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AN EVALUATION OF THE USE OF A QUANTITATIVE IMAGE ANALYZER TO DETERMINE MICROHARDNESS VALUES

P. E. Teaney and J. E. Selle

Monsanto Research Corporation
Mound Laboratory*
Miamisburg, Ohio 45342

ABSTRACT

The use of a quantitative image analyzer to determine microhardness values was investigated. Microhardness traverses were made across chemically polished, partially oxidized T-111 alloy specimens using both Vickers and Knoop indenters. Microhardness values were obtained from both area and diagonal readings using a Classimat image analyzer (Classimat is a registered trademark of E. Leitz, Inc., Rockliegh, N. J.). These values were then compared with those obtained by conventional optical measurements. The data obtained by the various methods are compared and the advantages and disadvantages such as accuracy, time requirements, versatility, and limitations of particular methods are discussed.

Objective

The purpose of this study is to determine if an image analyzer is as reliable for determination of microhardness values as conventional methods, and, if so, what method of microhardness determination is best.

In order to accomplish this, three specimens of partially oxidized T-111 alloy were selected which had been chemically polished to reveal the microstructure of the specimen. These specimens were selected because they offered most of the variables one might encounter in attempting microhardness measurements with an image analyzer in other specimens. The specimens had a range of microhardness values starting relatively high at the edge and tapering to the base hardness of the material toward the middle of the specimen. There were areas of etched grain boundaries and inclusions in the oxygen-affected area of the specimen and smooth, inclusion-free areas in the unoxidized portion of the specimen comparable to the as-polished condition of a specimen.

Microhardness traverses were made on the specimens using both a Leitz Miniload and a Tukon microhardness tester. A 50-gram load was used. The traverses consisted of 25 indentations each beginning 2 mils from the edge of the specimen and proceeding at 2 mil intervals to the middle. Both Knoop and Diamond Pyramid Hardness indentations were made. Values were obtained on each traverse from each of the instruments. Comparisons of these values showed that each instrument made equivalent indentations but the values obtained from the Tukon instrument were consistently 5% lower than the Miniload values. Tests on a standard test block verified these comparisons. The difference was real and not connected with the factors involved in converting from filar units to microns. Since the Miniload gave readings directly in μm and required no correction factor, the values obtained from the Miniload were chosen as the standard for comparison with the quantitative image analyzer.

A Leitz Classimat image analyzer was used for the study. The Classimat consists of a Plumbicon television camera connected to an optical microscope. The microscope is equipped

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with an automatic scanning stage and a prism that can be used to automatically rotate the image 90°. The camera displays the image under the microscope on a television monitor and feeds the signal into a video signal processing unit which can be used to obtain from the image on the monitor (1) the mask area, (2) the area of particles, (3) the number of chords, and (4) the number of particles. The desired values are requested from the video signal processing unit by means of a peg board. Data are fed into a computer and calculations are made according to programmed instructions.

For microhardness determination the area of the particle (obtained by the number of picture points in the indentation) and the number of chords (obtained by the number of TV lines intersected by the vertical diagonal of the indentation on the screen) were used to obtain the values.

The Classimat is calibrated so that up to ten gray levels ranging from white to black can be discriminated and measured. Since the microhardness indentation is below and at an angle to the surface of the specimen, less light is reflected by the indentation than by the surface of the specimen. The indentation therefore shows up darker than the surface of the specimen, allowing its gray level to be discriminated and measured.

The Classimat was programmed to obtain values on the microhardness indentations by both area and diagonal measurement in order to determine the advantages and disadvantages of each method. The method used for obtaining microhardness values by diagonal measurement on the diamond pyramid indentations is given as an example of the setup required to use the image analyzer for microhardness measurement.

The standard formula for computing Vickers Hardness is shown in Equation (1):

$$HV = \frac{1854.5 \cdot p}{d^2} \qquad (1)$$

where HV = Vickers Hardness in kg/sq mm

p = applied load in kg

d = the mean value of the diagonals in μm.

