READING THE HEGMAN GRIND GAUGE[1]

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The Sherwin-Williams Co.

The Sherwin-Williams Company, in an effort to analyze mill rates, found serious variations in the results obtained with the Hegman fineness of grind gauge. These variations were such that it was deemed necessary to investigate the entire grind test procedure in order to gain more accurate results.

This article deals with the investigation and the results together with a description of the modified test procedure. This modified method provides visual standards which can be used to identify grind patterns and which, if used properly, will bring fineness gauge results into closer agreement. Since this type of gauge has wide use in the paint industry, it is possible that others are also unaware of these variations and are operating under the same serious disadvantage that has existed in this company.

The Hegman Gauge represents an improved fineness of grind gauge. Historically, this gauge is the development that resulted in a simple and rapid method for judging dispersion quality. Earlier methods were subjected to all the possible errors than can exist when standard materials must be combined under exact conditions.

The earliest method for inspecting dispersion quality, and which is still much in use, involved the art of knifing out a thin film and examining it for quality of particle fineness. This required long experience in order to predict final product quality with any degree of accuracy. More important than this, however, is the fact that accurate agreement between testers is a matter of luck rather than skill.

In order to assist such testers in determining and standardizing quality, the North Standards were developed (2). These are actual pigment dispersions which cover a broad range of grind quality. To different portions of a high quality dispersion of zinc oxide in linseed oil are added varying grades of Aloxite abrasive. This produces six standard samples which indicate a graduated fineness of a grind. A sample is checked by knifing it out against the selected standard on a glass plate and comparing visually.

With the idea of producing more accurate comparisons, the St. Louis Paint and Varnish Production Club introduced the St. Louis Fineness Gauge (3) for use with the North Standards. They also added two more coarse standards to the North Series in order to extend the range. The gauge is a steel plate containing an inclined depression 0.005 inches deep at one end and zero inches at the other. The paint to be tested and the standard are placed side by side in the deep end, and a knife is drawn over the specimens to form a wedge of paint. By viewing the gauge in proper light at an oblique angle, coarse particles can be seen breaking through the smooth film surface. This gives an accurate comparison with the North Standards

The Hegman Grind Gauge (4) was developed, and it eliminated this dependence on standard samples. The fundamental feature is a wedge shaped channel ½" wide, ranging from zero to 5" long, which is cut in a hardened tool steel block. (See Figure I.) A linear scale is etched alongside the channel. It begins with zero where the channel is .004 inches deep and progresses in equal divisions to 8 where the channel is zero inches deep. The gauge has been made with multiple channels but recent models of the Hegman have only one. The side by side channels permit visual comparison of two samples in the same view. Although this has some advantages, it appears simpler and just as effective to evaluate samples by means of numerical designations.

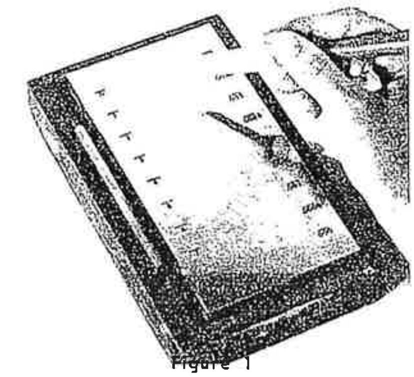

Figure 1

Originally, the channel was two inches long, but, in more recent models a 5 inch length has become more popular. The longer channel seems to give greater ease in reading. The actual calibration of the five inch channel is:

Hegman Designation	Depth of Channel	Distance from 0
0	0.0040"	0"
1	0.0035"	⅝"
2	0.0030"	1¼"
3	0.0025"	1⅞"
4	0.0020"	2½"
5	0.0015"	3⅛"
6	0.0010"	3¾"
7	0.0005"	4⅜"
8	0.0000"	5"

The Federation of Paint and Varnish Production Clubs has recommended a modification of this gauge (5). It employs two ½" x 5" grooves side by side One is calibrated in Hegman divisions of 8, while the other is scaled in Production Club units of 0 through 10. This gauge (as with the Hegman) has, as a part of the test equipment, a hardened tool straight edged scraper for spreading the paint sample in the channel to provide the wedge for viewing

Although these various modifications are available, their basic value lies in the development of a wedge of paint in a calibrated channel as the principal of the test. Since the gauges are basically the same, they are subject to the same variables, and, although this article deals with the Hegman gauge, it should be of interest to all fineness of grind gauge users.

