8 FIBRE OPTIC SPLICES

8.1 Introduction

The purpose of fibre optic splices is to join two fibres or several pair of fibres with as low insertion loss as possible. Fibre optic splices can be formed by fusioning or mechanical means. The mechanical splices can be either permanent or separable (although not intended to be separated).

The mechanical splices must have means to ensure fibre alignment. In addition, the splice must have some sort of grip mechanism to keep the fibre in position. The grip mechanism is intended to grip the primary fibre or the secondary coated fibre or both. In permanent splices the grip mechanism is replaced by an adhesive. In addition to this grip mechanism the splice may be provided with additional strain relief. Because a mechanical splice cannot expect to achieve physical contact at the fibre surfaces, index matching gel may be applied to reduce the backreflected signal.

Permanent splices with adhesives are often troublesome to make, because the alignment may be disrupted during curing of the adhesive. In space applications, strict requirements are put on the adhesives which have to withstand extreme temperatures, high vacuum levels and high levels of ionizing radiation. Since the mechanical tolerances are very narrow, few adhesives will be able to maintain the alignment during these loads.

Separable mechanical splices are based on mechanical alignment of the fibres. The mechanical alignment will depend on temperature and environmental loads such as vibration and shock. Since the tolerances are so narrow, heavy demands are put on the fibre alignment. The fibre must be kept firmly in place and the fibre grips may introduce cracks and flaws at the fibre surface. These cracks may cause fibre breakage as the fibre is put under tension because of strain due to different thermal expansion of the components in the splice [12].

In fusion splices the waveguides are fused together. After the splice is completed, the waveguide is continuous through the splice, as in a continuous fibre. Fusion splices are thus not dependent on mechanical alignment after the splice is completed. They will not have any backreflection, and the application of indexmatching liquid is not necessary. Neither is glue to mount the fibre. The fused area is protected either by reapplying the primary coating or applying some sort of stress relief. The stress relief is usually crimped to the fibre outside the fused region. The mechanical characteristics of the splice will then be determined by the characteristics of the strain relief and protection sleeve. When reapplying the primary coating, the splice will look no different than an ordinary fibre. The mechanical characteristics such as resistance to crush, drop, bump and impact will be the same as for the fibre itself. The tensile strength of such a splice will be determined by the characteristics of the fused area.

It can be expected that fusion splices will be the preferred fibre optic splice in space application. This is due to optical as well as mechanical and environmental characteristics. They are the highest performance splices in terms of insertion loss, and they do not introduce any backreflections in the system. The waveguide is continuous through the splice, and it is therefore not dependent on means for mechanical alignment which shall endure in an environment with a large temperature span and high levels of shock and vibration. The use of chemical substances such as glue or index matching liquid which may cause outgassing during vacuum operation, is eliminated. It is possible to make a fibre optic fusion splice without any other materials than in the fibre itself, and the splice will thus not introduce any extra material related effects. The fusion splice can be made very small and may be integrated in the cable structure.

The properties of the splice are to some extent dependent on the type of fibres being spliced (insertion loss, ionizing radiation). The splice should thus be qualified separately for each fibre type. In other cases the properties are dependent on the characteristics of the different materials and design of the splice (vacuum operation, resistance to crush, drop, bump and impact). In such cases it is not necessary to repeat the tests for different fibre types.

The splice is the result of a splicing operation. The splice cannot be considered a component before the splice is made, and the general test strategy described in Chapter 4 cannot be applied. An evaluation test strategy is described which covers all splices. The qualification test programme and production tests will only be applicable to fusion splices, with or without strain relief since this is regarded the preferred splice for space applications. The production testing is only applicable for the components, if any, of a fusion splice (protection sleeves, strain reliefs). The lot acceptance testing is replaced by an installation test programme, which include the installed splices and dummy splices.

8.1.1 Splicing procedure

The splicing procedure is crucial to the performance of a fibre optic splice. In addition to the obvious critical factors such as cleanliness, fibre alignment and mounting of strain reliefs, the characteristics of the splice will depend on factors such as temperature and humidity where the splice is performed [16]. In addition, the splicing operation involves handling of the bare fibre, which may introduce cracks and flaws, and thus induce failure. The performance of a splice is dependent on the training and skill of the person performing the splice [13]. Large variations in the performance of the splice can therefore be expected, and it is important to perform the splicing of the test samples in an atmosphere similar to the installation atmosphere.

8.2 Evaluation testing

8.2.1 Purpose

The purpose of the evaluation testing is to determine the operational limits of the fibre optic splice with respect to critical mechanical and environmental parameters, to overstress specific characteristics in order to identify failure modes, to demonstrate the suitability of the splice for proceeding on to qualification testing and to get information which can be of value for a detailed planning of the test programme to be used in the procurement of splicing equipment, accessories and installation of the splice.

8.2.2 Properties to evaluate

The main properties of interest are :

- mechanical properties
  with special emphasis on tensile strength and torsion
- effects of high levels of vibration and shock
- effects of temperature extremes
- effects of rapid depressurisation and vacuum operation
- effects of ionizing radiation
- effects of solar radiation and UV radiation
- resistance to solvents and contaminating fluids

For some special applications the optical power handling capability may be of concern.

It is expected that the fibre used in the splice is characterised with respect to space applications. It is thus not necessary to include tests for fibre properties such as bandwidth, coating dimensions, numerical aperture, etc. in the evaluation of the splice. The characteristics of the fibre with respect to environmental loads such as ionizing radiation and temperature extremes should therefore also be known.

Coatings, buffers and materials used in the strain relief and protection sleeves shall be space qualified, see Chapter 4. However, an evaluation related to their properties may be necessary to eliminate any undesired interactions between the various materials and effects of changes in the material properties on the behaviour of the splice.

The flammability of a fibre optic splice is not expected to be of special concern. The materials used in the splice should all undergo a test with respect to flammability in the material evaluation, see Chapter 4. These properties will not depend on the manufacturing or the assembly of the fibre optic splice, and the test is thus not included. A test with respect to dust is not included because this is not expected to be of concern in space applications. The splice is not tested with respect to the resistance to a corrosive atmosphere either, because unlike, for example a connector, the splice is seldom made of metal and the splice does not contain any moveable parts which could stick because of corrosion.

8.2.2.1 Mechanical properties.

An important characteristics of a fibre optic splice is the tensile strength, which will determine the reliability of a fibre link. The tensile strength is dependent on characteristics of the splice itself which is dependent on the environmental conditions of the splicing, as well as the means for strain relief and grip method. The ability to withstand torsion is also important. In splice boxes and splice organiser the fibre may be subjected to torsion because the fibre is coiled inside the box/organiser. Unless special precaution is taken, torsional stress might induce fracture. The ability to withstand acceleration, crush, drop, bump and impact will be important during installation of the system. These properties are dependent on the design of the protection around the splice rather than the splicing and will not be necessary to test if similar splices have been previously evaluated with another fibre.

8.2.2.2 Temperature extremes

Temperature extremes may introduce mechanical misalignment of the fibres because of different coefficient of thermal expansion in the materials used in the splice (only applicable to mechanical splices). Temperature extremes may also induce microbend loss because of expansion/contraction of the materials surrounding the fibre, which may be a problem both in mechanical splices and fusion splices with strain relief. Temperature extremes may also induce fibre fracture if different coefficients of expansion results in the fibre being put under tension [12].

8.2.2.3 Rapid change of temperature

Rapid change of temperature may cause excessive tension as the thermal response of the splice may be slower than the rate of change of temperature. Large thermal gradients across the splice may therefore arise, challenging the mechanical alignment and the strength of the mounting of each part of the splice. The splices are, however, quite small which should reduce the effect of rapid change of temperature. Fusion splices with secondary coating reapplied will not be sensitive to this load.

8.2.2.4 Rapid depressurisation

Rapid depressurisation may cause mechanical stresses in a mechanical splice and in the protection sleeves of a fusion splice because trapped air in pockets may give large pressure gradients. Rapid depressurisation will depend on splice structure rather than splicing, and the test is not necessary to perform if similar splices have been evaluated with another fibre.

8.2.2.5 Vacuum operation

The materials used in the splice shall be space qualified. This means that the effect of vacuum operation (outgassing, change of material properties) should be very small. Since the tolerances in a mechanical splice are so narrow, the component should be tested for possible interactions. The effects of vacuum operation will depend on splice structure rather than splice procedure. The test is therefore not necessary if similar splices have been evaluated previously with another fibre.

8.2.2.6 Ionizing radiation

In space applications fibre optic splices are exposed to high levels of ionizing radiation which may induce losses in the optical parts as well as change the properties of the materials in the protection and alignment part of the splice. Even if all the materials are space qualified, see Chapter 4, interactions may occur. Any possible interaction should be revealed during the evaluation of the component.

The effects on the splice is dependent on the design of the splice rather than the splicing operation and the fibre type. The test is therefore not necessary if similar splices and the radiation characteristics of the fibre have been previously evaluated.

8.2.2.7 Solar and UV radiation

Solar and UV radiation could affect the properties of the material in the splice protection. Solar and UV radiation may also be coupled into the fibre and interfere with the signal propagation.

The effects on the splice is dependent on the design of the splice rather than the splicing and the fibre type. The test is therefore not necessary if similar splices have been previously evaluated.

8.2.2.8 Resistance to solvents and contaminating fluids

During installation or service the fibre optic splice might be exposed to solvents and contaminating fluids. These fluids may deteriorate the materials used in the splice and thereby the performance.

8.2.2.9 Optical power handling capability

The power handling capability of a splice is limited by four different phenomena:

- heating due to absorbed power
- radiation induced colour centres which will cause loss
- various non-linear optical effects
- formation of cracks, pits, etc.

As with optical fibres, the splice is usually operated at wavelengths with low loss and power levels in the order of 1 mW or less. The above phenomena will only be of concern in special applications were the splice is applied in system used to transmit high power levels.

8.2.3 Sample distribution and test programme sequence

8.2.3.1 Sample distribution

The fibre optic splice shall be selected at random from a lot which is 2 times to 3 times larger than the number of selected samples. The splicing operation shall be performed according to the procedure. As is usual in any splicing operation, the insertion loss in the splices supplied for evaluation testing shall be measured before the programme. The splices shall also be subjected to a proof test, to verify a minimum strength of the splice before the evaluation programme is initiated.

Number of samples: 55-108, dependent on the extent of the test programme, as discussed in the text

The number of splices needed for the evaluation test programme is quite extensive. New samples are used for each test, both because each test is considered destructive and to be able to distinguish between the effects of the different parameters. The number of samples for each test is shown in Chart 8.1, see end of Chapter. In order to get a picture of the spread in values, the number of samples of each test is 5 or larger. This is more samples than for the other passive components, because a larger spread in results is expected. The evaluation test programme would give an even better picture of the statistical fluctuations if more components were used for each test. A sample size of 5 or larger will however, give an indication of the variations. If large variations are observed, the number of samples should be increased. In the most critical tests the number of samples is larger than in the other.

8.2.3.2 Test range and failure criteria

The different tests are performed on a step stress basis. This means that the load is increased in steps from a starting value. Generally, the load is increased until the splice or any of the materials used in the splice has suffered physical destruction or a substantial deterioration in performance, as appropriate. In some of the test the upper stress limit is determined from the most severe loads expected, as listed in Chapter 4, with some margin added. If more severe loads are expected, the upper test level should be increased accordingly.

The criteria for splice failure is an increase in insertion loss larger than 1 dB, unless otherwise specified.

All results shall be recorded.

8.2.3.3 Test programme sequence

The specified tests are summarised in Chart 8.1. The mechanical and environmental tests which may be dependent on application, type of splice and previous evaluation of similar splices, are shown in a dotted box.

The initial measurements are all optical measurements and will not have any influence on the properties of the tested splices. The indicated order is based on the importance of the different parameters. The insertion loss should be measured to establish the performance of the splice. The crosstalk shall be measured for multifibre splices. The return loss shall be measured on mechanical splices. The susceptibility to ambient light coupling shall be measured on all splices.

For the mechanical, environmental and endurance tests new test samples are used for each test. The test order will therefore not affect the test result and is as such of no importance. It is generally recommended to perform the easiest and least expensive tests first and the more complicated and expensive tests in the end. If the component fails during the cheap and least expensive part of the test programme, it can be stopped before large expenses have been incurred.

We suggest to do the mechanical tests first. The tensile strength of the device will be an important factor in the determination of fibre link reliability. The effectiveness of the clamping device against fibre or cable bending, pulling and torsion will is also important, especially as the fibre splice often is applied in splice boxes. The resistance to acceleration, crush, impact, drop and bump will not be of concern if the splice is applied in a splice box, which is meant to protect against such loads.

The environmental tests are performed after the mechanical tests. We recommend to do the temperature tests first. Testing with respect to temperature will both reveal fundamental temperature dependent properties of the design and temperature dependent properties of the materials/alignment. The temperature tests include testing with respect to temperature extremes, rapid change of temperatures and condensation. The test with respect to temperature extremes shall be performed first since information from this test may be needed for later tests.

The tests with respect to the effects of vibration and shock are tested before the vacuum and ionizing radiation test. The materials applied in the splice are, in advance, tested with respect to such material related effects. The latter tests are performed to ensure that no unexpected effects occur. The characteristics of the splice when it is exposed to loads such as vibration and shock is less predictable and in addition easier and less expensive to perform.

The tests with respect to the effects of rapid depressurisation and vacuum operation are performed on the same samples. The effects of rapid depressurisation is tested before the effects of vacuum operation. If the splice fails in the rapid depressurisation test, there will be no point in proceeding to the test with respect to vacuum operation.

The effect of radiation (ionizing as well as solar and UV radiation) is tested in the end, such that only splices that have passed the other tests are subjected to this test. Radiation resistance is a fundamental requirement for components in space application. The splice should be based on materials and fibres exhibiting minimal radiation effects, and the test is performed to ensure that no unexpected effects will occur.

In those cases where it is of special concern the resistance to solvents and contaminating fluids shall be tested.

The endurance tests are ageing and optical power handling capability, if applicable. The conditions of the ageing test are determined by the test with respect to temperature extremes. The test will thus have to be started after this test. The test with respect to ageing is a long term test with measurements at regular intervals and can be performed in parallel with the other tests.

8.2.3.4 Use of control group

The use of a control group is not considered necessary in the mechanical and environmental tests. In these tests the parameters of interest are usually monitored while the test is performed. The stability of the source output and the repeatability of the measurements are ensured by a control of the output power. If the post test investigations include optical measurements not performed during the test, the measurements shall also be performed on the control group. This may include measurements of spectral loss and return loss.

A control group is used in the construction analysis to be able to compare the devices that have been exposed to environmental and mechanical loads with a "fresh" sample.

8.2.3.5 Post test investigations

The standard test procedures (given in Chapter 8 Part 3) often specify that after the exposure to mechanical or environmental load is completed, some measurements should be made to look for permanent changes in one or more critical properties. In the evaluation programme there are in many cases specified additional tests to analyse the failure mechanisms, but also to reveal whether the load has induced changes not observed directly during the tests or revealed by the standard post test investigations. An example of such a test would be testing of the splice strength after the test with respect to temperature extremes, to investigate whether temperature extremes have affected the splice or strain relief in such a way that the strength is reduced.

8.2.4 Inspection

The purpose of the inspection is to make sure that the samples are suited for testing. All samples shall be inspected.

8.2.4.1 Visual inspection

The visual inspection shall be carried out in accordance with ESA/SCC Basic Specifications No. 20500.

8.2.4.2 Dimensions

Test method: 8.1.1

8.2.4.3 Mass

Test method: 8.1.2

8.2.4.4 Marking

All samples shall be marked in accordance with the standard procedure of the manufacturer.

8.2.5 Initial measurements

The purpose of the initial measurements is to determine the initial values of the most important optical parameters. The result from these initial measurements will be used as a basis for the evaluation of later measurements. Further, one wants to ascertain that the various samples meet the specified requirements and to get a picture of the spread in values. The spread in values will give an indication of the performance of the splicing personnel.

The initial measurements shall be performed on all samples.

8.2.5.1 Insertion loss

The measurement shall be performed over the specified wavelength range.
Test method: 8.2.1/8.2.5

8.2.5.3 Cross talk

The test applies to multi fibre splices only.
Test method: 8.2.3

8.2.5.4 Return loss

The test applies to mechanical splices only.
Test method: 8.2.2

8.2.5.5 Susceptibility to ambient light coupling

Test method: 8.2.4

<u>8.2.6 Mechanical tests</u>

The insertion loss is measured before, during and after the tests. If the post test investigation include optical measurements not performed during the tests, the measurements shall also be performed on the control group. Such measurements may include crosstalk, return loss and spectral dependence on insertion loss.

8.2.6.1 Tensile strength

In this test the splice is subjected to increasing load until breakage. The number of samples is chosen to get a picture of the spread in values.

