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Electronic components – Long-duration storage of electronic components – Guidance for implementation

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ELECTRONIC COMPONENTS –

Long-duration storage of electronic components – Guidance for implementation

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Following publication of this PAS, which is a pre-standard publication, the technical committee or subcommittee concerned will transform it into an International Standard.

This PAS shall remain valid for an initial maximum period of three years starting from 2005-09. The validity may be extended for a single three-year period, following which it shall be revised to become another type of normative document or shall be withdrawn.

INTRODUCTION

This PAS applies to the long-duration storage of electronic components.

Although it has always existed to some extent, obsolescence of electronic components and particularly of integrated circuits, has become increasingly intense over the last few years.

Indeed, with the existing technological boom, the commercial life of a component has become very short compared with the life of industrial equipment such as that encountered in the aeronautical field, the railway industry or the energy sector.

The many solutions enabling obsolescence to be resolved are now identified. However, selecting one of these solutions must be preceded by a case-by-case technical and economic feasibility study, depending on whether storage is envisaged for field service or production, for example:

– remedial storage as soon as components are no longer marketed;
– preventive storage anticipating declaration of obsolescence.

Taking into account the expected life of some installations, sometimes covering several decades, the qualification times, and the unavailability costs, which can also be very high, the solution to be adopted to resolve obsolescence must often be rapidly implemented. This is why the solution retained in most cases consists in systematically storing components which are in the process of becoming obsolescent.

The technical risks of this solution are, *a priori*, fairly low. However, it requires perfect mastery of the implemented process and especially of the storage environment, although this mastery becomes critical when it comes to long-term storage.

All handling, protection, storage and test operations must be performed according to the state of the art.

The application of the approach proposed in this document in no way guarantees that the stored components are in perfect operating condition at the end of this storage. It only comprises a means of minimizing potential and probable degradation factors.

ELECTRONIC COMPONENTS –

Long-duration storage of electronic components – Guidance for implementation

1 Scope

This Publicly Available Specification (PAS) is, first of all, a practical guide to methods of long-duration storage (more than five years) which summarizes the existing practices in the industry.

Unless otherwise specified, the approach, as well as the methods presented, apply to all families of electronic components, such as

- passive components, including quartz crystals, connectors and relays. However, components with "manufacturer's" specifications showing an expiry date or specific storage conditions are excluded from this document (for example, primary cells, storage cells, etc.);
- encapsulated or non-encapsulated active components of a silicon [Si] or gallium arsenide [GaAs] technology;
- micro-electronic assemblies.

2 Normative references

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

IEC 60068-2-17:1994, *Basic environmental test procedures – Part 2: Tests – Test Q: Sealing*

IEC 60068-2-20:1979, *Environmental testing – Part 2: Tests – Test T: Soldering*

IEC 60410:1973, *Sampling plans and procedures for inspection by attributes*

IEC 61340-5-1:1998, *Electrostatics – Part 5-1: Protection of electronic devices from electrostatic phenomena – General requirements*

IEC 61340-5-2:1999, *Electrostatics – Part 5-2: Protection of electronic devices from electrostatic phenomena – User guide*

IEC 61945, *Integrated circuits – Manufacturing line approval – Methodology for technology and failure analysis*

IEC 62380: *Reliability data handbook – Universal model for reliability prediction of electronics components, PCBs and equipment*

EN 190 000:1995, *Generic specification – Integrated monolithic circuits*

3 Storage decision criteria

Any creation of an electronic component inventory should be carried out

- on the one hand, after having compared with the following additional solutions:
  - modification to the printed board by adding a "backpack" macro-component;

  - development of a specific ASIC;
  - production relaunched at a manufacturer specialized in the resumption of obsolete technological processes and components;
  - complete revision of the board or the equipment;

- on the other hand, by taking into account the following aspects.

3.1 Advantages

3.1.1 Technical simplicity – Rapidity

When the various steps of the storage process are finalized and validated, the creation of a stock is a simpler, faster and technically less hazardous solution than developing or modifying electronic boards.

Storage can also be a temporary solution enabling equipment maintenance during modification or development of electronic boards.

3.1.2 Solution durability

Any equipment changes based on the use of new electronic components will be faced, eventually, with the obsolescence of these new components. Storage can resolve obsolescence problems until the end of the operating life of the equipment.

3.1.3 Preventive storage

Preventive storage (i.e., before the component becomes obsolete) presents several additional advantages compared with remedial storage (i.e., when the component has already become obsolete), for example, when

– the component price has not become prohibitive as in the case of specific obsolete components which have become very rare;

– the quality level is ensured if the component can be purchased direct from the manufacturer or approved distributor. When a component has been obsolete for a long time, it can only be found at specialists in purchasing, storage and resale of obsolete components ("brokers"). In this case, no component reliability guarantee will apply.