The standard Vickers formula was modified slightly and is shown in Equation (2). Equation (2) is essentially the same as Equation (1) except it was broken down for step by step operation of the instrument.

$$HV = \frac{1854.5 \cdot p}{\left(\frac{d_1 + d_2}{2} \cdot F\right)^2} \qquad (2)$$

where HV = Vickers Hardness in kg/sq mm

p = applied load in kg

d_1 and d_2 = chord measurements of the respective diagonals

F = conversion factor obtained from the screen with a stage micrometer (μm/chord).

The instrument was programmed by placing pins in a program board. The instrument was requested to (1) measure the number of chords intersected by the vertical diagonal, (2) rotate the prism 90°, (3) measure the number of chords intersected by the remaining diagonal, (4) return the prism and end the program. The computer was programmed to make the calculations required by Equation (2). The result was the Vickers Hardness number of kg/sq mm and the time interval from the moment the number was requested until the number was printed – about 3 seconds.

Except for the average Vickers diagonal measurements, the programs were set up to print ten values and then average the ten values for each indentation. A plot was then made to determine if repeated measurements were necessary to obtain accurate results.

The results of a typical plot are shown in Figure 1. The first value printed out was plotted against the average of the ten values for each indentation. It appears to make little difference which value is used. The first value is printed out approximately 1 second after the number is requested and each following value in 3 second intervals, requiring approximately 30 seconds' total time for the average. A considerable savings in time could be realized by only taking one value; however, some scatter occurred occasionally and a plot that does not match nearly as well could be obtained by plotting the extreme of the ten numbers of each indentation. This indicates that although ten values are unnecessary more than one should be taken to preclude the possibility of this occurring by chance.

The results obtained on all three specimens were similar, therefore the results on only one of the specimens are shown for simplicity.

Values obtained on a traverse of Knoop indentations on the example specimen are shown in Figure 2. This figure compares values obtained on the Classimat by measurement of the longer diagonal to those obtained on the Miniload. The Classimat values are 15 to 25% higher than those of the Miniload. The higher values were expected and the reason for this is shown in Figure 3. The longer Knoop diagonal makes such a gradual transition in gray level from the surface of the specimen into the indentation that selection of the chords to the extreme edges of the indentation also resulted in selection of chords outside of the indentation. When this occurs and a reasonable attempt is made to adjust the mask area to eliminate the interference, the only other alternative is to reduce the chord selection until only chords inside the indentation are measured. This sometimes leaves some chords inside the indentation unselected. For this reason the length measurement of the diagonal tended to be low.

An attempt was made to obtain more accurate measurement of the diagonal by adjustment of the microscope light. The f stop of the microscope was increased considerably in an attempt to obtain more contrast and improve resolution. The diagonals were then remeasured with the Classimat. The results obtained are shown in Figure 4. The values obtained with the light stopped down showed a considerable improvement over the original values obtained. This method, however, still gave results that tended to be about 5% higher than the Miniload values.

Values were then obtained on these same Knoop indentations by area on the Classimat. By considering the total area the effects of poor discrimination of picture points in the extremities of the longer diagonal should be minimized. Also, area can be measured with the indentation in any orientation. With the indentation being in the horizontal direction the longer diagonal lies along rather than across the chords of the screen. Discrimination of picture points in the extremities of the indentation is much easier in this direction. Figure 5 shows the values obtained with the indentation in both the horizontal and vertical position. The results indicate that regardless of the orientation of the indentation a good correlation with the Miniload values can be obtained. Additional values were obtained on these same indentations with the microscope light stopped down as before. A plot of these values showed no significant difference from those obtained by normal lighting.

Classimat values were also obtained on a traverse of diamond pyramid indentations. These indentations were parallel with the Knoop indentations previously analyzed. The values were obtained by average diagonal length and area measurements. The results are shown in Figure 6, along with values obtained on the Miniload.

