Objective Diamond Clarity Grading

Michael D. Cowing

The diamond clarity grading scale used worldwide today was introduced by the Gemological Institute of America (GIA) in 1953. To help address varying interpretations and inconsistencies in clarity grading between laboratories (and even within some labs), this article introduces an objective system for diamond clarity grading. The determination of the clarity grade is influenced by up to five factors: size, number, contrast (colour and relief), position and nature of the inclusions. The proposed system assesses these factors (with emphasis on the first four) by using an objective metric that emulates the intuitive analysis done by experienced diamond graders. Using high-quality photographs of more than 100 randomly selected diamond examples, this article demonstrates a high degree of agreement between clarity grades obtained using this system and those determined by GIA and the American Gem Society Laboratories (AGSL). The system's objective methodology may offer a means for improving inter- and intra-laboratory grading consistency.

The Journal of Gemmology, 34(4), 2014, pp. 316–332, http://dx.doi.org/10.15506/JoG.2014.34.4.316

Introduction

Diamond grading by gem laboratories, gemmologists, and valuers/appraisers consists of an evaluation of the four diamond characteristics of cut, colour, clarity and carat weight. These '4 Cs' are the criteria upon which cut and polished diamonds (e.g. Figure 1) are valued and marketed.

Clarity grading is a judgement of the degree to which a diamond is free of inclusions and imperfections when viewed with the 10× magnification of a jeweller's loupe or gemmological microscope. In April 1953, GIA under then-president Richard T. Liddicoat introduced systems for both the colour and clarity grading of diamonds (Shuster, 2003). GIA's clarity grading scale expanded upon terms and definitions that had evolved through trade usage over more than a century. For example, Wade (1916) described diamond imperfection with terms such as 'v. v. s., or very very slight', 'slightly imperfect' and 'imperfect'. GIA's expansion of clarity grading terminology was necessary, as Liddicoat noted, because "There weren't a large enough number of grades to fit the market.…We had to have more" (Shuster, 2003).

GIA's clarity grading scale, like its diamond grading system, has become the model for laboratories throughout the world. The terminology and definitions of this scale are universally used to communicate to the gem trade and consumers the purity aspect of diamond quality.

Today, non-GIA laboratories commonly employ clarity scales and terminology that largely retain the nomenclature and definitions of the original GIA system, although these systems have evolved and their implementations vary to

Figure 1: Faceted diamonds such as these are graded according to the '4 Cs' of cut, colour, clarity and carat weight. The round brilliants shown here have clarity grades ranging from VS_1 to SI_1 and weigh 1.12–1.83 ct. Photo by M. Cowing.

differing extents from GIA and from one another. This evolution has resulted in inconsistent grading from lab to lab and even within labs. Standardized clarity grading remains an elusive goal that, due to its subjective nature, many believe is unattainable.

This article introduces a new method of clarity grading that challenges this belief. It is comprised of objective metrics that are used to model the techniques of expert graders whose proficiency results from extensive experience and practice. Photographic examples that use GIA-graded diamonds demonstrate the accuracy and consistency of this system. First, a review of the GIA definitions of each clarity grade will show the subjective nature of existing methodology. Then the new objective system will be introduced and illustrated by various examples from several clarity categories.

The Diamond Clarity Grading Scale

GIA's clarity grading scale consists of 11 grades (Figure 2a): Flawless (Fl), Internally Flawless (IF), two grades of Very Very Slightly Included (VVS_1, VVS_2), two grades of Very Slightly Included (VS_1, VS_2), two grades of Slightly Included (SI_1, SI_2), and three grades of Included (formerly Imperfect; I_1, I_2, I_3).

Diamond imperfections are classified as either external surface features called blemishes or internal features called inclusions (which may also extend to the surface). Blemishes include features such as small extra crown facets, surface graining and certain naturals. They affect determinations between the top two clarity grades of Fl and IF. Below IF, inclusions are the principal determiners of a diamond's clarity grade. Surface scratches, which have depth, are graded as inclusions. In practice, no distinction is made between a shallow feather and a deep scratch. What counts most is inclusion noticeability, which is strongly weighted toward the face-up view (P. Yantzer, pers. comm., 2014). Although inclusions are three-dimensional in nature, it is their two-dimensional appearance mainly observed face-up that is assessed for noticeability.

A diamond's clarity characteristics are plotted using darkfield illumination (side lighting against a dark background), but the final judgement of clarity is made with the diamond held face-up using overhead (above-diamond) lighting. The latter arrangement reveals the noticeability of inclusions as seen under typical viewing circumstances.

The following clarity grade definitions (GIA, 1994; GIA, 2004, 2006) assume a skilled grader working with 10× fully corrected magnification (loupe or microscope) and effective illumination (diffused horizontal lighting with a loupe or darkfield illumination with a microscope):

- Flawless (Fl): No inclusions or blemishes of any kind.
- Internally Flawless (IF): No inclusions and only insignificant blemishes.

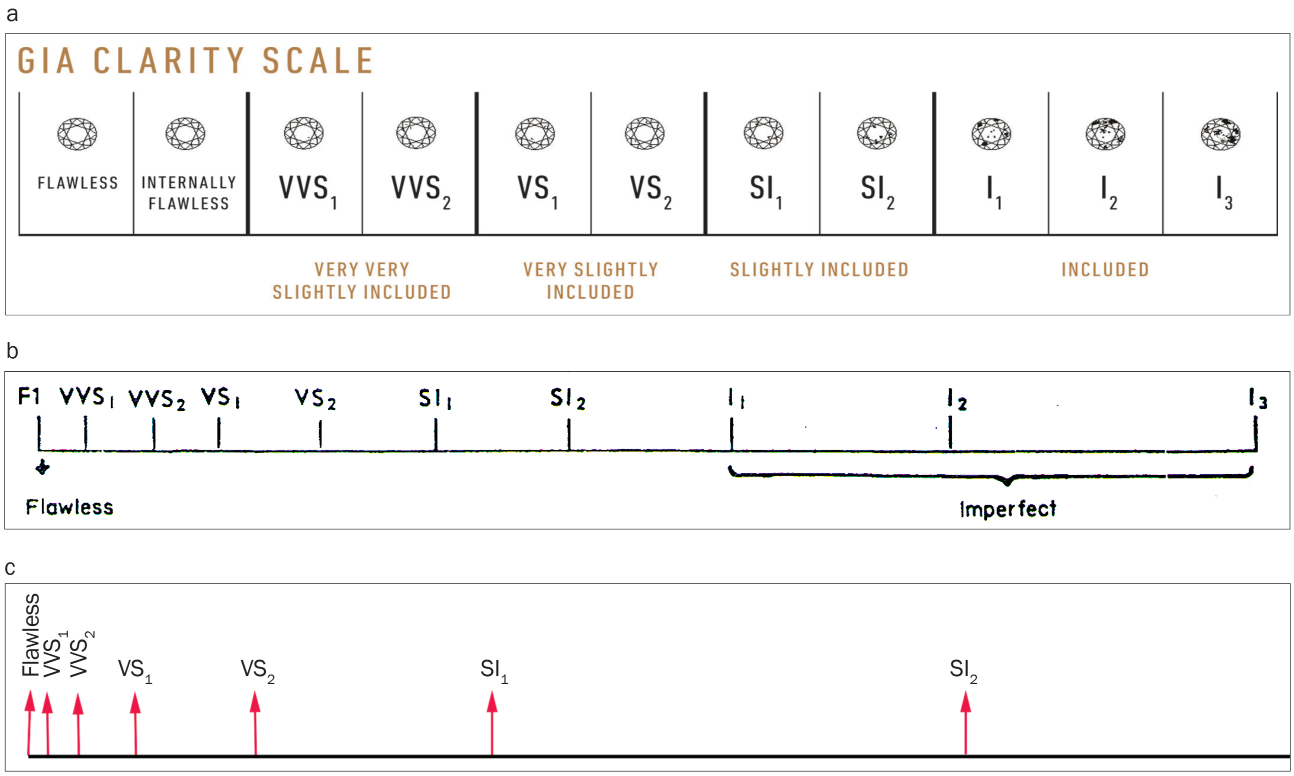


Figure 2: (a) GIA's clarity grading scale consists of 11 grades, ranging from Flawless to Included (formerly Imperfect). (b) This early representation of GIA's clarity scale (GIA, 1969) shows an increase in spacing from higher to lower grades. (c) This diagram shows the actual increase in spacing (and in inclusion dimensions) of a portion of the grading scale, corresponding to a doubling in dimensions of grade-setting inclusions from one grade to the next lower grade.

- Very Very Slightly Included: Minute inclusions that range from extremely difficult (VVS_1) to very difficult (VVS_2) to see.
- Very Slightly Included: Minor inclusions that range from difficult (VS_1) to somewhat easy (VS_2) to see.
- Slightly Included: Noticeable inclusions that are easy (SI_1) or very easy (SI_2) to see with 10× magnification, but usually are not easily noticeable to the unaided eye.
- Included (formerly Imperfect): Obvious inclusions under 10× magnification that are easily eye-visible face-up (I_1, I_2 and I_3); for I_3, they severely affect transparency and brightness, and may threaten durability.