3.2 Hazards – Drawbacks

3.2.1 Generic aging hazard

Stock dimensioning is based on the assumption of a constant component failure rate. The problem of generic aging of the components ("bath-tub curve") cannot be easily taken into account and quantified. However, the existing electronic components seem to have extremely long lives provided that they are manufactured with all quality guarantees and that they are used in accordance with their specifications.

3.2.2 Poor stock dimensioning

The calculation of the volume of components to be stored may be based on feedback (operational failure rate) and/or on theoretical models (predictive failure rate). Calculation using feedback is only valid if the sample is big enough (significant population of components installed, operation for several years, high number of failures evidenced). Predictive calculations do not generally take into account the extrinsic parameters of the components (defects caused by printed-board handling and repair, systematic replacement of the components (including functional components) during repairs, improper use of the components, etc.). Therefore, the stock volume may be improperly assessed.

Underestimating the stock may lead to a lack of components to repair printed boards, which will ruin the stock strategy. Overestimating it will lead to the purchasing and conditioning of components which will not be used, including to significant additional costs.

3.2.3 Incorrect control of reliability during storage

Storage conditions shall be precisely defined and controlled, in order to guarantee the reliability of the components stored (see Clause 5). In addition, it is important to check the quality of the components to be stored (see Clause 4). This may lead to the setting-up of fairly heavy and costly infrastructure and procedures.

Checking component quality may be an efficient means of reducing the risk of improper reliability control during storage. This can be done either by performing periodic sampling in order to carry out tests on the components (see Clause 6) or by checking that the components taken from the stock and used on the electronic boards operate correctly (provided that the consumption of the components in stock is sufficiently regular).

3.2.4 Freezing equipment functionalities

Storing components to ensure equipment maintenance over a long time implies that the equipment functionalities be frozen. A long-duration storage solution is therefore not very compatible with the desire to upgrade equipment and functionalities.

3.3 Storage cost

In order to assess the cost of a storage solution, various items should be taken into account, such as:

- component purchasing;
- validation/test of purchased component batches;
- conditioning and de-conditioning;
- stock management;
- maintenance of installations dedicated to storage by means of manufacturing tests and/or repair;
- staff ensuring storage, maintenance operations, etc.;
- financial cost of tied-up stocks.

3.4 Decision criteria

The following criteria should be taken into account:

- planned storage time;
- stock dimensioning;
- dimensioning reliability index;
- life of test means;
- life of manufacturing means and/or printed boards;
- competence traceability and related documentation;
- industrial consequences of under-dimensioning or a component failure at the end of storage;
- confidence level in the knowledge of potential component failure mechanisms;
- cost compared with other solutions.

4 Purchasing – Procurement

4.1 List of components

A detailed list of the components used shall be established. It should include the designations, specifications, manufacturers and the corresponding trade references.

This list shall be related with the various lists of electronic boards (by means of either a procurement code, or a generic designation).

The purpose of this list is to

– define all components of a market or a series of equipment;
– allow component approval at the beginning of their design stage;
– allow field service procurement

An example of this list is given in Annex A.

This list shall, as far as possible, mention the probable life of each component over a 10-year period.

4.2 Quantity of components to be stored

There are two types of requirements:

- production stock;
- field service stock.

Special attention shall be paid to

– specific components;
– single-source components;
– components becoming obsolete before the end of production.

Care will also be taken to make sure that the stored quantities take into account parts used for tests considered as destructive.

4.2.1 Production stock

This stock shall guarantee productions in progress and future productions (to relaunch the market).

4.2.2 Field service stock

This stock shall enable components to be kept operational during the whole life of the equipment and systems (for example, 25, 30, even 40 years for military, railroad or nuclear power plant equipment).

A stock of the various component types shall be made up from the parts lists, the bills of material and feedback (observed failure rate).

ASSESSMENT EXAMPLE: These batches of parts, calculated according to the following formula, should not be less than 3 % of the total number of components installed (the higher of the two values) on the relevant equipment:

$$N_{o} = N \times h \times \lambda \times A$$

where

N_o is the stock quantity;

N is the number of components in service;

h is the number of operating hours per year;

A is the number of years during which the requirement for these components must be guaranteed;

λ is the operational failure rate of the component, if known. Otherwise, the predictive failure rate is used. It is given either in a reliability data handbook (IEC 62380) or by the manufacturer.

4.3 When is it worth keeping in stock?

Depending on the component type

– the procurement of specific components should be launched at the latest at the same time as the last component production batch;

– if it is a single-source component, the order shall be launched in the time prescribed by the manufacturer.

4.4 Procurement recommendations

Every component batch should be clearly identified.

No batch should have date-codes older than two years at time of delivery.

Batches (compliance certificate, electrical test results, etc.) shall be accompanied by all the documents enabling the traceability of the components to be ensured.

Components shall be delivered, if required, in packages guaranteeing ESD protection and protection against humidity.

Packages will be correctly identified (date-code, manufacturer, component reference).

5 Technical validation of the components

5.1 Purpose

The purpose of the technical validation of the components with a view to their storage is to detect *a priori* the batches which do not offer proper reliability and life guarantees.