Number of samples: 10

The tensile force shall be applied smooth and controlled, the magnitude of the force shall be increased with a specified rate. The tensile force shall be increased until the fibre breaks.
Test method: 8.3.1

8.2.6.2 Effectiveness of clamping device against fibre or cable pulling, axial compression, bending and torsion

The test for fibre or cable pulling is covered by the tensile strength test.

8.2.6.2.1 *Axial compression*

The fibre leads of the splice shall be subjected to axial compression to establish the ability of the retention means to withstand axial compression. For each splice each fibre end shall be tested on an individual basis.

Number of samples: 2

The axial compression shall be applied smooth and controlled, the magnitude of the force shall be applied with a specified rate. The axial compression shall be increased until the fibre breaks.
Test method: 8.3.10

8.2.6.2.2 *Fibre or cable bending*

The test is intended to determine the ability of the strain relief to withstand bending.

Number of samples: 5

The load shall be increased in steps until the fibre breaks.
Test method: 8.3.2

8.2.6.2.3 *Fibre or cable torsion*

The test is intended to determine the ability of the strain relief to withstand torsion.

Number of samples: 5

The number of turns shall be increased until the fibre breaks.
Test method 8.3.2

8.2.6.3 Acceleration

Number of samples: 5
Start acceleration: as specified
The acceleration shall be increased in steps of 20% of the specified value until the component has failed or has suffered physical destruction.
Test method: 8.3.5

8.2.6.4 Impact

Number of samples: 5
Start energy: as specified
The energy shall be increased in steps of 20%. The load shall be increased until the component has failed or suffered physical destruction.
Test method: 8.3.7

8.2.6.5 Crush resistance

Number of samples: 5
Start force: as specified
The force shall be increased in steps of 20% of the specified value. The load shall be increased until the component has failed or suffered physical destruction.
Test method: 8.3.6

8.2.6.6 Drop

Number of samples: 5
Start height: as specified
The height shall be increased in steps of 20% of the specified value.The load shall be increased until the component has failed or suffered physical destruction.
Test method: 8.3.8

8.2.6.7 Bump

Number of samples: 5
Number of samples: 4000
Start acceleration: 40 g
The acceleration shall be increased in steps of 10 g. The load shall be increased until the

component has failed or suffered physical destruction.
Test method: 8.3.9

8.2.7 Environmental tests

8.2.7.1 Temperature extremes

The change in insertion loss shall be measured over the wavelength range of interest at each temperature.

Number of samples:	5
Thermal cycling:	first low, then high
Low temperature:	sufficient to induce component failure, but not below - 70°C.
High temperature:	sufficient to induce component failure, but not above 150°C.
Low starting temperature:	lowest specified temperature, or - 40°C if not given.
High starting temperature:	highest specified temperature or 90°C if not given.
Step change in temperature:	10°C
Duration of stay at each temperature:	1 hour
Test method:	8.4.2

8.2.7.1.1 *Post test investigation*

The post test investigation include a repetition of the measurement of insertion loss after the component has reached room temperature. A visual inspection and dimensional check shall be performed on each device to check any changes in material appearance. One of the samples used in the temperature test shall be subjected to constructional analysis. The tensile strength of the remaining splices shall be tested to investigate whether temperature influenced the strength of the splice or strain relief.

Insertion loss	ref: 8.2.5.1
Visual inspection,	ref: 8.2.4.1
Dimensions,	ref: 8.2.4.2
Tensile strength	ref: 8.2.6.1
Constructional analysis	ref: 8.2.9

8.2.7.2 Rapid change of temperature

The insertion loss shall be measured as a function of wavelength before and after the temperature change. The change in insertion loss shall be measured during the temperature change.

Number of samples:	5
High temperature:	10°C below high temperature limit established in 8.2.7.1
Low temperature:	10°C above low temperature limit established in 8.2.7.1
Rate of change of temperature:	as specified
Test method:	8.4.3

8.2.7.2.1 *Post test investigation*

The insertion loss shall be measured when the splice has reached room temperature after the test is finished. A visual inspection shall be performed on the splices. One of the samples subjected to a constructional analysis to check whether the internal structure has changed.

Insertion loss	ref: 8.2.5.1
Visual inspection	ref: 8.2.4.1
Constructional analysis,	ref: 8.2.9

8.2.7.3 Condensation

The change in insertion loss shall be measured at each change of test condition.

Number of samples:	5
Test conditions:	as specified in IEC 68.2.38
Test method:	8.4.5

8.2.7.3.1 *Post test investigation*

The insertion loss shall be measured after the splice has reached room temperature. The devices shall be subjected to a visual inspection and a dimensional check to look for changes in material structure and appearance. Constructional analysis is included in the post test investigation to find out whether combined humidity/heat would change any of the internal materials. The remaining devices are tested with respect to tensile strength to check whether this was affected by the combined humidity/heat.

Insertion loss,	ref: 8.2.5.1
Visual inspection,	ref: 8.2.4.1
Dimensions,	ref: 8.2.4.2
Tensile strength	ref: 8.2.6.1
Constructional analysis	ref: 8.2.9

8.2.7.4 Vibration

The change in insertion loss shall be monitored during the test.

Number of samples:	5
Vibration frequency:	100-2000 Hz
Starting acceleration:	as specified
The increase in acceleration:	steps of 20% of specified level until the level has reached 30 g or the splice has failed.
Duration:	90 minutes
Test method:	8.3.3

8.2.7.4.1 *Post test investigation*

The insertion loss shall be measured when the splice has settled after the test. The device shall be subjected to a visual inspection to look for changes in structure or appearance. Vibration may induce mechanical fractures not possible to reveal by visual inspection and measurement of insertion loss. One of the samples are therefore subjected to a condensation test. In this test condensed water may freeze in possible cracks and increase the crack. Another sample is subjected to constructional analysis to investigate whether vibration induce any changes in the internal structure of the splice.

Insertion loss	ref: 8.2.5.1
Visual inspection	ref: 8.2.4.1
Condensation	ref: 8.2.7.3
Constructional analysis	ref: 8.2.9

8.2.7.5 Shock

The insertion loss shall be monitored during the test.

Number of samples:	5
Pulse duration:	0.5 ms
Starting acceleration:	as specified
The increase in acceleration:	steps of 20% of specified level until the level has reached 2000 g or the component has failed.
Test method:	8.3.4

8.2.7.5.1 *Post test investigation*

The insertion loss shall be measured when the splice has settled after the test procedure. The splice shall be subjected to a visual inspection to look for changes in structure or appearance. Shock may induce mechanical fractures not possible to reveal by visual inspection and measurement of insertion loss. One of the samples are therefore subjected to a condensation test. In this test condensed water may freeze in possible cracks and increase the crack. Another sample is subjected to constructional analysis to investigate whether shock induce any changes in the internal structure of the splice.

Insertion loss	ref: 8.2.5.1
Visual inspection	ref: 8.2.4.1
Condensation	ref: 8.2.7.3
Constructional analysis	ref: 8.2.9

8.2.7.6 Rapid depressurisation

The change in insertion loss shall be measured during the rapid depressurisation.

Number of samples:	5
Test method:	8.4.14

8.2.7.6.1 *Post test investigation*

The post test investigation shall include measurement of insertion loss of the tested devices. One of the samples shall be subjected to constructional analysis to investigate whether rapid depressurisation may have influenced the internal structure of the splice.

Insertion loss	ref: 8.2.5.1
Visual inspection,	ref: 8.2.4.1
Constructional analysis,	ref: 8.2.9

8.2.7.7 Vacuum operation

The insertion loss is not measured during the vacuum test, because any changes is expected to be permanent.

Number of samples:	5
Vacuum:	10^{-3} Pa or less
Temperature:	125°C or high temperature limit established in 8.2.7.1, whichever is lower.
Duration:	24 hour
Test method:	8.4.4

8.2.7.7.1 *Post test investigation*

The post test investigation shall include measurement of the insertion loss of the tested samples as well as the control group. The device shall be subjected to visual inspection to look for changes in structure or appearance. One of the samples shall be subjected to constructional analysis to investigate whether vacuum operation influenced the internal structure of the device.

Insertion loss,	ref: 8.2.5.1
Visual inspection	ref: 8.2.4.1
Constructional analysis	ref: 8.2.9

8.2.7.8 Ionizing radiation

The change in insertion loss shall be measured at regular intervals during the exposure.

Number of samples:	5
Temperature:	Room temperature
Optical power:	As specified
Wavelength:	As specified
Dose rate:	5 rad(Si)/s
Duration:	The irradiation shall last until the component has failed or the total dose has reached 3 Mrad.
Test method:	8.4.11

8.2.7.8.1 *Post test investigation*

The materials have been evaluated with respect to ionizing radiation in advance. The changes in material are therefore known and no constructional analysis is necessary. The post test investigation will therefore only include optical measurements and visual inspection after the device has been removed from the radiation field.

Insertion loss,	ref: 8.2.5.1
Visual inspection	ref: 8.2.4.1

8.2.7.9 Solar radiation

The change in insertion loss shall be measured at regular intervals during the test.

Number of samples:	5
Temperature:	Room temperature
Radiation source:	source with representative spectral output
Duration:	until the component has failed or the maximum anticipated total dose has been reached
Test method:	8.4.9

8.2.7.9.1 *Post test investigation*

The insertion loss shall be measured after the test is completed. The splice shall be subjected to a visual inspection to look for changes in structure or appearance. One of the samples is subjected to constructional analysis to investigate whether solar radiation has changed the internal structure or materials of the splice.

Insertion loss,	ref: 8.2.5.1
Visual inspection,	ref: 8.2.4.1
Constructional analysis	ref: 8.2.9

8.2.7.10 UV radiation

The change in insertion loss shall be measured at regular intervals during the exposure.

Number of samples:	5
Temperature:	room temperature
Radiation source:	representative UV source
Duration:	until the component has failed or the maximum anticipated total dose has been reached.
Test method:	8.4.10

8.2.7.10.1 *Post test investigation*

The insertion loss shall be measured after the test is completed. The splice shall be subjected to a visual inspection to look for changes in structure or appearance. One sample is subjected to constructional analysis to investigate whether UV radiation has changed the internal structure or materials of the splice.

Insertion loss,	ref: 8.2.5.1
Visual inspection,	ref: 8.2.4.1
Constructional analysis	ref: 8.2.9

8.2.7.11 Resistance to solvents and contaminating fluids

Number of samples: 3

The splices shall be subjected to appropriate fluids and solvents. Reference is made to ESA/SCC Generic Specification No 3901, paragraph 9.21. No visible changes in appearance shall be induced. The insertion loss shall be measured after the test.

Test method: 8.4.12

<u>8.2.8 Endurance tests</u>

8.2.8.1 Ageing

The change in insertion loss shall be measured at regular intervals during the test.

Number of samples:	5
Temperature:	20°C above specified operating temperature, but at least 10°C below high temperature limit established in 8.2.7.1.

Duration:	Until the component has failed or the test has lasted 1000 hours.
Test method:	8.4.13

8.2.8.1.1 *Post test investigation*

The insertion loss shall be measured after the test. The splice shall also be subjected to a visual inspection and dimensional check to look for changes in the appearance and structure of the device. One of the samples shall be subjected to a constructional analysis to investigate whether long term high temperature has introduced changes in the internal structure. Another sample shall be tested with respect tensile strength to investigate whether long term high temperature have induced failure.

Insertion loss,	ref: 8.2.5.1
Visual inspection,	ref: 8.2.4.1
Dimensions,	ref: 8.2.4.2
Tensile strength	ref: 8.2.6.1
Constructional analysis,	ref: 8.2.9

8.2.8.2 Optical power handling capability

Number of samples:	3
Laser source:	as specified

Input power level shall be increased in steps and measurements made of insertion loss

The entrance and exit surfaces shall also be examined for visual damage. Input power level shall be increased until the component has failed or visual damage has occurred. The maximum input level will very likely be limited by the available optical source.

Test method:	8.2.6

8.2.9 Constructional analysis

A sample from the control group and samples exposed to the other tests, as noted under the post test investigation, shall be subjected to constructional analysis. The splice should be opened and the internal structure of the device investigated. The constructional analysis may include investigation of any fracture surfaces. It may also include an examination of the optical path in the splice by means of visible light, for example a HeNe laser.

8.3 Production testing

A splice is not completed before it is installed in the system. Production testing of the splice is thus only possible on the individual components of the splice. Only fusion splices are considered and thus only protection sleeves and strain reliefs are included in the production control.

The tests shall be performed in accordance with Chart 8.3. Unless otherwise specified, the measurements shall be performed on all samples.

8.3.1 Test procedures

8.3.1.1 Visual inspection

The individual parts shall be subjected to visual inspection according to ESA/SCC Basic Specification No 20500.

8.3.1.2 Dimensions

Test method: 8.1.1

8.3.1.3 Mass

Test method: 8.1.2

8.4 Burn-in

Burn-in is not relevant for optical splices.

8.5 Qualification testing

The qualification testing shall include all tests of relevance not included in the final production testing. The test programme shall start with the splicing operation, which should take place in an environment similar to the site of installation. All samples are proof tested before the qualification testing is started. The qualification testing only applies to fusion splices. The sensitivity to mechanical and environmental loads was evaluated in the evaluation test programme. Several of the characteristics of the device are dependent on design and technology rather than splicing procedure. It will therefore not be necessary to repeat some of the tests in the qualification test programme, this is noted, as appropriate, in the discussion of the qualification test strategy.

The qualification testing is divided in tests for endurance, mechanical and environmental properties. All samples supplied for testing shall however, be exposed to a climatic sequence before it is subjected to the other tests. This climatic sequence is performed to expose any strain reliefs and protective sleeves to temperature changes before the other loads are applied.

All samples are subjected to a condensation test at the end of the test programme. This condensation test includes humidity and temperatures below zero, which may reveal any cracks and failures induced by the mechanical/environmental test programme, but not detected by the post test investigations. A similar environmental stress sequence is also seen in other test programmes [14, 15].

All samples are tested with respect to tensile strength at the end of the test programme to obtain the strength distribution of the splices. The difference between a proof test and a test with respect to tensile strength is that the proof test is to ensure a given strength of the fibre. The test with respect to tensile strength is performed to break, and will give a specific value for the strength of each splice.

The environmental tests included in the qualification testing is climatic sequence, condensation, vibration and shock. These tests will reveal any production related failures in material and splicing operation. The effects of vacuum operation, rapid depressurisation, radiation (including ionizing radiation, solar and UV radiation) have all been investigated during the evaluation process. Any effects of these loads will be related to technology and not to production, and it will therefore not be necessary to repeat the tests in the qualification test programme.

The tests for splice endurance includes measurements of long term high temperature exposure (ageing).

The mechanical tests are performed to ensure that the components meet the specified mechanical requirements. The tests include tensile strength (proof test) and crush resistance (where applicable). Testing with respect to drop, bump and impact is not included because this is tested in the evaluation test programme and splicing related features will be covered by the test for crush resistance. The test with respect to the effects of acceleration is covered by the test for vibration and shock.

Each group consists of 10 splices, the samples in each group shall be taken from splicing performed by three different persons. The number of samples are chosen to get an indication of the spread in values, which is expected to be somewhat larger for splices than for other passive components. The qualification test programme uses few devices for each test, thus all samples shall meet the requirements.

8.5.1 Optical measurements

8.5.1.1 Insertion loss

Test method: 8.2.1

8.5.1.2 Cross talk

The test is only applicable to multifibre splices.

Test method: 8.2.3

8.5.2 Environmental tests

8.5.2.1 Climatic sequence

Test method: 8.4.1

8.5.2.2 Condensation

Test method: 8.4.5

8.5.2.3 Vibration

Test method: 8.3.3

8.5.2.4 Shock

Test method: 8.3.4

8.5.3 Endurance tests

8.5.3.1 Ageing

In those cases were the splice is intended to be used in a humid atmosphere, the splice shall be exposed to humidity at a specified level together with the high temperature level. Humidity may induce changes and failures not seen in an environment of dry heat.

Test method: 8.4.13

8.5.4 Mechanical tests

8.5.4.1 Tensile strength/proof test

Test method: 8.3.1

8.5.4.2 Crush resistance

Test method: 8.3.6

8.6 Installation testing

A fibre optic splice cannot be tested before it is installed. The lot acceptance testing is therefore replaced by an installation testing programme. Since the splice is within the system, the tests possible to perform on a splice are limited to optical measurements and certain mechanical measurement. It is not feasible to expose the splice in the system to environmental loads just for test purposes.

Because the nature of a fibre optic splice does not permit environmental and mechanical testing after installation, the installation shall include dummy splices. These splices are performed using the same procedure and the same operator as the splices in the system, but they are not to be used in the system. Instead these dummy splices are subjected to a test programme which includes optical as well as mechanical and environmental tests.

8.6.1 Splice testing during installation

The splice testing during installation shall include measurement of insertion loss on all installed splices. The splice shall also be proof tested with respect to tensile strength. The test shall be performed on all splices. The test is performed to ensure that the mechanical strength of the splice is sufficient. The test level shall be specified in the detailed specification.