Attaining Accuracy and Consistency in a Subjective Clarity Grading System

The subjective definitions of the clarity grades make it challenging to attain accuracy and consistency with this system. This is particularly the case for the beginning grader, as it is difficult to comprehend what an experienced observer sees as 'extremely difficult', 'very difficult', 'difficult' or 'somewhat easy' to locate under 10× magnification. In addition, GIA's diamond grading course notes that "It is important to remember…that it is impossible to develop a precise description of any clarity grade except flawless.…Clarity grading is like appraising a painting…: It is the overall picture that sets the clarity grade. Clarity grading is as much an art as an objective science; becoming really proficient at it takes time, experience, and practice" (GIA, 1994, p. 2).

Observations like these may seem daunting. However, GIA does offer this encouragement: "…most people learn to 'sense' the grade immediately. With a little practice, you will know by a sort of educated gut instinct what grade category a stone falls into, almost at first glance" (GIA, 1994, p. 15).

Developing a 'sense' for the clarity grade is subjective and open to variability in interpretation from grader to grader and from lab to lab. How is it possible that experienced graders can most often agree on a diamond's clarity grade, at least within a particular lab's system? The not very satisfying answer given in diamond courses is that consistency is only gained over time, through observation of diamonds of all clarities, sizes and shapes with their myriad inclusion variations.

Inclusion Characteristics that Impact Diamond Clarity Grades

Determination of the overall impact that inclusions have on the clarity grade is influenced by up to five factors: *size, number, contrast* (colour and relief), *position* and *nature*. "The nature of a clarity characteristic is based on two general distinctions. Whether it is internal or external is one: Below IF, the clarity grade is almost always set by inclusions; blemishes generally have little or no effect on it. The second is whether a particular characteristic poses any risk to the stone. Most do not" (GIA, 1994, p. 12). Below IF, this most often leaves the combined judgement of the first four of these factors as the determiner of the clarity grade.

The clarity grade of most diamonds is correctly established by assessing the single largest inclusion or a small number of similar major inclusions. Such factors are referred to as the 'grade-makers'. The four main clarity factors (size, number, contrast and position), judged together for the largest grade-maker inclusion(s), most often determine a diamond's clarity grade.

A salient feature among the four clarity factors is *size* which, along with the degree of *contrast* between the inclusion and the surrounding diamond, determines the visibility of a given inclusion. The larger the inclusion and the greater its contrast, the more it stands out and the lower the grade. *Number* comes into consideration when the largest 'grade-maker' inclusions are more numerous than one. Three or four similar grade-maker inclusions are likely to lower the clarity one grade more than would a single similar feature. Multiple grade-maker–size inclusions are effectively handled in most cases by grading them the same as an equivalent inclusion with similar total area. Lastly, consideration is given to the *position* of the grade-maker inclusions within the diamond. Viewed face-up, those under the table (in what is called the 'heart' of the diamond) are most noticeable and are graded most severely. Inclusions touching or near the girdle are least noticeable and are often graded more leniently. Features that are deep enough in the 'heart' often reflect in multiple positions, which may result in a lower grade. Early GIA instruction was to penalize by one grade an inclusion that had a lot of reflections (P. Yantzer, pers. comm., 2014).

To arrive at a clarity grade, the new objective system evaluates the four clarity characteristics together, combining them in a manner that emulates the practice of experienced graders. This is done by utilizing aspects of human perception concerning the noticeability of inclusions. An analysis of early efforts at objective clarity grading (discussed below) leads to two key observations:

1. The grade-defining property of inclusion noticeability is directly related to inclusion area. If inclusion 'grade-makers' have the same area and only differ in their length and width, they are perceived to have similar noticeability and most often will receive the same grade.
2. The increase in inclusion size from one grade to the next is not constant, but approximately follows a doubling of the inclusion's dimensions. That rough dimension doubling, which is a quadrupling in area, is surprisingly consistent from grade to grade across the entire clarity scale.

From Figure 2b it is clear that the range or distances on the GIA clarity grading scale between the lower grades is significantly larger than the distances between the higher grades. However, based on the inclusion size factor indicated in the second key observation mentioned above, the actual increase in distance from grade to grade is even more pronounced, as shown partially in Figure 2c. Surprisingly, an approximate doubling in dimensions of grade-setting inclusions occurs from grade to grade across the entire scale. Because of this doubling in dimension (and therefore an increase in area by about a factor of four), each decrease in clarity grade corresponds to a large multiplicative escalation in inclusion size and noticeability. Figure 3 provides an example of

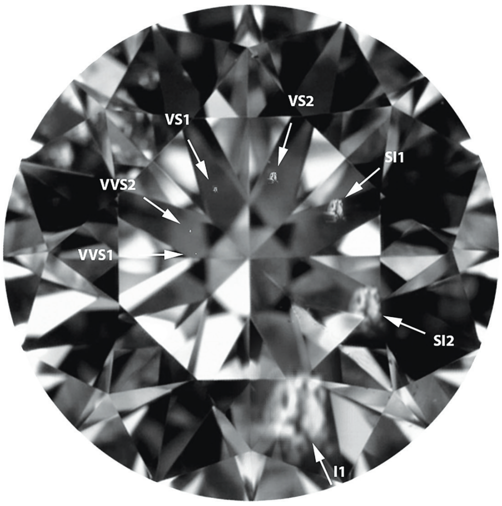


Figure 3: Illustrating the relative increase in inclusion size from grade to grade are these seven inclusions that have been digitally inserted in a 1.11 ct diamond (6.66–6.63 × 4.11 mm). The inclusions are sized according to clarity grades that range from VVS_1 to I_1.

Figure 4: This 1.11 ct diamond (6.66–6.63 × 4.11 mm) contains four SI_1-size inclusions that have different dimensions, but the same area and contrast, and thus similar noticeability. Each has an area determined to be approximately 35,000 μm².

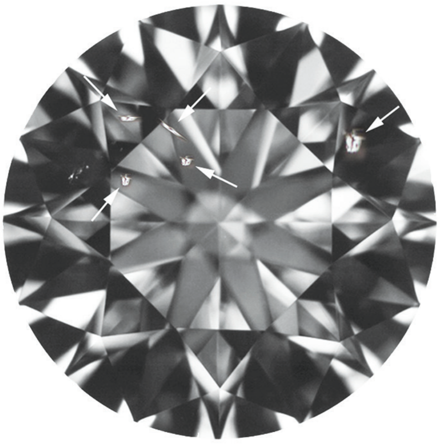


Figure 5: This 0.70 ct diamond (5.74–5.71 × 3.52 mm) contains four VS_2-size inclusions between the 10 and 11 o'clock positions near the table edge. All of these inclusions have the same area and noticeability, despite their varying dimensions.

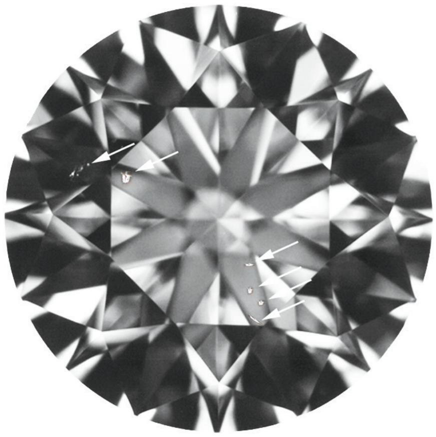


Figure 6: The same 0.70 ct diamond as in Figure 5 is shown here containing four VS_1-size inclusions at 5 o'clock inside the table. Each one has one-quarter the area of the VS_2-size inclusion seen at 10 o'clock. Taken together, the VS_1 inclusions would receive one lower grade of VS_2.

this increase in inclusion size from clarities of VVS_1 to I_1.* To provide visual support for the two key observations listed above, carefully sized inclusions also have been inserted into the darkfield diamond images in Figures 4–6.

* Unless otherwise noted, all of the diamond images from Figure 3 onward were taken by Jonathan Weingarten and are scaled to show 10× magnification. The original colour photographs were converted by the author to black-and-white images after it was determined that the colours resulting from diamond's high dispersion distracted from finding and judging the noticeability of inclusions.

In Figure 4, four SI_1-size inclusions in a 1.11 ct diamond have different dimensions but nearly identical area and contrast, and therefore each one has similar noticeability. Individually, each inclusion would be graded identically as SI_1 because each has the same area (roughly 35,000 μm²) and the same contrast (relief).

In Figure 5, the four inclusions between the 10 and 11 o'clock positions in the 0.70 ct diamond are the 'crystals' in Figure 4 reduced to half their dimensions and a quarter of their area (8,800 μm²). This reduces their noticeability and improves the clarity by one grade to VS_2 when

Figure 7: This 1.11 ct SI_2-graded diamond (6.66–6.63 × 4.11 mm) contains a white crystal and a string of five smaller dark-appearing inclusions, for a combined clarity grade of high SI_2.