5.2 Relevant field

All electronic components ("active" as well as "passive") are concerned.

However, active semiconductor components are the most affected by the obsolescence issue. This is why, in the following subclauses, we will only deal with active component validation methods.

The methods to be applied for passive components, save a few adaptations specific to their technologies, are directly applicable.

5.3 Test selection criteria

The first thing to be taken into account to select the tests to be implemented for storing components is to have these components previously qualified, depending on the profile of their expected mission.

In addition, in the case of multiple-source components, the selection of the sources shall have been validated by a method capable of evidencing "false" second sources.

The selection of the required tests and measurements will depend on the storage strategy adopted. It can cover a range from a minimal utilization with no tests to a maximal utilization, where all tests described in this chapter would be performed.

As a whole, the technical validation of the components requires the following items to be checked:

a) compliance with the visual inspection criteria;
b) solderability checking;
c) sealing/hermeticity checking (for components with hermetic packages);
d) compliance with the electrical specifications in the temperature range;
e) checking of manufacturing control (technological analysis);
f) checking of the supplied batch reliability.

The criteria for sanctions and the number of tested components may vary depending on the requirements and level of reliability, as well as the data collected from the manufacturer. At the end of the technical validation, a status is established for this batch in order to decide on its storage capability.

5.4 Measurements and tests

5.4.1 Sampling

Generally, the measurements of the component electrical parameters are performed on 100 % of the batch. However, if a batch is too large and, depending on the storage strategy adopted, the measurements can be made by sampling.

The sampling plan shall, in this case, adhere to the rules defined in the standards (for example, IEC 60410).

The technological analysis must be made on a sufficient number of components in order to check compliance with the characteristics required. Generally, three to 10 components are submitted to the analysis.

For reliability tests, except for the package sealing test, all other tests are destructive tests.

The number of parts to be tested will either be fixed or a sample, but, to be representative, there should not be less than 20 parts.

5.4.2 Visual examination, sealing, solderability

The purpose of these examinations is to check the integrity of the packages and the component mounting problems. The test methods used are described in the European or American standards.

It is worth mentioning, in particular:

– IEC 60068-2-17 for sealing;
– IEC 60068-2-20 for solderability;
  EN 190 000, Annex A, for visual examination.

5.4.3 Compliance with the electrical specifications

5.4.3.1 Measurement of electrical parameters

a) Measurement of static parameters

Static parameters determine the component inter-changeability in particular by measuring their pattern characteristics.

The main parameters to be measured are the following:

– input and output current strengths;
– power-supply currents;
– input and output voltages (pattern characteristics).

The values of these parameters are specific to each component technology.

b) Functionality check

This check ensures that the component is suited to its function.

For simple components (diodes, transistors), this check is performed implicitly during the measurements of static parameters.

This checking is often combined with the application of electrical conditions up to the limits of the component specification (minimum or maximum supply voltage application).

Depending on the component families (digital devices, memories, microprocessors), this check may require significant test means (case of microprocessors) and/or specific methods (case of pattern algorithms for memories). This is why the functionality check represents the most significant part of the costs and implementation difficulties of the electrical test.

c) Measurement of dynamic parameters

The purpose of the measurement of these dynamic parameters is to ensure that the dynamic elements of the component have been correctly respected, for instance, access time for a memory.

Within the framework of the technical check of the components before storage, this measurement may, for cost reduction reasons, be replaced by a so-called "dynamic and functional" check, which allows the functionality and the compliance with the dynamic parameter specifications to be verified simultaneously by performing one or two checks.

5.4.3.2 Temperature impact

Most electrical parameters of electronic components are influenced by temperature, either maximum or minimum.

Some parameters are only meaningful when measured at a certain temperature.

These include

– supply currents;
– refresh times;
– access times;
– input and output leakage currents;
– the functionality of some components (for example, oscillators).

For power or high-consumption devices, it is important to adhere fully to the measurement conditions specified by the manufacturers, not exceeding, in particular, the maximum junction temperatures.

5.4.4 Assessment of the supplied batch reliability

All failures affecting electronic components initiate originally from a mechanism of a mechanical, chemical, electrical type, or a combination of the three types (see Tables E.1, F.1 and F.2).

Any failure mechanism, as soon as the process has started, can be accelerated by a constraint adapted to the nature of the failure:

– temperature for chemical corrosion;
– temperature associated to a potential difference for an electrolytic migration.

The component environment varies depending on the application.

It is important to be able to estimate the impact of the constraints on the failure mechanisms in order to determine any possible induced acceleration (for example, humidity).

Depending on the defects and efficiency expected, and according to the technical means available as well as the affordable costs, various test methods may be used.

Table 1 recalls the main test methods, the nature of the defects, the relative cost and their efficiency, as well as the test conditions and average times.