8.6.1.1 Insertion loss

The measurement shall be performed at the operating wavelength.

Test method: 8.2.1

8.6.1.3 Tensile strength/proof test

Test method: 8.3.1

8.6.2 Dummy splice testing

The test specified shall be performed according to Chart 8.4. The dummy splice shall be selected according to the following scheme:

- a dummy splice shall be made at the beginning and end of each installation
- in addition every tenth splice made during installation shall be a dummy splice

The minimum number of dummy splices is thus two. For a system with many splices, 10% additional splices are made and supplied to the dummy test programme. This will give an indication how the combination of equipment/personnel performs under given conditions. If several persons perform splicing in one system, the dummy selection scheme shall apply to each person.

The dummy splices are subjected to the same test sequence as the system splices, i.e. optical measurements and tensile strength (proof test). It is thus possible to compare the results of the two groups. In addition, the dummy splices are subjected to a temperature test and tests with respect to vibration and condensation. In the end of the test programme the dummy test splices shall be tested with respect to tensile strength (i.e. load increased until splice or fibre breaks). These tests will cover the most important properties of the splice with respect to reliability and performance in the space environment.

All dummy splices shall meet specifications.

8.6.2.1 Insertion loss

The insertion loss shall be measured at the operating wavelength. In those cases where the spectral properties are of special concern, the spectral loss shall be measured.

Test method: 8.2.1/8.2.5

8.6.2.2 Crosstalk

The test applies to multifibre splices only.

Test method: 8.2.3

8.6.2.3 Tensile strength/proof test

Test method: 8.3.1

8.6.2.4 Temperature extremes

Test method: 8.4.2

8.6.2.5 Vibration

Test method: 8.3.3

8.6.2.6 Condensation

Test method: 8.4.5

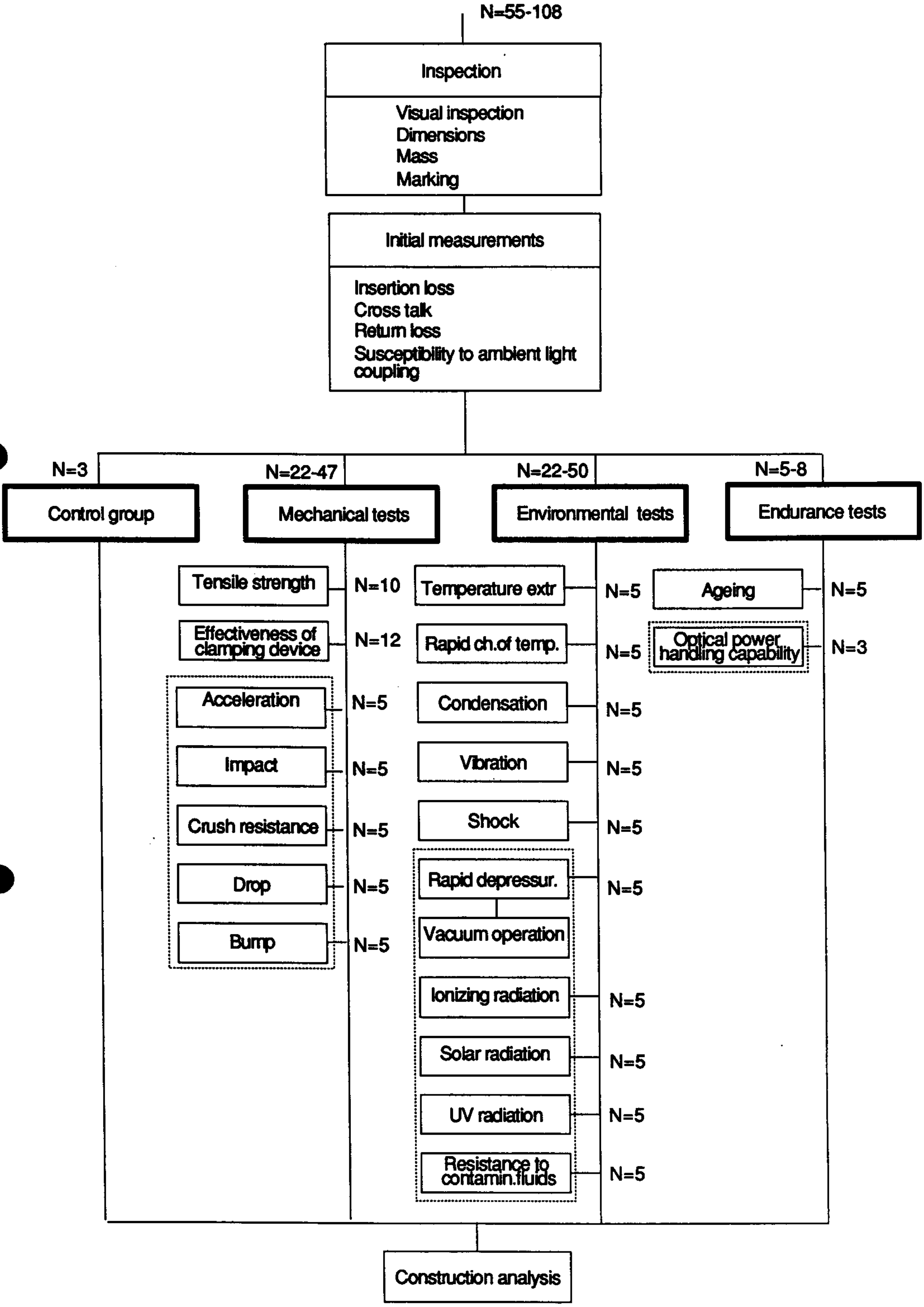

Chart 8.1 Evaluation testing for fibre optic splices

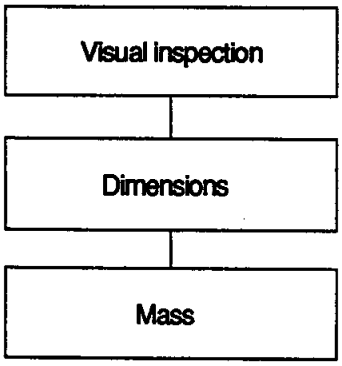

Chart 8.2 Final production testing for fibre optic splices

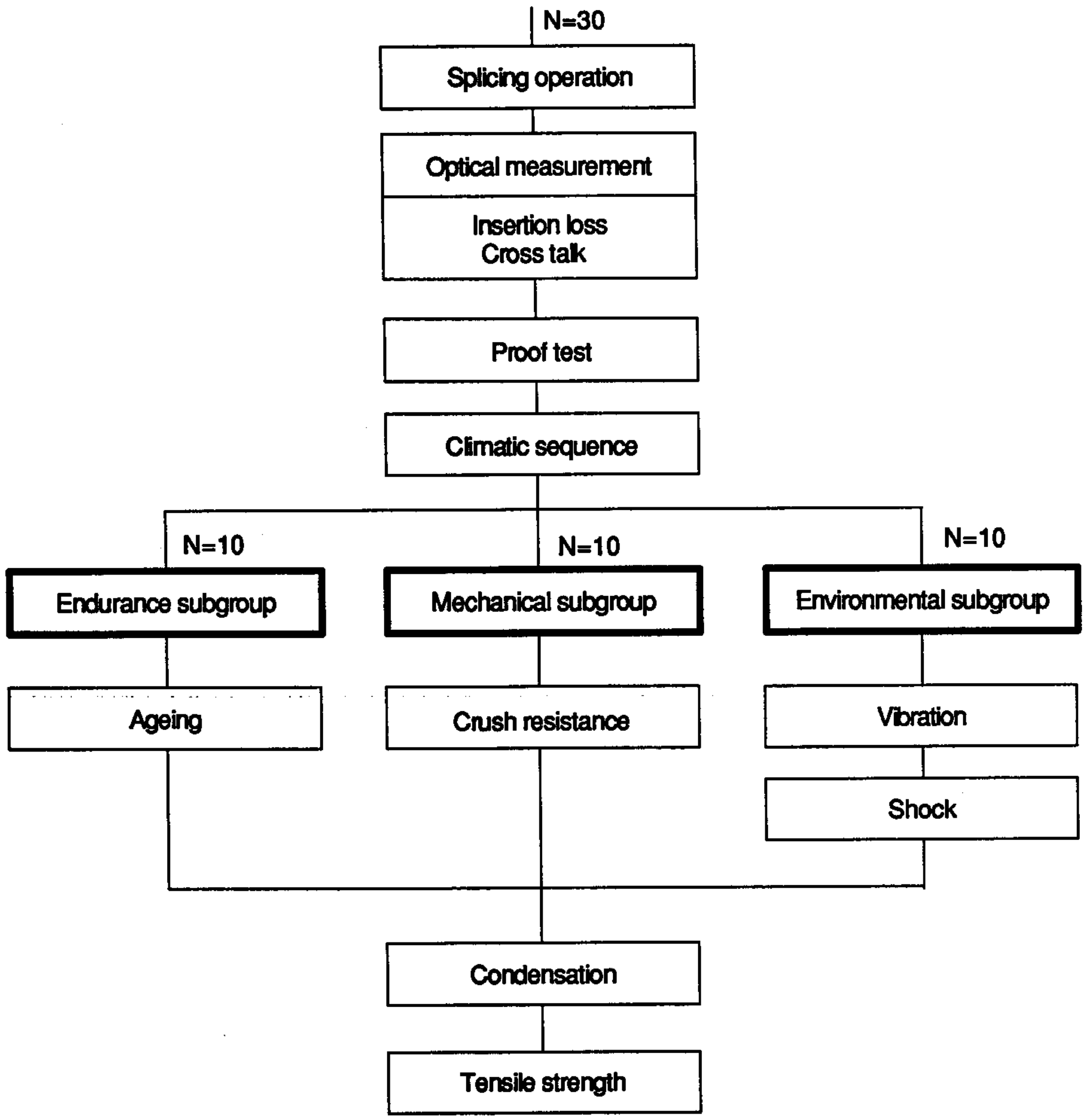

Chart 8.3 Qualification testing for fibre optic splices

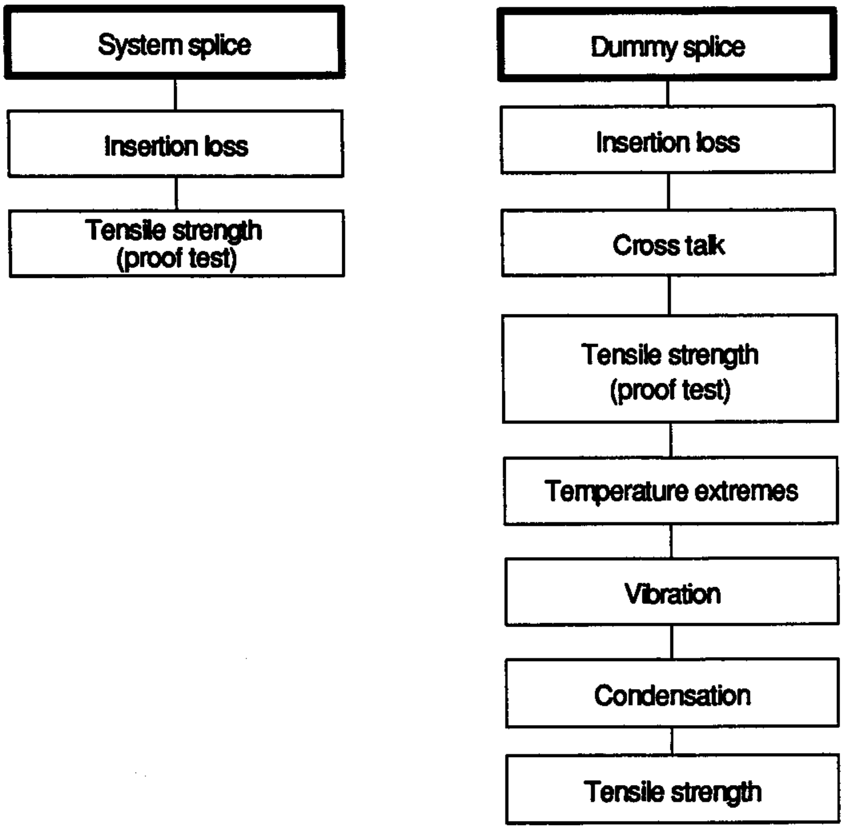

Chart 8.4 Installation testing for fibre optic splices

9. SPLICE HOLDERS, ORGANISERS AND CLOSURES

9.1 Introduction

The splice holder is a device, in which a number of protected fibre splices are stored and which may or may not be part of a splice. A splice organiser is a device which contains and organises splice holder(s) and/or protected fibre splices. The splice organiser is designed to store spliced optical fibres in an orderly manner for identification, protection and maintenance. The general design concept is based on storing spliced fibres in an organiser tray(s) while maintaining them in a flat position, conveniently spaced for accessibility, and arranged to minimise both micro and macrobending. The splice organisers are intended for use in a closure.

For the tests described in this Chapter, it is presupposed that a splice closure contains splice organiser(s) and splice holder(s), and that a splice organiser contains splice holder(s).

Splice organisers and closures can be divided into several groups, based on their basic construction. Typical examples are:

Organisers:
- For loose tube single fibre
- For loose tube multifibre
- For fibre ribbon

Closure:
- Kind of sealing (mechanical or shrinkable)
- Kind of protection (filled or pressurised)
- Kind of material (metal or plastic)

In addition the splice organisers and closures may differ in specification:

Splice organisers may differ in :

- configuration
- fixing point in the closure
- maximum overall size of the splice holder,
- fixing point in the organiser,
- maximum number of fibre splices which may vary with different fibre types,
- maximum outer diameter of the fibres,
- the maximum and minimum bending radius of the stored fibres,
- excess length of fibres which can be stored in the splice organiser.

Closures may differ in:

- fixing points of the closure,
- fixing points for the splice organiser,
- maximum size and configuration of the space available for splice organiser,
- maximum diameter and number of fibre cables which can be accommodated by the closure.

9.2 Evaluation testing

9.2.1 Properties to evaluate

The main properties of interest are:

- mechanical strength,
- effects of vibration and shock,
- effects of temperature extremes,
- rapid change of temperature,
- rapid depressurisation and vacuum operation,
- effects of radiation ie. ionizing, solar and UV,
- resistance to solvents and contaminating fluids.

9.2.1.1 Mechanical strength.

Splice holders, organisers and closures are used to protect the fibre and splices against mechanical loads, and must therefore withstand the environmental strains likely to occur with a safe margin. Mechanical loads are for example crush, impact, drop, bump and acceleration. Even though the effects of such loads can be reduced by proper installation of the components, a test is deemed necessary to ensure the functionality of the components. A splice closure is comprised of several parts which mechanically are put together. The closures are therefore vulnerable to mechanical loads such as vibration and shock. In addition, the components should be tested with respect to effectiveness of clamping device and axial compression.

9.2.1.2 Rapid change of temperature and temperature extremes.

Splice holders, organisers and closures will ce comprised of several materials with probably different thermal expansion. These devices shall protect the fibre and provide a stressfree storage of the fibres in an orderly manner. Any misalignment of the different parts inside may affect misalignment of the fibre, and thermal expansion may cause unintended stress to the fibre or the splice.

9.2.1.3 Rapid depressurisation and operation in vacuum.

Rapid depressurisation can cause pressure gradients to exist between the outside and inside affecting the properties of the component, e.g. misalignment or mechanical stresses or even damage to the enclosure. The materials used in the components shall be space qualified, see Chapter 4. This means that the effects of vacuum operation (outgassing, change of material properties) should be very small. Interactions between the different materials may however, arise with deleterious effects causing misalignment of the different parts inside which in turn may result in misalignment of the fibre.

9.2.1.4 Ionzing, solar and UV radiation.

In space applications the components are exposed to relatively high levels of ionizing radiation. Unshielded parts are also exposed to solar and UV radiation. Solar and UV radiation could affect the properties of the material. Even if the materials are space qualified, interactions may occur. The purpose of the evaluation tests will be to reveal such interactions.

9.2.1.5 Flammability

It is assumed that the materials used in the splice holders, organisers and closures have been tested with respect to flammability, see Chapter 4. A flammability test is included both to test the whole unit with respect to being a fire hazard and to test its ability to protect the splices in case of fire.

9.2.1.6 Resistance to fluids

The splice holders, organisers and closures may be subjected to various solvents and contaminating fluids during installation testing and possibly also when in operation.

9.2.2 Sample distribution and test programme sequence

9.2.2.1 Sample distribution

For the purpose of evaluation testing, it is intended that each distinct combination of closure size and configuration within a family should be tested according to the test outline. However, certain combinations of size and splice configurations can be eliminated from the test programme if it is clearly established that the combination selected for testing represents the 'worst case' conditions for evaluating the closure. Common and/or equal design features can also be reason for reducing the number of samples tested. For example, a family of closures having several sizes may only require testing the largest and smallest size in each configuration.

