

INTERNATIONAL STANDARD

NORME INTERNATIONALE



Quality assessment systems –

Part 3: Selection and use of sampling plans for printed board and laminate end-product and in-process auditing

Système d'assurance de la qualité –

Partie 3: Choix et utilisation de plans d'échantillonnage pour cartes imprimées et produits finis stratifiés et audits en cours de fabrication



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IEC Central Office
3, rue de Varembé
CH-1211 Geneva 20
Switzerland

Tel.: +41 22 919 02 11
Fax: +41 22 919 03 00
info@iec.ch
www.iec.ch

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QUALITY ASSESSMENT SYSTEMS –

Part 3: Selection and use of sampling plans for printed board and laminate end-product and in-process auditing

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The text of this standard is based on the following documents:

FDIS	Report on voting
91/1061/FDIS	91/1080/RVD

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts of the IEC 61193 series, under the general title *Quality assessment systems*, can be found on the IEC website.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC web site under "<http://webstore.iec.ch>" in the data related to the specific publication. At this date, the publication will be

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INTRODUCTION

A clear description in IEC standards and specifications and their reference to sampling plans in order to insure adherence to customer requirements is essential. All the details should be clear as to their implementation or adjustment for evaluation of the product to be shipped, the use of process control and SPC, or the applicability for using these principles in controlled experimentation. The general characteristics of these principles relate to a gradual reduction that might be needed in examining the product being manufactured. As such, they are sometimes referred to as the logical steps to process improvement. These steps are as follows.

a) STATISTICAL SAMPLING: where, when, and why

- To determine a proper amount of examples from a given lot of product and using statistics to evaluate the occurrence of anomalies.

b) ZERO DEFECT STANDARDS: role of specifications

- To adopt the role of attempting to achieve no defects in a production lot through the recommendations identified in standards or specifications that define the product requirements.

c) ECONOMICS: AQL versus cost of defects

- To establishing the highest level of non-conforming product characteristics, determining the cost that is incurred when these are discovered or delivered accidentally to the customer (cost of quality) and establishing an acceptable quality assessment methodology in order to reduce these occurrences.

d) SPC REDUCED INSPECTION: rules for use and control

- To create a process control program that is based on reject criteria, followed by controlled experimentation to improve the process and then using statistical analysis in order to determine that the process improvement has reduced the occurrences of these reject criteria.

The explosion of the electronics industry has led to a situation where the design of the printed board mounting structure or the material used to produce the product is so complex, that the quality level of these items delivered with known failures are no longer acceptable. The acceptable number of non-conforming products should be directed toward approaching zero in producer-customer contracts.

This has led to the development of new methods of quality assurance like the application of Statistical Process Control (SPC). The low number of permitted non-conforming product according to the AQL tables caused many to resort to 100 % testing or inspection.

At the same time the quality thinking has developed so that the idea to accept failures has become impossible, and the use of the AQL tables in the traditional way has been diminishing very rapidly.

QUALITY ASSESSMENT SYSTEMS –

Part 3: Selection and use of sampling plans for printed board and laminate end-product and in-process auditing

1 Scope

This part of IEC 61193 establishes sampling plans for inspection by attributes, including sample plan selection criteria and implementation procedures for printed board and laminate end-product and in-process auditing. The principles established herein permit the use of different sampling plans that may be applied to an individual attribute or set of attributes, according to classification of importance with regard to form, fit and function.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

IEC 60194:2006, *Printed board design, manufacture and assembly – Terms and definitions*

IEC 62326-4:1996, *Printed boards – Part 4: Rigid multilayer printed boards with interlayer connections – Sectional specification*

ISO 9000:2005, *Quality management systems – Fundamentals and vocabulary*

ISO 14560:2004, *Acceptance sampling procedures by attributes – Specified quality levels in non-conforming items per million*

3 Terms and definitions

For purposes of this document, the terms and definitions given in IEC 60194:2006, ISO 9000:2005 and the following apply.

3.1

attribute

aspect or characteristic of a unit of a defined product in terms of actual requirement and allowable deviation

Note 1 to entry: An actual requirement signifies the following:

- a requirement that is stated as a measurement with an allowable more and/or less deviation;
- a requirement stated as an absolute desired condition with allowable anomalies;
- a requirement stated as an absolute without exception (go/ no-go).

3.1.1

critical attribute

attribute where a defect, that judgment and experience indicate, is likely to result in hazardous or unsafe conditions for individuals using, maintaining, or depending upon the product; or where a defect is likely to prevent performance or function of a major end item such as a ship, aircraft, computer, medical equipment, or telecommunication satellite

3.1.2

major attribute

attribute where a defect, other than critical, is likely to result in failure, or where a defect reduces the usability of the unit of a product for its intended purpose

3.1.3

minor attribute

attribute where a defect is not likely to reduce materially the usability of the unit of product for its intended purpose, or where a defect is a deviation from established standards having little bearing on the effective use or operation of the unit

3.2

acceptable quality level

DEPRECATED: AQL

maximum percent of defects that can be tolerated as a risk, stated for the purposes of sampling inspection

Note 1 to entry: Sample inspection with associated risk tolerance is employed only where all units of a product within an inspection lot is expected to completely conform to the specification requirements.

Note 2 to entry: See 3.3.

3.3

acceptance quality limit

lower than perfect quality level

Note 1 to entry: Revised term for AQL.

Note 2 to entry: The term is used to indicate a certain degree of risk in that some products may have non-conforming characteristics. However, they do not impact the final performance. These decisions are based on customer/supplier agreements.

Note 3 to entry: The use of the abbreviation AQL to mean “acceptable quality level” (refer to 3.2) is no longer recommended.

3.4

defective

unit of product that contains one or more defects

3.4.1

critical defective

unit of product that contains one or more defects of critical attributes, and that may also contain defects of major or minor attributes

3.4.2

major defective

unit of product that contains one or more defects of major attributes, and may also contain defects of minor attributes, but contains no defects of critical attributes

3.4.3

minor defective

unit of product that contains one or more defects of minor attributes, but contains no defects of major or critical attributes

3.5

inspection

process of measuring, examining, testing, or otherwise comparing the unit of product with the specified requirements

3.5.1**inspection by attributes**

inspection of individual attributes (aspects or characteristics) of the unit of product per specified requirements, procedures, and/or instructions

3.5.2**inspection lot**

collection of product units that are identified and treated as a unique entity from which a sample is drawn and inspected in order to determine conformance with acceptability criteria

3.5.3**inspection rate**

number of features per unit of time that can be evaluated at specified false-alarm and escape-rate settings

3.6**risk management factor****RMF**

maximum tolerable percentage of possible defects within a lot (group) of units, based on approximately 95 % confidence level

3.7**shipment-ready product**

product shipped to the customer without having to meet any further acceptance criteria

3.8**unit of product**

item(s) being inspected in order to determine conformance to specific requirements

Note 1 to entry: These requirements consist of the following:

- a single article, a pair, a set, a length, an area, an operation, a volume, a component of an end product, or the end product itself;
- may or may not be the same as the unit of purchase, supply, production or shipment.

4 Sampling methodologies**4.1 General**

There is a considerable number of ISO standards on acceptance sampling (see Annex D for details). However, most of these standards contain plans that allow a lot to be accepted even when the sample from the lot contains one or more non-conforming items, although there are some exceptions (ISO 18414 and ISO 21247).

The zero acceptance number plans ($c = 0$) were originally designed and used to provide equal or greater consumer protection with less inspection than that required by corresponding sampling plans. The $c = 0$ plans are simple to use and administer since there is greater emphasis on zero defects and product liability prevention. The concepts stated herein provide a set of attribute plans for product lot inspection. The acceptance number in all cases is zero. This means that for some level of protection, a sample size is selected and if one or more non-conforming attributes are present, the lot will be withheld.

The terminology "withhold the lot" does not necessarily mean rejection. A lot is not automatically accepted or rejected if one or more non-conformances are found. It is only accepted if zero non-conformances are found in the sample.

Withholding the lot obliges engineering/management personnel to review the results and to withdraw the lot depending on the seriousness of the case. This relates to whether the attribute

was critical, major, or minor, or whether identifying the non-conformance to the requirements was defined as a critical, major, or minor defect.

The word "defective" is commonly used in quality control to describe a part, component, item, or any other unit of product that contains one or more defects. The word "defect" is commonly used to describe a particular non-conforming characteristic on a unit of product.

