

Australian Standard™

Procedures for acceptance testing of refractory products

Part 1: Batch procedure

This Australian Standard was prepared by Committee MN-007, Refractories and Refractory Materials. It was approved on behalf of the Council of Standards Australia on 15 June 2001 and published on 1 August 2001.

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Australasian Ceramic Society
Australasian Institute of Mining and Metallurgy
Australian Aluminium Council
Bureau of Steel Manufacturers of Australia
Cement Industry Federation
CSIRO—Manufacturing Science and Technology
Refractories Manufacturers Association of Australia
University of Wollongong

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STANDARDS AUSTRALIA

RECONFIRMATION

OF

AS 2497.1—2001

**Procedures for acceptance testing of refractory products
Part 1: Batch procedure**

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NOTES

Australian Standard™

Procedures for acceptance testing of refractory products

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PREFACE

This Standard was prepared by the Standards Australia Committee MN-007, Refractory and Refractory Materials as a revision of AS 2497—1981, *Sampling procedures for acceptance testing of shaped refractory products* to extend its scope to include all refractory products. The Standard provides a practical guide to manufacturers and users of refractory products on sampling for acceptance testing.

This Standard is Part 1 of a series and relates to batch sampling procedures. Part 2 will cover sequential sampling procedures.

The content and format of the original edition of AS 2497 were derived from a study of typical practical sampling problems taken from the records of large industrial users and suppliers and were decided on after undertaking a study of the provisions of all relevant national and international Standards* and draft Standards available to the Committee.

It was considered that relevant ISO Standards on refractory products were limited in scope and prescriptive. On the other hand the use of general Australian, other national and international Standards on sampling methods is daunting, particularly for users, because of the size of the Standards and the lack of practical examples.

This Standard utilizes general standards on sampling methods and applies them to the refractory industry.

The terms ‘normative’ and ‘informative’ have been used in this Standard to define the application of the appendix to which they apply. A ‘normative’ appendix is an integral part of a Standard, whereas an ‘informative’ appendix is only for information and guidance.

Statements expressed as mandatory terms in notes to tables are deemed to be requirements of this Standard.

* Specific references are given in Appendix A.

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STANDARDS AUSTRALIA

Australian Standard

Procedures for acceptance testing of refractory products

Part 1: Batch procedure

SECTION 1 SCOPE AND GENERAL

1.1 SCOPE

This Standard sets out the methodology for the acceptance testing of refractory products based on minimum quality levels associated with an agreed specification.

The Standard is suitable for shaped or unshaped products, raw materials or for a product in an intermediary phase. This Standard is applicable to all situations where a minimum quality level, as opposed to a mean quality level, is required for harm minimization.

This Standard does not cover the varied quality control methods used to meet performance requirements.

1.2 APPLICATION

The Standard recommends guiding principles to assist both purchasers and suppliers of refractory products in preparing sampling plans that will enable them to determine within practical limits whether or not the product complies with pre-set specifications. For a given set of conditions there will usually be several possible plans, a choice between them being made on the grounds of simplicity or cost.

1.3 REFERENCED DOCUMENTS

The documents referred to in this Standard are listed in Appendix A.

1.4 DEFINITIONS

For the purposes of this Standard, the definitions below apply.

NOTE: See also Appendix B and AS 2780.

1.4.1 Acceptable quality level (AQL)

A quality level which, in a sampling plan, corresponds to a specified but relatively high probability of acceptance. It is the maximum percent defective that, for purpose of sampling inspection, can be considered satisfactory as a process average.

1.4.2 Batch or lot (inspection)

A quantity of some commodity from which a sample is to be drawn and inspected to determine compliance with the acceptability criteria. (This may differ from a quantity of some commodity designated as a batch or lot from other purposes, e.g. for shipment. Other Standards may define batch and lot separately.) Each batch is assumed, as far as practicable, to consist of material or items of a single type, grade, class, size and composition, and to have been manufactured under essentially the same conditions at essentially the same time. It may therefore be necessary to subdivide a mixed consignment into homogeneous batches.

1.4.3 Batch, lot or population size

The number of items in the population. (Symbol: N)

1.4.4 Consumer's risk

For a given sampling plan, the probability of acceptance of a batch containing the percent defective originally planned to be rejected most of the time. It is thus the probability of accepting a batch with fraction defective equal to the limiting quality (LQ). (Symbol: β)

1.4.5 Fraction defective

The total number of defective items divided by the total number of items. When applied to the total number of items in a sample, it is known as the sample fraction defective. When applied to the total number of items in a batch, it is known as the batch fraction defective. The fraction defective multiplied by 100 gives the percent defective; symbol p is used for both the fraction defective or percent defective, depending on context. (Symbol: p)

1.4.6 Increment

A quantity of material taken at one time from a larger quantity of material.