Figure 8: Contrast the stone in Figure 7 with this 1.05 ct diamond (6.57–6.59 × 4.03 mm), which received the same SI_2 clarity grade despite having a much larger reflecting crystal inclusion.

they are considered individually. Again, despite their differing dimensions, all four inclusions are individually graded the same because each has the same area and amount of contrast. All four together have the same area as the single SI_1 inclusion seen at the 2 o'clock position in Figure 5. Thus, with similar overall area and impact on noticeability, four VS_2-size grade-maker inclusions evaluated together most often receive the same clarity grade as a single SI_1 grade-maker.

Reducing those four crystals by another factor of two in dimension (and factor of four in area) results in the group of four tiny crystals that are seen at the 5 o'clock position in the 0.70 ct diamond in Figure 6. Individually each of these inclusions is graded VS_1. Evaluated together as a group, they have similar total area and noticeability as the VS_2 inclusion at the 10 o'clock position in Figure 6. Therefore collectively these inclusions would receive one clarity grade lower (VS_2) than when they are considered individually.

An additional example is provided by this diamond's original string of three VS_1-size crystals under the crown main facet at 10 o'clock in both Figures 5 and 6. Considered together, GIA graded these inclusions VS_2.

Since for each successive grade a particular inclusion type increases in dimension by about a factor of two, the range of inclusion dimensions *within* each successive grade also increases by the same factor. For example, an inclusion in a low-borderline SI_2 can be almost twice the dimensions (and about four times the area) of a high borderline SI_2 of similar nature. Compare the large differences in size and noticeability between the identically GIA-graded (SI_2) ~1 ct diamonds in Figures 7 and 8. The SI_2 in Figure 7 should bring a large premium over the SI_2 in Figure 8, but price guides and the market in general currently value them the same. Shouldn't a clarity grading system account for what should be a significant value difference between these two widely different clarity appearances? The current scale lacks sufficient definition for the market in the grades of SI_2 and below. These two identically graded SI_2 diamonds bring to mind Liddicoat's statement "There weren't a large enough number of grades to fit the market.... We had to have more."

With more lower-clarity diamonds entering the market, the relatively large range of SI_2 and the much greater range of I_1 created market demand for an intermediate grade for stones containing inclusions with a combined area that is close to I_1 but that have too good an appearance to be lumped together with typical I_1 diamonds. That need prompted the introduction of an SI_3 grade in 1992, initially by Tom Tashey, then owner of EGL Los Angeles (T. Tashey, pers. comm., 2014). However, attempts to meet this market need have largely been frustrated by misuse. The lack

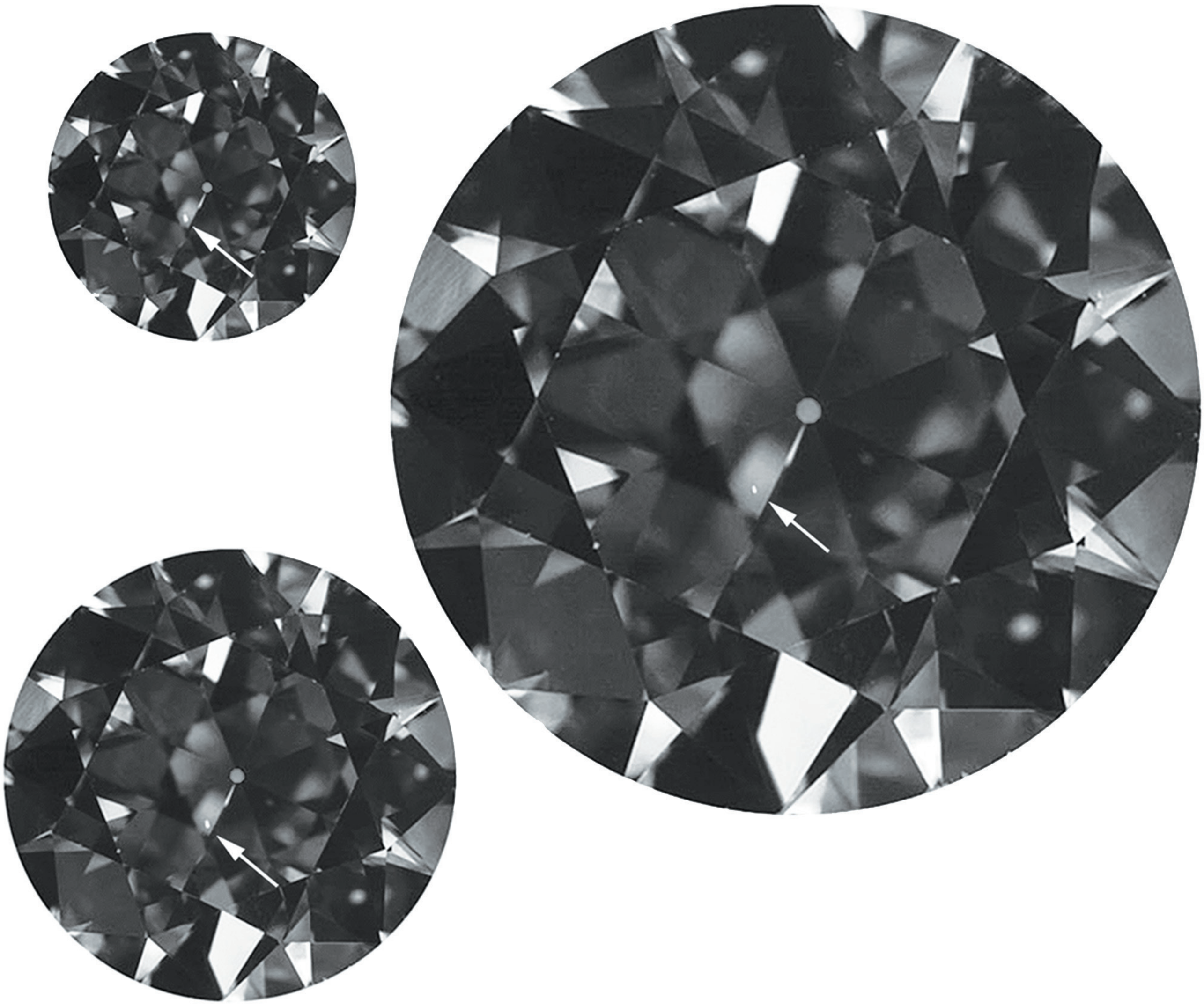


Figure 9: An identical VS_2-size crystal inclusion is shown in these diamond images that have been rescaled to the equivalent of ⅓, 1 and 6 ct. The inclusion has similar noticeability in all three images, and would result in the same grade over this large range of diamond sizes.

of objective grading standards has led to wide discrepancies and an increase in inclusion sizes that are assigned SI_3 grades. In fact, diamonds graded SI_3 often extend well into the GIA I_1 grade. (Note that although many in the diamond trade and some laboratories have adopted the SI_3 designation, it is not recognized by GIA.)

The Relationship of Inclusion Size to Diamond Size

Thus far absolute inclusion size has been addressed, but not inclusion dimension relative to diamond size. In very small diamonds, inclusions that occupy a significant percentage of the diamond's dimensions may be graded more severely. As well, an inclusion in a large diamond may be less noticeable and for that reason may be graded less severely. In general, the system presented here has been found to be accurate independent of diamond size over roughly the range of round diamond diameters from 4.5 mm (⅓ ct) to 11.8 mm (6 ct). This is particularly the case for clarities ranging from VVS_1 to VS_2, as well as most SI_1 diamonds. To illustrate this, the image of a VS_2-size inclusion in a 1.00 ct diamond was copied and pasted into the same location in two images of the same diamond scaled to ⅓ ct and 6 ct (Figure 9). The inclusion in all three diamonds is seen to be of the same category: a 'minor inclusion that is somewhat easy to see under 10× magnification', corresponding to VS_2 over this range of sizes.

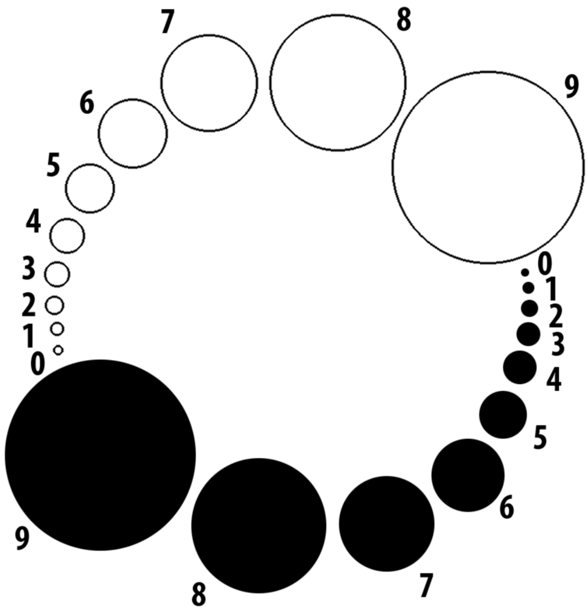


Figure 10: The Porton graticule consists of circle diameters increasing by the factor √2. Drawing by M. Cowing.