The Classimat diagonal measurement values are again consistently high. However, the problem encountered with the Knoop diagonal was not encountered with the diamond pyramid diagonal. An attempt was again made to improve the data by stopping down the light on the specimen, but no significant improvement was achieved in the data. With the exception, especially, of the first two indentations, a very good correlation exists between the Miniload values and those obtained on the Classimat by area. The error in the Classimat values for the first two indentations and slight scatter in the values obtained in the oxidized portion of the specimen were expected and serve to accent a problem encountered when measuring hardness indentations with an image analyzer. If the indentation lies across an etched grain boundary or if there are inclusions in the specimen where the indentation is made, shading of the indentation without shading the grain boundary or inclusions is very difficult, and microhardness values obtained in that area tend to be high. This disadvantage can be avoided easily by evaluating the specimen in the as-polished condition, as evidenced by the data obtained from the interior unetched area of the specimens.

It is concluded from this study that the image analyzer is a reliable instrument for microhardness value determination. The method of evaluation on the Classimat by area was far superior to any of the other methods studied. The Classimat area values were as accurate as values obtained by conventional measurement. In terms of versatility, ease of operation, and time requirements the method is clearly superior.

Table I lists the various methods and gives the approximate times required for evaluation of the traverses in this study. The conventional method is accurate but more time consuming than any other method. After hours of taking tedious measurements through the calibrated eyepiece the time required for evaluation of the specimens increases and the values are more subject to variation due to operator fatigue and eyestrain. The times given for the conventional method consider only one value per indentation.

The method of obtaining values on the Classimat by diagonal measurement was considered disadvantageous for several reasons. Evaluations must always be made with the diagonal in a perfectly vertical position. If interference is incurred from grain boundaries or inclusions it is not as easily masked out as with area measurements which can be made with the indentation in any orientation. When evaluating the diamond pyramid by average diagonal length, each indentation must be evaluated at only one particular spot on the screen so that when the prism rotates the indentation is still under the mask for the second measurement. This proved to be very difficult when measuring a series of indentations, and difficulty was even encountered when attempting a series of evaluations of the same indentation. With extra effort the accuracy of the values obtained by diagonal measurement could probably be improved and evaluation would not be as difficult on an as-polished specimen. However, the extra effort and time required by the method is not necessary when the evaluation can be accomplished more easily and quickly by area.

Area measurements with the Classimat can be made with the indentation in any orientation without greatly affecting the results. Varying the f stop on the microscope made very little difference in the accuracy of the data. In most instances several indentations could be brought onto the monitor, focused, and evaluated successively merely by moving the mask area from one to the other. When interference from grain boundaries and inclusions was incurred, the freedom to evaluate the diamond pyramid indentation as a square to match the mask was a considerable advantage. Evaluation of a 25-indentation traverse on a flat, as-polished specimen could easily be accomplished in 5 to 10 minutes with reasonable accuracy by this method.

TIME REQUIRED FOR MICROHARDNESS EVALUATIONS

Instrument	Method of Evaluation	Time
Miniload	DPH by Diagonal Measurement	1-1/2 - 2 hr/traverse
	KHN by Diagonal Measurement	1 - 1-1/2 hr/traverse
Tukon	———Same as for Miniload———	
Classimat	DPH by Diagonal Measurement	1. ~3 seconds for single value from moment of request 2. 35-45 minutes/traverse
	KHN by Diagonal Measurement	1. ~1 second for first value 2. ~3 seconds for each following value 3. ~30 seconds for average of ten values 4. 30-35 minutes/traverse
	DPH and KHN by Area Measurement	1. Same as above for individual steps 2. 25-30 minutes/traverse