The term 'closure' refers to a splice closure that has been completely assembled. When no optical measurements are required, the closure is to be installed over unspliced fibre cable, unless otherwise specified. When optical measurements are required for a particular test, the number of fibres spliced per cable is to be based on a minimum of one fibre per buffer tube or channel, depending on the particular cable design. Where the cable employs a single fibre bundle design, a minimum of six fibres are to be randomly selected. The cable lengths used with the splice closure must be adequate to permit monitoring the fibre before, during and after each test as required.

Number of samples: 14-28

The components should be selected at random from a production lot. The size of the lot should be 2 times to 3 times the total number of selected samples, minimum 16. The number of samples is determined by the number of different test procedures, and since each test is meant to be destructive, unused components should be used for each test. If deemed necessary, each test should be performed on several components in order to get an idea of the variation in characteristics and sensitivity to different mechanical loads. It is important to note that many tests cannot be performed unless splices are actually installed in the holders, organisers or closures. The properties of the splice itself must also be considered when evaluating the results. The components should have been produced by one manufacturer with essentially the same materials, processes, methods and at approximately the same time. Each component should be marked in order to identify its origin.

The tests specified should be performed in a sequence shown in Chart 9.1 (see end of Chapter). The various test methods are listed in Part 3 Chapter 9. All results should be recorded and a constructional analysis should be carried out.

9.2.2.2 Test range and failure criteria

The different tests are performed on a step stress basis. This implies that the load is increased in steps from an initial value. Generally, the load is increased until a splice has suffered a substantial deterioration in performance, fibre break or the component has suffered physical destruction. In some of the tests the upper stress limit is determined from the most severe loads expected, see Chapter 4, with some margin added. If more severe loads are expected, the upper test level should be increased accordingly.

The criteria for defining the component as failed is dependent on the performance of the component and the initial value of the parameter. An increase in the fibre/splice loss of 1 dB will be regarded as failure for evaluation test purpose.

9.2.2.3 Test programme sequence

The specified tests are summarised in Chart 9.1. Some tests are shown inside a dotted box indicating that they are of interest only for certain applications or in case similar components have not been tested before.

The initial measurements include measuring dimensions, mass, and if relevant also insertion loss, in order to obtain a reference value. No optical measurements can, however, be made before one or several splices actually are installed, as noted in 9.2.2.1.

As discussed in 9.2.2.1 all tests are done on new samples. The test order is thus not critical. It is generally recommended that those tests that are considered easiest and the least expensive to do are done first, and that the more complicated and expensive are done at the end. Within this framework the tests for the most important properties are done first.

It is recommended that the mechanical tests are done first. A vulnerable area is the attachment of the cable to the splice holders/organisers/closures. This is tested first. A major purpose of the splice holders, organisers and closures is to protect the splice(s) against mechanical loads such as crush, impact, drop, bump and axial compression. These are done next.

The environmental tests are generally more complicated, expensive and time consuming to do than the mechanical tests. The high/low temperature is done first. It is an important property of the closure that it can operate over a large temperature range. The test is thus a good measure of how well the closure is designed and produced. The test with respect to rapid change in temperature is done after the high/low temperature test since the results from the latter test are used to establish the test parameters of the former.

As mentioned before, a splice closure is comprised of several parts which mechanically are put together. The closures are therefore vulnerable to mechanical loads such as vibration and shock.

The sealing test is done to verify that the closure attains waterproofness. This is considered necessary for components located outside the space vehicle.

The flammability test is done next since it is regarded simpler to do than the other remaining tests. The vacuum related tests follows. The rapid depressurisation is done first since there is no purpose to do the vacuum test if the closure cannot tolerate a rapid depressurisation.

The purpose of the remaining tests are all to confirm the results from material tests. As noted before, the ionizing, solar and UV radiation tests are included as to reveal possible adverse

The test with respect to resistance to fluids should be carried out if deemed relevant for the intended application.

The tested samples shall be subjected to a constructional analysis.

9.2.2.4 Use of control group

The use of a control group is not considered necessary in the mechanical and environmental tests. In these tests the parameters of interest are usually monitored while the test is performed. The stability of the source output and the repeatability of the measurements are ensured by a control of the output power. If the post test investigations include optical measurements not performed during the test procedure, the measurements shall also be performed on the control group.

A control group is used in the constructional analysis to be able to compare the devices that have been exposed to environmental and mechanical loads with a 'fresh' sample.

9.2.3 Inspection

The purpose of the inspection is to make sure that the samples are suited for testing. All samples should be inspected.

9.2.3.1 Visual inspection

The inspection should be carried out in accordance with ESA/SCC Specification No. 20500.

9.2.3.2 Marking

All samples should be marked in accordance with the standard procedure of the manufactures and the requirements stated in 9.2.2.

9.2.4 Initial measurements

The purpose of the initial measurements is to determine the actual value of the various geometrical properties. The values will be used as base data for the later measurements. Further, one wants to ascertain that the various samples actually meet the specified requirements, and one also gets a picture on the sample variance.

The initial measurements should be done on all samples.

9.2.4.1 Dimensions

Required physical dimensions to be measured e.g. length, width, height, fixing points, mounting details.

Test method: 9.1.1

9.2.4.2 Mass

Test method: 9.1.2

9.2.4.3 Insertion loss

Test method: 9.2.1

9.2.5 Mechanical tests

The main mechanical properties to test are the effectiveness of clamping, pulling, cable torsion and cable bending. The test shall be done with a representative number of fibre splices installed and with the fibre/cable attached in the prescribed manner. The optical transmission through each splice shall be measured during the tests at the anticipated operational wavelength unless otherwise specified.

9.2.5.1 Effectiveness of clamping device

Number of samples: 2

To test the attachment of cable/fibre to the test specimen. Test to break.

Test method: 9.3.1

9.2.5.2 Crush resistance

Number of samples: 2

The test to be done without fibres/cables installed. The load to be applied stepwise until breakdown.

Test method: 9.3.4

9.2.5.3 Impact

Number of samples: 2

The test to be done without fibres/cables installed. The load to be applied stepwise until damage (fractured, cracks).

Test method: 9.3.5

9.2.5.4 Bump

Number of samples: 2
Number of bumps: 1000
Start acceleration: 10 g

The acceleration to be increased in steps of 10 g. The test to be done with fibres/cables installed. The load to be applied stepwise until splice or component has failed.

Test method: 9.3.6

9.2.5.5 Axial compression

Number of samples: 2

Apply load until fibre break or splice failure or damage to component.

Test method:	9.3.7

9.2.5.6 Post test investigation

Visual inspection
Geometrical characteristics

9.2.6 Environmental tests

The important properties are effects of temperature, vacuum and various forms of radiation.

9.2.6.1 Temperature extreme

The purpose of this test is to determine the suitability of specimens for use and/or storage at high and low temperatures. The test to be performed with a representative number of splices installed. The optical transmission at the anticipated operational wavelength will be monitored during the test through each splice.

Number of samples:	1
Thermal cycle:	First low, then high temperature
Low temperature:	Sufficient to give induced loss of 1 dB ,but not lower than -70 °C.
High temperature:	Sufficient to give induced loss of 1 dB or severe damage, but not more than 150 °C.
Low starting temperature:	Lowest specified operating temperature or -40°C if not specified.
High starting temperature:	Highest specified long term operating temperature or +90°C if not specified.
Step change in temperature:	10°C.
Duration of stay at each temperature:	1 hour.
Test method:	9.4.2

9.2.6.2 Rapid change of temperature

The test shall be performed with a representative number of splices installed. The change in insertion loss shall be measured before, during and after the temperature change.

Number of samples:	1
High temperature:	10°C below high temperature limit in 9.2.6.1
Low temperature:	10°C below above temperature limit in 9.2.6.1
Rate of change of temperature:	as specified
Test method:	9.4.3

9.2.2.3 Condensation

The change in splice loss shall be measured and the closure visually inspected at each change of test condition.

Number of samples:	1
Test conditions:	as specified in IEC 68.2.38
Test method:	9.4.5

9.2.6.4 Vibration

The fibre splice may loosen due to vibration.

Number of samples:	1 with fibre splices installed
Vibration frequency:	100-2000 Hz
Starting acceleration:	as specified
Increase in acceleration:	steps of 20% of specified level until acceleration has reached 30 g, or damage, or induced loss larger than 1 dB occurs.
Duration:	90 minutes
Test method:	9.3.2

9.2.6.5 Shock

The fibre splice may loosen due to shock.

Number of samples:	1 with fibre splices installed
Pulse duration:	0.5 ms
Starting acceleration:	as specified
Increase in acceleration:	in steps of 20% of specified level until acceleration has reached 2000 g, or damage, or induced loss larger than 1 dB occurs.
Duration:	90 minutes
Test method:	9.3.3

9.2.6.6 Acceleration

Number of samples: 1
Start acceleration: as specified
The acceleration to be increased in steps of 20% of the specified value until the splice or component has failed.
Test method: 9.3.8

9.2.6.7 Sealing

Test for waterproofness.

Number of samples: 1
Test method: 9.4.9

The remaining tests shall be done without the splices installed unless otherwise specified. However, upon completion of the test, the proper functioning of the specimen shall be tested including visual inspection, dimensions, installation of splices, assembly, etc.

9.2.6.8 Flammability

Number of samples: 1 with splice installed
Optical transmission to be measured during the test.
Test method: 9.4.8

9.2.6.9 Rapid depressurisation

Number of samples: 1 with splices installed

Optical transmission to be measured during the test.
Test method: 9.3.17

9.2.6.10 Vacuum test

The purpose of the test is to ensure operation in vacuum will not cause changes in mechanical properties and dimensions.

Number of samples: 1
Test method: 9.4.4

9.2.6.11 Ionizing test

The purpose of the test is to determine if the ionizing radiation has affected the material of the closure in such a way as to induce losses in the fibres. Since the ionizing radiation induce losses in the fibre directly, it will be difficult to distinguish between the two loss mechanisms unless the closure induced loss are significant with respect to the losses induced directly in the fibres. It must be assumed that the optical fibres can be estimated with confidence.

The only post test investigation proposed is to make a visual inspection and to measure the closure dimensions.

Test method: 9.4.12

9.2.6.12 Solar radiation

As noted in Chapter 5 UV radiation can induce losses in optical fibres. It seems, however, reasonable to assume that the closure etc. will protect the fibre from UV radiation. Any fibre induced losses observed in the tests should thus be caused by changes in the closure due to the UV/solar radiation. As discussed in 6.2.3.2 these tests are of interest only if the closure is exposed to UV and solar radiation.

Number of samples: 1
Test method: 9.4.10

9.2.6.13 UV radiation

See 9.2.6.12
Test method: 9.4.11

9.2.6.14 Resistance to fluids

The test should be carried out using the same procedure as for electrical components. A range of fluids is listed in the description of the test method. Which fluids to include in the test will depend on the application.

A visual inspection should be made after the immersion of the closure in the fluid.

Test method: 9.4.13

9.2.7 Endurance tests

9.2.7.1 Ageing

The purpose of this test is to determine the effects of long term operation/storage. The test to be performed with a representative number of splices installed. The optical transmission at the anticipated operational wavelength will be monitored during the test through each splice.

Number of samples:	2
Temperature:	20°C above specified operational temperature, but at least 10°C below high temperature limit established in 9.2.7.
Duration:	Until loss has increased to 1 dB or damage has occurred to specimen. But maximum 1000 hours.
Test method:	9.4.16

9.2.7.2 Corrosive atmosphere

Number of samples: 2

Optical transmission need not be measured during the test. Visual inspection upon completion of test.

Test method: 9.4.6

9.2.7.3 *Post test investigation*

Visual inspection,	ref: 9.2.3.1
Geometrical characteristics,	ref: 9.2.4.1
Insertion loss,	ref: 9.2.4.3

9.2.8 Constructional analysis

A sample from the control group and samples exposed to other tests, as noted under post test investigation, shall be exposed to constructional analysis. This involves that the device is opened and the interior examined. The constructural analysis may include investigation of any fracture surface.

9.3 Production testing

9.3.1 Introduction

Splice holders, organisers and closures cannot be fully tested unless splices are installed. Thus only visual inspection and checks of dimensions, mass and proper assembly can be included in the Final Production Test.

9.3.2 In production control

The outline dimensions are to be controlled during the manufacturing for parts that are not accessible at the final stage of production.

9.3.3 Final production testing

As the splices are not installed at this stage, the final production testing will include geometrical measurements, assembly/disassembly of closures, temperature extremes and vibration only.

The tests shall be done in accordance with Chart 9.2. The test shall be performed on all samples unless otherwise specified.

9.3.3.1 Visual inspection

To be performed in accordance with ESA/SCC Basic Specification No.20500.

9.3.3.2 Dimensions

The outline dimensions are to be controlled after the manufacturing at the final stage of production.

Test method: 9.1.1

9.3.3.3 Mass

Test method: 9.1.2

9.3.3.4 Assembly/disassembly of closures

The outline dimensions are to be controlled after the manufacturing at the final stage of production.

Test method: 9.4.15

9.3.3.5 Temperature extremes

The component shall be exposed to one temperature cycle. The high and low temperatures shall be chosen so as not to induce any permanent changes in the component.

Test method: 9.4.2

9.3.3.6 Vibrations

Test method: 9.3.2

9.4 Burn-in

Burn-in is not relevant for these components.

9.5 Qualification testing

The qualification test programme should include all tests of relevance not already done in the final production test. The geometrical properties have been measured in the final production test. The qualification testing will be concerned with optical, mechanical, endurance and environmental characteristics. The sensitivity to mechanical and environmental loads was evaluated in the evaluation test programme. Several of the characteristics of the device are dependent on technology rather than production parameters. This is noted, as appropriate, in the discussion of the qualification test strategy.

The qualification testing is divided in tests for endurance, mechanical and environmental properties. All samples supplied for testing shall however, be exposed to climatic sequence before they are exposed to other tests. This climatic sequence is performed to expose mechanical mounting to temperature variations and humidity before any other test is performed, which may change the properties of the components.

All samples are exposed to a condensation test at the end of the test sequence. This test includes humidity and temperatures below zero, which may reveal any cracks and failures induced by the mechanical/environmental tests, but not detected by the post test investigations.

The environmental measurements included in the qualification testing is climatic sequence, condensation, vibration and shock. The effects of vacuum operation, rapid depressurisation, radiation (including ionizing, solar and UV) have all been investigated during the evaluation process. Any effects of these loads will be related to technology and design, and not to production. Besides, this is expected not to be a particular problem with closures, organisers and holders. All materials used in these devices are to be space qualified. It will therefore not be necessary to repeat the measurements in the qualification.

The measurements for component endurance includes measurements of long term high temperature exposure (ageing).

The mechanical measurements are performed to ensure that the components meet the specified mechanical requirements. The measurements include effectiveness of clamping device and crush resistance. Testing with respect to drop, bump, and impact is not included because this is all covered in the evaluation testing. Mechanical properties which may effect the internal mounting of the component, for example acceleration, are covered by the vibration and shock tests.

Each group consists of 4 items taken by random from a production lot. The number of samples are chosen to get an indication of spread in the values. The qualification test programme uses few devices for each test, thus all samples shall meet the requirements.

Some tests are performed with splices installed and fibre (or fibre cable) attached to the device. Other tests are without splices installed.

The tests shall be performed in accordance with Chart 9.3.

9.5.1 Endurance tests

For tests 9.5.1.1 and 9.5.1.2 the optical transmission through each splice shall be measured.

9.5.1.1 Assembly and disassembly of closures

Test method: 9.4.15

9.5.1.2 Ageing

The test shall be done with a representative number of splices installed. This is a long term test at a high temperature. It should be done on the same sample(s) used in 9.5.2.1.

Test method: 9.4.16

9.5.2 Mechanical tests

Tests 9.5.2.1 and 9.5.2.2 shall be done with a representative number of splices installed unless otherwise specified. The optical transmission through each splice shall be measured.

9.5.2.1 Effectiveness of clamping devices

This test is to determine the effectiveness of the clamping device against fibre or cable pulling, cable torsion, and cable bending.

Test method: 9.3.1

9.5.2.2 Crush resistance

Splices need not be installed.

Test method: 9.3.4

9.5.3 Environmental measurements

9.5.3.1 Vibration

The fibre splice may loosen due to vibration.

Test method: 9.3.2

9.5.3.2 Shock

The fibre splice may loosen due to shock.

Test method: 9.3.3

9.5.3.3 Condensation

Test method: 9.4.5

9.6 Lot Acceptance Test (LAT)

LAT is performed on every lot delivered by the manufacturer. The LAT is divided in 3 different levels as discussed in Chapter 4. LA1 and LA2 are considered to be destructive and the tested samples shall not form part of the delivered lot. LA3 is comprised of tests which may reveal production failures such as wrong dimensions. LA 1 is performed once every two year; LA2 is performed every year; LA3 shall be performed on all deliveries.

