SLOVENSKI STANDARD
SIST EN 165000-4:2002

01-september-2002

Film and hybrid integrated circuits - Part 4: Customer information, product assessment level schedules and blank detail specification

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Integrierte Hybrid- und Schichtschaltungen -- Teil 4: Kundenangaben, Prüfablaufpläne für die Produktbewertung und Vordrucke für die Bauartzpezifikationen

Ta slovenski standard je istoveten z: EN 165000-4:1996

ICS:

31.200	Integrirana vezja, mikroelektronika	Integrated circuits. Microelectronics

SIST EN 165000-4:2002 **en**

EUROPEAN STANDARD
NORME EUROPÉENNE
EUROPÄISCHE NORM

EN 165000-4

April 1996

ICS 31.200

Descriptors: Quality, generic specification, hybrid circuits

English version

Film and hybrid integrated circuits
Part 4: Customer information, product assessment level schedules and blank detail specification

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CENELEC

European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

Central Secretariat: rue de Stassart 35, B - 1050 Brussels

Ref. No. EN 165000-4:1996 E

Foreword

This European Standard was prepared by CLC/TC CECC SC 47AX (former CECC/WG 21), Film and hybrid integrated circuits.

The text of the draft was submitted to the Unique Acceptance Procedure and was approved by CENELEC as EN 165000-4 on 1996-03-05.

The following dates were fixed:

– latest date by which the EN has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	1997-03-01
– latest date by which the national standards conflicting with the EN have to be withdrawn	(dow)	1997-03-01

The present standard, EN 165000-4, Film and hybrid integrated circuits - Part 4: Customer information, product assessment level schedules and blank detail specification, is intended to be read in conjunction with the other parts of EN 165000, which are:

Part 1: Generic Specification - Capability approval procedure
Part 2: Part 2: Internal visual inspection and special tests
Part 3: Self-audit checklist and report for film and hybrid integrated circuit manufacturers

Part 3 is primarily intended as a pro-forma for the manufacturer and is not considered *essential* for a customer *in this form.*

Part 4 is considered an essential document for all users; in particular it includes a helpful introductory section which is aimed at potential customers and seeks to explain the underlying philosophy upon which the whole standard is based.

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1. Introduction

1.1 How EN 165000 Works

This specification is part of the CECC quality assessment system which provides arrangements for the specification, Capability Approval, inspection and release of hybrid integrated circuits of assessed quality. This comprehensive scheme is more effective than individual standards, allowing the approved manufacturer to work to consistent, defined requirements and gives the customer a clear view of exactly what component quality will be received. Because hybrids are used in a variety of applications, it is important for the customer to be able to choose a manufacturer who can supply to those needs. EN 165000 is designed to meet a large cross section of these applications (such as automotive, military, space, telecommunications, professional).

To gain approval to EN 165000 the manufacturer shall

- meet the requirements of EN 29001 or EN 29002;
- carry out an audit and comply with the detailed technical process requirements of the checklist shown in EN 165000-3;
- test a representative product against the requirements of one of the Product Assessment Level Schedules (PALSs) detailed herein.

Having completed the approval, the manufacturer can release customer circuits for that particular technology against a PALS for which he is approved.

1.2 Customer/Manufacturer Interface

A customer, when entering into negotiation with a potential supplier of hybrid circuits released to EN 165000 needs to be aware of the various manufacturer/customer interfaces. At the design and layout stage, the two parties need to agree whether the manufacturer will be responsible for the complete design against an electrical, mechanical and environmental specification and whether the customer may contribute to the layout. In this latter case, the manufacturer has to ensure that the layout complies with his design rules. Although the test requirements of each PALS is clearly defined, the customer and manufacturer have a responsibility to ensure that the Customer Detail Specification clearly reflects the requirements of the customer without exceeding the capabilities of the manufacturer. In particular, any test or test sequence which allow a choice shall have that choice agreed and documented. The Customer Detail Specification requires physical dimensions of the hybrid to be stated. Some of these dimensions are essential for interchangeability requirements. These need to be agreed and toleranced since the manufacturer will inspect the finished product to these requirements.