4.2 Attribute sampling plans

4.2.1 General

The following subclauses provide an overview of lot size description attribute plans while relating them to other plans. Two broad categories of sampling exist and these are

- a) continuous;
- b) production lot.

4.2.2 Continuous sampling

Continuous sampling is often used when product units are submitted one at a time. This can apply to production processes where a product moves through various steps. Product moving along a conveyor can also be thought of as being a candidate for continuous sampling. Industry has moved away from inspecting quality at the end of the line; thus, in-process inspection or sampling is a way in which many companies maintain statistical process controls.

The continuous sampling plan may call for frequency checks, i.e. one unit out of five. Even if the products are good, this frequency check is maintained. If, however, a unit is non-conforming, 100 % inspection is reverted to until the specified number of consecutive conforming products result. At that point, the process returns to frequency inspection.

As an example, a quality decision for continuous sampling would be to examine five samples, within a particular hour, out of a total of thirty products passing through a process. Based on the characteristics being inspected (i.e., solder bridging on a particular part) nothing is observed in a certain number of hours, the time can be increased without changing the sample size. At this point, the sample taken represents a larger portion of an amount of products being processed. The samples are then monitored for a longer period of time before reducing to fewer samples again, or to increase the allotted time in which the samples are randomly selected.

4.2.3 Production lot attributes

Production lot size descriptions involve units of products that are presented in a group, batch, or lot for inspection, as opposed to being presented one at a time. In these cases, a sample of a specified quantity is drawn and compared with some acceptance criteria. In the past, sampling plans allowed a certain quantity of defectives in the sample; the $c = 0$ plan does not. In $c = 0$ plan, the attributes evaluated either conform or do not conform. Go/no go type gauges are often used in attribute plans.

4.2.4 Production lot variables

Another production lot sampling procedure involves the analysis of measured characteristics where the attributes vary with respect to their requirements. Variable sampling compared with attribute sampling essentially involves the inspection of a smaller sample size to obtain the same protection afforded by an attribute plan. The economics of these smaller sample sizes, however, are quite often offset by the calculation involved and the need to obtain and record measurements. In addition, the essential difference between variables and attributes sampling is not the relative sample sizes, but that variables sampling is based on measurements whereas attributes sampling is based on classifications.

Where variables' data is required from an inspection operation, variables' plans shall definitely be considered. The use of variable plans is necessary when the distribution of the variable data can significantly improve the process. It may also be important to establish an upper and lower characteristic so that the customer is aware of the changes that might be necessary to bring the two limits closer together in a manner that meets the customers' requirement (target). By the manufacturer retaining the records regarding meeting the target value of a particular requirement, the data can indicate when the process is starting to become out-of-control due to the distribution of measurements within the specified upper and lower acceptance limit. In variables' production lot sampling, the information is collected primarily to help assure the manufacturing of acceptable products by indicating the distance from the target that the lot inspection provides.

4.3 Non-statistical sampling plans

There are cases where zero defects can visually be assured, although the sample size cannot logically be defined in terms of statistical risks. Such sample sizes are generally exceptionally low for the more important attributes and, therefore, knowledge of the process and the control factors is essential. The drilling of printed circuit boards might use first article inspection as a methodology to determine that the automated tools creating the number of holes in the board meet the criteria of the requirements. No further inspection of the product is carried out. However, to ensure that the production process is still under control, a sampling may be made regarding the number of uses of a drill, any changes in speed or feed characteristics, or other features of the automated process that might impact the quality that was approved by the first article.

In order to avoid any confusion in justifying such sample sizes on inspection plans, specific notations should be used to avoid any tie-in with statistical risks. The reason for such a selection should be noted, either directly in the plan or in the quality engineering standards.

An example might be a sampling operation where just the first and last item from a lot, are inspected dimensionally. This is also accomplished where the first and last time a drill bit is used, it is drilled into an inspection coupon. This permits the first and last characteristics of the drilled hole to be examined and determined that all holes drilled in between are of a good quality. Another example might be evaluating a number of products during a particular time sequence. If the products are different, the technique can be normalized by evaluating the amount of unit area being processed along a conveyor over a particular time. In this case, a variety of products can be measured and evaluated. The system then would be judged in or out of control, depending on non-conformance per unit area over specific time sequences.

The higher index values in the $c = 0$ plans are also used where favourable process control has been demonstrated and just an audit is required. Although the statistical risks seem high, the risks from a practical standpoint would be exceptionally low.

4.4 Defining $c = 0$ plans

There are many plans that have used the $c \geq 0$ concepts. These plans are acceptable quality level (AQL) oriented. Essentially, the AQL is a specified percent that is considered to be good quality. In any sampling plan, an operating characteristic curve can be generated to define the risk of accepting lots with varying degrees of percent non-conforming or defective. These plans went out of favour in the late 1980's, due to the misunderstanding that it was good practice to release shipment-ready products with known, non-conforming attributes.

When the AQL concept is used, a high probability of acceptance associated with the AQL percentage exists. Normally, this is in the order of a 0,90 to 0,98 probability of acceptance level. The risk of rejecting this AQL percentage is in the order of 0,10 to 0,02 probability level. This rejection risk is called the "producer's risk."

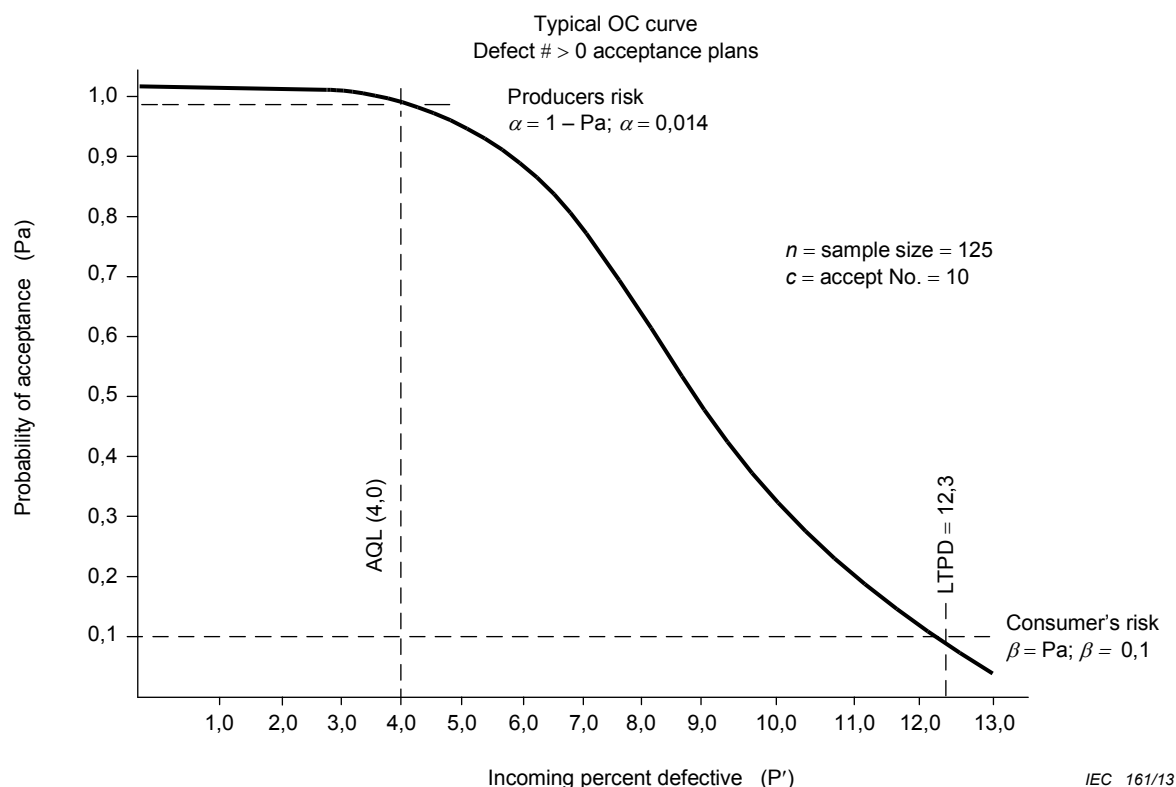
The assumptions in employing the AQL concept, is that some agreement has been reached between the producer and the consumer. Although the term 'quality' is implied by the initials AQL, selecting this method is the worst tolerable quality level, since non-conforming

may be found in the sample size and yet the production lot is still delivered to the customer, see Table 1. Since sampling is used, the producer assumes a risk of having a lot rejected, although the actual percentage defective in the lot is equal to or less than specified in the AQL.