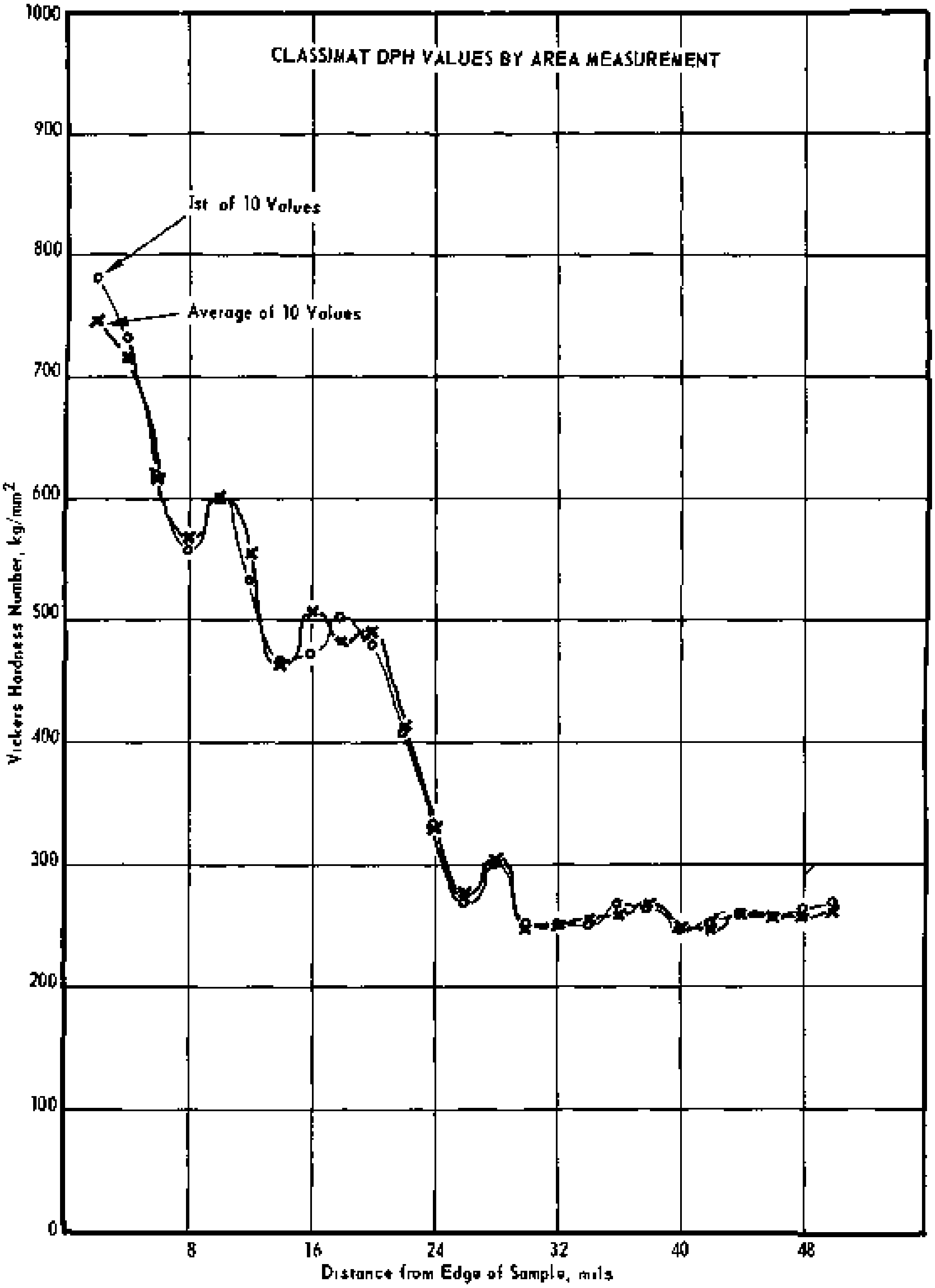
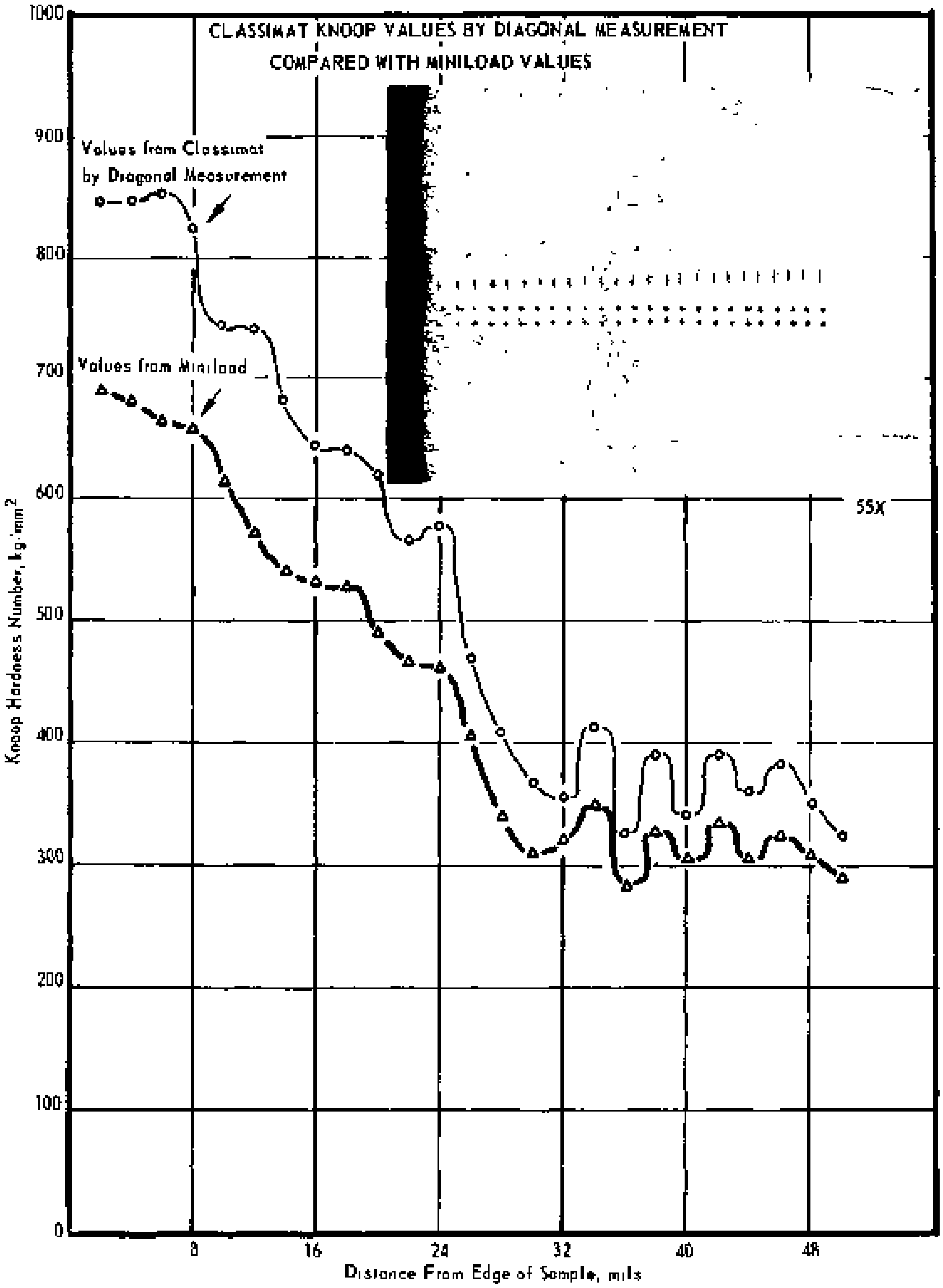