The Customer Detail Specification also requires information on the performance and design of the circuit, conditions under which it can be used and derating data, all of which needs to be agreed between customer and manufacturer. Further mutually agreed information in the Customer Detail Specification can include circuit diagrams, curves, drawings and explanatory notes.

Electrical testing needs very careful specification and agreement between customer and manufacturer. This minimises incorrect testing, tests which damage the circuit, tests being omitted and redundant testing. The PALSs refer to "those tests which define circuit functionality" and the remainder. The tests defining circuit functionality are those which prove that the device performs its prime function. These tests tend to be part of screening and are also used as post-test end-points. The remainder are more peripheral and, either for reasons of cost of test or perceived lack of importance, tend to be examined on a sampling basis. The customer and manufacturer need to agree which electrical tests are required and which are considered to "define circuit functionality". Where testing is performed at T_{min} and T_{max} or where burn-in and electrical endurance are concerned the manufacturer and the customer need to be aware that some devices dissipate heat during operation and this may raise the junction temperature much higher than that of the ambient. The control and definition of temperature and its reference point (eg. T_{amb}, T_{case}) can cause problems and needs to be discussed by the manufacturer and the customer in advance of the detail specification being agreed.

Further agreement needs to be reached over testing and structural similarity considerations. Where structural similarity is applicable, Design Evaluation Testing can be omitted since the manufacturer has already demonstrated assurance at his initial approval stage. Such omissions can only be permitted if both customer and manufacturer are confident of the correctness of such a decision.

For the first delivery, the customer's circuit has to be tested against all aspects of the PALS (Device Screening, Device Sample Testing and Design Evaluation) as well as any other requirements which are mutually agreed between manufacturer and customer. For subsequent deliveries circuits are tested against the requirements of Device Screening, Device Sample Testing and those tests from Design Evaluation which are mutually agreed. The circuits may have all, some or more of the Design Evaluation tests performed under any mutually agreed sampling plan, together with any other agreed testing. Tests additional to those specified in the PALS do not change release to the Product Assessment Level Schedule number. The full requirements are agreed between customer and manufacturer and documented in the Customer Detail Specification.

1.3 The Product Assessment Level Schedules

1.3.1 Derivation of the Product Assessment Level Schedules

Every hybrid manufacturer specialises in a number of technologies with respect to substrate type, metallisation, method of add-on component attachment and encapsulation. Dependent upon the market for which this product is designed (high volume, high reliability, military, consumer etc.) the manufacturer will offer a number of tests which may be adopted 100%, used on a sampling basis or performed once only purely as a means of design evaluation. These variants may be classified as a series of Product Assessment Level Schedules.
Table 1 shows 5 PALSs based on solder-attached or chip or wire components which are either unencapsulated or non-hermetically encapsulated. It can be seen that as the PALS number increases so does the amount of testing done on the hybrid. Similarly table 2 shows 6 PALSs based on hermetic assembly. Once again, the amount of testing increases as the PALS number increases.

A manufacturer who has completed an assessment against a PALS can release product of that same technology to customers. The manufacturer who is approved to a PALS may offer that PALS or a lower one in the same technology series.

Customers who purchase hybrid circuits may require them for a wide variety of uses. They may be for military or aerospace applications, medical or safety, telecommunications, automotive, commercial, professional or consumer. Each of these applications is driven by a diversity of requirements, such as cost, quality, reliability, ability to withstand extremes of temperature, mechanical or humidity environment etc. By examining the PALSs as displayed in tables 1 and 2, the customer is able to choose the PALS which most equates to his requirements and is thus able to choose a manufacturer who can release to this particular PALS. Where there is a requirement for testing in excess of that stipulated by a particular PALS, the customer and manufacturer may agree to this but release is still to that PALS.

Purely as guidance, the eleven PALSs against which a manufacturer can release may be used in the following applications.

1.3.2 Indication of Applications for the Product Assessment Level Schedules

Each of the PALS is characterised by a different assessment level, but not necessarily by a different application level. A device procured against PALS 1 or PALS 2 is not tested for its ability to withstand acceleration, although it may well withstand the test. The difference between the same device procured against PALS 1 and an identical device tested to PALS 4 or 5 is that in the latter case the ability to meet, amongst other requirements, acceleration is demonstrated and, importantly, it is paid for.