It is also important that a clear distinction be made by either the customer or the requirements of the specification regarding the characteristics of the non-conforming attribute. Many printed board or laminate standards identify some characteristics as a process indicator and allow these to be delivered since they do not impact the performance of the product. The sampling plan, therefore, allows a lower inspection number and uses the occurrences of the process indicators as something that needs to be improved. Scratches on copper conductors are an example of such an indicator. Other attributes are defined as defects since they do impact performance and, therefore, impact the entire production line.

If no prior AQL agreement exists, and sampling is to be performed simply because 100 % inspection is impractical, then over-inspection is usually the result. Also, when 100 % sampling is impractical, the producer is encouraged to inspect a small number of units of product on less critical attributes. To illustrate the concept, if the $c \geq 0$ plan were used, a 1,0 % AQL might be used for critical attributes and a 4,0 % AQL might be used for major attributes. The technique for sample selection under an Acceptable Quality Limit would correlate to a $c = 0$ plan which would allow no non-conforming product in the sample size.

It is a statistical fact that zero accept number ($c = 0$) plans provide equivalent statistical assurance than do plans associated with defect acceptance ($c \geq 0$). This can be verified by examining the operating characteristics (OC) curves, which should normally be provided with sampling plans. Figure 1 shows a typical OC curve from a $c \geq 0$ plan. There is a probability scale on the Y-axis and an incoming defective possibility scale on the X-axis. The curve is generated through probability calculations based on a sample size of 125 with an acceptable number of 10. Also shown is the producer's risk, which is a risk of rejecting a good lot of product and the associated consumer's risk, which is the risk of accepting a bad lot of product.



NOTE 1 Values come from Poisson distribution analysis. (α is 0,013 7 by Poisson distribution and is 0,011 9 by binomial distribution; β is 0,101 3 by Poisson distribution and is 0,086 8 by binomial distribution.)

NOTE 2 For typical OC curve refer to ISO 2859-1.

Figure 1 – Typical OC curve for $c \geq 0$ plan

In addition to the AQL and producer's risk, there is a parameter called the lot tolerance percent defectives (LTPD). This LTPD is considered poor quality, and is sometimes identified as consumer's risk quality. Several sampling plans can have OC curves pass through the same AQL/producer's risk point. For each of these plans, however, there will be a different LTPD at some constant probability of acceptance level. This probability of acceptance level corresponding to the LTPD is usually low with a 0,10 being widely accepted. This probability level is called the "consumer's risk".

The user of sampling plans shall select the plan that will provide reasonably good protection against accepting lots with percent defectives not a lot greater than the AQL. With the AQL/producer's risk point fixed, the closer the LTPD gets to the AQL, the larger the sample size and the acceptance number becomes. Figure 2 is a comparison of the $c \geq 0$ OC curve and an equivalent OC curve from the zero defect $c = 0$ plan. This example illustrates that the $c = 0$ curve with a small sample of 18 and an accept number of 0 is equivalent or better than the $c = 0$ plan with a relatively large sample of 125 and an acceptance number of 10. The producer's risk probability may be greater at certain levels with the $c = 0$ plan.

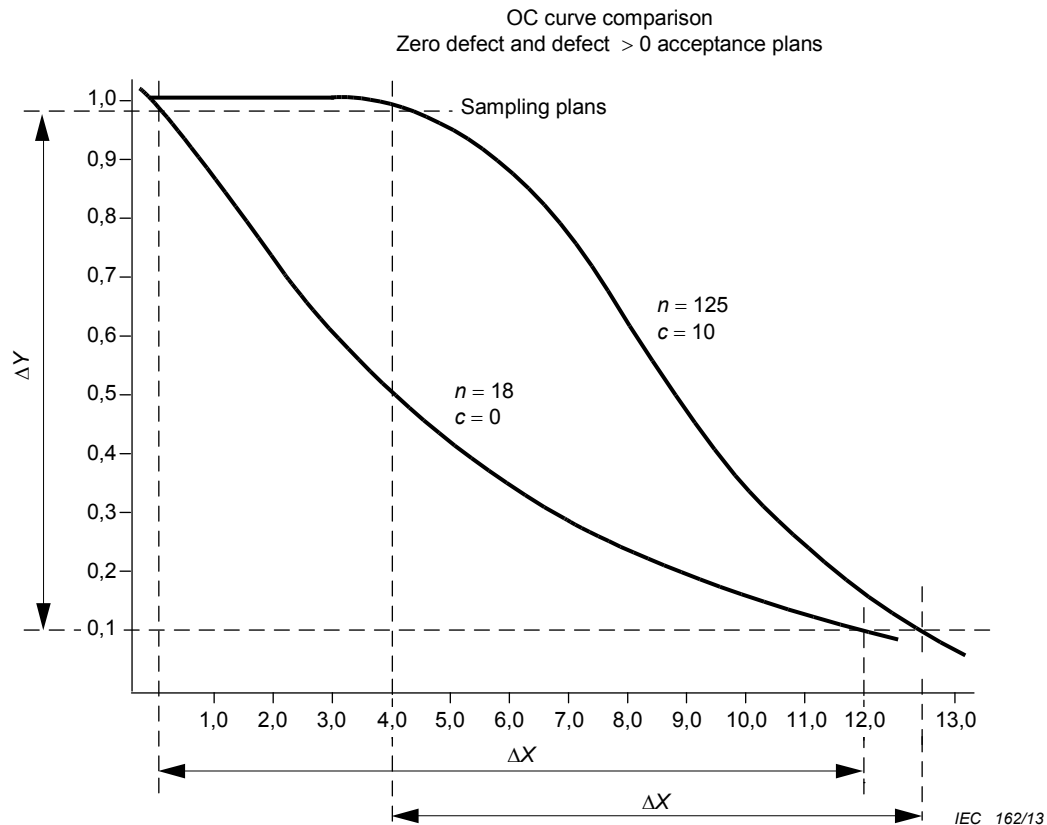


Figure 2 – OC curve comparisons between $c \geq 0$ and $c = 0$ plans

What industry has tended to do, is to measure output, determine yields, and then resign to an acceptable level of defectives based on the information. These systems usually AQL-based, remove incentives to review the validity of specifications, investigate defect causes, or to improve overall product quality.

Table 1 shows a comparison of a set of $c = 0$ plans with previous plans of $c \geq 0$.

Table 1 – Inspection plan comparison

$c \geq 0$ Plan	AQL	Sample size	Accept No.
	1,0 %	125	3
	4,0 %	125	10
$c = 0$ Plan	Associated AQL	Sample size	Accept No.
	1,0 %	42	0
	4,0 %	18	0

The $c = 0$ plan provides equal to or greater LTPD protection at the 0,10 "consumer's risk" level. There is also less inspection performed on less critical characteristics or attributes.

All of the $c = 0$ characteristics are shown in Table 2. They are "associated" with the AQL's of the $c \geq 0$ plans (AQ level) by using the same percent probability columns to evaluate the number of samples to be taken. In the $c = 0$ AQ limit plans, the plans provide equal protection to the consumer. The method of developing the plans provides for simple conversion from past practices to the $c = 0$ plans. The table labels these associated AQ Limits as "risk management index values" because they are not AQ levels. They are an indication of the probability of some occurrences of non-conforming products in the production lot, even though the sample size does not show these anomalies.

Table 2 – Risk management index values (Associated AQ Limits)

Lot size	0,010	0,015	0,025	0,040	0,065	0,10	0,15	0,25	0,40	0,65	1,0	1,5	2,5	4,0	6,5	10,0
	Sample size															
2 – 8	*	*	*	*	*	*	*	*	*	*	*	*	5	3	2	2
9 – 15	*	*	*	*	*	*	*	*	*	*	13	8	5	3	2	2
16 – 25	*	*	*	*	*	*	*	*	*	20	13	8	5	3	3	2
26 – 50	*	*	*	*	*	*	*	*	32	20	13	8	5	5	5	3
51 – 90	*	*	*	*	*	*	80	50	32	20	13	8	7	6	5	4
91 – 150	*	*	*	*	*	125	80	50	32	20	13	12	11	7	6	5
151 – 280	*	*	*	*	200	125	80	50	32	20	20	19	13	10	7	6
281 – 500	*	*	*	315	200	125	80	50	48	47	29	21	16	11	9	7
501 – 1 200	*	800	500	315	200	125	80	75	73	47	34	27	19	15	11	8
1 201 – 3 200	1 250	800	500	315	200	125	120	116	73	53	42	35	23	18	13	9
3 201 – 10 000	1 250	800	500	315	200	192	189	116	86	68	50	38	29	22	15	9
10 001 – 35 000	1 250	800	500	315	300	294	189	135	108	77	60	46	35	29	15	9
35 001 – 150 000	1 250	800	500	490	476	294	218	170	123	96	74	56	40	29	15	9
150 001 – 500 000	1 250	800	750	715	476	345	270	200	156	119	90	64	40	29	15	9
500 001 and over	1 250	1 200	1 112	715	556	435	303	244	189	143	102	64	40	29	15	9
Remarks:																
a) The symbol * indicates "inspect the entire lot".																
b) If the lot size is smaller than the sample size, the entire lot should be inspected.																
c) If samples contain no defects, the entire lot is accepted. If the sample contains one or more defects, the entire lot is rejected.																

