Daylight lamp, B-Type (GAAJ)

A five-sided open-fronted cabinet with two 6 W colour corrected fluorescent tubes designed to simulate north light and centered on a wavelength of 480 nm (4,800 Å). The tubes are mounted in the top of the cabinet and are covered with a diffusing plate of translucent acrylic sheet.

An independently controlled LW ultra-violet back light is also fitted to check diamonds for fluorescence. The unit is designed for 110 V, 50/60 Hz operation, and requires a step-down transformer for use on 220 V.

Figure 12.6
The Dialite diamond grading lamp (Eickhorst)



Daylight lamp stand, S-Type (GAAJ)

This uses two 6 W fluorescent tubes designed to simulate north light, with their emission centered on a wavelength of 480 nm (4800 Å). The tubes are covered with a translucent white plate.

Dialite desk lamp (System Eickhorst) (*Figure 12.6*)

This unit employs double spring-counterpoised arms enabling it to be adjusted to a variety of heights and positions. Two 8 W daylight fluorescent tubes (selected to comply with the 5000 degrees Kelvin ISO colour standard) are fitted in the lamp head and these can be used together or singly. The head also carries a LW ultra-violet lamp, and this is fitted so that it shines upwards. To test a diamond for fluorescence, the lamp head is moved to a position so that its top is level with the eyes. The diamond is then placed on top of the U-V lamp and viewed in line with the plane of the girdle. This method of viewing ensures that the eyes are protected from the U-V rays, and enables a fluorescing stone to be seen with best contrast.

Figure 12.7
The Koloriscope G + S diamond grading cabinet employs daylight tubes having a colour temperature of 5000° K (BAG Bronzewarenfabick AC)

Koloriskop G + S (BAG Bronzewarenfabrik AG) (*Figure 12.7*)

Developed from Mr. C. A. Schiffmann's specification, this Kolariskop diamond grading lamp is the latest in a series originated by Dr. Gübelin. The Kolariskop G + S produces a daylight illumination which has a colour temperature of 5000 degrees Kelvin, and meets the ISO Standard 2243 (a standard considered by CIBJO for diamond grading). The unit uses special fluorescent tubes with a refractor to produce the correct spectral illumination. The tubes are pre-aged to maintain the standard of illumination without noticeable variation for a working life of 3000 hours. A carefully selected shade of grey for the background of the instrument's grading chamber ensures neutral colour adaption by the eye.

A removable U-V filter is provided (with a sharp cut-off below 400 nm), and this removes any residual ultra-violet light from the source, enabling accurate colour comparisons to be made in non-fluorescing conditions. A diamond tray is provided with each unit. Mains supply is 110 V, 60 Hz or 220 V, 50 Hz.

CLARITY GRADING OF POLISHED DIAMONDS

The colour grading lamps just described are, of course, equally useful as sources of illumination when grading polished diamonds for clarity or purity (i.e. inspecting them for inclusions and flaws).

Apart from adequate illumination, the only other equipment necessary (assuming that the diamond has first been carefully cleaned) is a 10X hand loupe, or a microscope with a 10X magnification, this being the standard magnification specified for the clarity grading of diamonds.

GRADING STANDARDS

Table 12.1 shows the relationships between the various national colour grading systems and the international CIBJO[6] grades. The original top three grades in the CIBJO system (Exceptional White, Rare White and White) have now been subdivided into five grades, corresponding with the GIA grades D, E, F, G, H.

Table 12.1
Colour grading standards for polished diamonds

UK	*German RAL Scan. D.N. (0.5 carats upwards)*	*Scan. D.N. (under 0.5 carats)*	*GIA*	*AGS*	*CIBJO*
Finest White	River	Rarest White	D	0	Exceptional White +
			E		Exceptional White
Fine White	Top Wesselton	White	F	1	Rare White +
			G		Rare White
White	Wesselton		H	2	White
				3	
Commercial White	Top Crystal	Tinted White	I	4	Slightly Tinted White
Top Silver Cape	Crystal		J		
				5	
Silver Cape	Top Cape	Yellowish	K		Tinted White
			L	6	
Light Cape	Cape		M		Tinted Colour
			N	7	
Cape	Light Yellow		O		
			P	8	
			Q		
Dark Cape	Yellow	Yellow	R		
			S -X	9–10	

All of the grades shown in the table are based on carefully chosen sets of master stones. With the exception of the CIBJO grades, these master stones correspond to the centre colour of each grade. In the CIBJO system, the master stones are chosen to correspond to the lower limit of each grade, and this makes it much easier to decide to which grade a borderline stone belongs. For the original six CIBJO grades, sets of five master stones were chosen and supplied to the various grading laboratories. Now that two extra grades have been introduced, these master sets will comprise seven stones.

Table 12.2 shows the relationship between the various national clarity grading systems and the international CIBJO grades.

Table 12.3 explains briefly the range of inclusions or flaws associated with each clarity grade.

Peter G. Read

The author, a Chartered Engineer, is a Consultant specialising in gemmology and electronic engineering. He is a Fellow of the Gemmological Association of Great Britain and holds their Gem Diamond Certificate. His previous appointments include senior development engineer with Johnson Matthey & Co. Ltd, and Technical Manager of the Diamond Trading Co. (Pty) Ltd (De Beers Central Selling Organisation). He has contributed many articles on instruments to technical journals.

In his work as an engineer, Peter Read has designed automatic gold grain weighing machines for the production of 10-tola gold bars, and a specialised electron beam welder for the fabrication of platinum components. He has also designed many automatic diamond weighing and sorting equipments. At the present time he is investigating the use of the microprocessor as a diagnostic aid in gemstone identification.

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