A hybrid used in consumer applications, such as toys or audio-visual applications may need to be cheap and thus have less testing demonstrated. An overall quality of product is, nevertheless, implicit as a result of the enhanced processing requirements, which is ensured by compliance with the audit against the checklist of EN 165000-3. It is impossible to give any firm guidance on which PALS is required for a specific application, except to advise that the cost of procurement rises from PALS 1 through to PALS 5 (which are essentially solder-attached components without hermetic encapsulation) and from PALS 6 through to PALS 11 (which are hermetic cavity devices, probably containing bare die).

PALS 1 contains no mechanical, thermal or climatic testing and is thus assessed for benign mechanical and temperature environments. It is the cheapest schedule to perform and this would probably be suitable for commercial or consumer applications.

PALS 2 is identical except that Design Evaluation requires electrical endurance to be performed for 1000 hours, this giving some confidence of the life time capability of the device. The applications would be similar to those suggested for PALS 1.

PALS 3 contains damp heat testing, temperature cycling and measurement of essential electrical parameters at Tmin and Tmax. It thus demonstrates capability to withstand extremes of temperature and humidity but only for a benign mechanical environment. It could be suitable for certain telecommunications and computer-based applications as well as commercial and consumer.

PALS 4 introduces burn-in and electrical endurance up to 2000 hours, whilst adding acceleration and shock and/or vibration testing. For this type of build standard it gives a good assessment of the device's capability of withstanding non-benign mechanical and climatic conditions as well as the removal of early life failures. This level of testing makes the device suitable for those applications indicated for PALS 3 and possibly for automotive use and certain non-critical military applications.

PALS 5 gives the highest level of assurance for this hybrid build standard, including acceleration in the screening sequence and a limit on the percentage of defectives (PDA) allowed during screening. Its applications would be similar to those indicated for PALS 4.

PALS 6 is intended for non-critical applications but nevertheless includes electrical endurance testing and assessment at extremes of temperature. It could be used for consumer or commercial requirements where hermeticity is important, or perhaps telecommunication and computer requirements where demonstrations of life time is not required.

PALS 7 could be used for applications similar to PALS 6 but introduces burn-in and P.D.A. giving more confidence of screening and slightly greater applicability for telecommunication and computer use.

PALS 8 includes acceleration in the screening sequence, shock and/or vibrations in the design evaluation and a tighter P.D.A. It gives confidence that the device can survive harsh environmental and mechanical conditions and could be used for certain military applications.

PALS 9 contains PIND testing, endurance to 2000 hours and residual gas analysis. This level of testing and screening (PDA 5%) is generally only used where a very high level of assurance and reliability is required. One example of its application would be used in military systems.

PALS 10 exceeds the requirements of PALS 9 by the addition of dry heat testing and shock and vibration testing during device sampling. Other than use in space applications this schedule gives the highest level of quality and reliability assurance.

PALS 11 includes radiation hardness assessment and radiography. Testing to this schedule will be expensive and is only recommended for aerospace applications.

Table 1: Product Assessment Level Schedules for solder or chip & wire (non-hermetic) assembly

TEST	PAL 1	PAL 2	PAL 3	PAL 4	PAL 5
Device Screening (100%)					
Electrical test @ Tamb	*	*	*	*	*
Change of temperature (10 cycles)			*	*	*
Acceleration (5 000 g_n)					*
Burn-in 160 h				*	*
PDA (%)				10	10
Electrical test @ Tmax, Tmin, Tamb				*	*
External visual inspection				*	*
Device Sample Testing (IL=S4, AQL=0.4%)					
Electrical test @ Tamb	*	*	*	*	*
External visual inspection	*	*	*		
Electrical test @ Tmin, Tmax			*		
Design Evaluation					
Min sample size (accept on 0 failures)	8	8	8	8	8
Dimensions	*	*	*	*	*
Electrical test @ Tmin, Tmax	*	*			
Endurance 1000 h		*	*	*	*
Endurance 2000 h				*	*
Damp heat cyclic / steady state			*	*	*
Change of temperature			*	*	*
Min sample size (accept on 0 failures)	3	3	3	5	5
Resistance to solder heat	*	*	*	*	*
Solderability	*	*	*	*	*
Resistance to solvents	*	*	*	*	*
Acceleration				*	*
Shock and/or Vibration				*	*
Min sample size (accept on 0 failures)	3	3	3	3	3
Robustness of terminations	*	*	*	*	*
Flammability if applicable	*	*	*	*	*