Because of the zero accept number, the idea of combining lots under the $c = 0$ plans may arise because of the zero accept number. Aside from experience, which has shown that, in fact, considerable savings can be derived, one should consider the following:

- if the quality is very bad, acceptance numbers greater than zero will not be of much help;
- to allow acceptance numbers greater than zero in the plan, one is in effect authorizing an inspector to accept parts which may not be usable;
- the zero acceptance number forces a review of any defectives by quality assurance personnel in order to enable proper withdrawal of the defectives;
- if zero defects are to be achieved, it should be obvious that defectives should not knowingly allowed to be shipped.

The $c = 0$ plans were essentially designed to be equal or greater in consumer and average outgoing quality limit protection. Within a particular column of the details shown in Table 2 representing the index value, the operating characteristic curves actually differ for the most part between $c = 0$ and $c \geq 0$ plans, especially as the lot size increases. The reason for this common feature, in addition to satisfying the statistical relationship, is that it is generally considered more practical to obtain greater protection on larger lot sizes. Table 3 provides guidance to selection of sample sizes and comes from the standards developed for printed circuit board and laminate characteristic requirements. Table A.1 of Annex A provides a consensus sampling plan from IEC 62326-4 that identifies the different product characteristics, the number of samples that should be taken for performance levels A, B, and C, and the risk management index value to be used from Table 2.

Table 3 – Sample size selection guideline

Attributes	Defects		
	Critical	Major	Minor
Critical	0,1	1,0	2,5
Major	1,0	2,5	4,0
Minor	2,5	4,0	6,5

The use of constant sample sizes often results in a combination of over-inspection and under-inspection. For a broad range of lot sizes in general, however, in order to develop an inspection strategy, an evaluation should be made as to the attribute classification (critical, major, minor). This listing of comparisons should identify the risk management index value shown in the Table 2 and should allow the $c = 0$ plans to be used when

- manufactured parts are expected to completely conform to specification requirements,
- less inspection is desired on less critical characteristics,
- sampling is performed because 100 % inspection on all attributes of all units of products is impractical,
- inspections are not allowed to knowingly accept non-conforming products,
- auditing is required for assurance of process validation, potential transit damage, certification of suppliers, or inventory verification.

5 Classification of attributes

5.1 General

Attributes are classified as part of the process for selection of sampling plans applied to individual and/or grouped attributes for inspection.

5.2 Classification assignment

Classification of individual attributes associated with specified requirements is assigned according to importance or seriousness. Any failure to conform to the ultimate form, fit, function, and intended use of the product unit is usually understood as being non-conforming to the requirements. Attributes are classified as one of the following:

- a) critical;
- b) major;
- c) minor.

The market segment, or intended end use of a product unit will influence the attribute classification. Example: an identical attribute which may be considered as “critical” in the aircraft market segment may be considered “major” or even “minor” in the consumer market segment.

Table 4 shows basic “End use environments” as an aid for attribute classification.

Table 4 – Worst-case use environments

Use category	Temperature ranges			t_b h	Cycles/ year	Typical years of service	Approximate accept- acceptance failure risk %
	T_{min} °C	T_{max} °C	ΔT^b °C				
1) Consumer	0	+60	35	12	365	1 to 3	1
2) Computers	+15	+60	20	2	1 460	5	0,1
3) Telecom	–40	+85	35	12	365	7 to 20	0,01
4) Commercial aircraft	–55	+95	20	12	365	20	0,001
5) Industrial Automotive passenger compartment	–55	+95	20 & 40 & 60 & 80	12 12 12 12	185 100 60 20	10	0,1
6) Military Ground & ^a ship	–55	+95	40 & 60	12 12	100 265	10	0,1
7) Space leo Geo	–55	+95	3 to 100	1 12	8 760 365	5 to 30	0,001
8) Military Avionics	–55	+95	40 60 80 & 20	2 2 2 1	365 365 365 365	10	0,01
a							
b							
c							
9) Automotive Under Hood	–55	+125	60 & 100 & 140	1 1 2	100 300 40	5	0,1

^a & = in addition.

^b ΔT represents the maximum temperature swing, but does not include power dissipation effects.

Sometimes the contractual agreements between consumer and producer indicate performance acceptance to an approved standard. IEC 62326-4 is an example of a standard that uses $c = 0$ sampling plans. This standard specifies performance requirements in a table for multilayer printed boards used in electronic equipment.

Table 1 in IEC 62326-4 has established the sampling criteria for each attribute or requirement stated in the standard. These are identified as a risk management factor (RMF) as opposed to the old AQL identifications. This was done to highlight the recommendation that certain sample sizes "based on the risk management factor" required that the number selected is sufficient to provide protection on critical attributes through using lower percentage non-conforming parts in the sample being evaluated (see Annex A).

Assignment of classification to individual attributes is the responsibility of the user/customer. Annex A shows an example of acceptance characteristics for three levels of product performance.

5.3 Classification and adjustment of sampling plan criteria

Selection of a sampling plan for an attribute should normally be based upon classification. However, manufacturing process and procedure variability which affects the conformance to the requirements of a particular attribute should be considered. If, a known process once set-up, produces consistent results, piece-to-piece within a lot or batch with little to no variability, it is logical and cost effective to deviate from the strict implementation of a given sampling plan. In this situation it is possible to apply a non-statistical audit by selecting a lesser RMF sampling plan.

5.4 Process control

Sampling plan application for the electronics industry is best utilized by the assignment of separate sampling decisions based on the critical impact for each characteristic specified. For different product categories, plans are applied to such products as shown, but not limited to:

a) electronic components	IEC 61193-1
b) electromechanical parts	IEC 61193-1
c) mechanical parts	IEC 61193-1
d) product printed boards (printed circuits, printed wiring)	IEC 61193-3
e) component printed boards (printed circuits, printed wiring)	IEC 61193-2
f) hybrid circuits	IEC 61193-2
g) electronic single-chip modules	IEC 61193-2
h) electronic multi-chip modules	IEC 61193-2
i) electronic assemblies	IEC 61193-4 ¹
j) electronic backplanes	IEC 61193-3

The sampling risk levels would be applicable to the characteristics of units of a product category where the characteristics are critical to the reliability, customer satisfaction, or product liability potential. A more lenient plan can be applied to characteristics that are normally less critical to function or attributes that are identified as minor within a particular product category. In addition, the more lenient plans may also be appropriate where there is a known consistency of tooling and automatic processing.

¹ Under consideration.

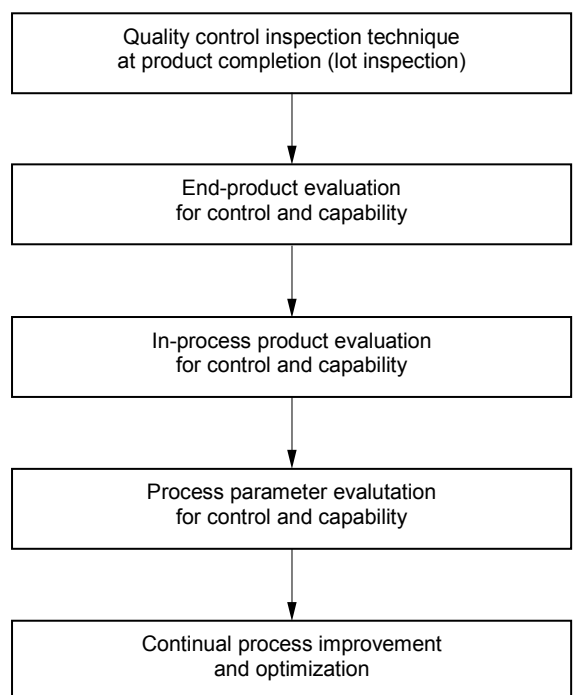
6 Defects and process deviation indicator (PDI) evaluation

6.1 General

Many performance standards list typical defects that are unacceptable and require disposition, e.g., rework, repair. The manufacturer is responsible for identifying other areas of risk and treating those additional concerns. Such items should be documented on the assembly drawing. Other than the unacceptable defects listed, anomalies and variances from within 'acceptable' limits are considered as process deviation indicators and shall be monitored when their occurrence is observed. Usually, disposition of process deviations revealed by PDIs is not required.