Previous Objective Clarity Grading Systems

In the 1970s, there were two notable attempts to reduce the subjectivity of diamond clarity grading through objective measurements of inclusion size combined with refinements in the factors of inclusion contrast, number, and location within the stone.

Contributions by Roy Huddlestone and DGL, London

Huddlestone introduced at the Diamond Grading Laboratories (DGL) the use of a Porton graticule to measure diamond inclusions. As mentioned by Bruton (1978), this graticule, a version of which is shown in Figure 10, consists of circles numbered 0 to 9 that increase in diameter by the factor √2 (a doubling in area). By fitting an inclusion's length and width to the nearest Porton circles that just enclose each dimension, a measure of inclusion size in Porton numbers is obtained. This transformation from dimensions to circle numbers is a useful and ultimately instructive process. An approximate representation of an inclusion's area (multiplication of length by width) is obtained by simply adding the corresponding circle numbers for its length and width. (Addition in the 'Porton domain' equates to multiplication of length times width, yielding a measure of an inclusion's area.) If the inclusion is rectangular, the area measurement is exact. Irregular or circular features have slightly less area than the product of length and width, but with a little ingenuity they are adequately characterized by this technique. For instance, a tapering inclusion's area is accurately approximated by adding the Porton circle number for its length to that for its average width.

In DGL's system, the total area score, which was obtained in this manner for each significant inclusion, was converted to a 'primary point count' (Burr et al., 1981) that was then adjusted for 'brightness' (the equivalent of contrast or relief) and 'its position in the stone' to arrive at a final point count establishing the clarity grade.

Contributions by Kazumi Okuda

Okuda incorporated his version of the circle graticule into his diamond grading microscope. Having been introduced to DGL's system by Roy Huddlestone (R. Huddlestone, pers. comm., 2014), he used a circle graticule to measure inclusion area in a manner similar to DGL. An important difference is that Okuda's circles increased in diameter not by the factor √2 but by a factor of 2. Table I shows Okuda's conversion from micrometre measurement to his circle numbers. As seen in an excerpt of the instruction manual (Figure 11), a representation of inclusion area is obtained by adding the circle numbers that just enclose the inclusion's length and width.

Okuda's most important contribution to objective clarity grading was his clarity conversion table (Figure 12), which converts the area score to a clarity grade. For cases in which no adjustment is needed for contrast or position, such as a grade-

Table I: Okuda's conversion from micrometres to circle number.

Size (μm)	Circle number
10	1
20	2
40	3
80	4
160	5
320	6
640	7
1,280	8
2,560	9
5,120	10

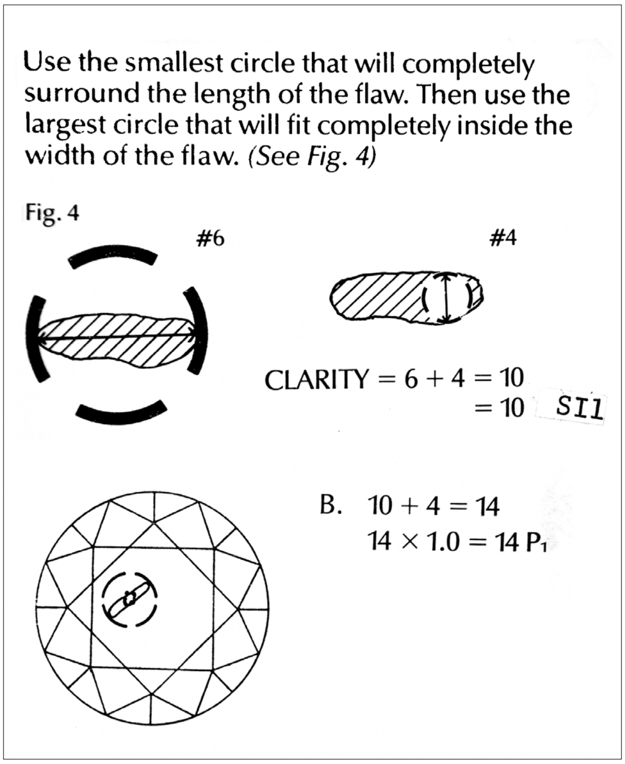


Figure 11: This excerpt from Okuda (1978) illustrates how a measure of inclusion area is obtained by the addition of circle numbers corresponding to their length and width.

Figure 12: The Okuda clarity conversion table shown here converts the area score obtained from the sum of the circle numbers for length and width to a clarity grade. From Okuda (1978).

CLARITY No.		CLARITY
(A)	(B)	
0	1	FL
2	3	VVS_1
4	5	VVS_2
6	7	VS_1
8	9	VS_2
10	11	SI_1
12	13	SI_2
14	15	P_1
16	17	P_2
18	19	P_3
20		Rejection

maker crystal or feather inclusions of medium contrast located under the diamond's table, the clarity grade is obtained directly from the conversion table using the area score obtained from the sum of the circle numbers for length and width. However, Okuda's grading system had two shortcomings:

1. It lacked an adjustment for variations in inclusion contrast.
2. Although there was an adjustment for position, it was applied to the area score as a multiplicative factor. As will be seen, this adjustment must be applied additively in the circle number domain in order to mirror GIA grading practice correctly in a uniform fashion throughout the clarity scale.

The New Clarity Grading System

The first step in the new clarity grading system is to measure the inclusion dimensions using 32× to 45× microscope magnification, employing either a vernier caliper or a reticule capable of approximately ±10 μm accuracy. The author recommends today's version of the 6-inch Mitutoyo Digimatic digital calipers that he has employed for over 30 years. The ±10 μm accuracy suffices for typical inclusion sizes of VS_1 and larger. VVS_1- and VVS_2-size inclusions are more easily and accurately measured (using the same digital calipers) from an enlarged photograph.

With insights from the transformation from inclusion dimensions to Porton circle numbers and Okuda's clarity table, the author has developed a new continuous grading scale consisting of a graph with a curve increasing with a $\sqrt{2}$ relationship; it will be included in the author's upcoming ebook (Cowing, in press). The graph is used to provide a transformation of inclusion dimensions to the exponential domain. The sum of the transformed length and width provides an inclusion area score like that obtained using the discrete circles of the Porton graticule. However, the advantage of using this graph over the discrete circles is its continuous nature. It does not require the nonlinear interpolation necessary when measuring an inclusion's length or width that falls between circle sizes.

Table II. Adjustment guidelines due to inclusion contrast.

Scale	1	2	3	4	5
Description	Low-contrast inclusion difficult to observe with overhead lighting; a 'cloud' is a good example	Inclusion with contrast in between a cloud and typical crystals and feathers	Typical contrast of a clear or white crystal or feather as seen with overhead lighting	A more solid white or darker than usual crystal or feather between typical and high contrast	High contrast with overhead lighting, either black on a light background or a bright reflector on a dark background
Adjustment to clarity grade	−2e to −4e (one to two grades higher)	−1e to −2e (one-half to one grade higher)	No adjustment	+0.5e to +1e (one-quarter to one-half grade lower)	+1e to +2e (one-half to one grade lower)

Adjustments to the Area Score due to Inclusion Number, Contrast and Position

After finding the starting clarity grade from the combined total inclusion area score of the grade-maker inclusions, adjustments are made according to inclusion number, contrast and position.

Number: Instances where there are a number of similar grade-maker–size inclusions are effectively handled by summing them to the approximate dimensions of a similar inclusion having the same total area. This commonly results in an adjustment of one grade lower when there are multiple (i.e. about four) similar grade-maker–size inclusions (four times the area of one of them). Note that near-borderline inclusion sizes may drop into the next lower grade with as few as two grade-maker–size inclusions.

Contrast: As taught by GIA, inclusion contrast, which is referred to as 'colour and relief', "can affect visibility as much as size….*Relief* is the contrast between the inclusion and the [surrounding field of the] stone; the greater the relief, the more it will affect the clarity grade" (GIA, 1994, p. 12).

To address the influence of contrast or relief on the clarity grade, the new system employs a simple 1-to-5 scale along with their corresponding adjustments (Table II). Any adjustment is applied additively in the exponential domain. A one-grade-lower clarity adjustment corresponds to an addition of +2e (the 'e' notation refers to an exponential scale).

Needing no adjustment is a medium-contrast crystal or white feather, which would be designated a 3 on the contrast scale. A very high contrast inclusion is 5 on the scale, and most often requires an adjustment of one grade downward (i.e. a +2e adjustment). For example, a black crystal that obviously stands out against the surrounding diamond with overhead lighting would receive a +2e adjustment to the clarity grade. In the other direction, a very low contrast inclusion that barely stands out, such as a cloud, is designated a 1 on the contrast scale and adjusts the initial clarity grade upward by 1–2 grades (a −2e to −4e change). Inclusions requiring intermediate adjustments (i.e. designated 2 or 4 on the contrast scale) may not change the clarity grade if the diamond falls near the middle of a particular grade. However, a borderline grade will probably change.

Position: Adjustments for position are based on observation of GIA practice and are described in Table III. No adjustment is needed for the easiest-to-locate inclusions under the table or just outside

Table III. Adjustment guidelines due to inclusion position.