The tests shall be performed according to Chart 9.4. Unless otherwise specified, the number of samples given in Chart 9.4 shall be used for testing.

9.6.1 Lot acceptance level 3 (LA3)

The components are subjected to a detailed final production testing. Measurements performed in the LA3 are repetition of these measurements, performed by different personnel to ensure that the quality of the delivered items as well as a control of the routine measurements performed in the final production testing.

9.6.1.1 Visual inspection

The visual inspection shall be performed according to ESA/SCC Basic Specification No.20500.

9.6.1.2 Dimensions

Required physical dimensions to be measured e.g. length, width, height, fixing points, mounting details.

Test method: 9.1.1

9.6.2 Lot acceptance level 2 (LA2)

In addition to the tests included in LA3 testing, the LA2 is comprised of the following tests. The tests are considered to destructive.

9.6.2.1 Ageing

The test shall include humidity if required by the application.

Test method: 9.4.16

9.6.2.2 Effectiveness of clamping device

Test method: 9.3.1

9.6.3 Lot acceptance level 1 (LA1)

In addition to the tests included in LA2 testing, the LA1 is comprised of the following tests. The test are considered to be destructive.

9.6.3.1 Temperature extremes

Test method: 9.4.2

9.6.3.2 Vibration

Test method: 9.3.2

9.6.3.3 Condensation

Test method: 9.4.5

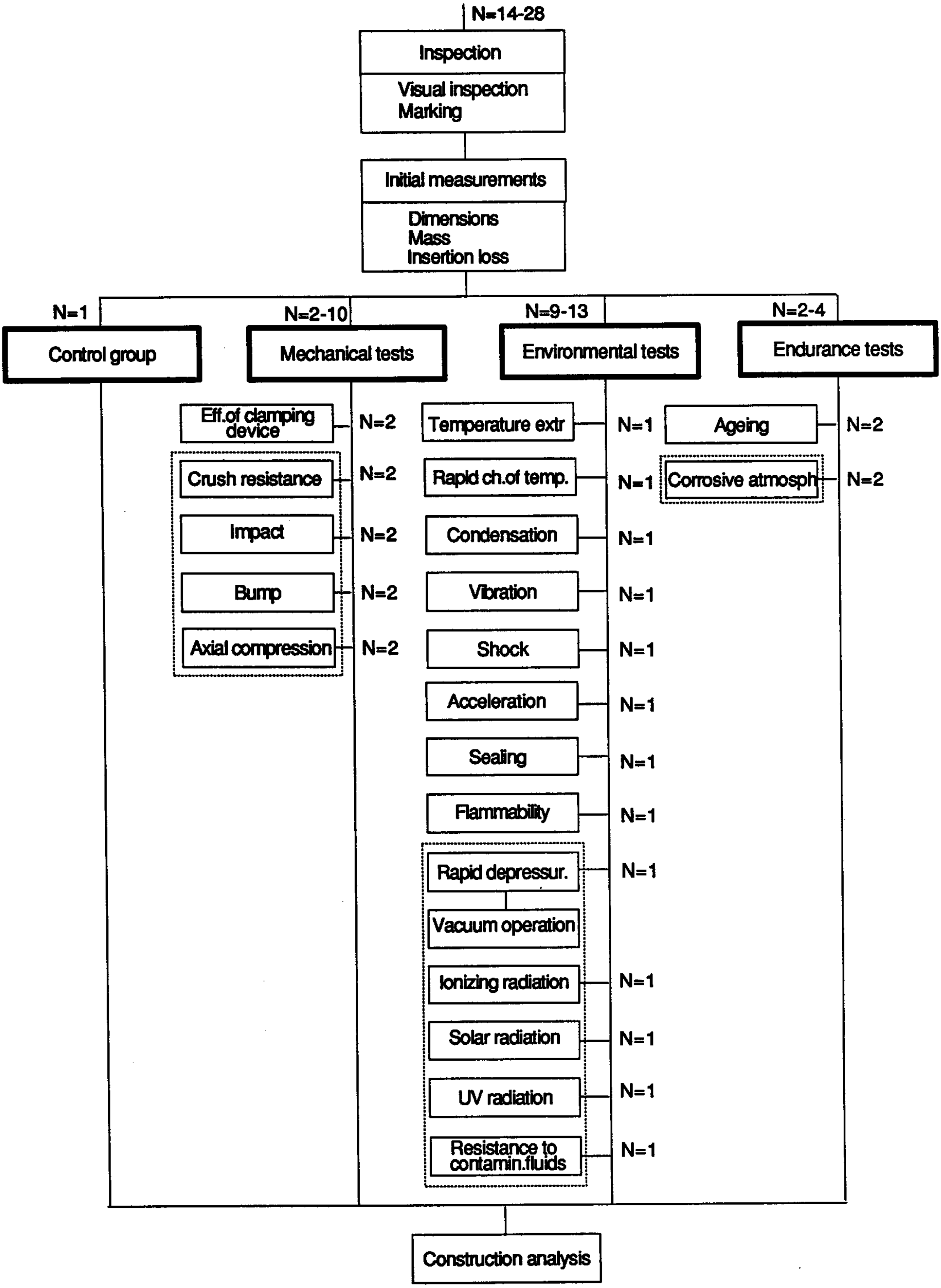

Chart 9.1 Evaluation testing for splice holders, organisers and closures

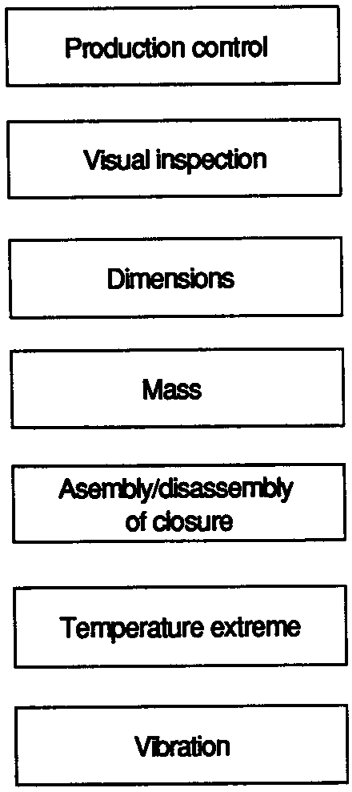

Chart 9.2 Final production testing for splice holders, organisers and closures

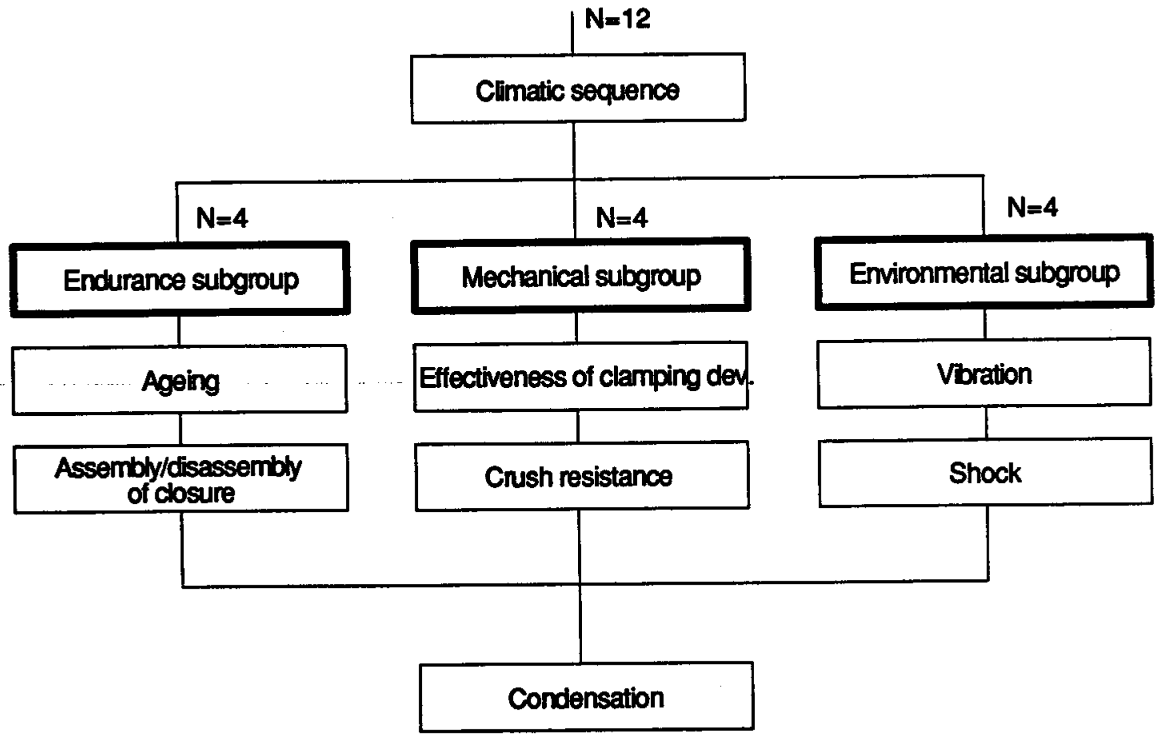

Chart 9.3 Qualification testing for splice holders, organisers and closures

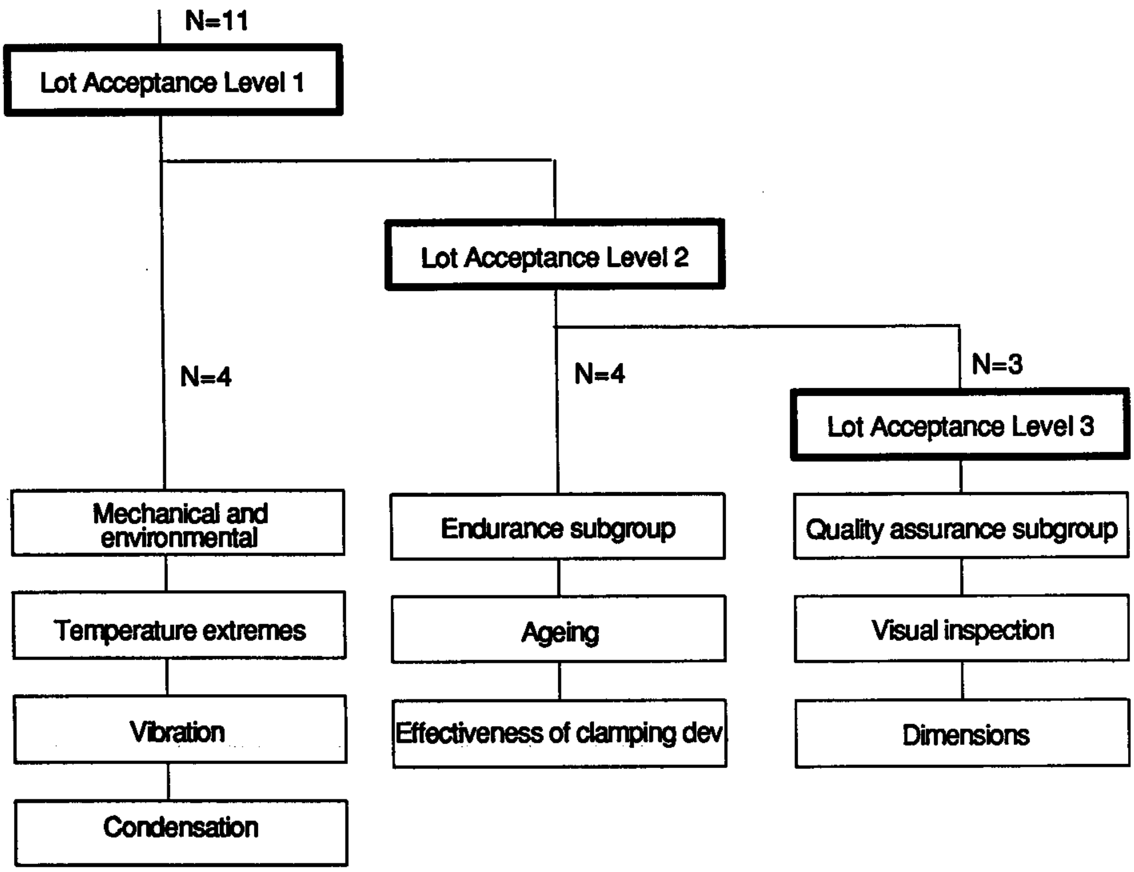

Chart 9.4 Lot acceptance testing for splice holders, organisers and closures

10 FIBRE OPTIC ATTENUATORS

10.1 Introduction

Fibre optic attenuators are passive fibre optic components applied in systems where the signal, or parts thereof, for some reason needs to be attenuated. The attenuation can be fixed or variable, wavelength dependent or wavelength independent. In some cases the fibre optic attenuator may be used as a spectral filter, such as when it attenuates light at a given wavelength or when it attenuates light except for a given wavelength. Fibre optic attenuators are based on either all-fibre or micro-optic technology.

In all-fibre devices the attenuation is accomplished by introducing loss in the fibre (for instance microbending or a fibre gap). In micro-optic devices the attenuation is accomplished by using miniature versions of bulk optical devices such as lenses, mirrors, beamsplitters and filters.

In fixed attenuators the attenuation is meant to be constant. In variable attenuators it is possible to adjust the attenuation, either by changing the attenuation or the wavelength dependence (tunable filters). To characterise these devices the attenuation shall be measured over the adjustment range of interest.

Fibre optic attenuators without any intended wavelength dependence will not very likely be applied in space applications. These components are most often used in laboratory applications to simulate the loss in a real system. Wavelength dependent devices may be used as filters in systems when several wavelengths are transmitted through the same fibre.

The characteristics of the fibre optic component is strongly dependent on the packaging. Nominally the same component, but with different packaging should therefore be tested and qualified separately.

The general test strategy is described in Chapter 4 and will also be followed here. Each test method has been given a number, and these numbers are tabulated and described in Part 3 Ch.10.

10.2 Evaluation testing

10.2.1 Purpose

The purpose of the evaluation testing is to determine the operational limits of the fibre optic attenuator with respect to critical mechanical and environmental parameters, to overstress specific characteristics in order to identify failure modes, to demonstrate the suitability of the attenuator for proceeding on to qualification testing and to get information which can be of value for a detailed planning of the test programme to be used in the procurement of the component.

10.2.2 Properties to evaluate

The main properties of interest are :

- mechanical properties
- effects of high levels of vibration and shock
- effects of temperature extremes
- effects of rapid depressurisation and vacuum operation
- effects of ionizing radiation
- effects of solar radiation and UV radiation
- resistance to solvents and contaminating fluids

For some special applications the optical power handling capability may be of concern.

It is expected that the fibre used in the input/output ports of the component is characterised with respect to space applications. It is thus not necessary to include tests for fibre properties such as bandwidth, coating dimensions, numerical aperture, etc. in the evaluation of the passive device. The characteristics of the fibre with respect to environmental loads such as ionizing radiation and temperature extremes should also be known.

Coatings, buffers and materials used in the packaging shall be space qualified, see Chapter 4. However, an evaluation related to their properties may be necessary to eliminate any undesired interactions between the various materials and effects of changes in the material properties on the behaviour of the device.

The flammability of the fibre optic attenuator is not expected to be of special concern. The materials used in the component should all undergo a test with respect to flammability in the material evaluation, see Chapter 4. These properties will not depend on the manufacturing or the assembly of component, and the test is thus not included. A test with respect to dust is not included because this is not expected to be of special concern in space applications. A test with respect to corrosive atmosphere is not included either. The materials in the component will be tested with respect to resistance to corrosion in the material evaluation, see Chapter 4 and the property is not expected to be critical to the performance of the device, as it is not meant to be mated like for instance a connector.

10.2.2.1 Mechanical properties.

The optical components as well as the packaging must withstand mechanical loads such as crush, impact, drop, bump and acceleration. In addition, the fibre attachment should be tested with respect to pulling, axial compression, flex and torsion. The largest mechanical loads are expected to occur during installation. The mechanical loads will therefore be imposed on the component before it is exposed to environmental effects. The mechanical properties such as strength of fibre attachment and resistance to crush, drop, impact and bump are determined by the package. A manufacturer of fibre optic components will usually apply the same mechanical design to several types of components (couplers, WDMs, isolators and attenuators). It will therefore not be necessary to evaluate these properties for each component type if it has previously been evaluated with another component with identical package.

10.2.2.2 Temperature extremes

A fibre optic attenuator may be comprised of several materials with probably different coefficient of thermal expansion. This may lead to misalignment of the different components and change in attenuation during temperature cycling. Thermal expansion may also induce microbend loss on the fibres within the component or put the fibres under tension.

If the device is intended to be used in applications where it may be exposed to humidity, this shall be included in the evaluation test programme. Humidity and temperature extremes may induce other failure mechanisms than dry heat.