Figure 1. (Reduced 83%)



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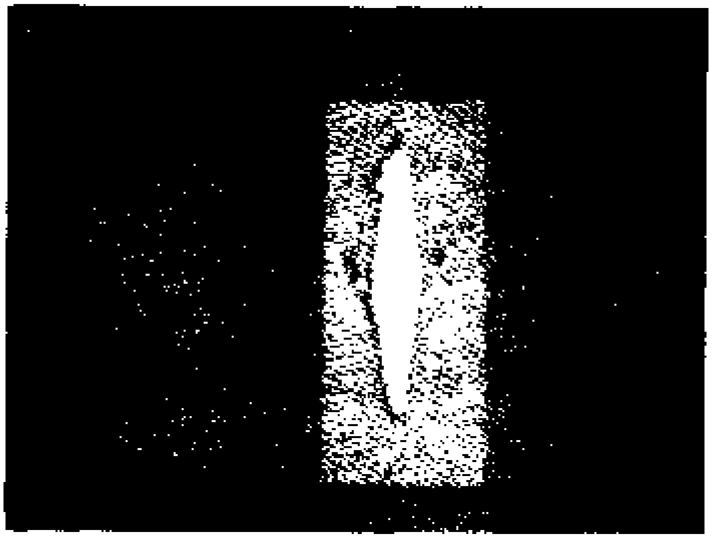

Figure 3. Photomicrograph from the Classimat of a Knoop microhardness indentation showing the difficulty encountered with chord discrimination in the extremities of the longer diagonal, especially in areas with grain boundaries and inclusions.