6.2 Process control and process improvement requirements

As the industry matures, inspection at the end of the process is not acceptable to many customers. They require the use of process control methodologies in the implementation and evaluation of processes used to produce electrical and electronic assemblies. Subject to agreement by the user, the manufacturer/assembler may be exempted from performing specific quality conformance inspection. Thus, sampling by attributes is not a desirable technique even with $c = 0$ inspection plans, since the practice implies that quality of the product is inspected at completion of all the work. Nevertheless, this practice helps the systematic process control of the path as shown in Figure 3.



IEC 163/13

Figure 3 – Systematic path for implementing process control

7 Inspection plans

7.1 General

The following paragraphs define procedures for implementation and operation of inspection by attributes using $c = 0$ sampling plans.

7.2 Zero acceptance number-based sampling plans

There are still some areas, where the attribute sampling has its merits, for example:

- the producer of electronic components can control the occurrence of so called rogue lots (something totally wrong), by using sampling, and at the same time in the long run collect valuable information of the failures in his process and products. This information can also be used to calculate assessed process average (APA) figures, if they are needed;
- there are still some areas of failures, like some visual/mechanical failures in complicated electromechanical products, where AQLs in traditional form can be of use;
- in the qualification and periodical testing of the components a representative sample has to be selected, because all components cannot be tested.

It is possible to generate the acceptance/reject tables for attribute testing based on zero acceptance number. **It is very important that no matter what statistical levels are used, the acceptance number of failures shall be zero.** This has a strong psychological meaning, and it builds trust between the producer and the customer. This is true, although it has to be understood that the statistical probabilities to have failures are not different from zero and non-zero acceptance numbers, if the statistics used are the same.

The attribute testing can still be a viable tool in the quality assurance, when only the zero acceptance number of failures is used.

7.3 Responsible authority

When specified by a responsible authority, this standard shall be called up in the specification, contract, inspection instructions or other documents and the provisions set forth herein shall govern. The “responsible authority” shall be designated in one of the control documents listed. It should be noted that the responsible authority will normally be the customer.

7.4 Application

Sampling plans designated in this publication are applicable to, but not limited to, inspection of the following:

- a) end items;
- b) laminate materials;
- c) printed board structures.

These plans are to be used primarily for lots or batches that are generally known to have been produced or manufactured under consistent and/or continuous conditions, from a single origination, and are expected to completely conform to specification requirements. The plans may also be used for inspection of isolated lots or batches, but in this latter case, the user may wish to consult the operating characteristics curves to find a plan that will yield the desired protection. These plans should normally only be used for completed items, such as out-going (at the supplier) and/or in-coming (at the customer). However, the sampling plans may be used in audit situations such as stock audit for assurance or potential transit damage, or used as part of a supplier certification procedure.

Statistical process control (SPC) methods and procedures should be used during the production/manufacturing steps in process.

7.5 Sampling plan specification

Normally an RMF and associated sample plan is generally specified by the user/customer for attributes in each classification, as influenced by market segment and variability factors. There is also a high impact derived from the technology sector for products in each market segment or the environment in which the product shall perform.

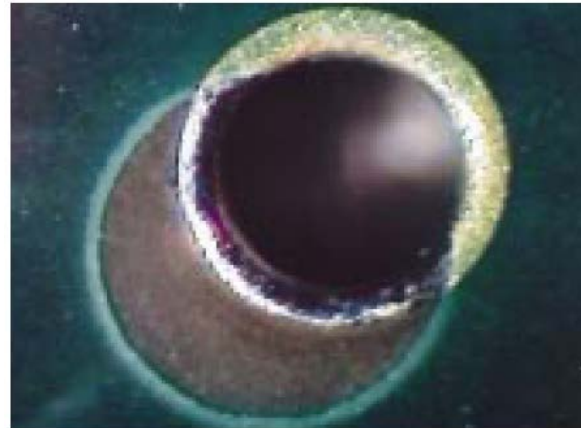
Table 5 is an example of how a user/customer might specify attribute sample plans for a particular market segment, for either internal or external contractual agreements. These are general categorizations and may be more stringent for critical attributes.

Table 5 – General sample plan criteria per industry markets/technology sectors

	High performance systems	Harsh environment systems	Handheld systems	Cost/performance sensitive	Low cost/high volume
Automotive	0,01	0,15	0,04	0,15	2,5
Military	0,01	0,15	0,04	0,25	2,5
Communication	0,015	0,025	0,065	0,25	4,0
Computer	0,025	0,4	0,10	0,25	4,0
Business	0,04	0,065	0,15	0,25	4,0
Instrumentation	0,065	0,10	0,15	0,40	6,5
Industrial	0,10	0,15	0,40	1,0	6,5
Consumer	0,40	0,65	2,5	6,5	10

7.6 Submission of product

Quality conformance evaluations are performed on products manufactured and intended to be delivered to the customer. When quality conformance evaluation is accomplished through sampling inspection techniques, sample size selection shall be taken from Table 2. For performance, the RMF for lot inspection is prescribed in the standard, customer specification, or derived from the example in Table 5. The lot inspection sample size prescribed is applicable, unless in-process controls have been established, with verifiable evidence of correlation to finished product requirements. For the purpose of the quality conformance inspection, products that are structurally similar may be aggregated into one inspection lot. Figure 4 shows some examples of different attributes that have been judged defective based on inspection criteria.

Non-conductive burrs	Board edges nicks
	
Foreign inclusions	Solder mask registration
	

IEC 164/13

Figure 4 – Non-conforming attributes with specification requirements

For a lot to be accepted, all test specimens of the sample shall conform to the requirements. If an inspection lot is rejected, the manufacturer may inspect 100 % of the lot and screen out the defective units for the defect(s) identified in the sample. The defective units may be reviewed and accepted by agreement between customer and manufacturer. To be accepted, the screened out inspection lot should be reinspected by selecting an additional sample in the sampling plan per the described RMF.

When lot inspection techniques are utilized for quality assessment, the manufacturer may reduce the sample size designated in Table 2 to the next less stringent RMF shown, as follows:

- five consecutive inspection lots, of similar size, have been accepted using the specified performance level and current assessment criteria;
- the time elapsed between the first and fifth inspection lots has been no longer than 12 months;
- the reduced assessment is applied to inspection lots of similar size or less;
- the certifying record shall indicate and verify changes in assessment levels.

This procedure can be undertaken twice, if the same criteria are met. Normal inspection shall be resumed if one inspection lot is rejected.

Lot inspections may be further reduced or discontinued, if process control techniques are established, with correlation to the finished product requirements.

Customers shall be made aware of the quality assessment procedures in operation, and shall be notified of reduced lot inspection or changes from lot inspection to in-process testing and control.

Annex A shows an example of the sampling requirements for multilayer boards; Annex B shows an example for the sampling and test method requirements for a copper clad laminate.

8 Classification of defects

8.1 General

An IEC standard will usually contain complete information on quality evaluation for any product to be fully compliant with the requirements for various performance levels. The sampling plan data shall specify the appropriate level of quality conformance inspection from Table 2, as well as the attributes (critical, major, minor), and defect characteristics (critical, major, minor).

Unless otherwise specified, specially designed test specimens may be used for carrying out tests for the lot inspection and the periodic inspection.

When specially designed test specimens are to be used, their description shall be included in the documentation. They may be based on the appropriate characteristics of the shipment-ready product. Consultation between manufacturer and customer is usually necessary.

8.2 Customers detail specification (CDS) data

A customer detail specification should also contain all information necessary to define the product clearly and completely. This includes the target acceptance conditions as well as what constitutes non-conformance.

Care shall be taken to avoid unnecessary requirements. Permissible deviations shall be stated where necessary and nominal values without tolerances or simple maxima or minima shall be given where sufficient. Where precise tolerances are necessary for certain products, they shall be applied and restricted to those products.

Lot 1 through lot m shall include all lots sampled from lot 1 through lot m .

9 Percent defectives per million opportunities

9.1 General

The objective of the defect per million opportunities (DPMOs) approach is to characterize the quality of shipment-ready lots of products. This assumes a uniform manufacturing process which has controls for eliminating non-representative lots.