Table 1 – Tests

Operation	Defects concerned	Efficiency	Relative cost	Criteria/ duration	Remarks
Rapid temperature variations (RTV)	• Packagings • Sealings • Electrical connections • Chip crack • Differential expansion	Good	Very low	Min. T = –55°C Max. T = +125°C N = 500 to 1000 cycles 30 min/30 min	One of the most efficient for chips mounted with aluminium connecting wires and power components (diodes, transistors, etc.)
High-temperature storage power off	• Jitter • Bonding • Corrosion • Substrate	Good	Very low	125 °C or 150 °C depending on the component 1 000 h or 2 000 h	Good method
High-temperature storage with static operation	• Bonding • Substrate • Oxide films • Inversion layer • Design • Contamination	Good	High	125 °C or 150 °C depending on the component 1 000 h or 2 000 h	Efficient method, especially for MOS technology
High-temperature storage with dynamic operation	• Bonding • Substrate • Oxide films • Inversion layer • Design • Contamination	Very good	High	Generally 125 °C or as per Tj 1 000 h or 2 000 h	Very efficient method
High-temperature storage with reverse bias	• Inversion layer • Contamination	Good	Very low	125 °C or 150 °C 1 000 h or 2 000 h	Efficient for discrete components
Damp heat 85 % HR, 85 °C	• Package • Sealings • Chip crack • Differential expansion • Contamination	Very good	Very low	1 000 h or 2 000 h	Efficient for non-cavity packages, especially plastic packages
HAST High accelerated stress test 85 % HR polarized components		Very good	Very high	240 h or 500 h	Very efficient for plastic packages
PCT (pressure cooker test) 121 °C 100 % HR components power off		Very good	High	240 h or 500 h	Very efficient for plastic packages
Package sealing	• Leakage of cavities • Significant with fluorinert or galden • Small with helium	Very good	Low		For sealed package with cavity
Thermal stress	Mounting	Very good	Very high	T_j ≥ 70 °C 10 000 cycles on/off	For power components

5.4.5 Manufacturing control check (technological analysis)

The purpose of this checking is to evidence manufacturing defects or their improper control in order to identify potential risks undetected during the tests.

One of the methods which may be used is based on the IEC 61945.

The recommended tests are destructive tests and the number of components used shall be deduced from the quantity of components to be stored.

A wide range of data can be collected during the technological analysis or destructive physical analysis (DPA) depending on the means implemented. These can be simple (binoculars, for example) or sophisticated (electron beam microscope).

The technological analysis shall be performed by classifying the tests and their limits in order to match the objectives fixed for storage with the investigation processes and means to be implemented.

The main feasible tests (classified by order of complexity) are the following:

– external (package) and internal (chip) visual examination;
– electron beam microscope (analysis of dimensional anomalies on chip surface, data on the implemented technology);
– construction analysis (fine analysis of the technology and anomalies present in the volume of the package and chip).

5.5 Sanction

The sanctions to be applied for the tests are those defined in the manufacturer's specifications or recommended in the standards. For instance, in EN 190 000, the high-temperature storage test with dynamic functioning is performed on a sample of 45 parts, with zero failure after 2 000 h.

In the event of any detected nonconformity during the technical validation, it is recommended that the faulty components be assessed in order to understand the origin and anticipate on other batches likely to present the same defect.

The statement of conformities or nonconformities will help establish a final status for the batch of components and decide whether it should be stored or not.

6 Conditioning and storage

6.1 Type of environment

There are various types of environment:

– air without any special check;
– "dry" air (relative humidity lower than 50 %);
– nitrogen (racks, bags, tubes, etc.);
– vacuum.

The selection of a solution shall be made following the storage time, the application of the technology and the accepted risks. For long-duration storage, a dry-air, nitrogen or vacuum solution is recommended.

6.2 Elementary storage unit

The elementary storage unit is defined as the smallest entity related to the reference of a stored component.

The elementary storage unit shall be adapted to the expected consumption, in order to reduce the number of conditioning and de-conditioning operations, to which the components are subjected.

For example, let us assume that

– the expected consumption of a specific component is one part per year;
– this part number is stored for 20 years;
– the 20 components are stored in the same storage unit.

The storage unit will therefore be de-conditioned and reconditioned 20 times, which multiplies the risks of component degradation.

6.3 Stock management

In the event of a preventive storage, the batch turn-over will be appreciated depending on the storage implementation costs, compared with the need for renewing the stock.

6.4 Redundancy

In order to avoid common mode defects (for example, fire, flooding, etc.), it is desirable to store the components at several physically separated locations. For instance, a 100 % over-dimensioning of the stock stored at two different locations will avoid common-mode defects.

Storage in containers which can be evacuated rapidly is a solution against disasters.

6.5 Identification – Traceability

Various data are recorded during conditioning and de-conditioning, at least:

– the component manufacturer's name and part number;
– the procurement source;
– the date-code;
– the conditioning/de-conditioning history;
– the validation tests performed;
– the origin of the request for part number storage;
– the equipment on which the component shall be used.