10.2.2.3 Rapid change of temperature

Rapid change of temperature may cause excessive tension as the thermal response of the component may be slower than the rate of change of temperature. Large thermal gradients across the component may therefore arise, challenging the mechanical alignment and the strength of the mounting of each part of the component. The components involved are, however, quite small which should reduce the effect of rapid change of temperature.

10.2.2.4 Rapid depressurisation

Rapid depressurisation may cause mechanical stresses because trapped air in pockets inside the component may give large pressure gradients.

The test with respect to the effect of rapid depressurisation will not be necessary if devices with similar structure have been previously evaluated. This applies to devices with different functions (attenuators, branching devices, WDM, isolators), but with nominally the same package.

10.2.2.5 Vacuum operation

The materials used in the attenuator shall all be space qualified, see Chapter 4. This means that the effects of vacuum operation (outgassing, change of material properties) should be very small. Interactions between the different media may however, arise with deleterious effects such as misalignment of the different parts of the component and mechanical stresses.

The test with respect to vacuum operation will not be necessary if devices with similar structure have been previously evaluated. This applies to devices with different functions (attenuators, branching devices, WDM, isolators), but with nominally the same package.

10.2.2.6 Ionizing radiation

In space applications fibre optic components are exposed to high levels of ionizing radiation which may induce losses in the optical components as well as change the properties of the other materials in the package. Even if all the materials are space qualified, see Chapter 4, interactions may occur. Any possible interaction should be revealed during the evaluation of the component.

The test with respect to the effects of ionizing radiation might not be necessary if devices with identical optical design, but slightly different package (with respect to mechanical design, but not to material selection) have been previously evaluated.

10.2.2.7 Solar and UV radiation

Solar and UV radiation could affect the properties of the material in the package. If the attenuator is not properly designed, solar and UV radiation may also be coupled into the optical path and interfere with the signal propagation.

The test with respect to solar and UV radiation might not be necessary if devices with the identical optical design, but slightly different package (with respect to mechanical design, but not to material selection) have been previously evaluated.

10.2.2.8 Resistance to solvents and contaminating fluids

During installation or service the component might be exposed to solvents and contaminating fluids. These fluids may deteriorate the materials in the component and thereby the performance.

10.2.2.9 Optical power handling capability

The power handling capability of a attenuator can be limited by four different phenomena:

- heating due to absorbed power
- radiation induced colour centres which will cause loss
- various non-linear optical effects
- formation of cracks, pits, etc.

As with optical fibres, the fibre optic attenuator is usually operated in systems with power levels in the order of 1 mW or less. The above phenomena will only be of concern in special applications were the component is used to attenuate high power levels. Most of the power will then be absorbed within the component and excessive local heating may occur. (In a 3dB attenuator half the incident optical power will normally be absorbed inside the attenuation).

<u>10.2.3 Sample distribution and test programme sequence</u>

10.2.3.1 Sample distribution

The fibre optic attenuator shall be selected at random from a representative production lot. The size of the lot shall be 2 times to 3 times the total number of the selected samples.

Number of samples: 19-60, dependent on the extent of the test programme, as discussed in the text

The number of devices needed for the evaluation test programme is quite extensive. New devices are used for each test, both because each test is considered destructive and to be able to distinguish between the effects of the different parameters. The number of samples for each test is shown in Chart 10.1, (see end of Chapter). In order to get a picture of the spread in values, the number of samples in each test is 3 or larger. The evaluation test programme will give a better picture of the statistical fluctuations if more components were used for each test. A sample size of 3 will however, give an indication of the variations. If large variations are observed, the number of samples should be increased.

10.2.3.2 Test range and failure criteria

The different tests are performed on a step stress basis. This means that the load is increased in steps from a starting value. Generally, the load is increased until the component has suffered physical destruction or a substantial deterioration in performance, as appropriate. In some of the tests the upper stress limit is determined from the most severe loads expected, as listed in Chapter 4, with some margin added. If more severe loads are expected, the upper test level should be increased accordingly.

The criteria for defining the component as failed is dependent on the performance of the component and the initial value of the parameter. Table 10.1 shows the criteria we have chosen to use in the evaluation test programme. If the wavelength dependence of the device is an important feature, the criteria in Table 10.1 shall apply at each wavelength.

Range of attenuation	Attenuation variation
0-10 dB	± 2 dB
11-50 dB	± 3 dB
above 50 dB	± 5 dB

Table 10.1 Maximum allowable variation in attenuation loss.

All results shall be recorded.

10.2.3.3 Test programme sequence

The specified tests are summarised in Chart 10.1. The mechanical and environmental tests which may be dependent on application and previous evaluation of similar components, are shown in a dotted box.

The initial measurements are all optical measurements and will not have any influence on the properties of the tested components. The indicated order is based on the importance of the different parameters. The attenuation is measured first to establish the functionality of the device. The polarisation dependence is measured thereafter to find out the dependence on characteristics of the signal in this respect. The modal noise is measured to find out whether the attenuation is dependent on the modal distribution in the fibre. The return loss is measured for applications were the backreflected light may deteriorate the performance of the system or components in the system.

For the mechanical, environmental and endurance tests new test samples are used for each test. The test order will therefore not affect the test result and is as such of no importance. It is generally recommended to perform the easiest and least expensive tests first and the more complicated and expensive test in the end. If the component fails during the cheap and least expensive part of the test programme, it can be stopped before large expenses have been incurred.

We suggest to do the mechanical tests first. This is a test of the component's and the package's ability to withstand mechanical loads and the package's ability to protect the optical part of the component. The strength of fibre attachment is tested first. This will be an important property during installation and handling of the component of the system. The resistance to acceleration, impact, drop, bump and crush is tested thereafter.

The environmental tests are performed after the mechanical tests. We recommend to do the temperature tests first. Testing with respect to temperature will both reveal fundamental temperature dependent properties of the optical design and temperature dependent properties of the assembly. The temperature tests include testing with respect to temperature extremes, rapid change of temperatures and condensation. The test with respect to temperature extremes shall be performed first to establish the limits for the other tests.

The tests with respect to the effects of vibration and shock are tested before the vacuum and ionizing radiation test. The materials applied in the component are, in advance, tested with respect to such material related effects. The latter tests are performed to ensure that no unexpected effects occur. The characteristics of the component when it is exposed to loads such as vibration and shock is less predictable and in addition easier and less expensive to perform.

The tests with respect to the effects of rapid depressurisation and vacuum operation are performed on the same samples. The effects of rapid depressurisation should be tested before the effects of vacuum operation. If the device fails in the rapid depressurisation test, there will be no point in proceeding to the test with respect to vacuum operation.

The effect of radiation (ionizing as well as solar and UV radiation) is tested in the end, such that only components that have passed the other tests are exposed to this test. Even if radiation resistance is a fundamental property for components in space application, the device should be based on materials and fibres with minimal radiation effects and the test is performed to ensure that no unexpected effects will occur.

In those cases where it is of special concern the resistance to solvents and contamination fluids shall be measured.

The endurance tests are ageing and optical power handling capability, if applicable. The conditions of the ageing test are determined by the test with respect to temperature extremes. The test will thus have to be started after this test. The test is a long term test with measurements at regular intervals and can be performed in parallel with the other tests.

10.2.3.4 Use of control group

The use of a control group is not considered necessary in the mechanical and environmental test analysis. In these tests the parameters of interest are usually monitored while the test is performed. The stability of the source output and the repeatability of the measurements are ensured by a control of the output power. If the post test investigations include optical measurements not performed during the test procedure, the measurements shall also be performed on the control group. This may include measurements of attenuation as a function of signal wavelength.

A control group is used in the construction analysis to be able to compare the devices that have been exposed to environmental and mechanical loads with a "fresh" sample.

10.2.3.5 Post test investigations

The standard test procedures given in Chapter 10 Part 3 often specify that after the exposure to mechanical or environmental load is completed, some measurements should be made to look for permanent changes in one or more critical properties. In the evaluation programme there are in many cases specified additional tests to analyse the failure mechanisms, but also to reveal whether the load has induced changes not observed directly during the tests or revealed by the standard post test investigations. An example of such a test would be testing of the strength of fibre or cable entry after the test with respect to temperature extremes, to investigate whether temperature extremes have affected the materials in the fibre attachment in such a way that the strength is reduced.

10.2.4 Inspection

The purpose of the inspection is to make sure that the samples are suited for testing. All samples shall be inspected.

10.2.4.1 Visual inspection

The visual inspection shall be carried out in accordance with ESA/SCC Basic Specifications No. 20500.

10.2.4.2 Dimensions

Test method: 10.1.1

10.2.4.3 Mass

Test method: 10.1.2

10.2.4.4 Marking

All samples shall be marked in accordance with the standard procedure of the manufacturer.

10.2.5 Initial measurements

The purpose of the initial measurements is to determine the initial values of the most important optical parameters. The result from these initial measurements will be used as a basis for the evaluation of later measurements. Further, one wants to ascertain that the various samples meet the specified requirements and to get a picture of the spread in values. The spread in values will give an indication of the production control and be a valuable input to, for instance, the lot acceptance testing programme.

The initial measurements shall be performed on all samples.

10.2.5.1 Attenuation

The measurement shall be performed over the specified wavelength range.
Test method: 10.2.1/10.2.3

10.2.5.2 Polarization dependence

The test applies to single mode devices only.
Test method: 10.2.4

10.2.5.3 Modal distribution

The test applies to multimode devices only.
Test method: 10.2.5

10.2.5.4 Return loss

The measurement shall be performed over the wavelength range of interest.
Test method: 10.2.2

10.2.5.5 Susceptibility to ambient light coupling

Test method: 10.2.6

10.2.6 Mechanical tests

The main mechanical properties to test are strength of attachment of fibre which includes tests for pulling, axial compression, flex and torsion. The component should also be tested with respect to mechanical loads such as crush, impact, bump, drop and acceleration.

The attenuation is measured before and after the test. The attenuation is monitored at the specified wavelength during the test.

10.2.6.1 Strength of attachment of fibre

The test with respect to strength of attachment of fibre includes pulling, axial compression, flex and torsion tests. In some commercial devices input and output ports of the attenuator are connectors. In such a case these connectors should be tested for mechanical strength and durability as given by Chapter 7.

10.2.6.1.1 *Pulling*

In this test the fibres constituting the input and output ports of the component is subjected to increasing load until the fibre attachment breaks. The number of samples is chosen to get a picture of the spread in values. For each component each fibre attachment shall be tested on an individual basis.

Number of samples: 2

The tensile force shall be applied smoothly and controlled, the magnitude of the force shall be increased at a specified rate. The tensile force shall be increased until the fibre breaks.
Test method: 10.3.8

10.2.6.1.2 *Axial compression*

The fibre leads of the attenuator shall be subjected to axial compression to establish the ability of the retention means to withstand axial compression. The number of samples is chosen to get a picture of the spread in values. For each component each fibre attachment shall be tested on an individual basis.

Number of samples: 2

The axial compression shall be applied smooth and controlled, the magnitude of the force shall be applied with the specified rate. The axial compression shall be increased until the fibre breaks.
Test method: 10.3.8

10.2.6.1.3 *Flex*

The test is intended to determine the ability of the fibre interface and strain relief to withstand flexing. For each component each fibre attachment shall be tested on an individual basis.

Number of samples: 2

The load shall be increased in steps until the fibre breaks.
Test method: 10.3.8

10.2.6.1.4. *Torsion*

The test is intended to determine the ability of the fibre attachment to withstand torsion of the fibre. Each fibre shall be tested on an individual basis.

Number of samples: 2

The torque shall be increased until the fibre breaks.
Test method 10.3.8

10.2.6.2 Acceleration

Number of samples: 3
Start acceleration: as specified
The acceleration shall be increased until the component has failed or has suffered physical destruction.
Test method: 10.3.6

10.2.6.3 Impact

Number of samples: 3
Start energy: as specified
The energy in the impact shall be increased in steps of 20 % of the specified value. The load shall be increased until the component has failed or suffered physical destruction.
Test method: 10.3.4

10.2.6.4 Crush resistance

Number of samples: 3
Start force: as specified
The force shall be increased in steps of 20 % of the specified value. The load shall be increased until the component has failed or suffered physical destruction.
Test method: 10.3.3

10.2.6.5 Drop

Number of samples: 3
Start height: as specified
The height shall be increased in steps of 20 % of the initial value. The load shall be increased until the component has failed or suffered physical destruction.
Test method: 10.3.5

10.2.6.6 Bump

Number of samples: 3
Number of bumps: 4000 at each level of acceleration
Start acceleration: 40 g

The acceleration shall be increased in steps of 10 g. The load shall be increased until the component has failed or suffered physical destruction.
Test method: 10.3.7

10.2.7 Environmental tests

10.2.7.1 Temperature extremes

The attenuation shall be measured over the specified wavelength range at each temperature.

Number of samples:	3
Thermal cycling:	first low, then high
Low temperature:	sufficient to induce component failure, but not below - 70°C.
High temperature:	sufficient to induce component failure, but not above 150°C.
Low starting temperature:	lowest specified temperature, or - 40°C if not given.
High starting temperature:	highest specified temperature or 90°C if not given.
Step change in temperature:	10°C
Duration of stay at each temperature:	1 hour
Test method:	10.4.2

10.2.7.1.1 *Post test investigation*

The post test investigation include a repetition of the measurement of attenuation after the component has reached room temperature. A visual inspection and dimensional check shall be performed on each device to check any changes in material appearance. One of the samples used in the temperature test shall be subjected to constructional analysis. The remaining samples shall be tested with respect to fibre attachment to ensure that the materials in the fibre attachment are not influenced by temperature extremes.

Attenuation,	ref: 10.2.5.1
Visual inspection,	ref: 10.2.4.1
Dimensions,	ref: 10.2.4.2
Strength of fibre attachment, pulling strength.	ref:10.2.6.1.1
Constructional analysis	ref: 10.2.9

10.2.7.2 Rapid change of temperature

The attenuation shall be measured as a function of wavelength immediately before and after the temperature change. The attenuation shall be measured at the specified wavelength during the rapid change of temperature.

Number of samples:	3
High temperature:	10°C below high temperature limit established in 10.2.7.1
Low temperature:	10°C above low temperature limit established in 10.2.7.1
Rate of change of temperature:	as specified
Test method:	10.4.3

10.2.7.2.1 *Post test investigation*

The attenuation shall be measured when the component has reached room temperature after the test is finished. A visual inspection shall be performed on the devices. One of the samples shall be subjected to a constructional analysis to investigate whether rapid change of temperature has influenced the internal structure.

Attenuation,	ref: 10.2.5.1
Visual inspection	ref: 10.2.4.1
Constructional analysis	ref: 10.2.9

10.2.7.3 Condensation

The attenuation shall be measured each time the test conditions/temperature are changed.

Number of samples:	3
Test conditions:	as specified in IEC 68.2.38
Test method:	10.4.5

10.2.7.3.1 *Post test investigation*

The attenuation shall be measured after the component has reached room temperature. The devices shall be subjected to a visual inspection and a dimensional check to look for changes in material structure and appearance. Constructional analysis is included in the post test investigation to find out whether combined humidity/heat would change any of the internal materials. The remaining samples shall be tested with respect to strength of fibre attachment to investigate the effect on the materials in the fibre mounting.

Attenuation,	ref: 10.2.5.1
Visual inspection,	ref: 10.2.4.1
Dimensions,	ref: 10.2.4.2
Strength of fibre attachment, pulling strength,	ref: 10.2.6.1.1
Constructional analysis	ref: 10.2.9

10.2.7.4 Vibration

The attenuation shall be measured at the specified wavelength during the test.

Number of samples:	3
Vibration frequency:	100-2000 Hz
Starting acceleration:	as specified
The increase in acceleration:	steps of 20% of specified level until the level has reached 30 g or the component has failed
Duration:	90 minutes
Test method:	10.3.1

10.2.7.4.1 *Post test investigation*

The attenuation shall be measured when the device has settled after the test. The device shall be subjected to a visual inspection to look for changes in structure or appearance. Vibration may induce mechanical fractures not possible to reveal by visual inspection and optical measurements One of the samples is therefore subjected to a condensation test. In this test condensed water may freeze in possible cracks and increase the crack. Another sample is subjected to constructional analysis to investigate whether vibration induce any changes in the internal structure of the device

Attenuation,	ref: 10.2.5.1
Visual inspection	ref: 10.2.4.1
Condensation	ref: 10.2.7.3
Constructional analysis	ref: 10.2.9

10.2.7.5 Shock

The attenuation shall be measured at the specified wavelength during the test.

Number of samples:	3
Pulse duration:	0.5 ms
Starting acceleration:	as specified
The increase in acceleration:	steps of 20% of specified level until the level has reached 2000 g or the component has failed
Test method:	10.3.2

10.2.7.5.1 *Post test investigation*

The attenuation shall be measured when the device has settled after the test. The device shall be subjected to a visual inspection to look for changes in structure or appearance. Shock may induce mechanical fractures not possible to reveal by visual inspection and optical measurements. One of the samples is therefore subjected to a condensation test. In this test condensed water may freeze in possible cracks and increase the crack. Another sample is subjected to constructional analysis to investigate whether shock induce any changes in the internal structure of the device.