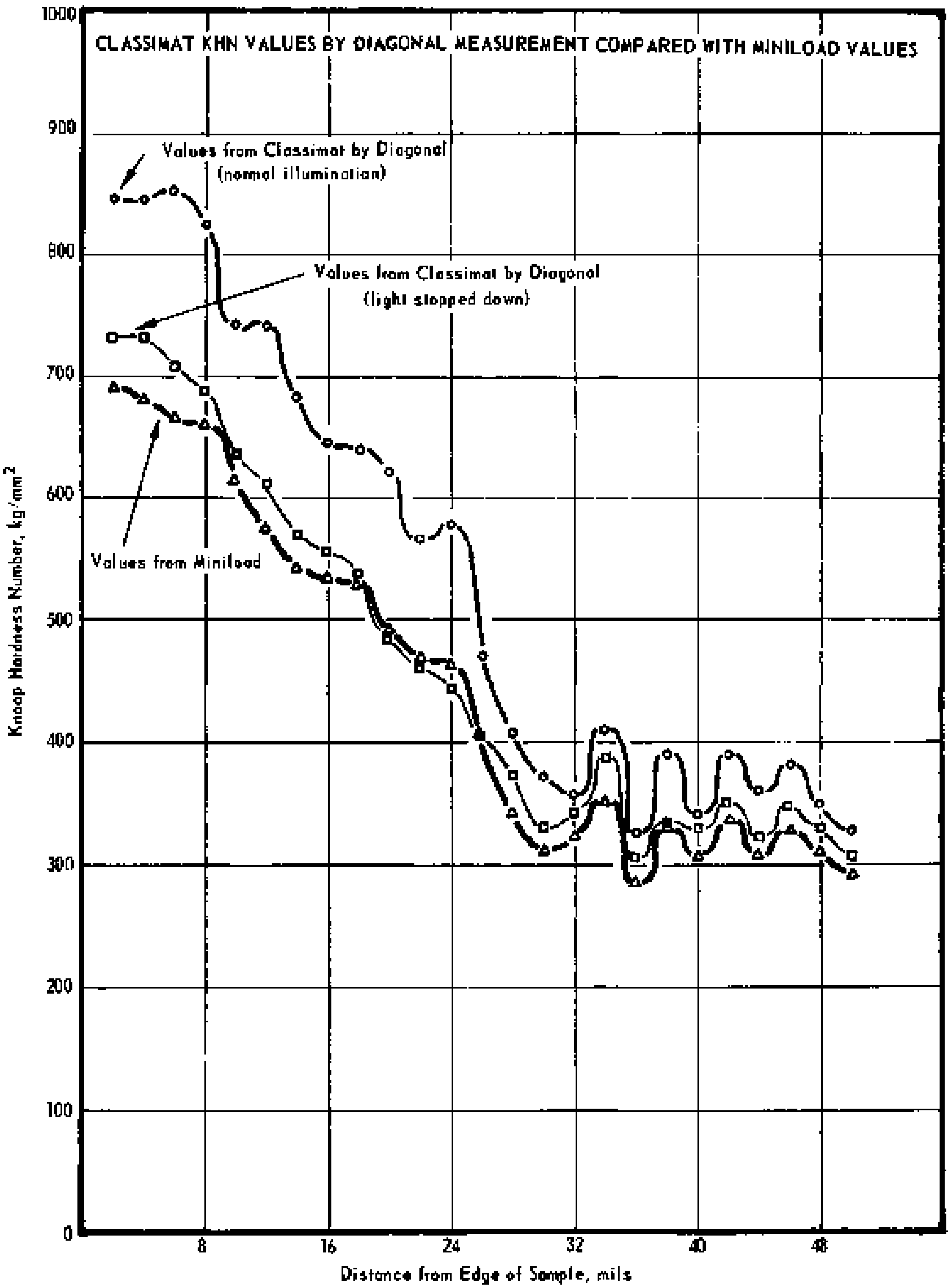

Figure 4. (Reduced 83%)