Samples, which are drawn at random from the individual lots which comprise the population are assessed based on audits performed on shipment-ready products. See ISO 14560:2004.

The pass/fail result is used as final lot acceptance data. Lots/batches of products which fail acceptance inspection criteria are assumed to be either reprocessed 100 % with all non-conforming parts being removed from the lot/batch or the lot/batch is removed from consideration for shipment and discarded.

9.2 Classes of DPMO

9.2.1 General

Non-conformances shall be classified by the preparer of the IEC specification under one or more of the following classes (no device shall be counted more than once in any one of the five classes).

9.2.2 DPMO-1 – Functional non-conformances only

Those non-conforming devices which are inoperative.

9.2.3 DPMO-2 – Electrical non-conformances

Those devices non-conforming to specified parameters which define essential electrical characteristics of a product (includes DPMO-1 electrical).

9.2.4 DPMO-3 – Visual/mechanical non-conformances

Those devices non-conforming to specified parameters which define the essential visual/mechanical characteristics of a product (includes DPMO-1 visual/mechanical)

9.2.5 DPMO-4 – hermetic non-conformances

Those devices non-conforming to the hermetic requirements of a product (includes DPMO-1 hermetic).

9.2.6 DPMO-5 – all non-conformances

All devices non-conforming to any specification requirement of a product. This includes all of DPMO-2, DPMO-3, and DPMO-4, plus all other specification non-conformances.

9.3 Estimation of DPMO

9.3.1 General

Estimation of the non-conformance level in DPMO can be calculated using the assumption that attribute sample inspection is being conducted for a product which has completed all manufacturing processes to the criteria being reported. In addition, the manufacturing processes used to produce the product are maintained statistically in control.

Lots/batches of product which fail acceptance inspection are either reprocessed 100 % and all the non-conforming parts removed from the lots/batches or the lots/batches are removed from consideration for shipment and discarded.

All reprocessed lots/batches (second or other submissions) are segregated from non-sampled lots/batches. Data from these lots (i.e. other than first submission lots) will not be used in the compilation of DPMO.

9.3.2 DPMO reporting

For each DPMO value being reported, the manufacturer will specify what parameters were actually measured and used for that calculation. Non-conformities which are not related to parts, such as administrative errors, shall not be included in these calculations.

Since the plans are on a $c = 0$ basis, the sample size is based on the probability that some percentage (RMF) of non-conforming parts are included in the lot. The probable percentage number should be used in the calculation.

Data obtained from assumptions made on lots/batches that were not tested because of a skip lot sampling plan or a waiver of test requirements, cannot be used in any assessment of DPMO.

When products are manufactured at more than one location, data from these different locations may not be combined to form a composite DPMO value.

9.4 DPMO calculations

9.4.1 General

Estimation of the non-conformance level in DPMO is calculated as follows:

$$DPMO \# = \frac{0,7 + \frac{\sum_{i=1}^m x_i}{m}}{\frac{\sum_{i=1}^m n_i}{m}} \times 10^6$$

That is,

$$DPMO \# = \frac{0,7 + \text{Total number nonconforming}}{\text{Total number inspected (tested)}} \times 10^6$$

where

x_i is the number of non-conforming parts found in the actual inspection (testing of n_i parts from the i^{th} lot of m total lots; and

is the designated class of DPMO.

9.4.2 Sampling requirements

x_i and n_i are determined when performing the final audit or lot acceptance on a lot before it is shipped to a customer. The only requirement on the sampling procedure is that the parts shall be selected randomly.

Lot 1 through lot m shall include all lots sampled from lot 1 through lot m .

10 Use of sampling plans

10.1 General

There are many ways to apply the $c = 0$ sampling plan criteria. Each application has its merits and it is important to use the most reliable method which correlates to the products being manufactured.

10.2 Grouping of tests

Tests may be subdivided into categories in order to reflect various grouping of inspection.

The categories cover lot inspection and periodic tests. The tests may be destructive and may require the use of standard test specimens. The specimens may be included on the production lot or may be produced separately in conjunction with the production lot. Test specimens should be of the same materials and processes so as to be representative of the product and

the process. If separate specimens are manufactured, they shall be spaced out in production in such quantities that a good average assessment can be made.

10.3 Categorization

Various techniques can be used to categorize the inspection and quality assessment of the attributes associated with shipment-ready products. Each category consists of sub-groupings depending on the products being assessed. Some of these are the following.

- Category V – Visual inspection
- Category D – Dimensional inspection
- Category S – Surface condition inspection
- Category E – Electrical inspection
- Category P – Physical inspection
- Category Y – Structure integrity inspection
- Category Z inspection – This category covers all tests which may be necessary in addition to tests of inspection categories V, D, S, E, P, and Y to complete an entire test program. Category Z tests are usually carried out at intervals of 12 months. They may be carried out progressively within a 12 month period.

10.4 In-process testing and control

In-process testing and control may be applied to any requirements listed in the standard, specification, or customer detail specification (CDS), and is required at some stages. In-process testing and control data shall be kept as verifiable evidence of conformance to requirements. Data shall be available which verifies correlation to finished product requirements. In process testing and control may be implemented for selected requirements while continuing lot inspection for other requirements. Depending upon the progress made in implementing in-process/process control the manufacturer may prove compliance to specifications with:

- quality conformance lot inspections;
- finished product control;
- in-process control;
- process parameter control.

A manufacturer may choose to use a combination of these techniques to prove conformance to requirements.

When agreement has been reached between customer and manufacturer, in-process testing and control may be substituted for the relevant test(s) and sampling prescribed in the quality conformance inspection schedule, provided that:

- the in-process testing and control is carried out under the authority of the appointed management representative (chief inspector);
- the process steps or storage periods between in-process testing and the completion of the units of product are not likely to affect the characteristics tested;
- the data provided by in-process testing is correlated to the finished product requirements and assures the same level of performance for characteristics as would be demonstrated in the prescribed finished product sampling plan and testing.

End-product statistical control should normally be established prior to implementation of in-process or process parameter control. However, some product requirements are preferably always evaluated in-process.

In process control requirements are indicated in Table 2 as risk management factors. The priority implementation code signifies how the sampling should be applied. The codes given in Table 6 can be used to communicate requirements between the user and the manufacturer.

Table 6 – Process control

Code	Priority implementation
C1	In-process and/or process parameter control, required implementation
C2	In-process and/or process parameter control, first priority implementation
C3	In-process and/or process parameter control, second priority implementation
C4	In-process and/or process parameter control, third priority implementation
C5	Periodic laboratory test (in conjunction with related in-process/process control for correlation to test criteria and product requirements)

10.5 Indirect measuring methods

Where appropriate, indirect measuring methods may be substituted for direct methods, provided the necessary accuracy and calibration are ensured.

EXAMPLE: Instead of directly measuring dimensions, a gauge of suitable characteristics may be used.

Where appropriate, control of a process parameter may be the most effective method of assuring product conformance to specification requirements. In this case, the process parameter control may be accepted as the primary quality assessment method for the affected characteristics, provided that a periodic product inspection for the relevant characteristic(s) is performed.

EXAMPLE: Process control of plating chemistry is the primary method of assuring adhesion of plated on component leads; maintaining process control coupled with periodic shipment-ready product inspection is preferred to lot inspection prescribed in a sampling plan.

Annex A (informative)

Example of consensus sampling plan for three levels of conformance to requirements of IEC 62326-4 multilayer printed boards

Table A.1 indicates the performance requirements with respect to IEC 62326-4 multilayer printed boards. Note that in column "B" of "Specific requirements for performance level", "GR" is used to indicate that only the general requirements shall be met. For an explanation of the abbreviations and all the conditions of the sampling plan, see referenced IEC standards in Annex A.