Table 2: Product Assessment Level Schedules for chip and wire (hermetic) assembly

TEST	PAL 6	PAL 7	PAL 8	PAL 9	PAL 10	PAL 11
Device Screening (100%)						
Electrical test @ Tamb	*	*	*	*	*	*
Change of temperature (10 cycles)	*	*	*	*	*	*
Acceleration (5 000 g_n)			*	*	*	*
Burn-in 160 h		*	*	*	*	*
PDA (%)		10	7	5	5	5
Sealing (fine & gross)	*	*	*	*	*	*
External visual inspection	*	*	*	*	*	*
Electrical test @ Tmax, Tmin, Tamb			*	*	*	*
PIND				*	*	*
Dry heat (500 h)					*	*
Radiography						*
Device Sample Testing (IL=S4, AQL=0.4%)						
Electrical test @ Tamb	*	*	*			
Electrical test @ Tmax, Tmin, Tamb	*	*		*	*	*
Endurance 1000 h				*	*	*
Endurance 2000 h				*	*	*
Shock					*	*
Vibration					*	*
Design Evaluation						
Min sample size (accept on 0 failures)	8	8	8	8	13	13
Dimensions	*	*	*	*	*	*
Acceleration				*	*	*
Endurance 1000 h	*	*	*	*	*	*
Endurance 2000 h			*	*	*	*
Endurance 8000 h						*
Shock and/or Vibration			*	*		
Min sample size (accept on 0 failures)	3	3	3	3	5	5
Resistance to solder heat	*	*	*	*	*	*
Solderability	*	*	*	*	*	*
Resistance to solvents	*	*	*	*	*	*
Damp heat steady state / Salt mist	*	*	*	*	*	*
Radiation hardness assessment						*
Min sample size (accept on 0 failures)	3	3	3	3	3	3
Robustness of terminations	*	*	*	*	*	*
Internal moisture content				*	*	*

1.4 Test Requirements of the PALS's and Their Applicability to Real Life Application

1.4.1 The Origin of the Inspection Requirements

The test procedures detailed in the inspection requirements of the PALSs have largely been derived from National Standards for discrete transistors and integrated circuits. Although a film hybrid can contain many diverse add-on components and be considerably bulkier than those devices envisaged by these earlier standards, the test procedures have needed little modification to encompass the changes in technology dictated by hybrids.

The origins of inspection requirement test procedures can be traced back to the basic reasons for testing a product. Probably the most fundamental reason is to reveal weaknesses, potential or otherwise, before the shipment. The PALSs divide inspection requirements into Screening, Sample Testing and Design Evaluation.

Screening tests are performed on every device of every lot. They are non-destructive, electrical, mechanical or short term endurance tests which are employed to assess the principal characteristics of the component and whether it is capable of meeting its fundamental requirements.

Sample tests (which may be electrical, medium term endurance or mechanical, such as shock and vibration) are carried out on each lot but only a representative sample is examined. These tests are generally non-destructive but in order to minimise the cost of testing, an acceptable level of quality is assured by sample testing.

Screening, sample testing and design evaluation testing are also performed by the manufacturer during the initial approval exercise on product or products representative of the scope of capability to the highest PALS selected. This shall be done to the satisfaction of the ONS.

Design Evaluation testing is performed on the initial delivery lot of each individual customer product for the full set of Design Evaluation tests unless structural similarity rules apply and they are mutually agreed by manufacturer and customer. The tests performed during Design Evaluation comprise long term electrical endurance, mechanical and environmental tests: in some cases they are destructive and, quite often, expensive. The tests are meant to provide a check on the overall design of the hybrid rather than a periodic check on quality. Because of this, the manufacturer and customer may agree not to repeat the Design Evaluation tests on subsequent delivery lots.

Note: some of the test methods in the IEC 68-2 series already incorporate guidance on their use and application and this is indicated in the title of the document, for example'Test Ea and guidance'. there also exist other documents in this series which are specifically concerned with guidance and where these are relevant to this standard they have been indicated in 1.2 Related documents of the Generic Specfcation, their status being indicated by the use of square brackets.