The method of gauge use is best described by quoting the test procedure. Again, specific gauges and organizations have variations in methods, but the basic procedure is the same. Since it was the starting point for this investigation, the Sherwin-Williams' test method will be quoted.

"With the gauge lying flat, a sufficient amount of material to be tested is put in the deep end (0-Hegman) of the channel so it will overflow slightly. With the scraper held perpendicular between the thumb and index finger with both hands, it is drawn down the channel using firm pressure. The gauge is then immediately held at such an angle as to get good light reflectance (grazing incidence). It is read at that point where many particles appear on the surface of the film in the channel, disregarding isolated or occasional

(1) This article is based on the work and results of a special committee appointed to investigate this problem. The committee was composed of the following men: D. Doubleday as chairman (Dispersion Research Laboratory), R. Bruhn (Paint Research Laboratory), A. Brolin (Technical Service Laboratory).

(2) Scientific Section Circular No. 423; National Paint, Varnish and Lacquer Association, Inc.

(3) Scientific Section Circular No. 471, 329 (1934); National Paint, Varnish and Lacquer Association, Inc.

(4) E. W. Fasig; Drugs, Oils and Paints 54, 138 (1938).

(5) Official Digest: 283, 575 (1948)

particles in the deeper end of the channel. Viscous pastes should be reduced with solvent to a flowing consistency before testing."

Figure II shows the draw-down being made (using a modified gauge with a two inch channel width), while Figure III illustrates a gauge user inspecting the paint wedge film surface.

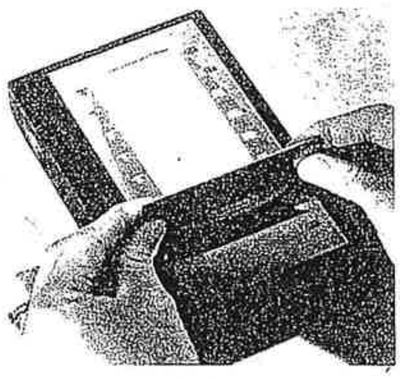

Fig. II

The simplicity of the equipment and the procedure makes this an ideal test method. Perhaps it is this simplicity that has lead to a false sense of faith in test results. The method is so free of complications that results can be readily accepted without question. The one possible point that seems open to question is the actual end point designation, because this can be affected by an individual's interpretation. However, with the above quoted procedure, allowance has been made for this variation due to interpretation. It has been understood that the grind should be designated only in whole units and then always to the next lowest numerical designation. For example, a sample read 5⅛ or one read at 5¾ would both be reported at 5. This method of designation was felt to compensate for minor disagreements and it seemed like it should be satisfactory as a tolerance.

On the face of it, there is no reason why such a method should not be completely satisfactory. It was accepted as such, and results were not questioned. However, this investigation brought to light errors, mostly of omission, that proved to have serious effects on gauge results. Since they came as such a surprise to experienced individuals, it is felt that there might be many others handling their grind tests in the same manner that has been routine here. If this is so, they are probably suffering from the same serious variations and should be able to take advantage of these corrective measures.

The test method was brought under critical examination through observations made during an investigation of mill production rates. It was found, especially with a high quality dispersion, that accurate grind designation was a rigid requirement if maximum production rates were to be maintained. Under normal practices, it was possible that two identical batches could, and would, be designated as 6H dispersions, but one would have twice the output rate as the other. The only variable was the dispersion; both would be in the 6H range, but the high output batch tended toward a 6 designation, while the other tended toward a 7. Obviously, it was advantageous to correct this, because, as long as specifications were being met, maximum production should be obtained.

Immediate steps were taken to remedy this situation, but this brought to light serious uncontrolled variables that existed within the gauge reading procedure. It was impossible, under the conditions of the test method, to call grinds with the accuracy required. Furthermore, as will be shown later, the startling fact was uncovered that various testers could interpret an identical pattern anywhere from 6 to 2. As can be imagined, the investigation proceeded rapidly.