1.4.7 Individual value

The value of measurement on the i th item of the sample size n . (Symbol: x_i)

1.4.8 Inspection level

A characteristic of some sampling schemes which determines the relationship between the batch size and the sample size.

1.4.9 Item, unit, unit of product

An object or a defined quantity of material on which an observation or a measurement may be made.

1.4.10 Limiting quality (LQ)

A quality level which in a sampling plan corresponds to a specified but relatively low probability of acceptance. It is the limiting percent defective (or fraction defective, if relevant) that the consumer is willing to accept with a very small probability that a batch of this percent defective would occur.

1.4.11 Mean (of sample)

The sum of the individual values divided by the size of the sample. (Symbol: $\bar{x}$)

$$\bar{x} = \frac{1}{n} (x_1 + x_2 + \dots + x_n) = \frac{1}{n} \sum_{i=1}^n x_i$$

The mean value of the population is designated by the symbol μ .

1.4.12 Operating characteristic (OC) curve

A curve showing, for a given sampling plan, the probability of acceptance of a batch as a function of the fraction defective of that batch.

1.4.13 Population

The totality of the set of items that is under consideration.

1.4.14 Producer's risk

For a given sampling plan, the probability of rejection of a batch containing the percent defective originally planned to be accepted most of the time. It is thus the probability of rejecting a batch with fraction defective equal to the AQL. (Symbol: α)

1.4.15 Sample

One or more items taken from a batch and intended to provide information about the batch and possibly to serve as a basis for a decision on the batch or on the process which has produced it.

1.4.16 Size of the sample

The number of items in the sample. (Symbol: n)

1.4.17 Specification limit

The desired maximum (U) or minimum (L) result of a measured property on a batch. (Symbols: U or L)

1.4.18 Standard deviation

The square root of the sample variance. (Symbol: s)

$$s = \sqrt{\frac{1}{n-1} \sum_{i=1}^n (x_i - \bar{x})^2} \quad \dots 1.1$$

The Standard deviation of the population is designated by the symbol σ .

1.5 NOTATION

All quantity symbols used in the equations of this Standard are listed in Appendix G.

SECTION 2 METHODS

2.1 VARIABLES AND ATTRIBUTES

2.1.1 Variables

A variable is a characteristic that may be appraised in terms of values which are part of a continuous scale of measurement, e.g. compressive strength or apparent porosity. The quality of a unit, in the variables method, may be assessed by referring the measured value of the unit to either a specified quality value, when a single limit is involved (e.g. a compressive strength of 20 MPa minimum), or to specified quality values in the case of double specification limits (e.g. an apparent porosity between 20 percent and 25 percent).

2.1.2 Attributes

An attribute is a characteristic which is appraised in terms of whether it does or does not exist with respect to a given requirement (e.g. cracks or laminations), or for dimensional requirements when checked against fixed gauges.

2.1.3 Comparison of use

The variables method (Clause 2.1.1) has the advantage that, *provided certain assumptions hold* (see Clause 2.2.4), it requires a smaller sample size than the attributes method (Clause 2.1.2) to attain a similar degree of protection against incorrect decisions. The attributes method is free from assumptions on normality and may be simpler to use. For appropriate test methods, such as checking dimensions with a fixed gauge, the unit cost of inspection can be lower.

Nearly all of the test methods in the AS 1774 series give a quantitative measured result, which can be used in a sampling scheme based on variables. As this information is usually of value to both the producer and the consumer there may be a preference to use a variables method. This particularly applies to unshaped refractory materials and products made from them.

2.2 PRACTICAL CONSIDERATIONS

2.2.1 General

When production is regular or continuous, quality control information may be made available to the purchaser and the acceptance of the batch based upon it without further sampling. In other cases a combination of supplied information and acceptance sampling may be appropriate. For example, some information about the quality of past production may assist in the choice of a smaller sample size. In MIL-STD-414, AS 1199 and AS 1399 this corresponds to special inspection levels.

2.2.2 Batch quality measurement

Batch quality measurement, either by variables or attributes, is restricted to the percent defective. In situations where the mean alone is a reasonable quality guide, other methods, not detailed in this Standard, are appropriate, e.g. conformance by using confidence limits for the mean, see ISO 5022.

2.2.3 Item size

For unshaped products the minimum mass of an increment is either the larger of the amounts shown in Table 2.1 or the total amount required for testing purposes.

NOTE: If the amount of the item is more than that required for test purposes it may be possible to place the remainder in a sealed container for later use.