The purpose of these data is to perfectly identify the components stored, to ensure the traceability of maintenance operations and to organize feedback.

When there are periodic checks, the relative data are recorded (date, nature of the checks, components tested, results, etc.).

6.6 Initial packaging

Generally speaking, electronic components shall be stored in their initial packaging if it plays a protective role against electrostatic discharges and if it is consistent with the expected storage duration.

When packaging may fail to assume its protective role over time the components shall be placed in a new packaging. This type of operation can only be performed exceptionally during storage because the components may be degraded. When the use of antistatic strips is required, carbon-charged antistatic strips, the properties of which will not deteriorate in the course of time, shall be preferred.

6.7 Stabilization bake

Stabilization bake (for example, at 125 °C for 24 h) is recommended for humidity-sensitive components, where the conditioning line continuity has not been ensured.

Once baked, the components are rapidly conditioned (within 24 h). If they cannot be conditioned within the required time, the components are temporarily placed in a dry pack. Final conditioning is performed before the expiry date of the dry pack.

6.8 Storage conditions

In order to ensure the integrity of the stored component properties, different parameters of the storage environment are checked. Environmental parameters shall be especially controlled in the case of long-term storage.

6.8.1 Storage area

The stock shall be stored in clean premises, in compliance with the requirements of the following subclauses.

6.8.2 Temperature

Many aging mechanisms are accelerated by temperature. It is mandatory to control the storage area temperature. It is recommended to maintain temperature close to 20 °C.

6.8.3 Temperature variations

Generally, temperature variations provoke the premature aging of assemblies made of different materials. Temperature variations shall, therefore, be controlled and lower than ± 5 °C per year.

6.8.4 Relative humidity – Chemical attacks – Contamination

Humidity, as well as any form of chemical attack or contamination, create a corrosion hazard for electronic components.

By reducing all contamination sources and by maintaining a relative humidity lower than 50 %, these risks are significantly reduced. It is worth pointing out, however, that a relative humidity lower than 20 % will favour the development of electrostatic discharges.

Dry nitrogen storage practically eliminates all corrosion and contamination problems.

6.8.5 Pressure

The possible pressure variation between the storage environment and the outside atmosphere should be taken into account.

6.8.6 Electrostatic discharges

Electrostatic discharges (ESDs) are an important cause of failure in electronic components. Specific measures to reduce failures to a minimum must be taken (see IEC 61340-5-1 and 61340-5-2), for instance:

– component storage in antistatic protections (bags, strips, conductive foams);
– metallic racks connected to earth;

– component storage in antistatic containers;
– protection of the conditioning/deconditioning stations (straps, working surfaces, dissipators, etc.)
– arousing awareness to ESD problems of the operators in charge of conditioning the components and managing the stock;
– use of air ionizers;
– etc.

Antistatic protections (bags, strips) generally have an efficiency limited over time, either because of surface treatment abrasion phenomena or under the impact of ultraviolet rays.

6.8.7 Vibration – Mechanical impacts

Stored components shall be kept away from any vibration source. The maintenance, destocking operations of part of the components, etc. shall be performed by keeping to a minimum the risks of mechanical damage to the stock.

Antistatic protection of the strips shall be ensured by surface treatment (except for carbon-charged strips). This treatment can be highly damaged by abrasion due to friction of the component leads in the strip. Components shall, therefore, be blocked in the strips. Stored component handling is kept to a minimum, in order to avoid the premature aging of the strips.

6.8.8 Electromagnetic field – Radiations

Stored components must be kept away from any radiation and electromagnetic field source.

6.8.9 Light

Light, and especially ultraviolet rays, may lead to a degradation of organic materials (packing bags, antistatic strips, etc.). The components shall, therefore, be stored away from light.

6.9 Maintaining storage conditions

The role of the equipment is to ensure that storage conditions are maintained within the limits defined to ensure the best integrity of the component properties. They shall be regularly checked and adjusted or repaired if required: heating, air conditioning, temperature and relative humidity measurement systems, ionizer, protections against ESDs (see IEC 61340-5-1), etc.

Checking and maintenance operations are recorded.

7 Periodic check of the components

7.1 Objectives

The most important stresses an electronic component may suffer during storage are of the mechanical, thermal and chemical types. These stresses may be internal or external to the component (see Annexes E and F).

The risks of alteration to quality and reliability justify

– an environmental check;
– a periodical component conformity check;
– a component check during de-stocking.

Depending on the risk/cost compromise, the periodic check may be replaced by a check during de-stocking.

7.2 Periodicity

If the stock is not used regularly, it is necessary to carry out a check, the periodicity of which depends on

– the level of risk envisaged;
– the findings of the initial evaluation tests;
– the findings of previous periodic checks.

7.3 Tests during periodic check

Generally, the tests or measurements will be made

– on a representative sample of the components stored;
– on the same samples, in order to avoid stresses caused by handling and test operations;
– in compliance with the specifications and quality levels used during initial procurement;
– following the electrical parameters identified as critical with regard to the application;
– following the expected risk/cost compromise.