1.4.2 Electrical Tests

The electrical tests required by the PALSs are subdivided into
a) those tests at ambient temperature which define circuit functionality
b) those test at ambient temperature other than (a), above
c) those tests which define circuit functionality at T_{min} and T_{max}

d) those tests other than (a), above, at T_{min} and T_{max}
e) burn-in
f) electrical endurance

(a) is sometimes known as major static and dynamic characteristics and (b) as minor static and dynamic characteristics, but the difference between them is not clear cut. The differentiation between (a) and (b) needs to be agreed between the manufacturer and the customer when the detail specification is drawn-up but the tests at (a) are those which the customer perceives as a measure of whether the circuit is functioning properly.

Tests performed at T_{min} and T_{max} (whether they are those tests which define circuit functionality or the rest) are necessary if the circuit is required to meet its specification at extremes of temperature. Unless otherwise specified, devices shall be considered to be T_{amb} rated, whereby they will function at the maximum specified air temperature (T_{max}) without the need for further thermal management considerations. Devices which generate significant amounts of heat during operation should be T_{case} rated, whereby the responsibility for the thermal management of the devices is placed on the customer, with the manufacturer providing the required thermal management data.

Burn-in is a non-destructive test designed to screen out infant mortalities or early lifetime failures. It is assumed that by placing the device under its operating electrical load at an elevated temperature (generally the maximum operating temperature without exceeding the thermal rating of the device) the life of the device will be accelerated. The value of this test and the extension of it to Electrical Endurance up to 8000 hours need to be examined in the light of its derivation. 8000 hours endurance testing of a TTL device at 125°C can be roughly equated to 50 years life under normal operating conditions at 70°C. If failure rate with time of such a discrete device is assumed to obey the classical bathtub curve, successful completion of the 8000 hour test is an indication that the end of life wear-out phase has not yet begun. Similarly, accelerated operation of the discrete device for 160 hours simulates avoidance of early failure (infant mortalities) whereas 2000 hours is an assessment of the medium term life or flat portion of the bathtub curve. Thus, with a discrete device it is possible to gain a degree of insight into the short, medium and long term life expectancy. With a film hybrid, the complexity and variety of components make any such calculation much more difficult but, nevertheless, the burn-in and electrical endurance tests provide some confidence as to reliability of the manufacturer's hybrids.

The post test end-points may need to be relaxed or otherwise modified after burn-in or electrical endurance testing. Such changes (delta values) shall be agreed between customer and manufacturer in advance and be included in the Customer Detail Specification.

1.4.3 Other Screening Tests

1.4.3.1 General

Certain of the PALSs contain a screening sequence designed to stress the device mechanically by temperature cycling (generally between the storage temperature limits) followed first by an electrical check and then either a leak test or exposure to damp heat cyclic. The sequence may also contain acceleration. The philosophy of the test sequence is that the required minimum of 10 complete temperature cycles, whilst not representing the device life, will turn a latent defect into a patent failure.

The test is intended to stress die bonds, wire bonds, package seals and, where applicable, the integrity of leads through package walls. Any damage to the circuit within the package is then obvious when the device is electrically tested. Where the temperature cycling has resulted in damage to the package hermeticity, the fault can be recognised for a cavity package by leak detection.

1.4.3.2 Acceleration test

The acceleration test is intended to assess the satisfactory performance of components when subjected to forces produced by steady acceleration environments (other than gravity) such as occur in moving vehicles, especially flying vehicles, rotating parts and projectiles. The standard levels of test quoted in IEC 68 range from 3 g_n to 50 000 g_n (30 to 500 000m/s^2) which are put into context when it is realised that the maximum acceleration achieved by a space rocket is only in the order of 500 g_n (although this can produce associated ringing and flexing transients up to above an order higher). Nevertheless, the acceleration test still offers a range of standard severities between 10 g_n and 30 000 g_n, not to simulate life but to apply an artificial stress on wire bonds, die bonds and other attachments. If a stress level of 20 000 g_n is considered on a wire bond the associated force is somewhere in the order of 1 gram whereas in the case of a large semiconductor chip the force is about 0,5 kilogram for the same acceleration. If applied to a large (say 64 lead) chip carrier, the force rises to about 40 kilograms. For wire bonds and chip adhesion the forces involved are really only testing for the poorest quality of bond and thus provide a useful back-up check once the lid has been sealed on. The situation is different for large components such as the chip carrier, since although the solder joints should comfortably bear the 20 000 g_n and its associated 40Kg force, the acceleration could cause flexing, bowing and even cracking of the mounting board which would result in premature joint fracture. It is, therefore, essential for both manufacturer and customer to set a realistic value of acceleration. The normal screening level for non-destructive acceleration testing is set at 5 000 g_n.