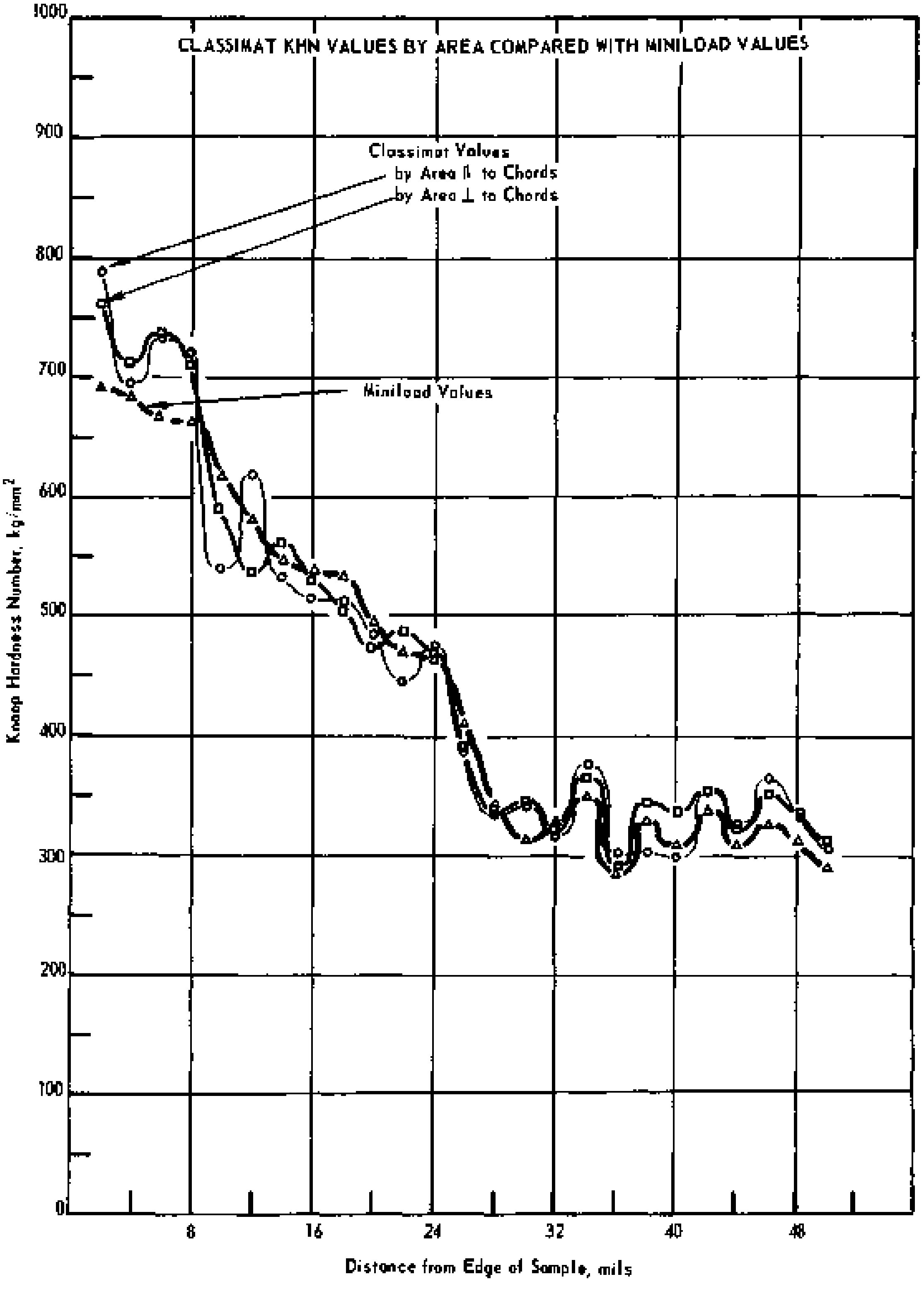

Figure 5. (Reduced 83%)