8 De-stocking

8.1 Precautions

It is important not to interrupt the chain of precautions taken for storage, such as temperature variations, relative humidity, aggression, contaminations, electrostatic discharges, radiation and light.

Any destored component can only be stored again if the storage rules provided for this type of component have been adhered to. It will be considered as a new component to be stored.

8.1.1 Electrostatic discharges

It is mandatory to perform destocking maintaining the continuity of the conditions described in 6.8.6.

8.1.2 Mechanical impacts

The components are kept as long as possible in their original storage unit, until the component is checked or mounted on the board, in order to avoid distortion of the connections.

8.2 Inspection

De-stocking is generally made following the date-code of the component, in order to use the component with the oldest date-code.

De-stocking inspection is made in accordance with Clause 7.

9 Feedback

Feedback is one of the most important building blocks in constructing equipment reliability control. This is why all major companies and industrial groups have, for some time, implemented feedback from experience. Feedback is absolutely necessary in storage, process validation, stored product quality check, and stock correct dimensioning. In addition, it is easily conceivable to integrate the follow-up of the stored components during their life cycle in the equipment in a more global feedback action for all components of a specific equipment. The components which have been stored should therefore be clearly identified, in order to differentiate them from the others.

By identifying the faulty components which have been stored in a specific field, it is possible to integrate them in an existing component feedback database. Then only automatic routine operations are required to isolate the faulty components which have been stored or, more simply, to perform manual sorting and grouping. Data quality must be demonstrated. To do so, the component traceability shall be rigorous. The adding of the storage characteristics (duration, conditions, etc.) directly in this REX base may be envisaged. These approaches would then make it possible to carry out surveys according to the products, production batches, storage conditions, and storage duration. Over and above the statistics, it is also interesting to carry out failure analyses on a representative sample of components, in order to evidence the failure mechanisms and causes.

Feedback is interesting for storage for both technical and economical reasons.

- In fact, data resulting from feedback in service (for example, failure analyses and statistics) will evidence problems connected with the storage process or connected to poor products or batches of products. This is how, depending on the findings and their analyses, corrective actions shall be started to modify the storage process, to discard the faulty product or batch, to start additional procurement actions for similar components, etc.
- Feedback must therefore, in the long term, enable replacement of, or at least simplification of, the technical validations, and especially periodical checks performed on the components stored.

Feedback can also be used to improve dimensioning of the stocks and to correct dimensioning rules regularly during the life of the equipment.

Annex A
(informative)

Example of a component list

A.1 Component lists

a) Passive components

Resistors
Capacitors
Varistors
Thermistors
Etc.

b) Discrete semi-conductors

Transistors
Rectifier diodes
Signal diodes
Regulator diodes
Blocking diodes
Thyristors
Etc.

c) Microstructures

Logic
Analogue
Hybrid
Etc.

d) Optoelectronic components

Photocouplers
Light-emitting diodes
Displays
Etc.

e) Quartz crystals, oscillators, filters

f) Magnetic circuits
Transformers
Inductors
Filters

g) Switching and cut-off components

Relays
Circuit-breakers, pushbuttons
Connectors

h) Printed circuit boards

i) Mechanical parts

Spacers
Varnishes
Labels
Etc.

A.2 Data description

a) Manufacturer's code

This code represents the item code, the manufacturer's store code; it allows the link between the list of circuit boards and the parts list.

b) Component description

- type;
- function;
- model (standardized each time it exists, or generic name);
- electrical characteristics (voltage or power, value, tolerances);
- temperature range;
- package type.

c) Manufacturers

Name of the two or three approved manufacturers.

d) Manufacturers' part numbers

Specific commercial part numbers corresponding to each manufacturer.

e) Definition and test specification

Accurate specification number

f) Qualification level, quality assurance, etc.

Information related to the component qualification.

g) Component position in the life cycle

Corresponding category in the component life cycle, such as the following: “introduction”, “growth”, “maturity”, “decline”, “phase-out”, “discontinuance”, etc.

Annex B
(informative)