TABLE 2.1
MINIMUM MASS OF INCREMENT

Maximum grain size mm	Minimum mass of increment
>100	30 kg
100	15 kg
50	5 kg
20	2 kg
10	500 g
3	200 g
1	50 g

NOTES:

- 1 The masses of the increments relate to a bulk density greater than 1000 kg/m³. For lower bulk densities, the mass of the increment may be determined by multiplying the numerical value in the table by the bulk density of the material.
- 2 Special agreements should be made in the case of very lumpy material.
- 3 The actual increment masses should depend on the sampling equipment and the tests to be performed. This is the case for unshaped products if the physico-mechanical properties of specimens taken from these products are to be determined.
- 4 See AS 4433.1 for a detailed calculation of sample mass for specific materials.

2.2.4 Inspection by variables

The theory governing inspection by variables depends on the properties of the normal distribution and therefore this method of inspection is only applicable when there is reason to believe that the frequency distribution is normal. Techniques for testing normality are given in BS 6002: Part 1.

Test results will include errors in sampling of bulk materials, errors in sample preparation and testing errors. These errors tend to be normally distributed.

Errors in sample preparation and testing are known as repeatability. Typical values may be given in the Standard for the test method.

It can also be expected that there will be biases in different laboratories because of different personnel and different equipment. The difference between laboratories is known as reproduceability. Typical values may be given in the Standard for the test method.

An allowance for repeatability and reproduceability needs to be made when setting quality levels (*U* or *L*), AQL and LQ.

2.2.5 Multiple properties

It is recommended that the number of properties inspected by variables (excluding chemical analysis) should not be greater than three.

When more than one property is being considered, several approaches are possible, as follows:

- (a) One property is paramount and the sampling plan is devised for this property alone. The other properties may still be measured, but do not take part in the acceptance or rejection procedure.

- (b) Several plans are devised, one for each property. To avoid sampling correlations between measurements on the same unit, a separate sample would be required for each property unless they were known to be uncorrelated properties. In this circumstance the total risks to producer and consumer are modified.

Equations relating the total risks for j properties (α_j , β_j) to the separate risks (α , β) are—

$$\alpha_j = 1 - (1 - \alpha)^j \quad \dots 2.1$$

$$\beta_j = \beta^j \quad \dots 2.2$$

For convenience of calculations, all risks in the above equations are expressed as decimals rather than percentages, and final results reconverted to percentages.

Where the separate risks $\alpha = 5\%$ and $\beta = 10\%$ are specified for each property then, for example, for three properties the total risks $\alpha_3 = 14.26\%$ and $\beta_3 = 0.1\%$. Where the total risks are specified, e.g. for three properties $\alpha_3 = 5\%$ and $\beta_3 = 10\%$, the equations give $\alpha = 1.7\%$ and $\beta = 46.4\%$. Thus, when comparing an acceptance plan based on three properties with one based on a single property, account must be taken of the change in risks. An example illustrating this point is given in Clause 4.1.4 where it is shown that a plan based on three properties leads to a total sample size of 27 items (i.e. 9 for each property) that is comparable to a plan based on a single property with a sample size of 20.

- (c) Several properties could be considered jointly and condensed into an attribute, i.e. satisfactory or not for all properties being considered. This method will only be used in practice if it leads to a smaller total sample size than approach (b) described above.

2.3 GUIDE TO CHOICE OF METHODS

The field of sampling inspection recognizes two basic methods of inspection for evaluating quality characteristics, viz. variables and attributes. Typical areas of application of variables are situations where measurement of physical properties are involved, such as apparent porosity or compressive strength. The corresponding areas of application of attributes are situations which deal with a classification of an item as defective or non-defective, such as visual defects (cracks and laminations), or use of fixed gauges for dimensional requirements. The choice of a sampling scheme, therefore, principally depends on whether the quality characteristics is classified as either a variable or an attribute.

By comparing results from any test with a nominated quality value and classifying them into defective or non-defective (or pass and fail) will allow the use of a method of inspection by attributes. However, as indicated in Clause 2.1.3 the sample size for the same risk levels will be larger. This could be done if it is suspected that the variation of actual quality was not normally distributed.

For testing of bulk materials and unshaped products there would normally be little reason to use inspection by attributes.

This Standard offers a recommended method and an alternative for both variables and attributes, as outlined in Table 2.2.

The recommended methods are based on well established procedures and require the specification of only a few parameters to select a sampling scheme. The setting of these parameters depends on a number of factors including knowledge of the existing level of quality in production, and the consumer's quality requirements. These are considered in the sections relevant to the method selected.

In the situations when the consumer and the producer agree to control the quality and risk at prescribed levels, the alternative methods are presented in this Standard for both variables and attributes.

The recommended methods do not provide information on producer's or consumer's risk. These risks can be high when the sample size is small. The risk levels can be calculated from the OC curve as shown in Appendix C. If one or both risk levels need to be fixed the alternative methods would be preferred.