Attenuation,	ref: 10.2.5.1
Visual inspection	ref: 10.2.4.1
Condensation	ref: 10.2.7.3
Constructional analysis	ref: 10.2.9

10.2.7.6 Rapid depressurisation

The attenuation shall be measured at the specified wavelength during the test.

Number of samples:	3
Test method:	10.4.15

10.2.7.6.1 *Post test investigation*

The post test investigation shall include measurement of attenuation. If any of the components fail, a failed sample shall be subjected to constructional analysis to investigate whether rapid depressurisation may have influenced the internal structure of device. If all components pass the test, they shall be used in the test with respect to vacuum operation (10.2.7.7)

Attenuation,	ref: 10.2.5.1
Visual inspection,	ref: 10.2.4.1
Constructional analysis,	ref: 10.2.9

10.2.7.7 Vacuum operation

The attenuation is not measured during the vacuum test, because any changes is expected to be permanent.

Number of samples:	3
Vacuum:	10^{-3} Pa or less
Temperature:	125°C or high temperature limit established in 10.2.7.1, whichever is lower.

Duration:	24 hour
Test method:	10.4.4

10.2.7.7.1 *Post test investigation*

The post test investigation shall include measurement of the attenuation of the tested samples as well as the control group. The device shall be subjected to visual inspection to look for changes in structure or appearance. One of the samples shall be subjected to constructional analysis to investigate whether vacuum operation influenced the internal structure of the device.

Attenuation,	ref: 10.2.5.1
Visual inspection	ref: 10.2.4.1
Constructional analysis	ref: 10.2.9

10.2.7.8 Ionizing radiation

The attenuation shall be measured at regular intervals during the exposure.

Number of samples:	3
Temperature:	Room temperature
Optical power:	As specified
Wavelength:	As specified
Dose rate:	5 rad(Si)/s
Duration:	The irradiation shall last until the component has failed or the total dose has reached 3 Mrad.
Test method:	10.4.12

10.2.7.8.1 *Post test investigation*

The attenuation is measured after the exposure has been removed. One of the samples are subjected to constructional analysis to investigate whether ionizing radiation influenced the internal structure of the device.

Attenuation,	ref: 10.2.5.1
Visual inspection	ref: 10.2.4.1
Constructional analysis	ref: 10.2.9

10.2.7.9 Solar radiation

The attenuation shall be measured at regular intervals during the test.

Number of samples:	3
Temperature:	Room temperature
Radiation source:	source with representative spectral output
Duration:	until the component has failed or the maximum anticipated total dose has been reached
Test method:	10.4.10

10.2.7.9.1 *Post test investigation*

The attenuation shall be measured after the test is completed. The device shall be subjected to a visual inspection to look for changes in structure or appearance. One of the samples shall be subjected to constructional analysis to check whether solar radiation has influenced the materials inside the component.

Attenuation,	ref: 10.2.5.1
Visual inspection,	ref: 10.2.4.1
Constructional analysis,	ref: 10.2.9

10.2.7.10 UV radiation

Number of samples:	3
Temperature:	room temperature
Radiation source:	representative UV source
Duration:	until the component has failed or the maximum anticipated total dose has been reached.
Test method:	10.4.11

10.2.7.10.1 *Post test investigation*

The attenuation shall be measured after the test procedure is completed. The device shall be subjected to a visual inspection to look for changes in structure or appearance. One of the samples shall be subjected to constructional analysis to check whether the materials inside the component has changed during exposure.

Attenuation,	ref: 10.2.5.1
Visual inspection,	ref: 10.2.4.1
Constructional analysis,	ref: 10.2.9

10.2.7.11 Resistance to solvents and contaminating fluids.

Number of samples: 3

The components shall be subjected to the appropriate solvents and fluids. Reference is made to ESA/SCC Generic Specification No 3901, paragraph 9.21. No visible changes in component appearance shall be observed. The attenuation shall be measured after the test.

<u>10.2.8 Endurance test</u>

10.2.8.1 Ageing

The attenuation shall be measured over the specified wavelength range at regular intervals during the test.

Number of samples:	3
Temperature:	20°C above specified operating temperature, but at least 10°C below high temperature limit established in 10.2.7
Duration:	Until the component has failed or the test has lasted 1000 hours.
Test method:	10.4.14

10.2.8.1.1 *Post test investigation*

The attenuation shall be measured after the test. The device shall also be subjected to a visual inspection and dimensional check to look for changes in the appearance and structure of the device. One of the samples shall be subjected to a constructional analysis to investigate whether long term high temperature has introduced changes in the internal structure. Another sample shall be tested with respect to fibre attachment to investigate whether long term high temperature have influenced the materials used in the fibre attachment.

Attenuation,	ref: 10.2.5.1
Visual inspection,	ref: 10.2.4.1
Dimensions,	ref: 10.2.4.2
Strength of attachment of fibre, pulling strength	ref: 10.2.6.1.1
Constructional analysis,	ref: 10.2.9

10.2.8.2 Optical power handling capability

Number of samples:	3
Laser source:	as specified

Input power level shall be increased in steps and measurements made of attenuation over the specified wavelength range

The entrance and exit surfaces shall also be examined for visual damage. Input power level shall be increased until the component has failed or visual damage has occurred. The maximum input level will very likely be limited by the available optical source.

Test method:	10.2.7

10.2.9 Constructional analysis

A sample from the control group and samples exposed to the other tests, as noted under the post test investigation, shall be subjected to constructional analysis. This involves that the package is opened and the internal structure of the device is investigated. The constructional analysis may include investigation of any fracture surfaces. It may also include an examination of the optical path of the system by means of visible light, for example a HeNe laser.

10.3 Production testing

10.3.1 Introduction

A number of non-destructive tests can be performed on an attenuator during and after production to ensure that all adjustments and other production parameters are according to specifications. The production testing includes geometrical measurements as well as control of the mass of the component. The production control also includes control of some optical properties.

10.3.2 Production control

The attenuation shall be controlled during production. The attenuation is controlled at the specified wavelength(s).

The dimensions as well as the mass of all components shall be controlled prior to assembly. This applies to optical components as well as package.

10.3.3 Final production testing

The tests shall be performed according to Chart 10.2. Unless otherwise specified, all samples shall be tested. In addition to a final control of the dimensions and the mass of the device, the optical performance shall be tested. This includes attenuation, polarisation sensitivity and sensitivity to modal distribution, where applicable. The susceptibility to ambient light coupling is dependent on the optical and mechanical design. The optical design in this respect is not production dependent. Changes in mechanical structure which would change the susceptibility to ambient light coupling will probably be disclosed by the visual inspection. The component shall be temperature cycled and subjected to vibration tests to reveal any failures in mechanical alignment and mounting. The temperature test is performed before the vibration test. Any temperature induced changes in glue or screws should then be revealed by the succeeding vibration test.

10.3.3.1 Visual inspection

To be performed in accordance with ESA/SCC Basic Specification No. 20500.

10.3.3.2 Dimensions

The dimensions of the package as well as the length of the fibre leads shall be controlled.

Test method: 10.1.1

10.3.3.3 Mass

Test method: 10.1.2

10.3.3.4 Attenuation

The attenuation shall be measured over the wavelength range of interest. The measurement is included in the final production testing even though it is controlled in the production process to ensure that the package has no influence on the attenuation.

Test method: 10.2.1/10.2.3

10.3.3.5 Polarisation dependence

Test method: 10.2.4

10.3.3.6 Modal distribution

Test method: 10.2.5

10.3.3.7 Temperature extremes

The component shall be exposed to one temperature cycle. The high and low temperature shall be chosen so as not to induce any permanent changes in the component.

Test method: 10.4.2

10.3.3.8 Vibration

Test method: 10.3.1

10.4 Burn-in

Burn-in is not relevant for fibre optic attenuators.

10.5 Qualification testing

The qualification testing shall include all tests of relevance not included in the final production testing. The test programme will therefore not include any test for just optical characteristics since this is covered by the final production testing. The sensitivity to mechanical and environmental loads was evaluated in the evaluation test programme. Several of the characteristics of the device are dependent on design and technology rather than production parameters. It will therefore not be necessary to repeat some of the tests in the qualification test programme. This is noted, as appropriate, in the discussion of the qualification test strategy.

The qualification testing is divided in tests for endurance, mechanical and environmental properties. All samples supplied for testing shall however be exposed to a climatic sequence before it is exposed to the other tests. This climatic sequence is performed to expose mechanical mounting and glue to temperature variations and humidity before any other test is performed, which may change the properties of these components.

All samples are exposed to a condensation test at the end of the test programme. This condensation test includes humidity and temperatures below zero, which may reveal any cracks and failures induced by the mechanical/environmental test programme, but not detected by the post test investigations. A similar environmental stress sequence is also seen in other test programmes [14,15].

The environmental tests included in the qualification testing is climatic sequence, condensation, vibration and shock. The effects of vacuum operation, rapid depressurisation, radiation (including ionizing radiation, solar and UV radiation) have all been investigated during the evaluation process. Any effects of these loads will be related to technology and design and not to production, and it will therefore not be necessary to repeat the tests in the qualification test programme.

The tests for component endurance includes measurements of long term high temperature exposure (ageing).

The mechanical tests are performed to ensure that the components meet the specified mechanical requirements. The tests include strength of fibre attachment (fibre pulling, axial compression, flex and torsion) and crush resistance. Testing with respect to drop, bump and impact is not included because this is all testing of the package. These characteristics are evaluated in the evaluation phase, and production related failures will probably be revealed by the test with respect to crush resistance. Mechanical properties which may effect the internal mounting of the component, for example acceleration, are covered by the vibration and shock tests.

Each group consists of 4 attenuators. The number of samples are chosen to get an indication of the spread in values. The qualification test programme uses few devices for each test, thus all samples shall meet the requirements.

10.5.2 Environmental tests

10.5.2.1 Climatic sequence

Test method: 10.4.1

10.5.2.2 Condensation

Test method: 10.4.5

10.5.2.3 Vibration

Test method: 10.3.1

10.5.2.4 Shock

Test method: 10.3.2

10.5.3 Endurance tests

10.5.3.1 Ageing

In those cases were the component is intended to be used in a humid atmosphere, the component shall be exposed to humidity at a specified level together with the high temperature level. Humidity may induce changes and failures not seen in an atmosphere of dry heat.

Test method: 10.4.14

10.5.4 Mechanical tests

10.5.4.1 Strength of attachment of fibre

Test method: 10.3.8

10.5.4.2 Crush resistance

Test method: 10.3.3

10.6 Lot acceptance testing

Lot acceptance testing (LAT) shall be performed on every lot delivered by the manufacturer. The purpose of the tests which have been included in the LAT-test programme is discussed in 10.2. The sequence of the tests in each level is discussed in 10.2 and 10.5.

LAT is divided in three levels, as discussed in Chapter 4. LA2 and LA1 are considered destructive, and the tested samples shall not form part of the delivered lot.

All tested samples shall meet specifications.

The LAT shall be carried out in accordance with Chart 10.4

10.6.1 Lot acceptance level 3 testing (LA3)

All components are subjected to a detailed final production control. Measurements performed in the LA3 testing are repetition of these measurements, performed by different personnel to ensure the quality of the delivered item as well as a control of the routine measurements performed in the final production control.

10.6.1.1 Visual inspection

The visual inspection shall be performed in accordance with ESA/SCC Basic Specification No 20500.

10.6.1.2 Attenuation

The measurement shall be performed over the specified wavelength range.

Test method: 10.2.1/10.2.3

10.6.2 Lot acceptance level 2 testing (LA2)

In addition to the tests included in the LA3 testing, the LA2 is comprised of tests with respect to long term temperature and strength of fibre attachment. The tests are considered destructive. The test with respect to the strength of the fibre attachment is performed after the ageing test to reveal any ageing related defects.

10.6.2.1 Ageing

The test shall include humidity if required by the application.

Test method: 10.4.14

10.6.2.2 Strength of attachment of fibre

Test method: 10.3.8

10.6.3 Lot acceptance level 1 testing (LA1)

In addition to the tests included in the LA2 testing, the LA1 is comprised of tests with respect to mechanical and environmental properties. The tests are considered destructive. The sequence is discussed in 10.2 and 10.5.

