

Australian Standard<sup>®</sup>

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**METHODS FOR THE  
DETERMINATION OF  
GRAIN SIZE IN METALS**

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The following scientific, industrial and governmental organizations and departments were officially represented on the committee entrusted with the preparation of this standard:

Associated Chambers of Manufactures of Australia  
Bureau of Steel Manufacturers of Australia  
Commonwealth Aircraft Corporation  
Department of Defence  
Federated Chamber of Automotive Industries  
Institute of Steel Service Centres of Australia  
Metal Trades Industry Association of Australia  
Railways of Australia Committee  
Society of Automotive Engineers— Australasia  
Telecom Australia  
University of New South Wales (School of Metallurgy).

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**RECONFIRMATION**

**OF**

**AS 1733–1976**

**Methods for the determination  
of grain size in metals**

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Major stakeholders of this publication have reviewed the content of this publication and in accordance with Standards Australia procedures for reconfirmation, it has been determined that the publication is still valid and does not require change.

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## NOTES

Australian Standard<sup>®</sup>

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## PREFACE

This standard was prepared by the Association's Committee on Metallography as a revision of AS G13—1968, which it accordingly supersedes.

The standard has been sectionalized for ease of reference; general requirements are given in Section 2, Section 3 covers the austenite grain size in steels, and Section 4 covers the measurement of grain size of metals which consist essentially of a single phase.

Section 3, on the determination of the austenite grain size in steels, is primarily based on ISO/R 643, Micrographic Determination of the Austenite Grain Size of Steels. The committee also considered BS 4490: 1969 The Determination of the Austenite Grain Size of Steel. Whereas ASG13, which was

based on ASTM E112, Estimating the Average Grain Size of Metals, was limited to the 'comparison method' for determining grain size, this standard permits the use of the planimetric and intercept methods for the calculation of the grain size.

Section 4 is intended to cover all types of metals and alloys for which grain size measurements are normally required to be known.

For the assistance of committees drafting steel specifications, detailed guidance is given in Appendix A. A short list of etchants is included in Appendix B. The list is not comprehensive and is not intended to be restrictive. Grain size charts have been included in an appendix for ready reference.

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## STANDARDS ASSOCIATION OF AUSTRALIA

**Australian Standard  
for  
METHODS FOR THE DETERMINATION OF GRAIN SIZE IN METALS**

## SECTION 1. SCOPE AND APPLICATION

**1.1 SCOPE.** This standard describes methods for the determination of the grain size in metals and alloys.

**1.2 APPLICATION.** The standard is divided into sections covering various applications as follows:

- (a) Section 2 covers the general procedures for determining grain size.
- (b) Section 3 covers procedures for determining the prior austenite grain size in transformed steels.
- (c) Section 4 covers procedures for determining the grain size of metals and alloys which consist principally of a single phase.

## SECTION 2. GENERAL PROCEDURES FOR METHODS OF GRAIN SIZE DETERMINATION

**2.1 SCOPE OF SECTION.** This Section outlines the basis for estimating the grain size by the comparison method and the calculation of the grain size number by the intercept and planimetric methods.

**2.2 GRAIN SIZE NUMBER.** The standard grain size numbers given in Table 1 are based on the following formula:

$$m = 8 \times 2^G$$

where  $m$  = number of grains per square millimetre

and  $G$  = grain size number.

NOTE: The ASTM index ( $N$ ) derived from formula  $N = G + 0.0456$  gives a grain size slightly larger than that defined by this standard. The difference is not more than 0.5 unit, and the estimation of grain size cannot generally be closer than 0.5 unit under the most favourable circumstances. For these reasons ASTM charts may be used for the determination of grain size number.

**2.3 ESTIMATION OF GRAIN SIZE.**

**2.3.1 General.** It is important to recognize that the estimation of grain size is not precise. The metal structure is an aggregate of three-dimensional grains of varying sizes and shapes. Even if these grains were identical in size and shape, the grain cross-sections produced by a random plane (surface of observation) through such a structure would have a distribution of areas varying from a maximum value to zero depending upon where the plane cuts each grain. Clearly no two fields of observation can be exactly the same.