Position	Inside table or just outside it	VS_2 size or smaller, touching or very near girdle	VS_2 size or smaller, near girdle	SI_1 size, near or touching girdle	SI_2 or larger, anywhere in diamond
Adjustment to clarity grade	No adjustment	−1e to −2e (one-half to one grade higher)	−0.5e to −1e (one-quarter to one-half grade higher)	−0.5e to −1e (one-quarter to one-half grade higher in a large diamond)	No adjustment

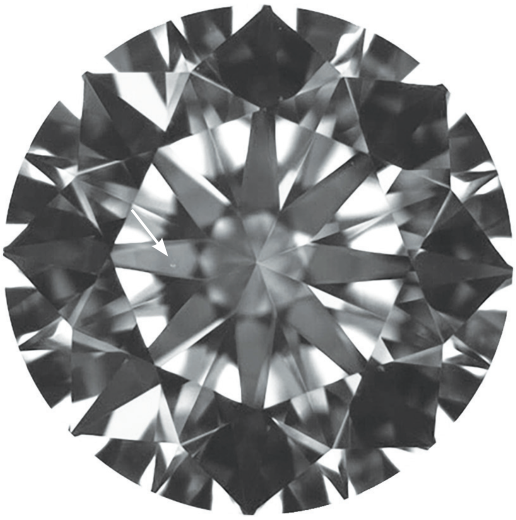


Figure 13: This 1.20 ct VS_1-graded diamond (6.83–6.85 × 4.17 mm) contains a crystal inclusion measuring 90 × 42 μm (under the table at 9 o'clock), which corresponds to a clarity grade of VS_1 using the new system.

it. An adjustment is made for as much as a one grade upward (–1e to –2e) for VS_2 and smaller inclusions that touch the girdle or are just inside it. A position adjustment of one-quarter to one-half grade upward may apply to inclusions outside the table but not very near the girdle. This would only change the clarity grade in borderline cases. Larger inclusions (SI_2 and greater) are unlikely to be adjusted for position because of their obvious nature anywhere in the diamond from girdle to table.

Final Grading Call Considerations

It is important to point out that these inclusion measurements and judgements are all made from a face-up two-dimensional perspective. However, if a grade-maker inclusion extends deeper into the stone than the dimensions of its face-up measurement (so that it appears significantly larger when viewed from the side), consideration must be given to lowering the grade obtained by face-up observation. In most instances, such an adjustment is not more than one grade lower than the face-up call.

It is also important to note that the final clarity grade is made by observation of the overall inclusion visibility in the face-up position under overhead lighting (not darkfield illumination). This is usually accomplished in the laboratory by viewing the diamond with a 10× loupe under the small 7-inch fluorescent-tube light attached to the microscope; diamond traders more commonly use a fluorescent desk lamp.

Objective Clarity Grading Example

Figure 13 provides an example of a single grade-maker crystal inclusion of medium contrast (3 on the contrast scale) located under the table:

1. Measure inclusion length and width (in microns): 90 × 42 μm.
2. Convert length and width from microns to the exponential domain (see Table I): 4.2e + 3.1e.
3. Sum the exponent numbers to obtain the inclusion area score: 7.3e.
4. Make adjustments for contrast and position: In this case there are none, since the inclusion has typical contrast (3) and its position is under the table.
5. Look up the total adjusted clarity grade for 7.3e (see, e.g., Figure 12): VS_1.

Comparison with Clarity Grades Determined by Gem Laboratories

To evaluate numerous laboratory-graded diamonds in conjunction with this study, it was expedient to experiment with grading of inclusions using high-quality photographs. Without the actual diamonds in hand, the question was: Can inclusions, their sizes and their contrast/relief be measured and adequately judged from diamond photographs? With good photographs where the grade-maker inclusions are in focus, the answer is yes. An initial experiment involved grading the diamonds photographed in Roskin (1994). From the darkfield diamond images in that book, a vernier caliper was used to measure the dimensions of each diamond's grade-maker inclusions along with the stone's dimensions. The actual inclusion dimensions were then obtained by scaling according to the ratio of actual diamond diameter divided by the diamond image diameter. Objective grading using inclusion measurements from the images resulted in near-perfect agreement with the stated clarity grades of all the diamonds pictured in the book.

The majority of images in the author's database, and all of those used in this article, were obtained

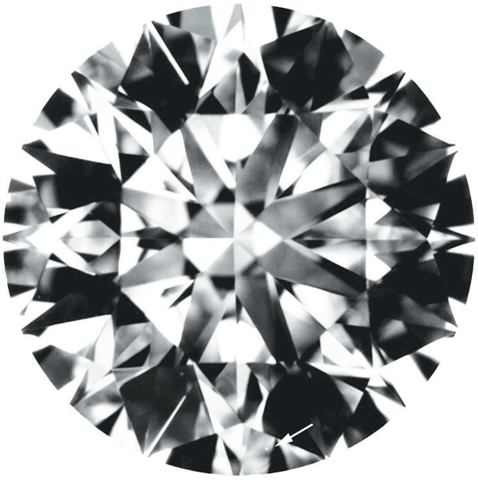


Figure 14: This 0.92 ct VVS$_1$-graded diamond (6.22–6.23 × 3.85 mm) contains a VVS$_2$-size pinpoint. The position of this inclusion near the girdle at 6 o'clock calls for a half-grade adjustment, making the clarity grade a low VVS$_1$.

from the website for the diamond and jewellery retailer Good Old Gold (www.goodoldgold.com), which lists the company's diamond inventory, commonly with corresponding grading reports from GIA or AGSL. Also available are darkfield images pointing out the grade-maker inclusions, and for some diamonds there are images taken with overhead lighting. Owner Jonathan Weingarten graciously granted the author access to this ready-made database. The inclusion dimensions and other noticeability factors were measured and judged from the available darkfield and overhead lighting images in a manner similar to that employed for 'grading' Roskin's (1994) diamond images. The clarity grades obtained with the new objective system were compared to laboratory-determined grades for more than 100 randomly selected diamonds in Good Old Gold's inventory, over a range of sizes from ⅓ to 6 ct and clarities from VVS$_1$ to I$_2$. The grades obtained with the new system accurately reflected laboratory grading in over 90% of the examples. 'Solid' clarity grades (those in the middle half of a grade range) almost always matched those determined by the laboratory. In fact, the author has been employing this objective system's methodology since the early 1980s, and has found throughout this time period a close agreement with the clarity grading calls of both GIA and AGSL. The author continues to augment the current database with GIA-graded diamonds he has examined and photographed (both with darkfield and overhead lighting) and then graded with this new system.

The following examples were selected to show the application of the new system to GIA-graded diamonds with a range of clarities.

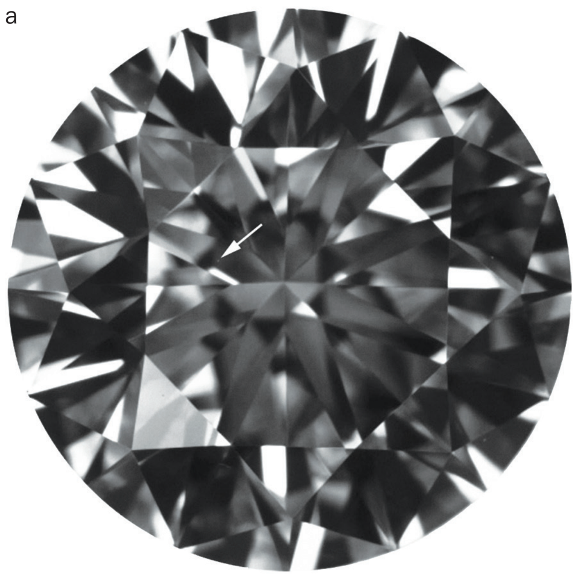
VVS$_1$ Example

The VVS$_1$ clarity grade is defined by the presence of minute inclusions that are extremely difficult to see with 10× magnification. The question of when an inclusion becomes visible to the experienced observer at 10× magnification is important, as it defines the boundary between Fl or IF and VVS$_1$. According to Bruton (1978), a possible example of such an inclusion is a white pinpoint of approximately 5 μm that appears bright with very high contrast against a dark background. However, if the pinpoint has medium contrast, then the threshold of 10× visibility doubles to 10 μm. This inclusion area of 10 × 10 μm corresponds to a clarity score of 1e + 1e = 2e, which is the boundary between IF (0e–1.999e) and VVS$_1$ (2.0e–3.999e).

The 0.92 ct diamond in Figure 14 has a single pinpoint at 6 o'clock near the girdle under a crown half. The inclusion has a diameter of 24 μm for a clarity score of 2.3e + 2.3e = 4.6e, corresponding to an initial grade of VVS$_2$. The pinpoint's position outside the table near the girdle calls for a half-grade adjustment of 4.6e – 1e = 3.6e, for a final clarity grade of a low VVS$_1$.