2.4 SUGGESTIONS FOR APPROPRIATE AQL, INSPECTION LEVEL, PRODUCER'S RISK, LQ, CONSUMER'S RISK AND SPECIFICATION LIMIT

2.4.1 AQL Values

The following considerations may be used to determine an appropriate AQL.

- (a) Classification of characteristic according to application of refractory product:

Classification of characteristic	AQL
Crucial	Low
Normal	Medium
Non-crucial	High

In general, a low AQL would be a value of 1.5% or less; a medium AQL would be 2.5% to 6.5%; and a high AQL value greater than 6.5%. However, the final differentiation between low, medium and high will depend upon the particular situation being considered.

- (b) The preservation of an existing level of quality in production, or encouraging an improvement over an existing level of quality in production.
- (c) Setting a reasonable quality standard, based on past achievement with a similar product.
- (d) Selection on the basis of specified tolerance; a low AQL is usually associated with a tight tolerance, and a high AQL, with a loose tolerance.

2.4.2 Inspection level

Inspection level applies to the recommended methods for variables and attributes.

The following considerations may be used to determine the inspection level:

- (a) Having set the AQL, the inspection level is set by considering what quality should have a high chance of rejection if an occasional lot of that quality should be offered. As an example, inspection level II for both variables and attributes may be selected as a first trial. Higher or lower inspection levels offer correspondingly greater or lesser degree of discrimination, respectively, between good and bad batches. That is both producer's and consumer's risks are affected.
- (b) A lower inspection level may be desirable for economic or practical reasons if testing procedures are costly and/or destructive. However, the consumer should be aware of increased LQ associated with the particular sampling plan.

(Several of the references in Appendix A give further guidelines for AQL and inspection level selection).

TABLE 2.2
GUIDE TO CHOICE OF METHODS

Sampling scheme	Recommended methods		Alternative methods	
	Variables	Attributes	Variables	Attributes
	Method 1	Method 2	Method 1A	Method 2A
Agreed parameters	Specification limit, AQL, inspection level	Specification of defective, AQL, inspection level	Specification limit, AQL (p_0), LQ (p_1), α , β	Specification of defective, AQL (p_0), LQ (p_1), α , β
Sample size	Related to batch size		Related to quality and risk levels	
Introduction	Clause 3.1.1	Clause 3.2.1	Clause 4.1.1	Clause 4.2.1
Sampling procedure	Clause 3.1.2	Clause 3.2.2	Clause 4.1.2	Clause 4.2.2
Practical example	Clause 3.1.3	Clause 3.2.3	Clause 4.1.3, 4.1.4	Clause 4.2.3
Relevant tables	Table D1, D2	Table F1, F2	Table D3	Table F3
Advantages	Minimum number of agreed parameters		Product and consumer control quality and risk levels	
Disadvantages	Producer and consumer do not have control over risk levels		More parameters must be specified	

References in Appendix A for the four methods are: Method 1, MIL-STD-414; Method 2, AS 1199; Method 1A, JIS Z9004 and Method 2A, Wetherill*.

2.4.3 Producer's and consumer's risks

BS 6000 states:

'The producer requires a high probability of acceptance if the quality is good while the customer would want a low probability of acceptance if the quality is poor.

Conventionally these probabilities have been set at 0.95 (i.e. α is 5%) and 0.10 (i.e. β is 10%) respectively. It is becoming increasingly common practice to make both α and β equal to 5%.

By way of contrast AS 1379 requires for the given AQL (5%) and LQ (30%) maximums of 50% and 2% for α and β respectively.

2.4.4 LQ Values

As stated in Clause 1.4.4, β and LQ are associated (similar to α and AQL). Similar comments apply for LQ as for AQL in Clause 2.4.1 but with slightly higher values. A normal LQ may be 10%.

With the same sample size, a higher LQ will result in a lower β . Appendix E has an example with a sample size of 10. If the LQ is increased from 5% to 10%, β reduces from 59.9% to 34.9%. With an LQ of 30%, β reduces to 2.8%.

* WETHERILL, G.B., *Sampling Inspection and Quality Control*, Methuen and Co (1969).

2.4.5 Specification limit (*U* or *L*)

AQL and LQ are based on a specification limit which is a desired minimum or maximum result of a measured property on a batch of refractories. While it is not recommended practice, it is possible for consumers to set specification limits, which are different to their actual requirements. This could allow sampling schemes with smaller sample sizes, which would increase the risk of accepting defectives at the set specification limit but achieve an acceptable risk level at actual required specification limit. Such a situation would not normally arise in a long term relationship between supplier and consumer where there is some knowledge of product variability.