In each of the three methods for determination of the grain size number good judgement on the part of the metallographer is necessary to select the magnification to be used, the proper size of the area, the proper number of grains (normally not less than 50 per given area), and the number and location in the test piece of representative sections and fields.

**2.3.2 Accuracy of Equipment.** The actual magnification used shall be verified to within an accuracy of 1 percent by direct comparison with an engraved micrometer. All distance measuring equipment used in the determinations shall be accurate to  $\pm 1$  percent.

**2.4 COMPARISON METHOD.**

**2.4.1 Method.** The test piece shall be examined at an appropriate magnification and the grain size determined by direct comparison with the standard grain size chart (see Appendix C) the appearance of which most closely resembles that of the test piece. The estimated grain size shall be reported to the nearest unit listed in Table 1.

NOTE: The standard grain size charts cover three categories of microstructure as follows:

Plate 1 — Untwinned grains, hat etch, 100×

Plate 2 — Twinned grains, flat etch, 100×

Plate 3 — Heavily twinned grains, contrast etch, 75×

Where grain sizes significantly different from the average are observed, the range shall be reported and also an indication of the distribution within the range.

Grain size of a given test piece shall be determined on a minimum of three representative fields.

**2.4.2 Alternative Magnification.** Where the grains are of a size outside the range covered by the standard charts, alternative magnifications that are usually simple multiples of the standard 100 diameters may be employed. (See Table 2.) A correction factor shall then be added to the apparent grain size observed.

The correction factor  $Q$  to be added to the apparent grain size number viewed at magnification  $M$  to give the standard grain size number shall be determined from the following formula:

$$Q = 6.64 \log_{10} \left( \frac{M}{100} \right)$$

**Examples:**

For a magnification of 50 diameters, the true grain size number is 2 units less than that of the corresponding chart or micrograph at 100 diameters,

$$\text{i.e. } Q = -2$$

Similarly, at a magnification of 200 diameters—

$$Q = +2$$

**2.5 PLANIMETRIC METHOD.** In this method the grain size is determined by counting the number of grains inside a known area. A circle or rectangle of known area (usually 5000 mm<sup>2</sup>) shall be inscribed on a micrograph or the ground-glass screen of the microscope. The magnification selected shall give at least 50 and preferably about 100 grains in the field to be counted. The sum of all the grains included within the figure plus one-half of the number of grains intersected by the circumference of the area gives the number of equivalent whole grains  $n$  measured at the magnification used.

The nominal number of grains per square millimetre shall be determined from the following formula:

$$m = n \times f$$

where  $f$  is a factor that varies with magnification.

NOTE: Values of  $f$  for various magnifications are given in Table 3.

The grain size number shall then be derived from Table 1.

**2.6 INTERCEPT METHOD.** The intercept method is more convenient than the planimetric method and is recommended particularly for grains that are not equiaxed.

The grain size shall be determined by counting, on the ground-glass screen of the microscope or on representative micrographs or on the test piece, the number of grain boundaries intersected by one or more lines of known length. A total of 50 to 100 intercepts should be counted and, in order to

remove effects due to anisotropy in shape, the lines should be applied over a series of directions 15 degrees apart.

A circular test figure avoids the effects of anisotropy and is therefore preferable to a straight line. An appropriate figure may be inscribed on an eyepiece reticule and the magnification should be such that about 7-10 intersections are made in any one field of view. Boundaries that are tangential to the test figure count as one intersection and intersected triple points as 1.5 intersections.

The length of the line, in millimetres, divided by the average number of grains intersected gives the average intercept distance. The nearest corresponding grain size number shall then be obtained from Table 1. Alternatively, the grain size number shall be determined from the following formula:

$$G = -10.0456 + 6.64 \log_{10} \left( \frac{10NM}{P} \right)$$

where

$P$  = total length of test line, in millimetres

$M$  = magnification

$N$  = total number of intersections.