VVS$_2$ Example

The VVS$_2$ clarity grade is defined by the presence of minute inclusions that are very difficult to see with 10× magnification. Earlier it was stated that a number of grade-maker–size inclusions are effectively handled by grading them as an equivalent inclusion with similar total area. The presence of about four similar grade-maker inclusions is likely to lower the clarity one grade more than would a single similar feature by itself. An evaluation of the 1.55 ct VVS$_2$-graded diamond in Figure 15a provides a practical example illustrating both principles. The stone contains five pinpoints (see plot in Figure 15b), but the largest and only one visible at 10× magnification measures 23 × 21 μm = 2.1 + 2.1e = 4.2e, which corresponds to a high borderline VVS$_2$. Two of the additional pinpoints (visible in



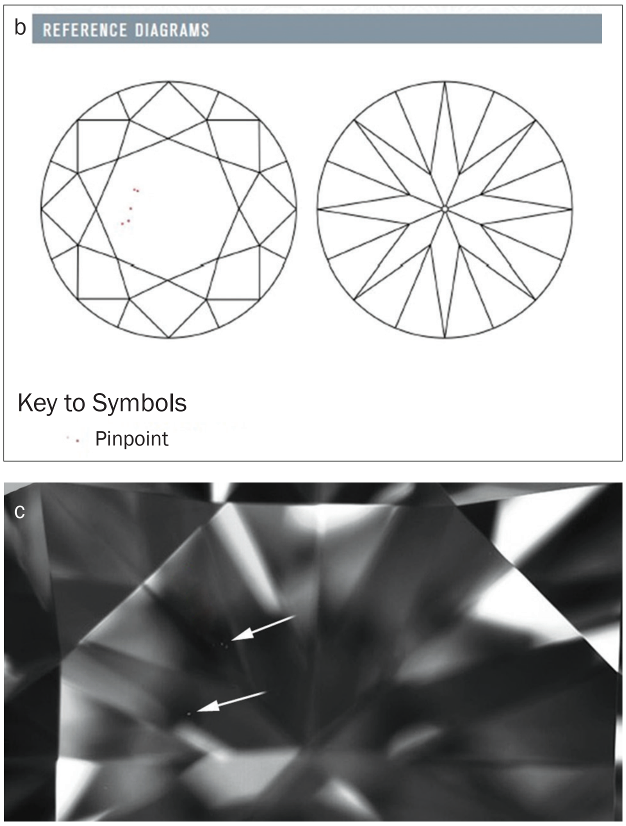


Figure 15: (a) This 1.55 ct VVS_2-graded diamond (7.46–7.42 × 4.58 mm) provides an example where multiple VVS_1-size pinpoints result in a one-grade-lower clarity of VVS_2. The plot from its GIA report (b) shows the location of all the pinpoints, and some of them are visible in the enlarged photo (c, magnified 20×).

Figure 15c) are each 18 × 18 μm = 1.9 + 1.9e = 3.8e (low VVS_1 pinpoints individually) and the other two are even smaller. An inclusion having the combined total area of all five pinpoints would be approximately 70 × 20 μm = 3.8e + 2.0e = 5.8e, which would have a final clarity grade of low VVS_2.

There is an additional way to arrive at the clarity grade for this example. The three pinpoints mentioned above are low-VVS_1 in size, and along with the two additional tiny VVS_1 pinpoints that are not visible in the photos, the group has the equivalent noticeability of four low-VVS_1 grade-makers, bringing the call down one grade from a low VVS_1 to a low VVS_2.

VS_2 Examples

The VS_2 clarity grade is defined by the presence of minor inclusions that are somewhat easy to see with 10× magnification. The 0.90 ct VS_2-

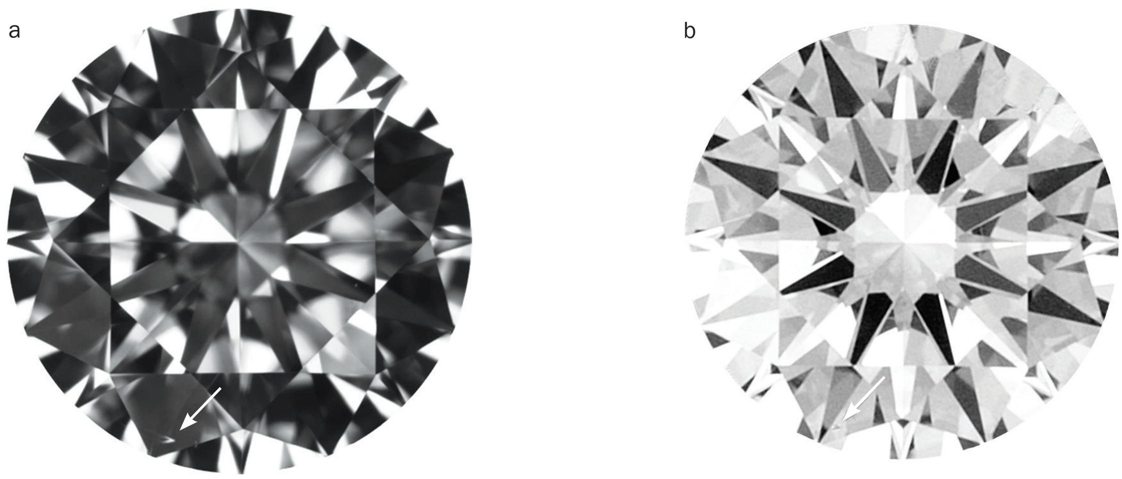


Figure 16: A 0.90 ct VS_2-graded diamond (6.26–6.24 × 3.76 mm) containing an arrowhead-shaped feather located at 7 o'clock is shown with darkfield illumination (a) and overhead lighting (b). This example illustrates how inclusions typically appear less distinct with overhead lighting (where the final clarity grade call is made) than with darkfield.

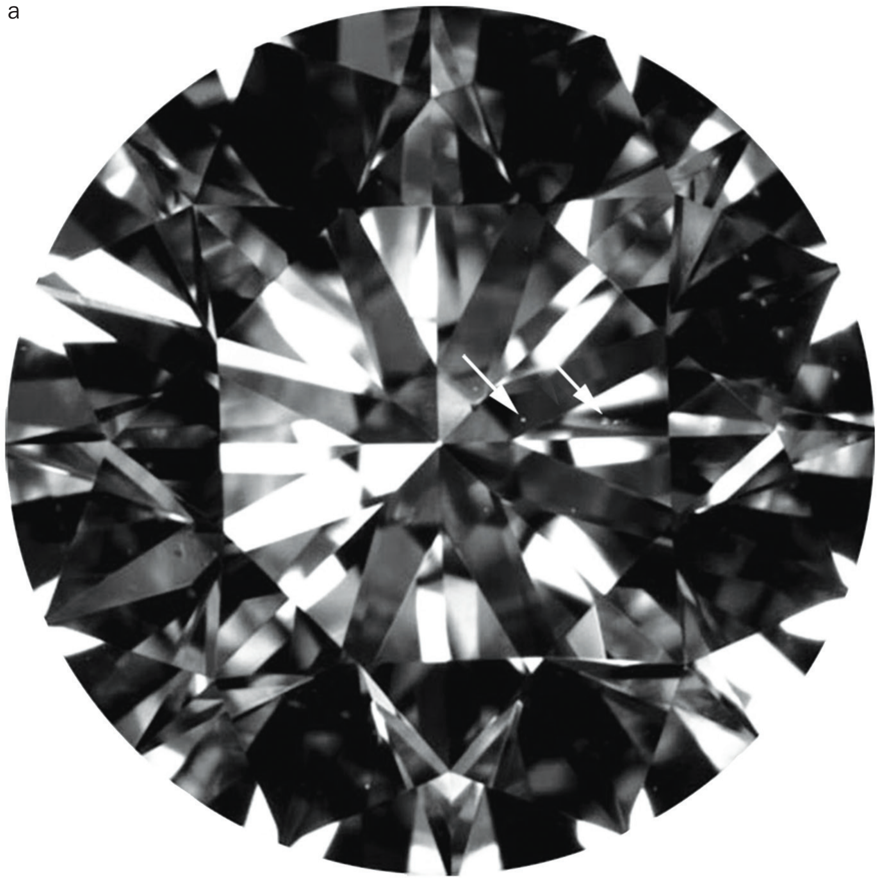
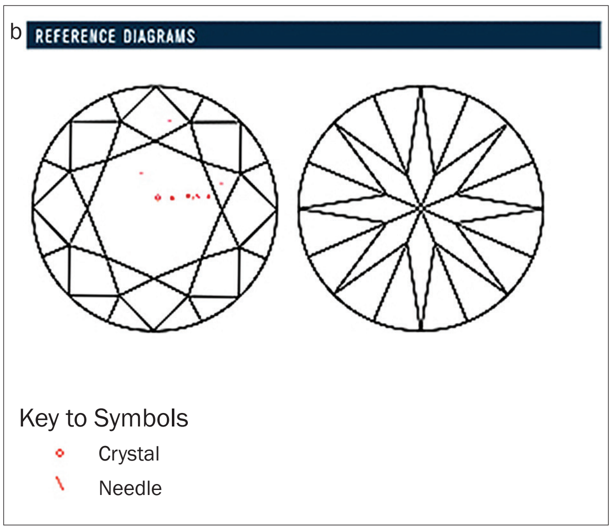
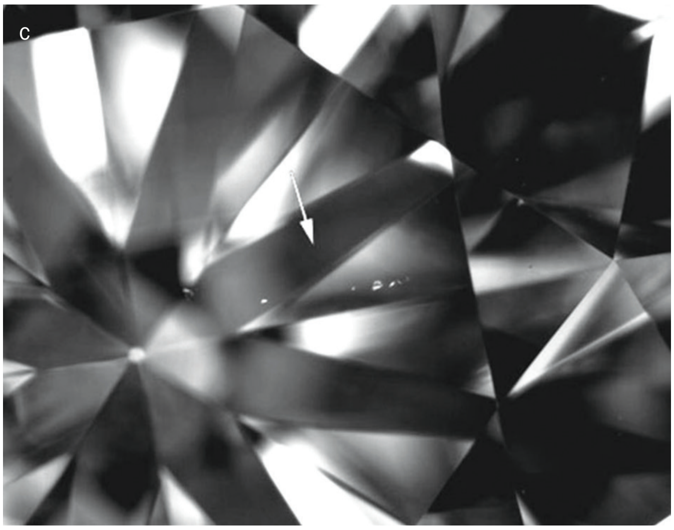