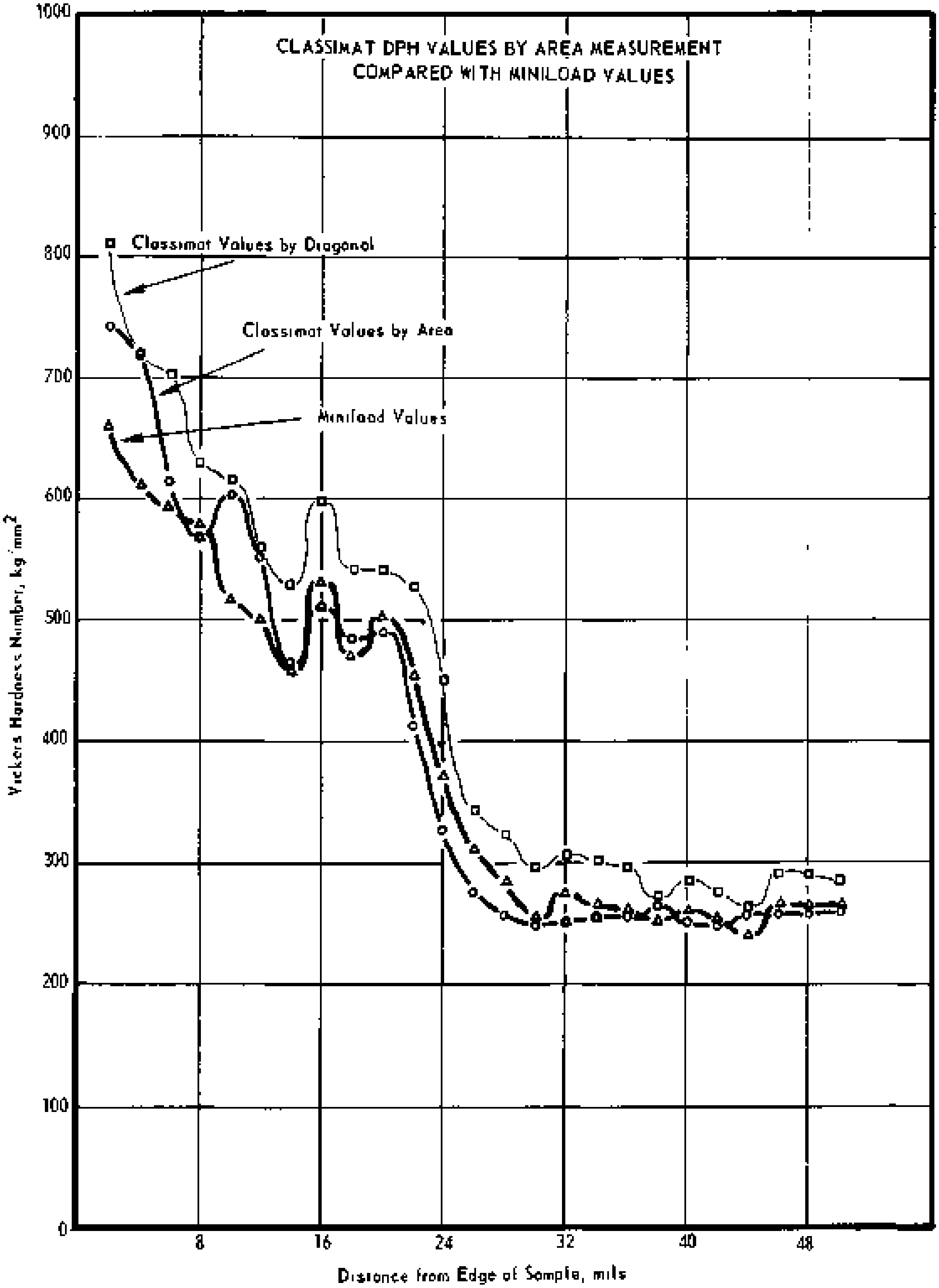

Figure 6. (Reduced 83%)