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Grain Size Measurement Methods: A Review and Comparison

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This paper presents measurements of grain size using the planimetric method using a circular test pattern developed by Albert Sauveur, and defined by Jay Zeffries, and the modified planimetric method of Sarkis Saltykov using a rectangular test pattern and a modified counting method. The same test figures were used to determine grain size by the triple-point count method. Grain size was also measured using the intercept method. The talk will show and compare the results using these methods. ASTM E 112 has stated that at low counts of the number of grains within the Jeffries test circle, bias will occur. The experiments tested this claim and did not detect bias but substantial data scatter. For the intercept method, E 112 states that low counts lead to low precision, which is correct.

Grain size measurements began in 1894 with the publication by Albert Sauveur who reported the grain size in terms of the number of grains per unit area. But, Sauveur did not describe his test method. Later, his graduate student, Zay Jeffries, described the approach in detail. Jeffries was a founding member of ASTM Committee E-4 on Metallography in 1916 and he incorporated the "planimetric" grain size measurement method in E-4's first standard, E 2. Emil Heyn's intercept method was described briefly. In 1964, John Hilliard introduced the use of test circles to average out grain shape non-uniformities and Halle Abrams expanded this to the use of three concentric circles with a total circumference of 500 mm for better statistics in his 1974 revision of E 112. A rectangle for the planimetric method, as suggested by Sarkis A. Saltykov, was also used.

Two images of a ferritic stainless steel were used for the experiments. The magnifications were 100 and 400X and they were located at the same area. These images were printed on paper at different sizes and circles or rectangles of various size, plus test lines, were superimposed over the images to generate a wide variation in counts.

For the planimetric method, Saltykov's rectangular test pattern yielded the most consistent grain size results to the lowest number of counts per placement. Bias was not observed at low counts, only data scatter – this was the same result with the Jeffries test circle. Test results for the intercept and planimetric methods are shown in Figures 1 and 2 and Table 1.

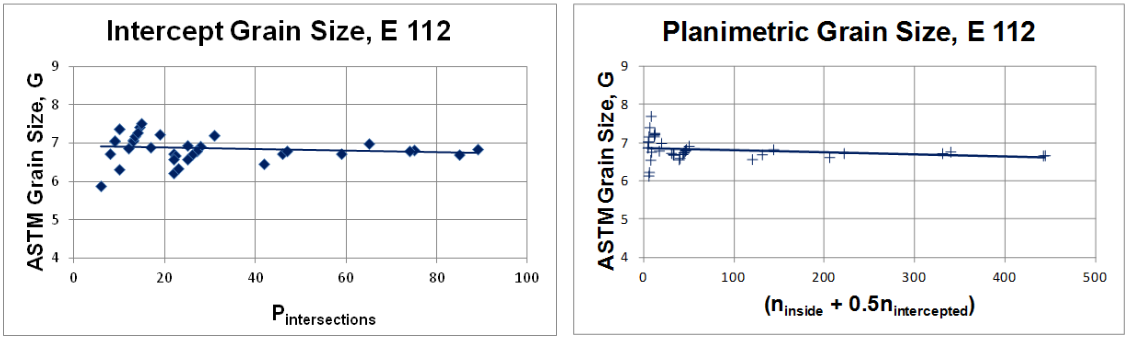

Figure 1: (Left) Results for 40 measurements using the E 112 intercept method (but with a single test circle) with $P_{intersections}$ varying from 6 to 89. (Right) Results for 40 measurements using the E 112 planimetric method with ($n_{inside} + 0.5n_{intercepted}$) varying from 5 to 444.

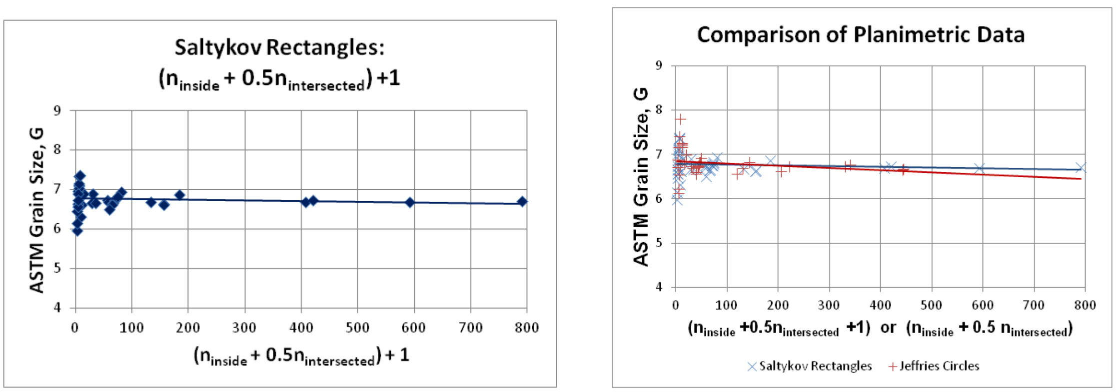

Figure 2. (Left) Planimetric grain size measurements using rectangles and Saltykov's counting method for 43 rectangles with ($n_{inside} + 0.5n_{intersected}$) + 1 values ranging from 2.5 to 790.5. (Right) Over the mutual measurement range for the two methods, the data agreement is excellent.

Table 1: Comparison of Grain Size Results as a Function of Counts and Method.

E112 Planimetric	Circle	($n_1 + 0.5n_2$)	No.	Avg. G ± 95% CL
		>120	9	6.695 ± 0.059
		>30	23	6.72 ± 0.0378
Saltykov Planimetric	Rectangle	($n_1 + 0.5n_2 + 1$)		
		≥29	20	6.722 ± 0.049
		>10	24	6.732 ± 0.047
E112 Intercept	Circle	P_i		
		≥42	9	6.76 ± 0.108
		>20	23	6.76 ± 0.101

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