Examples of periodic and/or de-stocking tests

Table B.1 – Periodic and/or de-stocking tests

FAMILIES	TECHNOLOGY	PERIODIC AND/OR DE-STOCKING TESTS
HYBRID CIRCUITS	CHIPS AND WIRES TECHNO	V.B.E.ES.D ES (sealed packages only: residual gas analysis (RGA) on two parts per batch if not stored in dry gas (the two parts with the highest leakage rates)
INTEGRATED CIRCUITS and TRANSISTORS	BIPOLAR	V.B.E.D
	J FET	
	CMOS	
	MOS FET	
CAPACITORS	CERAMIC DISC	V.B.E.ES Measurements preceded by storage for 4 h at 125 °C
	POLYCARB.	Under study
	OTHER FILM	V.B.E.ES
	GLASS / PORCELAIN	VP.B.E
	SOLID TANTALUM	V.B.E.ES.D ES: charges/discharges + burn-in for 96 h at 85 °C
	JELLIFIED TANTALUM SILVER PACKAGE	Under study
	JELLIFIED TANTALUM TANTALUM PACKAGE	V.B.E.ES.D ES: charges/discharges + burn-in for 96 h at 85°C
CONNECTORS	HARD INSULATING MATERIAL	V.ES ES: electrical measurements at 100 %, two contacts per connector
	FLEXIBLE INSULATING MATERIAL	V.ES ES: ditto, hard insulating material, but performed at the manufacturer
	CONTACTS (ALONE)	V
	FILTERS	V.ES ES: electrical measurements: two contacts per type of filters and per connector
	HERMETICAL CONNECTOR	VT.ES.H ES: electrical measurements, two contacts per connector
DIODES	GLASS AND DROPLET	V.B.H.E
	METALLIC	V.B.E.D
WIRES AND CABLES		V.E.B
FILTERS		V.E.B.ES ES: measure of Ri and C at 25 °C
FUSES		V.B.E.D
INDUCTORS		V.E.B.ES ES: measure of 100 % measurements at 125 °C

FAMILIES	**TECHNOLOGY**	**PERIODIC AND/OR DE-STOCKING TESTS**
SWITCHES		V.B.E.ES.D ES: burn-in and electrical measurements consisting of 10 switchings
MICRO-COMPONENTS		TO BE DEFINED CASE BY CASE
OPTOELECTRONIC		V.B.E.D
CRYSTAL	CRYSTAL ALONE	V.B.E.D
	QUARTZ OSCILLATOR	TO BE DEFINED CASE BY CASE
RELAYS		V.B.E.ES + H.D ES: burn-in and measurements consisting of 10 switchings
RESISTORS	WIRE-WOUND	V.B.E
	HIGH PRECISION WIRE-WOUND	V.B.E.ES High-temperature measurements at 100%
	OXIDE FILM	V.B.E
	METAL FILM	V.B.E
	TRIMMER	V.B.E.
THERMISTORS		V.B.E Resistance and alpha measurement at 25 °C
HEATERS		V.B.E
THERMOSTATS		V.B.E.ES.D ES: Burn-in and electrical measurements consisting of 10 switchings
COILS		V.E

NOTE Abbreviations used:

V	:	Visual inspection by sampling or 100 %
B	:	Solderability tests
E	:	Electrical measurements by sampling or 100 %
ES	:	Specific tests by sampling or 100 %
D	:	Destructive physical analysis (DPA)
H	:	Sealing (if applicable to the technology) by sampling or 100 %

Annex C
(informative)

Parameters influencing the final price of the component storage

A t_0

Component purchasing cost Technical validation cost Conditioning cost	$\}$ Associated management cost

A t_{0+n}

- Financial expenses associated with the locking-up of the capital
  - ➨ financial performance of the locked-up capital
  - ➨ trade income taxes on locked-up capital
- Periodic checks
- Logistic cost of the storage
  - ➨tied-up surface
  - ➨ administrative stock management (database, human and material resources)
- Technical management (return, conditioning, maintenance of storage means, consumables)
- De-stocking management.
- Insurances, if any

Annex D
(informative)

Parameters influencing the quantity of components to be stored

- Components to be stored: ➡Requirements for manufacture

  ➡Maintenance

- Duration

- Needs for maintenance

  1) operational λ

  2) provisional λ
  -Data collection
  -Manufacturers' models
  -Internal models

- Technical validation needs
  -Initial
  -Follow-up, if any

- Contingency factor
  -Stock destruction
  -Fluctuation in manufacturing need

Annex E
(normative)

Failure mechanisms – Encapsulated and non-encapsulated active components

Table E.1 – Failure mechanisms: encapsulated and non-encapsulated active components

MECHANISM NAME	PHYSICAL ORIGIN	FAILURE MODE	ACCELERATION PARAMETER	FAMILY-RELATED COMPONENTS	NON-ENCAPSULATED COMPONENTS	STORAGE CRITICALITY
1) Contamination	Presence of contaminants (Na)	Parametric shift	E , T	All components	YES	✳
2) Surface charges	Presence of surface charges in gate oxides	Parametric shift	E , T	All components	YES	
3) Charge Inversion	Induced charges	Parametric shift	E , T	Bipolar	YES	
4 Accumulation of surface charges	Ionic impurity in resin	Parametric shift	E , T	Plastic packages, components mainly	YES	✳
5) Charge losses(?)	Poor programming or oxide quality	Stored information loss	T	Electrically programmable components	YES	✳✳✳ (✳✳✳✳✳for very long term)
6) Cracking of dielectric	Poor oxide manufacturing quality	Isolation loss	T ,ΔT ,E	All components with isolating oxides	YES	✳ ✳✳(polyimide dielectric)
7) Dielectric breakdown ----------------------------- Melting of metal or Si	**ESD**	Short circuits Open circuits Leaks …….	T , HR Environment	All bipolar components concerned Hypersensitivity of power MOS	YES	✳✳✳✳✳
8) Inter-metallic growth	Formation of compounds Au_x -Al_y	Open circuits	T favoured by contaminants (for example, Br and Si)	All components including an Au and Al contact	YES	✳
9) Separation or break (shearing) of the connecting wires	Mechanical stress relieving -------------------------------- Welding and wiring weaknesses	Open circuits	T , ΔT , HR --------------------- ΔT , humidity inside the package	Plastic package components	NO	✳✳✳ --------------------- ✳✳
10) Pop-corn	Water absorption in the encapsulation. Resin permeability	Open circuits	Temperature/ die bonding profile	Plastic package components/SMD (refer to JEDEC xxx)	NO	✳✳✳✳
11) Metal-Si interaction	Metal diffusion in Si	Short circuits		Bipolar integrated circuits and discretes		