It should be mentioned, since it was another factor that tended to emphasize the variations, that within the Sherwin-Williams Company there is a modified Hegman gauge in use. It differs from the standard model in that the channel is 2" x 5" instead of ½" x 5" (shown in Figure II). This gauge was introduced primarily to check sample cleanliness. The larger area gave a better sample representation, and, since dirt particles are usually widely scattered, a more accurate indication of the concentration was shown. It is logical that such a gauge would come to be used for grind designations, because one draw-down then served two purposes. However, it was early in the life of the 2 inch channel when it became apparent that identical samples would be given a poorer grind designation on the wide channel than on the narrow. It was necessary that this be corrected if they were to be interchangeable.

As the investigation got under way, preliminary work indicated that two main problems exisited, and, as points came up, the following study outline developed:

- I. The effects of various physical conditions involved with the technique of sample and gauge handling.
  - A. Method of sampling
  - B. Sample conditions
    - 1. Viscosity
    - 2. Type of liquids involved
    - 3. Pigment concentration
  - C. Draw-down conditions
    - 1. Speed of scraper blade
    - 2. Angle of scraper blade
  - D. Time lapse between completion of draw-down and actual reading.
  - E. Viewing the gauge
    - 1. Light source
    - 2. Angle of viewing
  - F. Gauge block and blade wear
- II. The variation due to differences in grind pattern interpretation when selecting a designating line

The original assumption was that the mechanics of gauge usage would provide the field in which major corrections could be made. This proved to be false, because the variation in interpretation was startling. However, assuming that interpretation of grind patterns can be rigidly controlled, technique of gauge usage assumes great importance. No effort will be made to single out any one point as being the most important. The value of each is dependent on the allowable variations in all the others, and each must be handled correctly if the complete test is to be satisfactory.

In the interest of simplification, the points will be discussed as they appear in the above outline.

A. Method of Sampling

It is obvious that no test method is satisfactory unless the reported results indicate a true picture for every portion of the batch or lot. This means that a submitted sample must be truly representative of the entire batch. The general methods for tank sampling in the paint industry leave much to be desired and do not conform with accepted sampling procedures. Sampling procedure was beyond the scope of this investigation and is mentioned here only to accentuate the fact that a perfect test means nothing if it is performed on an unrepresentative sample.

B. Sample Conditions

Sample conditions assume particular importance where paste products are concerned. Specifications for any product are based on the finished material, and control tests during production must be handled in such a manner that the results indicate final conditions. In paint testing, complications arise on this point, because samples are often partially completed products whose characteristics differ from the final material. A tester must work with samples varying in consistency from the final reduced product back through heavy pastes. It is important that the physical properties of these pastes do not affect gauge readings in some manner which would produce apparent results not in agreement with actual final results.

It was found that the critical variable in sample conditions was pigment concentration. Gauge readings will vary with pigment concentration; the higher concentrations for any one paste will show the poorer grinds. For this reason, pastes or samples at other than their final reduction should be reduced in such a manner that they may be tested at pigment concentrations closely approximating that of the final product.

There had been some belief that viscosity and volatility of liquids had a noticable effect on grind readings, but this was found to be of rather minor importance when considered after the other variables were controlled. It has been concluded that viscosity effects have been confused with pigment concentration effects. For example, compare a heavy paste that has been reduced with a solvent against the same paste reduced with varnish. Normally, the solvent reduction will read slightly poorer in grind. There is logic to the conclusion that solvent evaporation and thin body accounts for this difference. However, because of the consistency effects of the two reducers, the solvent reduction reaches test consistency at a much higher pigment concentration than does the varnish reduction; consequently, the poorer reading.

Assuming proper pigment concentration, it is impossible to vary the viscosity sufficiently to affect the gauge reading.

In making the statement that liquid volatility is not critical in grind reading, it should be remembered that this investigation uses the original test method as a reference point. Extreme conditions can markedly affect gauge readings, but, within the normal limits of the procedure, volatility has no apparent effect. Evaporation rates are intimately tied in with the time lapse between completion of draw-down and the actual reading, and a fuller explanation is made there. The point is that the normal time lapse is short enough to eliminate any reading variation due to volatile solvents in all but highly pigmented lacquers. In these few exceptional cases, it is wise to reduce test samples with some less volatile liquid to slow down initial evaporation rates.