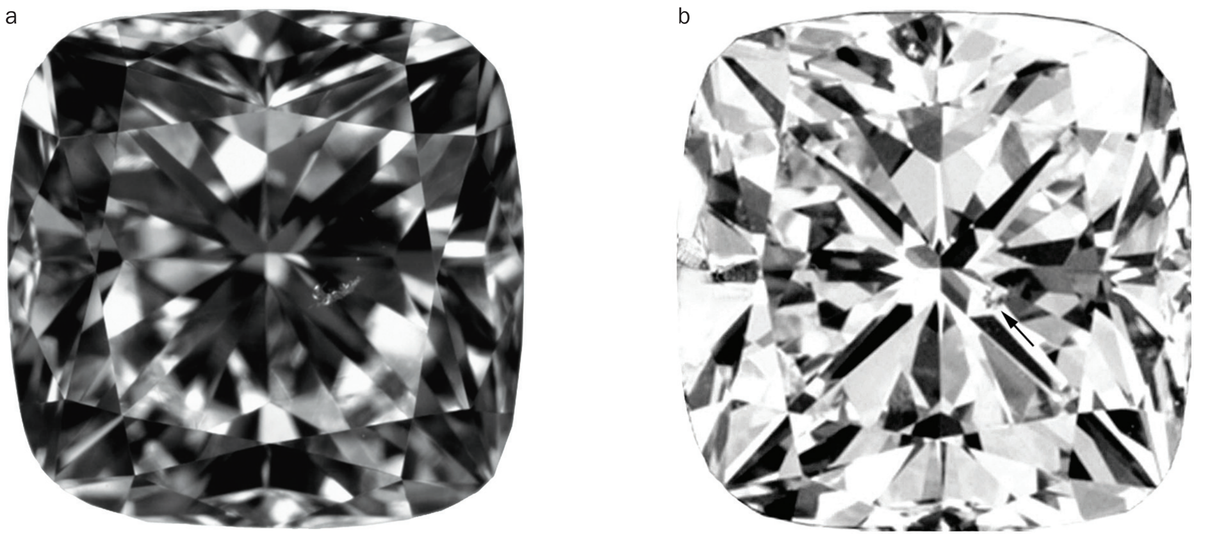
Figure 17: (a) This large VS_2-graded diamond (5.70 ct, 11.48–11.53 × 7.13 mm) contains a string of five tiny crystals that taken together have the combined area of a VS_2. The plot from its GIA report (b) shows the location of all the inclusions, most of which are visible in the enlarged photo (c, magnified 20×).





graded round brilliant in Figure 16 contains an arrowhead-shaped feather of medium contrast (3) located under a crown main facet at 7 o'clock. The two images of Figure 16 illustrate the fact that with overhead illumination (where the final clarity grade call is made), inclusions of medium contrast are typically less distinct than they are with darkfield. This is because darkfield illumination is designed to illuminate inclusions by making them appear bright against a dark background. The feather has approximate dimensions of 162 × 65 µm = 5.2e + 3.8e = 9e, which corresponds to an initial call of a solid VS_2. An adjustment is needed due to the feather's location near the girdle; about –0.7e is appropriate, making the final score 8.3e, and the clarity grade a high VS_2.

The 5.70 ct VS_2-graded round brilliant in Figure 17 contains a string of five tiny crystals under the table around 3 o'clock. Together they add up to an equivalent inclusion size of 167 × 83 µm that translates to 5.2e + 4.1e = 9.3e, for a clarity grade of VS_2.



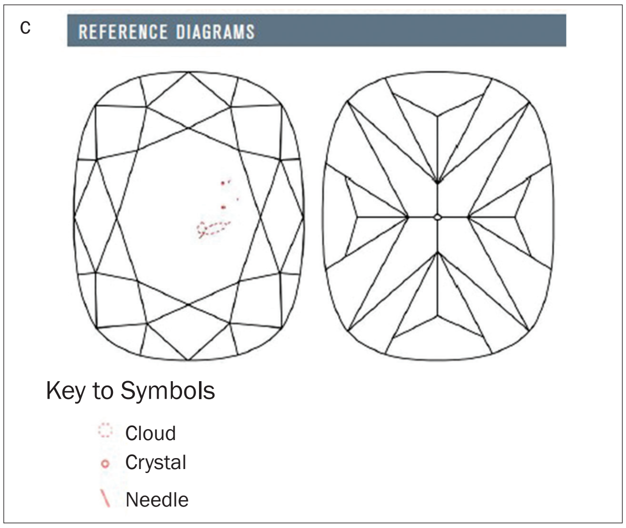


Figure 18: This 1.70 ct SI_1-graded diamond (6.82–6.78 × 4.74 mm) contains a low SI_1-size crystal/cloud combination with low contrast that adjusts the clarity grade to a solid SI_1. It is shown with darkfield illumination (a) and overhead lighting (b), along with a plot of the inclusions from its GIA report (c).

SI_1 Example

The SI_1 clarity grade is defined by the presence of noticeable inclusions that are easy to see with 10× magnification, but usually not easily noticeable to the unaided eye. The 1.70 ct SI_1-graded diamond in Figure 18 contains a grade-maker inclusion group consisting of a crystal/cloud combination under the table at about 3 o'clock. The group of inclusions is of low contrast (2) and has a combined area equivalent to 649 × 130 μm, which translates to 7.1e + 4.6e = 11.7e. After a half-grade adjustment (–1e) for the low contrast of the inclusions, the score is 10.7e, which corresponds to a clarity grade of SI_1.

SI_2 Example

The SI_2 clarity grade is defined by the presence of noticeable inclusions that are very easy to see with 10× magnification, but typically not easily noticeable to the unaided eye. The 0.74 ct SI_2-graded diamond in Figure 19 contains a grade-maker cluster of low-contrast (2) feathers extending deep under the table. Summing the area of each feather yields an approximate inclusion area of 685 × 372 μm = 7e + 6.2e = 13.2e, corresponding to a middle SI_2. An adjustment of one-half grade upward (–1e) for the low inclusion contrast yields a clarity score of 12.2e. However, this diamond provides an unusual case of having features that are not apparent with darkfield illumination but are noticeable with overhead lighting (numerous feather reflections located outside the table). It is challenging to speculate from the photo how apparent these reflections were to the grader. They appear to warrant an adjustment of one-half to one full grade downward (+1e to +2e), yielding a score of 13.2e to 14.2e, corresponding to a low SI_2 bordering on a high I_1. The SI_2 clarity grade received at the laboratory was probably due to the fact that these additional features are reflections that were not very noticeable.