For non-equiaxed structures, measurements shall be made on lines that lie in all three principal directions of the test piece. If  $n_l$ ,  $n_t$  and  $n_n$  are the number of grains per millimetre intercepted by lines in the longitudinal, transverse and normal directions, then the number of grains per cubic millimetre  $n_{1tn}$ , may be determined from the following formula:

$$n_{1tn} = \frac{2}{3} \times n_l \times n_t \times n_n$$

The grain size number nearest to the observed value of grains per cubic millimetre shall be obtained from Table 1.

Grain shape shall be indicated by appending the ratios

$\frac{n_n}{n_l}$  and  $\frac{n_t}{n_l}$  as subscripts after the grain size number.

**TABLE 1**  
**MICROGRAIN SIZE NUMBER**

| 1                             | 2                                          | 3                                 | 4                                                   | 5                                             | 6                                    |
|-------------------------------|--------------------------------------------|-----------------------------------|-----------------------------------------------------|-----------------------------------------------|--------------------------------------|
| Grain size number<br><i>G</i> | Calculated diameter of average grain<br>mm | Average intercept distance*<br>mm | Calculated area of average grain<br>mm <sup>2</sup> | Average number of grains per cubic millimetre | Nominal grains per square millimetre |
| 00†                           | 0.500                                      | 0.444                             | 0.250                                               | 8                                             | 4                                    |
| 0                             | 0.353                                      | 0.313                             | 0.125                                               | 23                                            | 8                                    |
| 0.5                           | 0.289                                      | 0.257                             | 0.083 3                                             | 42                                            | 12                                   |
| 1                             | 0.250                                      | 0.222                             | 0.062 5                                             | 64                                            | 16                                   |
| 1.5                           | 0.204                                      | 0.181                             | 0.041 7                                             | 118                                           | 24                                   |
| 2                             | 0.177                                      | 0.157                             | 0.031 2                                             | 181                                           | 32                                   |
| 2.5                           | 0.144                                      | 0.128                             | 0.020 8                                             | 333                                           | 48                                   |
| 3                             | 0.125                                      | 0.111                             | 0.015 6                                             | 512                                           | 64                                   |
| 3.5                           | 0.102                                      | 0.090                             | 0.010 4                                             | 941                                           | 96                                   |
| 4                             | 0.088                                      | 0.078                             | 0.007 81                                            | 1 449                                         | 128                                  |
| 4.5                           | 0.0722                                     | 0.064                             | 0.005 2                                             | 2 661                                         | 192                                  |
| 5                             | 0.0625                                     | 0.055                             | 0.003 9                                             | 4 096                                         | 256                                  |
| 5.5                           | 0.050                                      | 0.043                             | 0.002 6                                             | 7 526                                         | 384                                  |
| 6                             | 0.0442                                     | 0.0392                            | 0.001 95                                            | 11 571                                        | 512                                  |
| 6.5                           | 0.0361                                     | 0.0320                            | 0.001 3                                             | 21 281                                        | 768                                  |
| 7                             | 0.0313                                     | 0.0278                            | 0.000 98                                            | 32 768                                        | 1 024                                |
| 7.5                           | 0.0255                                     | 0.0226                            | 0.000 65                                            | 60 211                                        | 1 536                                |
| 8                             | 0.0221                                     | 0.0196                            | 0.000 49                                            | 92 631                                        | 2 048                                |
| 8.5                           | 0.0181                                     | 0.0161                            | 0.000 325                                           | 170 189                                       | 3 072                                |
| 9                             | 0.0156                                     | 0.0138                            | 0.000 244                                           | 262 144                                       | 4 096                                |
| 10                            | 0.011                                      | 0.0098                            | 0.000 122                                           | 741 457                                       | 8 192                                |
| 11                            | 0.0078                                     | 0.0069                            | 0.000 061                                           | $2097 \times 10^3$                            | 16 384                               |
| 12                            | 0.0055                                     | 0.0049                            | 0.000 031                                           | $5931 \times 10^3$                            | 32 768                               |

\* Value of intercept for equiaxed grains.

† The use of 00 is recommended instead of '-1' or 'minus 1' to avoid confusion.