Concern over pigment concentration will occur only when the sample represents a paste product. It has been found that the safest method to test such a sample is to reduce with formula specified liquids in the same proportions used in the actual batch let-down. The varnish should be the same material. The remaining liquids can be combined in amount and a formula thinner, proportional to this total amount, used. For example:

Reduction		Ratio	Sample Reduction
Paste — 50 Gallons		5 parts	¼ pint paste in pint can
Varnish — 50 Gallons		5 parts	Add ¼ pint varnish
Thinners — 8 Gallons	Combine to 10 gallons of one thinner	1 part	Add ½ ounce thinner
Driers — 2 Gallons			

The sample amounts of paste and varnish can be visual estimates, but it is wise to measure the smaller amounts of thinner. Such a sample reduction, even with estimated amounts, will always be close enough to actual pigment concentration to eliminate any gauge variation on this point.

C. Draw-down Conditions

It was found that these conditions were not critical. Blade speed and blade angle to block surface were varied over a wide range with no apparent effect on grind reading.

D. Time Lapse Between Completion of Draw-down and Actual Reading

This is an important variable which is directly related to drying characteristics. This ties it closely to solvent volatility, and it is only past performance that leads to the earlier statement that volatility, in general, is not important. As a general rule, it was found that no grind change occurred within the first ten seconds. Since a separate survey, made on many gauge users, indicated that the average time lapse was 4 to 6 seconds, drying characteristics had little effect on gauge readings. It is for this reason that the statement has been made that solvent volatility is not critical.

The actual findings were that in grinds of 6H and poorer, little or no change was noted during the first 30 seconds. For grinds of 7H and better, it was possible to note significant changes starting about 10 seconds after draw-down completion. It is advisable to make the reading as rapidly as possible, because there will always be a few exceptional cases where change will start almost immediately. For this reason, it is recommended that at least three separate draw-downs be made for each sample. The first allows for proper alignment of a good light source and a preliminary study of the grind pattern to understand what must be looked for with its particular type. With this information, the succeeding draw-downs can be made rapidly, and reading time can be kept within 3 seconds. Under no conditions should a reading be used when the time lapse is more than 10 seconds.

E. Viewing the Gauge

As such, the light source does little to vary gauge readings. The importance of the light lies in the speed with which the pattern can be picked out. It has a direct effect on the reading time lapse and, as such, an indirect effect on gauge reading. The best light is that which the individual can use to most rapidly pick out the grind pattern. The consensus seems to indicate diffused light is preferred over direct. Natural light on a cloudy day or light received through windows from the shady side of the building seems

Fig. III

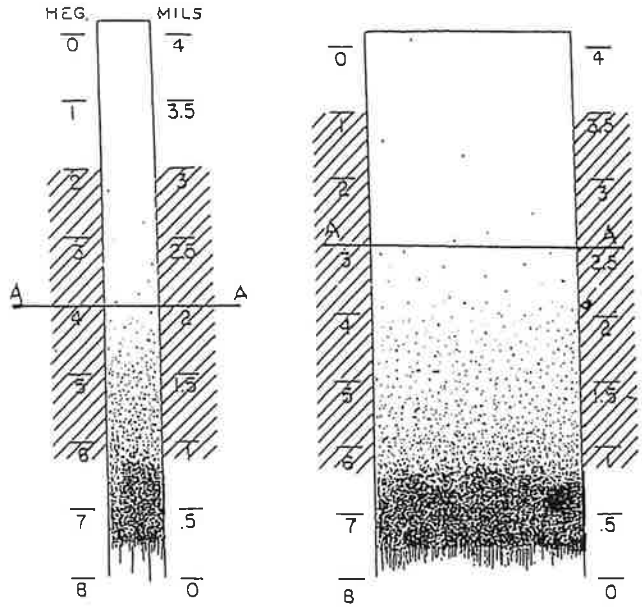

Fig. IVa and IVb

best. Direct or bright light allows too much glare, and the gauge reader tends to miss a portion of the pattern that will be clear in more subdued light.

The angle of viewing the gauge is important. In this company, where a gauge with a 2" wide channel is also in use, the importance is magnified. The test method specifies that the grind should be called at that point where the particles are first sufficiently concentrated to form a straight line across the gauge. It must be remembered that, when viewed at an angle, the tester does not actually see a ½" width. The apparent width to his eye can vary from zero to ½", depending on the angle between the line of vision and the surface of the block. As this apparent width narrows, the actual concentration of particles remains the same. The result is that the smaller the angle, the more concentrated appear the particles, because the same number is viewed in a (apparently) narrower area. At small angles, the tendency is thus to find the specified concentration at a lower grind than at larger viewing angles.