Table A.1 – Performance requirements

Test code	Characteristics	General requirements	Specific requirements for performance level			Assessment			
			A	B	C	RMF IEC 62326-1	Test specimen IEC 62326-4-1	Test no. IEC 61189-3	Process control code IEC 62326-1
V	VISUAL EXAMINATION								
V1	Conformity	Pattern, marking identification and material finishes shall comply with the CDS when viewed without magnification. There shall be no apparent defects.	As specified	– As specified	– As specified	6,5 4,0	Complete PB/DP	3V04	C4
V2	<i>Appearance and workmanship</i>	The boards shall appear to have been processed in a careful and workmanlike manner, in accordance with good current practice.	GR –	– GR	– GR	6,5 4,0	Complete PB/DP	3V01	C4
V3	<i>Plated-through holes as received</i>	Plated-through holes shall be clean and free from inclusions of any sort that could affect component insertion and solderability when viewed without magnification.	GR –	– GR	– GR	4,0 2,5	Complete PB	3V04	C4

Test code	Characteristics	General requirements	Specific requirements for performance level			Assessment			
			A	B	C	RMF IEC 62326-1	Test specimen IEC 62326-4-1	Test no. IEC 61189-3	Process control code IEC 62326-1
		The number of holes with plating voids shall not exceed the specified percentage of the total number of plated-through holes when viewed without magnification.	5 % –	– 1 %	– None	4,0 2,5			C2
		The number of holes with plating voids shall not exceed the specified percentage of the total number of plated-through holes when viewed without magnification.	5 % –	– 1 %	– None	4,0 2,5			C2
	Holes showing plating voids	Total area of plating voids within a hole shall not exceed the specified percentage of the total area.	5 % –	– 2 %	– 2 %	4,0 2,5			C2
		The largest dimension of voids shall not exceed the specified percentage of the hole circumference in the horizontal plane or the same percentage of the board thickness in the vertical plane.	15 % –	– 10 %	– 5 %	4,0 2,5			C2
V4	Plated-through holes after microsection	Plated-through holes (levels B and C) shall be tested in as-received conditioning and after preconditioning according to test code Y4. Voids shall not coincide with internal or external copper layers. Remarks – All examinations executed at 100× magnification – Process control data may be used to supplement/minimize this test	– –	GR –	– GR	1,5 1,0	A or B (3 holes)	3X09	C1

Test code	Characteristics	General requirements	Specific requirements for performance level				Assessment			
			A	B	C		RMF IEC 62326-1	Test specimen IEC 62326-4-1	Test no. IEC 61189-3	Process control code IEC 62326-1
V4.1	Resin smear at interface	Resin smear between the edge of the inner layer copper and the continuous plating shall not interrupt electrical continuity or exceed the specified percentage of inner layer copper thickness at the interface (see IEC 62326-4:1996, Figure 1)	≤30 % – –	– ≤15 % –	– – None		2,5 1,5 1,0			C1
V4.2	Circumferential cracks of copper plating	There shall be no circumferential cracks of the copper, or circumferential separation of the copper from the wall in the plated-through hole (see IEC 62326-4:1996, Figure 2)	GR – –	– GR –	– – GR		2,5 1,5 1,0			C1
V4.3	Copper barrel to hole separation	There shall be no separation of plating from the hole wall exceeding the specified percentage of the hole circumference (see IEC 62326-4:1996, Figure 2). <i>Remark</i> Where necessary, this shall be verified by dimensional examination using test 3D01	≤50 % – –	– ≤40 % –	– – ≤30 %		2,5 1,5 1,0			C1
V4.4	Foil cracking	There shall be no foil cracking	GR – –	– GR –	– – GR		2,5 1,5 1,0			C1

Test code	Characteristics	General requirements	Specific requirements for performance level			Assessment			
			A	B	C	RMF IEC 62326-1	Test specimen IEC 62326-4-1	Test no. IEC 61189-3	Process control code IEC 62326-1
V5	Conductors								
V5.1	External conductors	There shall be neither cracks nor breaks. Imperfections such as voids or edge defects are permissible provided that the conductor width or land area is not reduced by more than the specified percentage (see IEC 62326-4:1996, Figure 3). <i>Remarks</i> - Where necessary, this shall be verified by dimensional examination using test 3D01 - In the effective contact areas there shall be no imperfections - For test specimens supplied with solderable temporary protective coating the above requirement is not applicable	≤30 % (no occurrence >10 mm) –	– ≤20 % (no occurrence >5 mm)	– ≤10 % (no occurrence >3 mm)	4,0 2,5	Complete PB	3V02	C3
		When specified, the conductors shall be covered with a smooth and bright solder coating with not more than 5 % of scattered imperfections, such as pinholes, unwetted or dewetted areas. The imperfections shall not be concentrated on one area.	GR – –	– GR –	– – GR	6,5 4,0 2,5	Complete PB	3V02	C1

Test code	Characteristics	General requirements	Specific requirements for performance level			Assessment			
			A	B	C	RMF IEC 62326-1	Test specimen IEC 62326-4-1	Test no. IEC 61189-3	Process control code IEC 62326-1
V5.2	Internal conductors	There shall be neither cracks nor breaks. Imperfections such as voids or edge defects are permissible provided that the conductor width is not reduced by more than the specified percentage (see IEC 62326-4:1996, Figure 3). <i>Remarks</i> – Where necessary, this shall be verified by dimensional examination using test 3D01. – This examination shall be in-process	≤30 % (no occurrence >10 mm) –	– ≤20 % (no occurrence >5 mm)	– ≤10 % (no occurrence >3 mm)	4,0	Complete PP	3V02	C3
V6	<i>Particles between conductors</i>								
V6.1	External conductors	Residual metallic particles are permissible provided that the leakage path is not reduced by more than the specified percentage or to less than the distance required for the circuit voltages in isolated areas discounting conductor undercut, edge roughness, spikes, etc. (see IEC 62326-4:1996, Figure 3). <i>Remark</i> Where necessary, this shall be verified by dimensional examination using test 3D01	≤30 % –	– ≤30 %	– ≤20 %	4,0 2,5	Complete PB	3V02	C3

Test code	Characteristics	General requirements	Specific requirements for performance level			Assessment			
			A	B	C	RMF IEC 62326-1	Test specimen IEC 62326-4-1	Test no. IEC 61189-3	Process control code IEC 62326-1
V6.2	Internal conductors	Residual metallic particles are permissible provided that the leakage path is not reduced by more than the specified percentage or to less than the distance required for the circuit voltages in isolated areas discounting conductor undercut, edge roughness, spikes, etc. (see IEC 62326-4:1996, Figure 3). <i>Remarks</i> – Where necessary, this shall be verified by dimensional examination using test 3D01. – This examination shall be in-process	≤30 % –	– ≤20 %	– ≤10 %	4,0 2,5	Complete PP	3V02	C3
V7	<i>Permanent polymer coating</i> (including solder resist)	The polymer coating pattern shall comply with the CDS and the general requirements given below. There shall be no apparent defects. <i>Remark</i> When necessary this shall be verified by dimensional examination using test 3D01	As specified –	– As specified	– As specified	4,0 2,5	Complete PB/DP	3V01	C4
		When noted in the CDS that the polymer coating is used as an insulation all parts shall be completely covered.	As specified –	– As specified	– As specified	2,5 4,0			C3
		Imperfections in the polymer coating on the base material, such as pinholes, small uncovered areas, scratches, etc. are permitted.	GR –	– GR	– GR	4,0 2,5			C3

Test code	Characteristics	General requirements	Specific requirements for performance level			Assessment			
			A	B	C	RMF IEC 62326-1	Test specimen IEC 62326-4-1	Test no. IEC 61189-3	Process control code IEC 62326-1
		Polymer coating used as solder resist shall cover the top surface of the conductor and shall be substantially free of pinholes. At least one or two adjacent conductor edges shall be covered.	GR –	– GR	– GR	4,0 2,5			C3
		Board edges and the areas near slots, notches, etc., shall be free from polymer coating (as specified on the master drawing when using a production board).	GR –	– GR	– GR	4,0 2,5			C3
		All metallic areas intended for solder attachment, electrical contact, or indexing marker shall be free from polymer coating residues.	GR –	– GR	– GR	4,0 2,5		3V02	C2
D	DIMENSIONAL EXAMINATION								
D1	Board dimensions (external boundary)	Dimensions including thickness shall comply with the CDS.	As specified –	– As specified	– As specified	4,0 2,5	Complete PB (3 places)	3D04	C4
D2	Board thickness in the zone of edge board contacts	The total board thickness over the edge board contacts shall comply with the CDS.	As specified B	B As specified	B As specified	4,0 2,5	Edge contact areas of PB	3D04	C4
D3	Holes (see also D8)								
D3.1	Diameter	Diameters of tooling holes, mounting holes and component holes shall comply with the CDS. <i>Remark</i> A recommended range of hole sizes and tolerances are given in IEC 61188-6 ^a	As specified –	– As specified	– As specified	4,0 2,5	Complete PB/DP (10 holes per size)	3D04	C2