MECHANISM NAME	PHYSICAL ORIGIN	FAILURE MODE	ACCELERATION PARAMETER	FAMILY-RELATED COMPONENTS	NON-ENCAPSULATED COMPONENTS	STORAGE CRITICALITY
12) Chip corrosion (bonding and pads)	Presence of an electrolyte favoured by contaminants Passivation integrity	Open circuits Parametric shifts Leaks	T , HR , E	Mainly plastic package components	YES	✳✳
13) Pin corrosion	Presence of an electrolyte, aggressive contaminants, nature of the pin coatings	Open circuits Solderability loss	T , HR Aggressive atmosphere	All components except golden pins	NO	✳✳✳✳
14) Pin oxidation	Presence of oxidants, nature of the pin coating	Solderability loss	T	All components except golden pins	NO	✳✳✳✳
15) Intermediate diffusion of materials at the pins	Nature of coatings	Solderability loss	T	All components	NO	✳✳✳✳
16) Chip crackings	Si defect created by a manufacture (for example, sawing) Relieving stresses related to chip mounting	Open circuits Parametric shifts	ΔT Mechanical impacts	All components Especially big chips	YES	✳
17) Hermetic package crackings	Pin feed through cracking	Hermeticity loss	ΔT Mechanical impacts	Sealed package components (mainly glass)	NO	✳
18) Delamination (packages, chips, chip mounting)	Adhesion weakness	Open circuits Parametric shifts Thermal and electrical resistor degradation. Leaks	T , ΔT	Active components, plastic packages	NO	✳
19) Si defect	Impurities, dislocations Stress installation	Leaks	T , ΔT Mechanical stress	Power components for the most part	YES	✳
20) Stress-voiding	Mechanical stress induced by a stress difference between successive coatings	Open circuits	T	Integrated circuits	YES	✳✳

NOTE 1 At the “corrosion” level, there may be rare cases where nitrogen is not inert and may act as a reducing agent; for example, ZnO in lightning arresters.

NOTE 2 Defects related to voltage are not taken into account.

NOTE 3 E: electric field; T: temperature; ΔT: temperature variation; HR: relative humidity.

Annex F
(normative)

Failure mechanisms: GaAs components

Table F.1 – Failures compared with initial table on the Sis

	Mechanism	Applicable GaAs	Criticality during storage
1	Ion contamination	Yes	**
2	Surface charges	No	No
3	Charge inversion	No	No
4	NA		
5	Charge losses	No	No
6	Dielectric cracking insulation	According to technologies	*
7	Dielectric breakdown	Yes	***
8	Inter-metallic growth	Yes	*
9	Wire rupture separation	Yes	***
10	Pop corn	Yes	****
11	NA		
12	Chip corrosion	Yes	**
13	Pin corrosion	Yes	****
14	Pin oxidation	Yes	****
15	Material diffusion at the pins	Yes	****
16	Chip cracking	Yes	***
17	Package cracking	Yes	*
18	Package delamination, chip, chip mounting	Yes	*
19	GaAs defect	Yes	**
20	Stress-voiding	Yes	** For Al technologies

Failures specific to GaAs components

	mechanism	**physical origin**	**Failure mode**	**accele-ration parameter**	**relevant components**	**criticality during storage**
22	embedded gate	Au gate diffusion in GaAs	Parametric shift	T	Au gates	*
23	degradation of ohmic contact	Au diffusion in GaAs Ga diffusion in Au	Parametric shift	T, E	allied contacts	**
24	channel degradation	diffusion of doping products	Parametric shift	T, E	HEMT	no
25	degradations linked to hydrogen	H diffusion in GaAs	Parametric shift	T, E hydrogen %	gates with P+ or Pd	***
26	degradations linked to surface conditions	surface conditions in gate - drain and gate-source	Parametric shift	T, E		no
27	degradations due to moisture	formation of metallic hydroxides	Parametric shift	T,HR	components in non hermetic packages	**
28	chip soldering defects	component overheat further to poor thermal draining	Parametric shift	T	power components	no

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