1.4.3.3 Leak test

The leak test is performed in two steps called fine and gross. The commonest form of fine leak test consists of placing the device in a chamber which is evacuated, back filled with a specified pressure of helium and left for a period of time. It is assumed that for a given pressure and time that the helium will pass through any holes or cracks into the main cavity of the package at a rate proportional to the size of the hole or crack. On removal from the helium "bomb" the helium flows back into the atmosphere and the rate at which it does so is again proportional to the size of the hole or crack. If this flow rate is between certain limits the helium can be detected by the mass spectrometer of a commercial leak detector. This particular test is sensitive to leak rates between 10^{-8} and 10^{-5} atm. cm^3/s (10^{-3} and 1 Pa cm^3/s). It is generally assumed that a device with a leak rate of better than 10^{-8} atm. cm^3/s is "hermetic". Where the leakage path is very large the helium forced into the package flows out very quickly and by the time the device is in the mass spectrometer it may well have disappeared, giving the appearance of a pass. It is, therefore, essential to complement fine leak testing with a gross leak test. In essence this is done by placing the device in a hot liquid which causes the gas in the package to expand and bubble out through any hole or crack. The presence of bubbles coming from the package signifies a failure. Leak testing is not performed on non-cavity plastic encapsulated devices or plastic sealed devices.

1.4.3.4 Particle Impact Noise Detection (PIND) test

Particle Impart Noise Detection (PIND) is used to detect loose particles (such as fragments of die) within cavity packaged hybrids. The test is labour-intensive and is normally only performed where the highest level of quality and reliability are required. The test consists, essentially, of a vibration shaker and driver assembly capable of producing a sinusoidal signal to the device under test and a shock mechanism or tool able to produce shock pulses of 1 000 g peak to the device. Any loose particle activated by the shock and vibration strikes the case and activates a transducer whose signal is amplified. The device under test is bonded acoustically to the transducer and is subjected to a series of shocks and vibrations in accordance with the test specification.

1.4.3.5 Dry Heat test

The Dry Heat Test is designed simply to verify that the hybrid is capable of being stored at elevated temperatures. It is not intended to assess the hybrid's ability to withstand variations in temperature nor is it meant to demonstrate the hybrid's capability under electrical load. In keeping with possible worst case conditions the test called up by EN 165000-1 requires the device to be taken from ambient and placed directly into the oven at test temperature, allowing no time for gradual increase in temperature. The temperature chosen for the test should be the maximum that the device will see in normal life. The test will act as a screen for devices whose electrical parameters drift out of specification during storage at elevated temperature or are subject to thermally induced failures such as loss of hermeticity or bonding separation.

1.4.3.6 Radiographic Inspection

Radiography is the use of X-ray equipment to detect defects within a packaged device. The radiographic inspection is made in one or more of the axes of the device depending upon the package size and individual requirements. It is an expensive test (both in terms of equipment and time required) and is only used where the highest levels of quality and reliability are required. The test is capable of detecting foreign or extraneous material, either loose or attached, excessive semiconductor die or substrate bonding material or voids in the bonding material, cracks, splits or chips, inadequate clearance (e.g. bond wire to lid) etc. It is predominantly used to detect defects which have occurred after the package sealing process since most other defects (apart from voids in attach material) would have been eliminated during pre-cap visual inspection.

1.4.4 Device Sample Testing

In order to keep device testing to a realistic minimum some tests on each lot produced by the manufacturer are done only on a sample. This is done using statistical methods to ensure that the sample reflects the quality of the whole lot.

Apart from electrical testing and endurance testing, sample testing in EN 165000 is confined to shock and vibration and then only where a high degree of assurance is required.