Test code	Characteristics	General requirements	Specific requirements for performance level			Assessment			
			A	B	C	RMF IEC 62326-1	Test specimen IEC 62326-4-1	Test no. IEC 61189-3	Process control code IEC 62326-1
D3.2	Plating thickness	The plating thickness shall comply with the CDS. <i>Remark</i> Examinations at 400× magnification.	As specified –	– As specified	– As specified	4,0 2,5	A or B (3 holes)	3X09	C1
D4	Slots, cut-outs and notches	The dimensions of applicable slots, cut-outs or notches shall comply with the CDS.	As specified –	– As specified	– As specified	4,0 2,5	Complete PB	3D04	C3
D5	Conductor width								
D5.1	External layer	The width shall comply with any specific dimensions given in the CDS. <i>Remarks</i> – To be measured together with V5.1 – If no tolerances are stated, the coarse deviations given in IEC 61188-6 ^a will apply	As specified –	– As specified	– As specified	4,0 2,5	Complete PB	3D01	C2
D5.2	Internal layer	The width shall comply with any specific dimensions given in the CDS. <i>Remarks</i> – To be measured together with V5.2 – If no tolerances are stated, the coarse deviations given in IEC 61188-6 ^a will apply – This measurement shall be in-process	As specified –	– As specified	– As specified	4,0 2,5	Complete PP	3D01	C2
D6	Spacing between conductors								

Test code	Characteristics	General requirements	Specific requirements for performance level			Assessment			
			A	B	C	RMF IEC 62326-1	Test specimen IEC 62326-4-1	Test no. IEC 61189-3	Process control code IEC 62326-1
D6.1	External layer	The spacing shall comply with any specific dimension given in the CDS. <i>Remark</i> To be measured together with V6.1	As specified –	– As specified	– As specified	4,0 2,5	Complete PB	3D01	C3
D6.2	Internal layer	The spacing shall comply with any specific dimensions given in the CDS. <i>Remarks</i> – To be measured together with V6.2 – This measurement shall be in-process	As specified –	– As specified	– As specified	4,0 2,5	Complete PP	3D01	C3
D7	<i>Alignment of hole and conductive pattern</i>	There shall be no interruption of the conductive pattern and there shall be no hole break-out (land cut off) at the junction of the land and the conductor in excess of that specified below. This applies to both internal and external layers (see IEC 62326-4:1996, Figure 4, Figure 5 and Figure 6).					Complete PB (10 holes, random selection over total area)	3D01	
D7	<i>Alignment of hole and conductive pattern</i>	There shall be no interruption of the conductive pattern and there shall be no hole break-out (land cut off) at the junction of the land and the conductor in excess of that specified below. This applies to both internal and external layers (see IEC 62326-4:1996, Figure 4, Figure 5 and Figure 6).					Complete PB (10 holes, random selection over total area)	3D01	
D7.1	External pattern alignment to plated-through holes	The requirements shall be as specified.							

Test code	Characteristics	General requirements	Specific requirements for performance level			Assessment			
			A	B	C	RMF IEC 62326-1	Test specimen IEC 62326-4-1	Test no. IEC 61189-3	Process control code IEC 62326-1
		Minimum annular width W_1 of external land at conductor junction (see IEC 62326-4:1996, Figure 4).	There shall be no defects at conductive pattern and through-hole plating –	– $W_1 \geq 0,03 \text{ mm}$	– $W_1 \geq 0,05 \text{ mm}$	4,0 2,5			C1
		Minimum annular width W_1 of external land at the other parts.	–	Break-out $\theta \leq 90^\circ$ (see IEC 62326-4:1996, Figure 6)	$W_1 \geq 0,05 \text{ mm}$ (see IEC 62326-4:1996, Figure 4)	2,5			
D7.2	External pattern alignment to plain holes holes	The requirements shall be as specified.	No breakout. No conductor junction reduction –	– No break-out: No conductor junction reduction	– No break-out: Minimum annular width 0,4 mm	4,0 2,5			C1
D7.3	Internal pattern alignment to plated-through holes	The requirements shall be as specified. Remarks – 100× magnification. – Any other adequate method may be used							

Test code	Characteristics	General requirements	Specific requirements for performance level			Assessment			
			A	B	C	RMF IEC 62326-1	Test specimen IEC 62326-4-1	Test no. IEC 61189-3	Process control code IEC 62326-1
		Minimum annular width W_2 of internal land at conductor junction (see IEC 62326-4:1996, Figure 5).	$W_2 \geq 0,03$ mm – –	– $W_2 \geq 0,03$ mm –	– – $W_2 \geq 0,05$ mm	2,5 1,5 1,0	A or B (3 hole) and/or R for electrical continuity and/or F for process control	3X09	C1
		Minimum annular width W_2 of internal land at the other parts.	Break-out $\theta \leq 180^\circ$ see IEC 62326-4: 1996, Figure 6) – –	– Break-out $\theta \leq 90^\circ$ (see IEC 62326-4: 1996, Figure 6) $W_2 \geq 0$ mm (see IEC 62326-4: 1996, Figure 5)	– – $W_2 \geq 0$ mm (see IEC 62326-4: 1996, Figure 5)	2,5 1,5 1,0			C1
D7.4	Landless holes	<i>Test under consideration</i>							
D8	<i>Positional accuracy</i>								
D8.1	Position of conductive pattern and holes relative to the position data	The position of all holes shall comply with any specific details given in the CDS. <i>Remark</i> When specially called for, the deviations given in IEC 61188-6 a will apply	As specified –	– As specified	– As specified	4,0 2,5	Complete PB (10 holes, random selection over total area)	3D04	C3

Test code	Characteristics	General requirements	Specific requirements for performance level			Assessment			
			A	B	C	RMF IEC 62326-1	Test specimen IEC 62326-4-1	Test no. IEC 61189-3	Process control code IEC 62326-1
D8.2	Positional tolerance of hole centres with respect to the position data	The hole centres shall be within the specified tolerances in the CDS. <i>Remark</i> When specially called for, the deviation given in IEC 61188-6 a will apply	As specified –	– As specified	– As specified	4,0 2,5	Complete PB (10 holes, random selection over total area)	3D04	C2
D9	<i>Permanent polymer coating</i> (including solder resist)								
D9.1	Dimensions	The dimensions of the polymer coating pattern shall comply with the CDS.	As specified –	– As specified	– As specified	4,0 2,5	Complete PB/DP (10 places)	3D01	C3
D9.2	Thickness of polymer coating	The thickness shall comply with the CDS.	As specified –	– As specified	– As specified	4,0 2,5	Complete PB (3 places)	3D04 or	C3
		<i>Remark</i> The thickness shall be measured at the location stated in the CDS when using Test 3X09 with 400× magnification.	As specified –	– As specified	– As specified	4,0 2,5	1 time A or B (per panel)	3X09	C3
D10	<i>Flatness</i>	The allowable bow and twist shall not be more than the specified value for printed boards with a diagonal of ≥ 100 mm.	1,5 % of the diagonal –	– 1 % of the diagonal	– 0,5 % of the diagonal	4,0 2,5	Complete PB/DP	3M04	C3

Test code	Characteristics	General requirements	Specific requirements for performance level			Assessment			
			A	B	C	RMF IEC 62326-1	Test specimen IEC 62326-4-1	Test no. IEC 61189-3	Process control code IEC 62326-1
S	SURFACE CONDITION TESTS								
S1	Plating finishing								
S1.1	Adhesion of plating, tape method or	There shall be no evidence of plating adhering to tape after removal from the conductor, other than permitted by the CDS. <i>Remark</i> Specimen N shall be tested prior to fusing	As specified – –	– As specified –	– – As specified	6,5 4,0 2,5	N	3X01	C3
	Adhesion of plating, burnish method	There shall be no evidence of blistering or detachment of the plating. <i>Remark</i> For contact finishes only	GR – –	– GR –	– – GR	6,5 4,0 2,5	Edge contact area of PB	3X02	C3
S1.2	Thickness of plating (contact area)	The thickness shall comply with the CDS.	As specified – –	– As specified –	– – As specified	6,5 4,0 2,5	Edge contact area of PB	3X06	C3
S1.3	Thickness of plating (other than contact area)	The thickness shall comply with the CDS.	As specified – –	As specified –	– – As specified	6,5 4,0 2,5	N	3X06	C3
S1.4	Porosity, gas exposure or	The total number of pores shall not be more than the number of the effective contact areas. The maximum number of pores per contact area shall be two. The percentage of contact areas with two pores shall not be more than specified.	– –	40 % –	– 20 %	4,0 2,5	N	3X03	C3