As far as this point of reading is concerned, the angle of viewing needs only be the same to permit duplication of readings. After many trials, it appeared to be easier to pick out the pattern at a viewing angle of about 25° from the block's surface. Consequently, the recommendation is that the viewing angle should be confined within 20° to 30° from the plane of the gauge surface. (Figure III.)

There was serious consideration given to the possibility of making up a gauge reading apparatus which would contain a gauge equipped with a fixed light source and a fixed sighting station. This would make it possible to provide a gauge whose pattern would be immediately visible and which would always be viewed from an exact angle. This idea was shelved in hopes that satisfactory results would be obtained without it and only if proof is obtained that the refinement is necessary will it be reconsidered.

F. Gauge Block and Blade Wear

Discrepancies were noted in gauge readings that could only be charged to instrument variation. A preliminary investigation proved that blade wear rather than block wear was causing the trouble.

During any draw-down, the portion of the scraping edge traveling over the channel is subject to less wear than that portion having metal to metal contact. It is a fact that the blade can drift laterally in successive tests. This results in increasing the portion of the scraping edge subject to block contact during the draw-down. However, the tester's tendency is to center the blade, and this causes scraper blades to wear faster at the ends than the middle. Eventually, the wear is enough to allow the center portion to dip into the channel, reducing the paint film thickness and allowing an apparent grind reading which is poorer than actual. Because of this wear, blades have been found which have caused grinds to be lowered a full Hegman division.

At present, there is not enough knowledge concerning the rate of wear to predict when a scraper blade should be replaced. The simplest recommendation is to keep a master blade on hand to check those in regular use. Any such blade should be used sparingly to prevent wear. Based on only scattered information, the cautious path would be quarterly checks for gauges in regular use.

As was stated earlier, these mechanical conditions seemed to offer the most opportunity for improvement in accuracy of results. However, the findings to date had not offered a satisfactory answer to the degree of variation that was known to exist. In special cases, these could account for variations up to 1¼ Hegman units, but only through a stretch of the imagination could they be charged with the wide spread disagreement. The investigation then turned to interpretation of the grind pattern.

The problem was to find out just how much variation existed when the only condition that could change was the tester. In other words, how would everyone read the identical grind pattern. Several methods for reproducing the grind pattern were tried. Although it has an obvious disadvantage, the decision was made that drawn reproductions would be the most satisfactory for the information desired.

Once this was decided, reproduction of grind patterns at "2H," "4H," "6H," and "7H" were made for both the ½" and the 2" channels. Copies were sent to approximately 150 gauge users with instructions to mark the print at that point they would use to designate the grind. Figures IVa and IVb show why the results were startling. These represent the samples sent out as a "4H" dispersion. The crosshatched length shows the range over which this pattern was read. Line A-A represents the optimum grind designating line as established by the distribution curve of testers. This curve is shown in Figure V. The graph is a plot of the number of sample readers against their grind designations with the curves being smoothed from the actual data to give a clearer indication of the trend. Since Figure IVa consists of an exact reproduction of a ½" section of Figure IVb, the distribution curve gives graphic proof that the 2" section will produce lower readings than a ½" when the same material is tested.

The degree of variation was the same on the other dispersion reproductions.

Here, then, was the major point for immediate correction. The results dictated the necessity of a rigid description of grind pattern appearance in order to restrict the variations that grew from unrestricted interpretation.

After several attempts at written description, it became apparent that this was the wrong approach. For consistent interpretation, all gauge users must have the same visual picture of a given grind. Photographs would be the ideal solution, but they were not satisfactory. The decision was made to employ drawn standards similar to Figure IV. They were made up to cover the whole gauge range, and each was given the grind designation that was indicated from the results of the survey. With these bound in booklet form, it is possible for all testers to have the same visual pictures of various grinds and so make it possible to bring them in closer agreement on results.