I_1 Example

The I clarity grades are defined by the presence of obvious inclusions with 10× magnification that are eye-visible face-up. The 1.01 ct I_1-graded cushion brilliant cut in Figure 20 contains a large grade-maker inclusion under the table edge at 7 o'clock that shows moderately high relief (4) with overhead illumination. The approximate

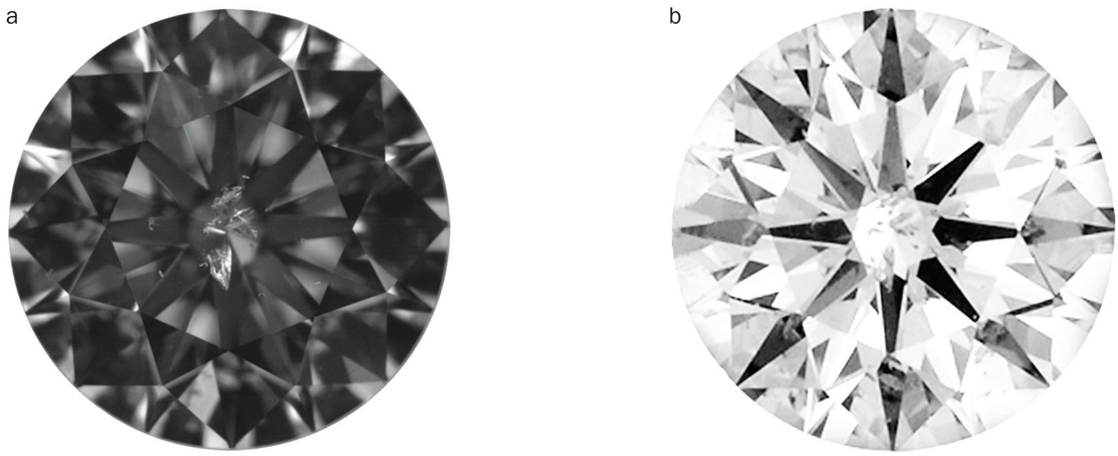


Figure 19: Shown with darkfield illumination (a) and overhead lighting (b), this 0.74 ct SI_2-graded diamond (5.80–5.82 × 3.60 mm) has a grade-maker cluster of feathers with a combined area that sums to SI_2 size. An adjustment for their low contrast is more than offset by the fact that they reflect outside the table. With overhead illumination the reflections outside the table are apparent, leading to a low-borderline SI_2 clarity grade.

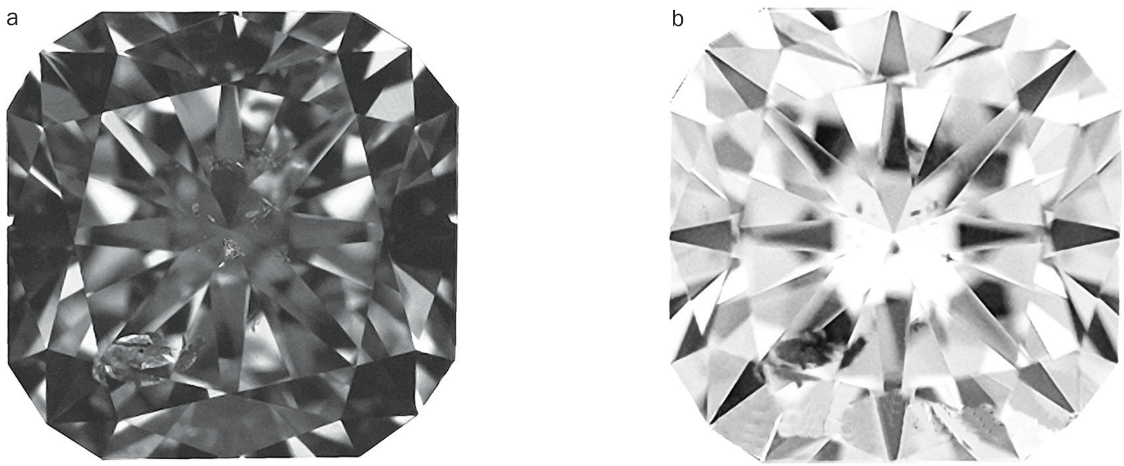


Figure 20: Shown with darkfield illumination (a) and overhead lighting (b), this 1.01 ct I_1-graded diamond (5.85–5.89 × 3.85 mm) contains a large I_1-size inclusion. The high contrast seen with overhead lighting adjusts the grade downward to a low I_1.

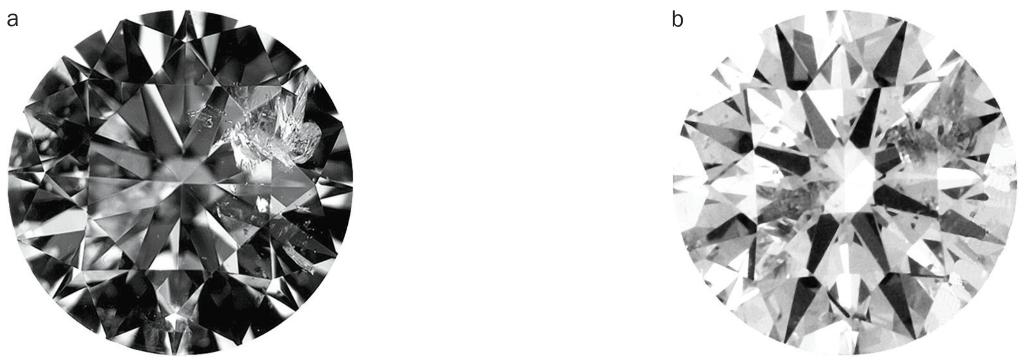


Figure 21: This 0.35 ct I_2-graded diamond (4.55–4.54 × 2.78 mm) contains a large I_1-size fracture that is best seen with darkfield illumination (a). Viewed with overhead lighting (b), a reflection of the fracture causes a doubling of its apparent area, which combined with the relatively small size of the diamond leads to a solid I_2 clarity grade.

dimensions are 1026 × 545 µm = 7.7e + 6.8e = 14.5e, for a clarity grade of high-medium I_1. After adjusting one-half grade downward (+1e) for the moderately high contrast, the final score is 15.5e, corresponding to a low I_1.

I_2 Example

The 0.35 ct I_2-graded round brilliant in Figure 21 contains a large fracture that is best seen and measured using darkfield illumination. It is 1165 × 757 µm = 7.8e + 7.3e = 15.1e, for an initial clarity grade of middle I_1. When the stone is examined with overhead lighting, the reflection of this fracture requires an adjustment of one-half to one grade downward (+1e to +2e), for a score of 16.1e to 17.1e, corresponding to a high-to-middle I_2. In addition, since the inclusion's appearance constitutes a significant percentage of this rather small diamond, the +2e adjustment is appropriate for a final grade of a solid I_2.

Conclusions

This article introduces a new objective form of clarity grading based on metrics that model the techniques of experienced graders. The system emulates the analysis performed by these graders, who assess the combined factors of inclusion characteristics (size, number, contrast, position and nature) to arrive at the clarity grade.

A small sampling of grading examples are discussed here that compare the results obtained from this new system to photographs of GIA-graded diamonds. They were selected from more than 100 recently documented photographic examples that support the success of this system in matching clarity grades obtained by gem laboratories.

A particularly notable outcome of this study is the approximate but consistent four times increase in inclusion area from grade to grade across the entire GIA clarity scale. This multiplicative relationship resulted from the natural evolution and expansion of the clarity grades and terms used in the diamond trade well before GIA's formalization of the grading scale. It speaks to human perception of the relative noticeability of diamond inclusions.

With the success of this objective system in matching GIA grading, its accuracy and consistency suggests the possibility of its use for improving inter- and intra-laboratory grading consistency.

References

Bruton E., 1978. *Diamonds*. N.A.G. Press Ltd., London, p. 517.

Burr K.F., Brightman R.F., Chandler R. and Huddlestone R.V., 1981. The D.G.L. Clarity Grading System for Polished Diamonds. Diamond Grading Laboratories Ltd., London, 81 pp.

Cowing M.D., in press. *Grading Diamond Clarity Objectively*. To be self-published.

GIA, 1969. Diamond Grading Assignment 20. Gemological Institute of America, cover page.

GIA, 1994. Diamond Grading Assignment 4. Gemological Institute of America.

GIA, 2004, 2006. Diamond Grading Lab Manual. Gemological Institute of America, pp. 109–120.

Okuda K., 1978. Okuda Diamond Grading Microscope Reference Manual. Okuda Jewelry Technical Institute Co. Ltd., New York, New York, USA, 16 pp.

Roskin G., 1994. *Photo Masters for Diamond Grading*. Gemworld International Inc., Northbrook, Illinois, USA, 94 pp.

Shuster W.G., 2003. *Legacy of Leadership*. Gemological Institute of America, Carlsbad, California, USA, p. 121.

Wade F.B., 1916. *Diamonds—A Study of the Factors that Govern Their Value*. G. P. Putnam's Sons, New York, New York, USA, 150 pp.

The Author

Michael D. Cowing, FGA
AGA Certified Gem Laboratory
1035 St. Stephens Church Rd.
Crownsville, Maryland 21032 USA
Email: michaelgem@gmail.com

Acknowledgements

The author is grateful to Jonathan Weingarten of Good Old Gold (Massapequa Park, New York, USA) for supplying the raw diamond photographs in this article. He is grateful to the following individuals for discussions and review:

- Peter Yantzer, executive director of the AGSL in Las Vegas, Nevada, USA, and former director of GIA's diamond grading laboratory in Santa Monica, California, USA, concerning aspects of GIA and AGSL clarity grading.
- Phil Yantzer, vice president of laboratory services at GIA in Carlsbad, concerning aspects of GIA clarity grading.
- Gary Roskin, former GIA assistant lab director in Santa Monica, concerning aspects of GIA clarity grading.
- Roy Huddlestone, former director of DGL in London, concerning aspects of DGL's clarity grading system.
- Thomas Tashey, owner of Professional Gem Sciences Laboratory in Chicago, Illinois, USA, concerning aspects of GIA clarity grading and the SI_3 grade.