**TABLE 2**  
**RELATIONSHIPS BETWEEN ACTUAL GRAIN SIZE OF TEST PIECES VIEWED AT VARIOUS**  
**MAGNIFICATIONS AND THE STANDARD SERIES OF PHOTOMICROGRAPHS**

| Grain size number | Actual grain size expressed as diameter of average cross-section when magnified image of test piece matches standard series of photographs at 100 ×, mm* |       |       |       |
|-------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------|-------|-------|-------|
|                   | Magnification                                                                                                                                            |       |       |       |
|                   | 25×                                                                                                                                                      | 50×   | 75×   | 100×  |
| 0                 | 1.412                                                                                                                                                    | 0.706 | 0.466 | 0.353 |
| 0.5               | 1.156                                                                                                                                                    | 0.578 | 0.381 | 0.289 |
| 1                 | 1.000                                                                                                                                                    | 0.500 | 0.330 | 0.250 |
| 1.5               | 0.816                                                                                                                                                    | 0.408 | 0.269 | 0.240 |
| 2                 | 0.708                                                                                                                                                    | 0.354 | 0.234 | 0.177 |
| 2.5               | 0.576                                                                                                                                                    | 0.288 | 0.190 | 0.144 |
| 3                 | 0.500                                                                                                                                                    | 0.250 | 0.165 | 0.125 |
| 3.5               | 0.408                                                                                                                                                    | 0.204 | 0.135 | 0.102 |
| 4                 | 0.352                                                                                                                                                    | 0.176 | 0.116 | 0.088 |
| 4.5               | 0.288                                                                                                                                                    | 0.144 | 0.095 | 0.072 |
| 5                 | 0.248                                                                                                                                                    | 0.124 | 0.082 | 0.062 |
| 5.5               | 0.200                                                                                                                                                    | 0.100 | 0.066 | 0.050 |
| 6                 | 0.176                                                                                                                                                    | 0.088 | 0.058 | 0.044 |
| 6.5               | 0.144                                                                                                                                                    | 0.072 | 0.047 | 0.036 |
| 7                 | 0.124                                                                                                                                                    | 0.062 | 0.042 | 0.031 |
| 7.5               | 0.100                                                                                                                                                    | 0.050 | 0.033 | 0.025 |
| 8                 | 0.088                                                                                                                                                    | 0.044 | 0.029 | 0.022 |
| 8.5               | 0.072                                                                                                                                                    | 0.036 | 0.028 | 0.108 |
| 9                 | 0.064                                                                                                                                                    | 0.032 | 0.021 | 0.016 |
| 10                | 0.044                                                                                                                                                    | 0.022 | 0.015 | 0.011 |
| 11                | 0.032                                                                                                                                                    | 0.016 | 0.010 | 0.008 |
| 12                | 0.020                                                                                                                                                    | 0.010 | 0.007 | 0.005 |

\* It is recommended that micrograin size numbers be used (see ASTM E112) for grain sizes larger than 0.5 mm, 25× be used only for grain sizes larger than 0.210 mm, 50× be used only for grain sizes larger than 0.075 mm. For the smaller grain sizes, greater accuracy generally can be secured by increasing the magnification. This table can be used for comparisons at 250×, 500×, 750× or 1000× by dividing by 10 the grain size indicated at 25×, 50×, 75× and 100× respectively.

**TABLE 3**  
**RELATIONSHIP BETWEEN MAGNIFICATION USED AND**  
**MULTIPLYING FACTOR FOR AN AREA OF 5000 mm<sup>2</sup>**

| Magnification used | Multiplying factor <i>f</i> |
|--------------------|-----------------------------|
| 1                  | 0.002                       |
| 10                 | 0.02                        |
| 25                 | 0.125                       |
| 50                 | 0.5                         |
| 75                 | 1.125                       |
| 100                | 2                           |
| 150                | 4.5                         |
| 200                | 8                           |
| 250                | 12.5                        |
| 300                | 18                          |
| 500                | 50                          |
| 750                | 112.5                       |
| 1000               | 200                         |