These standards,* combined with the revised test procedure, comprise the altered test method. Based on this work, the test procedure has become—

1. Sample to be tested must be representative of the batch under consideration.
2. Prepare sample for testing.
   (a) If the sample represents a final reduced product, use it directly for the test.
   (b) If the sample is a paste paint or pigmented base, reduce it approximately as it would be for application and use. Reductions should be made with materials equivalent to those used in the actual letdown. Use the same varnish as specified by the formula. The remaining liquids should be considered as all thinner and that proportionate volume used.
3. Check draw-down blade edge for nicks or uneven wear. This can be done by placing the blade edge on the block's level surface and sighting through the contact line against good light.
4. Lay the gauge on a flat surface and wipe clean with a lint free cloth.
5. Put a sufficient amount of material to be tested in the deep end of the slot so it slightly overflows the slot.
6. Using the draw-down blade, draw the material down the length of the slot. The blade should be held with the thumb and index finger of each hand. Its position throughout the draw-down is perpendicular to the block's surface and at right angles to the slot's length. Pressure should be firm enough to clean the level surface of the block. (See Figure II.)
7. Read grind immediately. (See Figure III.)
   (a) View the gauge from the side so the line of vision is at right angles to the slot's long dimension.
   (b) Hold the gauge in such a light

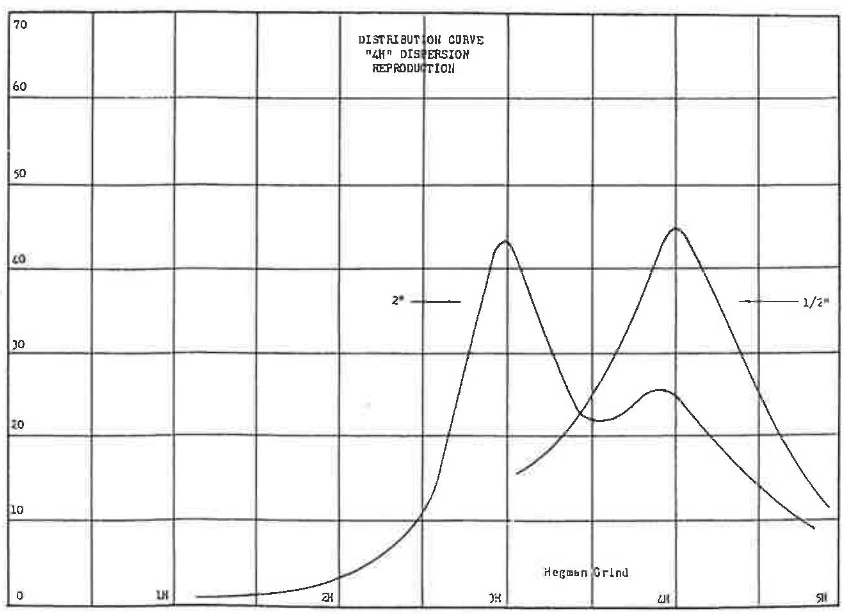

Fig. V

*It is impractical to show the standards here. However, Figure IV, which follows the basic pattern, can be used as an example.

source that the pattern is readily visible.

(c) For actual reading, the angle between the surface of the block and the line of vision should be no more than 30° nor less than 20°.

(d) Interpret pattern and designated grind.

8. Starting at Step Four, repeat the above procedure, with a new portion of the sample, until three readings are obtained. The first draw-down and reading is preliminary in order to establish ideal conditions and to indicate type of grind pattern. With this knowledge, the second and third readings can be made with a minimum time lapse between completion of draw-down and the actual reading. No reading should be considered for the reported grind when this time lapse exceeds 10 seconds. Average the last two readings for the reported grind.

Method for Interpreting Grind Pattern

1. Inspect the initial draw-down for the type of grind pattern and the approximate grind.
2. Check this pattern against the visual standards, and select the one that most nearly matches it.
3. Using this standard, determine which imaginary line will be used on this particular pattern.
4. On the successive draw-downs, select the end-point line according to Item 3.
5. Average the last two readings.
6. Report the grind to the next lowest ½ of a Hegman division. Example:
   (a) Between 6H and 6½H—Grind is 6H
   (b) At 6H—Grind is 6H
   (c) At 6½H—Grind is 6½H

The visual standards plus this test method, although not perfect, offer the opportunity for a duplication of results which has not been possible heretofore. Pin-point accuracy on selection of designating lines is not expected and was not the aim of the committee. Grind pattern appearance can vary too much for such a goal to be practical, and the method is issued with the hopes that reading tolerances can be reduced to ½ of a Hegman division.