10.6.3.1 Temperature extremes

Test method: 10.4.2

10.6.3.2 Vibration

Test method: 10.3.1

10.6.3.3 Condensation

Test method: 10.4.5

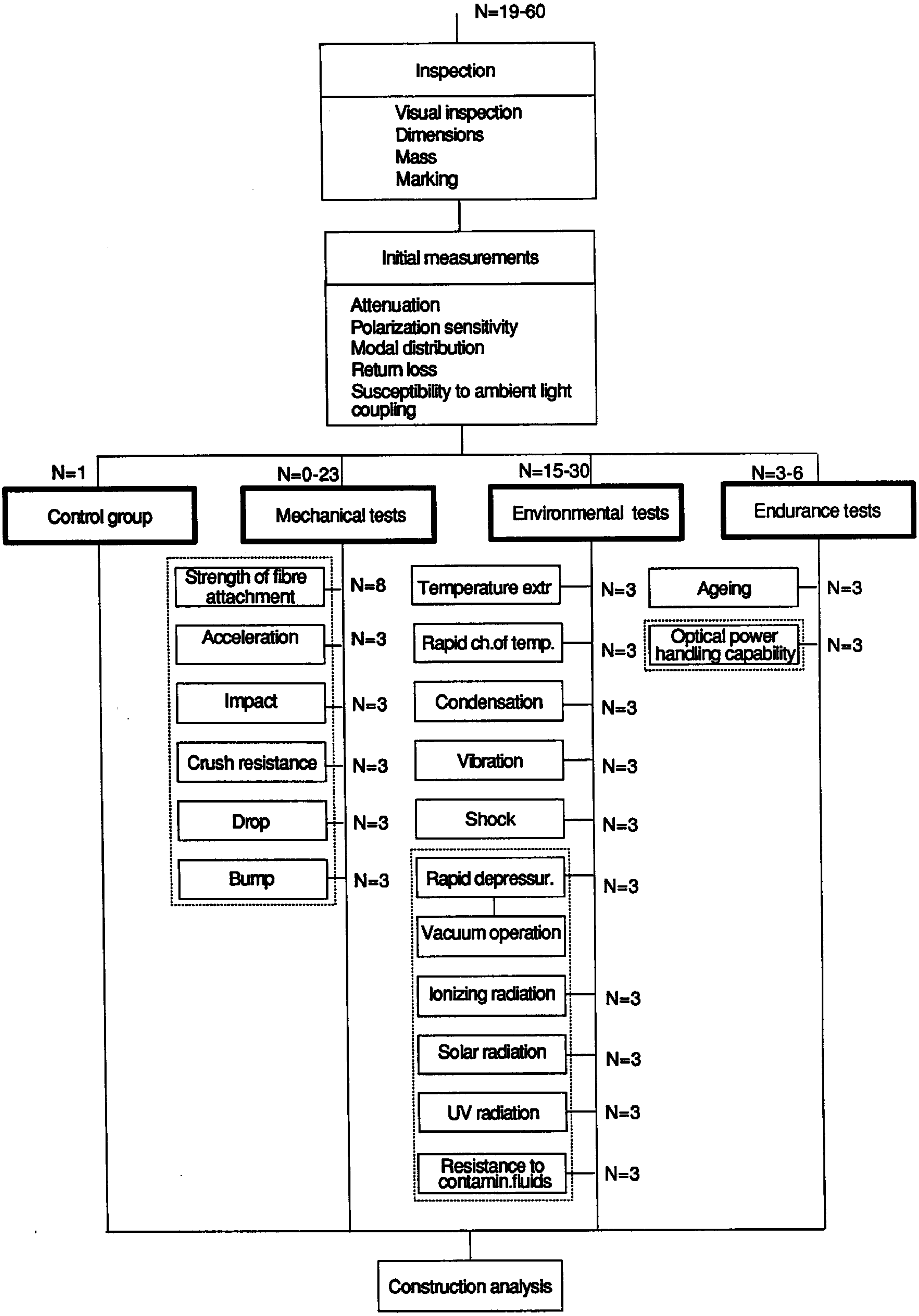

Chart 10.1 Evaluation testing for fibre optic attenuators

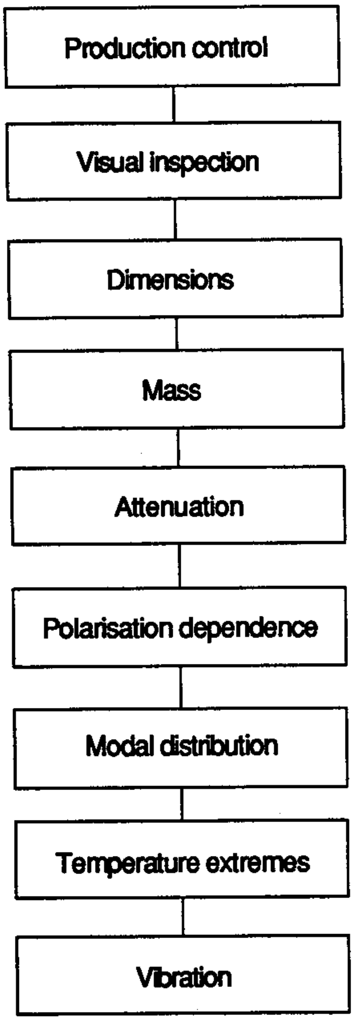

Chart 10.2 Final production testing for fibre optic attenuators

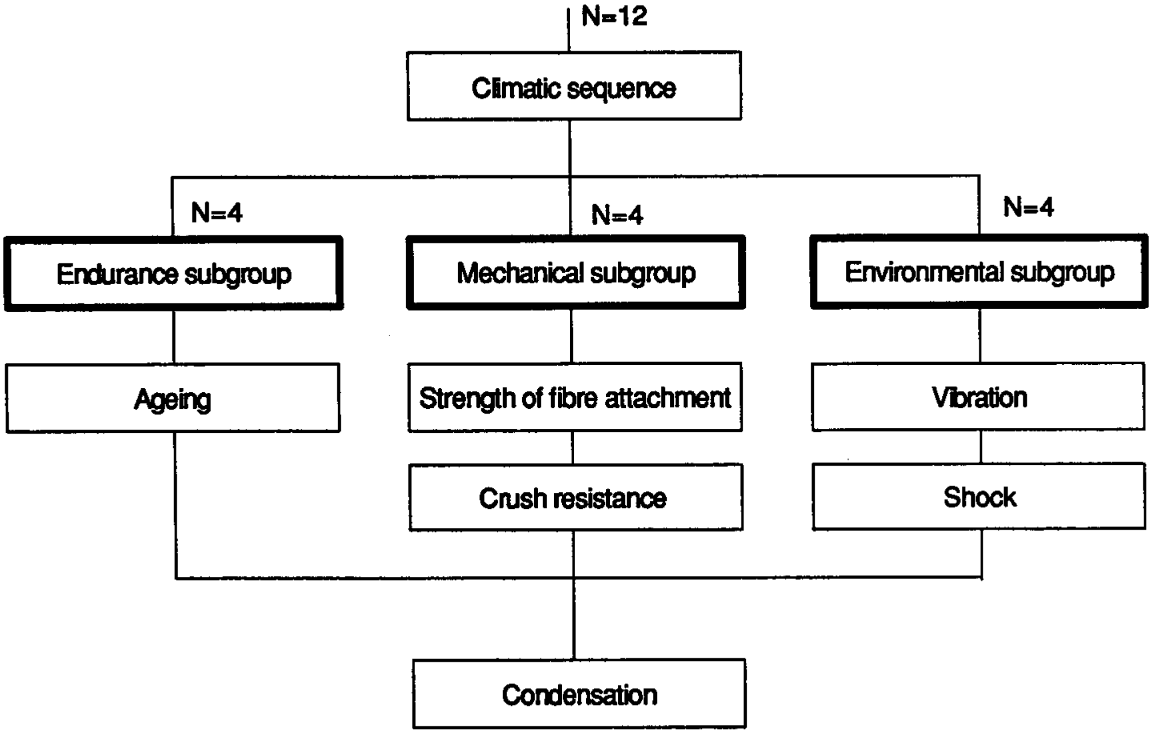

Chart 10.3 Qualification testing for fibre optic attenuators

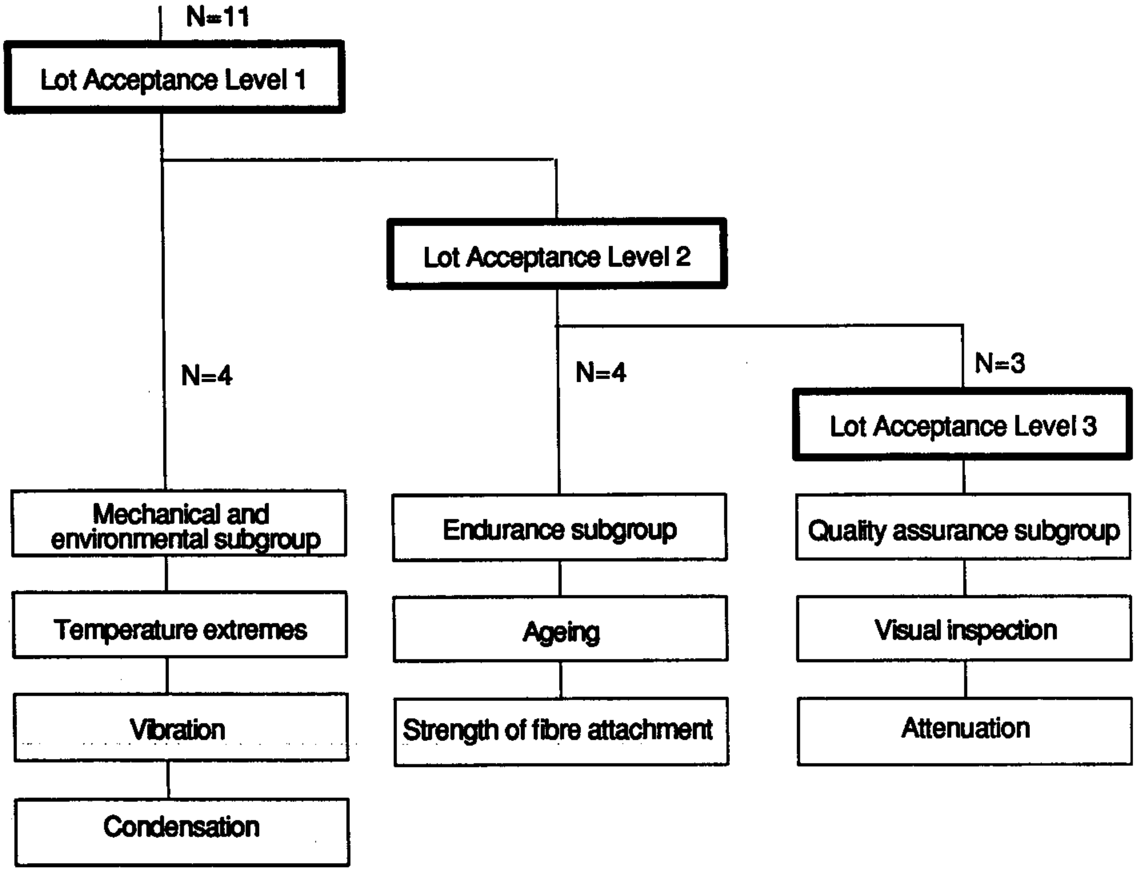

Chart 10.4 Lot acceptance testing for fibre optic attenuators

11 FIBRE OPTIC BRANCHING DEVICES (COUPLERS)

11.1 Introduction

Fibre optic branching devices are passive components that combine or split the incoming light in a predetermined fashion. Fibre optic branching devices are manufactured using several different technologies, i.e. fused biconical taper, micro-optics, and waveguides formed on either electro-optical materials or glass substrates (integrated optics).

In fused biconical taper devices the transfer coefficients between the different input and output ports are determined by the characteristics of the area where the fibres are fused together. The coupling ratio is measured during fusion to obtain the desired characteristics.

In micro-optics devices the coupling is achieved by using miniature versions of bulk optical devices such as lenses, mirrors, beamsplitters etc. The component is strongly dependent on the mechanical alignment of the different components, which have to be screwed or glued in position.

In integrated optic devices the coupling is determined by the waveguide structure in the substrate. This structure is made by the exchange of ions and determined by a mask. The same mask can be used for several components, and several components can be made from a single wafer. The difference between a substrate made of glass and a substrate made of electro-optical material is that in devices made of the latter the waveguide properties can be changed by applying an electric field. In passive fibre optic branching devices this attribute is not necessary because the transfer coefficients are meant to be constant throughout the lifetime of the component. Electro-optical materials are used in switches.

Devices based on the different technologies will have different characteristics with respect to environmental loads such as temperature and vibration because of the different optical design. The mechanical properties will mainly be determined by the packaging and the mounting of the fibre. The sample selection will depend on the technology involved. Fused devices and micro-optic devices are manufactured on a one to one basis while the integrated devices are manufactured in a more automated manner using the same mask and the same wafers for several components.

The characteristics of the fibre optic component is strongly dependent on the packaging. Nominally the same component, but with different packaging should therefore be tested and qualified separately.

The general test strategy is described in Chapter 4 and will also be followed here. Each test method has been given a number, and these numbers are tabulated and described in Part 3 Ch.11.

11.2 Evaluation testing

11.2.1 Purpose

The purpose of the evaluation testing is to determine the operational limits of the fibre optic branching device with respect to critical mechanical and environmental parameters, to overstress specific characteristics in order to identify failure modes, to demonstrate the suitability of the branching device for proceeding on to qualification testing and to get information which can be of value for a detailed planning of the test programme to be used in the procurement of the component.

11.2.2 Properties to evaluate

The main properties of interest are :

- mechanical properties
- effects of high levels of vibration and shock
- effects of temperature extremes
- effects of rapid depressurisation and vacuum operation
- effects of ionizing radiation
- effects of solar radiation and UV radiation
- resistance to solvents and contaminating fluids

For some special applications the optical power handling capability may be of concern.

It is expected that the fibre used in the input/output ports of the component is characterised with respect to space applications. It is thus not necessary to include tests for fibre properties such as bandwidth, coating dimensions, numerical aperture, etc. in the evaluation of the passive device. The characteristics of the fibre with respect to environmental loads such as ionizing radiation and temperature extremes should also be known.

Coatings, buffers and materials used in the packaging shall be space qualified, see Chapter 4. However, an evaluation related to their properties may be necessary to eliminate any undesired interactions between the various materials and effects of changes in the material properties on the behaviour of the device.

The flammability of the branching device is not expected to be of special concern. The materials used in the component should all undergo a test with respect to flammability in the material evaluation, see Chapter 4. These properties will not depend on the manufacturing or the assembly of component, and the test is thus not included. A test with respect to dust is not included because this is not expected to be of special concern in space applications. A test with respect to corrosive atmosphere is not included either. The materials in the component will be tested with respect to resistance to corrosion in the material evaluation, see Chapter 4, and the property is not expected to be critical to the performance of the device, as it is not meant to be mated like for instance a connector.

11.2.2.1 Mechanical properties.

The optical components as well as the packaging must withstand mechanical loads such as crush, impact, drop, bump and acceleration. In addition, the fibre attachment should be tested with respect to pulling, axial compression, flex and torsion. The largest mechanical loads are expected to occur during installation. The mechanical loads will therefore be imposed on the component before it is exposed to environmental effects. The mechanical properties such as strength of fibre attachment and resistance to crush, drop, impact and bump are determined by the package. A manufacturer of fibre optic components may apply the same mechanical design to several types of components (couplers, WDMs, isolators and attenuators). It will therefore not be necessary to evaluate these properties for each component type if it has previously been evaluated with another component with identical package.

11.2.2.2 Temperature extremes

A fibre optic branching device will be comprised of several materials with probably different coefficient of thermal expansion. This may lead to misalignment of the different components and increased insertion loss during temperature cycling. Thermal expansion may also induce microbend loss on the fibres within the component. Fused fibre optic branching devices are usually made of bare fibres packed in an external protection sleeve. When the coupler is exposed to thermal variation, the bare fibres inside the package may be subjected to excessive strain due to different thermal expansion from that of the package. For devices based on waveguides the main temperature effect is expected to be related to the mounting of the fibre pigtails to the substrate.

If the device is intended to be used in applications where it may be exposed to humidity, this shall be included in the evaluation test programme. Humidity and temperature extremes may induce other failure mechanisms than dry heat [17].

11.2.2.3 Rapid change of temperature

Rapid change of temperature may cause excessive tension as the thermal response of the component may be slower than the rate of change of temperature. Large thermal gradients across the component may therefore arise, challenging the mechanical alignment and the strength of the mounting of each part of the component. The components involved are, however, quite small which should reduce the effect of rapid change of temperature.

11.2.2.4 Rapid depressurisation

Rapid depressurisation may cause mechanical stresses because trapped air in pockets inside the component may give large pressure gradients. Fibre optic branching devices can be made quite compact (integrated devices), but fused devices and devices based on micro-optics are dependent on the refractive index of the media surrounding the fused region and the optical components, respectively. The components inside the device is therefore usually filled with air [17].

The test with respect to the effect of rapid depressurisation will not be necessary if devices with similar structure have been previously evaluated. This applies to devices with different functions (branching devices, WDM, isolators), but with nominally the same package.

11.2.2.5 Vacuum operation

The materials used in the branching device shall all be space qualified, see Chapter 4. This means that the effects of vacuum operation (outgassing, change of material properties) should be very small. Interactions between the different media may, however, arise with deleterious effects such as misalignment of the different parts of the component and mechanical stresses.

The test with respect to vacuum operation might not be necessary if devices with a similar structure have been previously evaluated. This applies to devices with different functions (branching devices, WDM, isolators), but with nominally the same package.

11.2.2.6 Ionizing radiation

In space applications fibre optic components are exposed to high levels of ionizing radiation which may induce losses in the optical components as well as change the properties of the other materials in the package. Even if all the materials are space qualified, see Chapter 4, interactions may occur. Any possible interaction should be revealed during the evaluation of the component.

The test with respect to the effects of ionizing radiation might not be necessary if devices with identical optical design, but slightly different package (with respect to mechanical design, but not to material selection) have been previously evaluated.

11.2.2.7 Solar and UV radiation

Solar and UV radiation could affect the properties of the material in the package. If the branching device is not properly designed, solar and UV radiation may also be coupled into the optical path and interfere with the signal propagation.

The test with respect to solar and UV radiation might not be necessary if devices with the identical optical design, but slightly different package (with respect to mechanical design, but not to material selection) have been previously evaluated.

11.2.2.8 Resistance to solvents and contaminating fluids

During installation or service the component might be exposed to solvents and contaminating fluids. These fluids may deteriorate the materials in the component and thereby the performance.

11.2.2.9 Optical power handling capability

The power handling capability of a fibre optic branching device can be limited by four different phenomena:

- heating due to absorbed power
- radiation induced colour centres which will cause loss
- various non-linear optical effects
- formation of cracks, pits, etc.

As with optical fibres, the fibre optic branching device is usually operated at wavelengths with low loss and power levels in the order of 1 mW or less. The above phenomena will only be of concern in special applications were the component is used to transmit high power levels.

11.2.3 Sample distribution and test programme sequence

11.2.3.1 Sample distribution

The fibre optic branching devices shall be selected at random from a representative production lot. The size of the lot shall be 2 times to 3 times the total number of the selected samples. For fibre optic branching devices based on fused technology and micro-optics, the branching devices are selected at random. For fibre optic branching devices based on planar waveguide technology the fibre optic branching devices shall be selected from three different wafers.

Number of samples: 19-60, dependent on the extent of the test programme, as discussed in the text

The number of devices needed for the evaluation test programme is quite extensive. New devices are used for each test, both because each test is considered destructive and to be able to distinguish between the effects of the different parameters. The number of samples for each test is shown in Chart 11.1 (see end of Chapter). In order to get a picture of the spread in values, the number of samples of each test is 3 or larger. The evaluation test programme will give a better picture of the statistical fluctuations if more components were used for each test. A sample size of 3 will however, give an indication of the variations. If large variations are observed, the number of samples should be increased.

11.2.3.2 Test range and failure criteria

The different tests are performed on a step stress basis. This means that the load is increased in steps from a starting value. Generally, the load is increased until the component has suffered physical destruction or a substantial deterioration in performance, as appropriate. In some of the tests the upper stress limit is determined from the most severe loads expected, as listed in Chapter 4, with some margin added. If more severe loads are expected, the upper test level should be increased accordingly.

The criteria for defining the component as failed is dependent on the performance of the component and the initial value of the parameter. For transmission paths were the signal is meant to be transmitted the insertion loss should be as small as possible. The allowable insertion loss variation in these transmission paths are chosen on the basis of the nominal value, which is determined by the number of input and output ports. We have chosen to use the same criteria as Bellcore [18], see Table 11.1. For transmission paths were the transfer coefficient nominally is zero, the criteria for failure is that the transfer coefficient shall not exceed the specified value.

Coupler configuration		**Insertion loss variation**
Number of input ports	**Number of output ports**	**(dB)**
1 to 2	1 to 2	± 1.0
3 to 8	3 to 8	± 2.0
9 to 32	9 to 32	± 4.0

Table 11.1 Maximum allowable variation in insertion loss [18]

All results shall be recorded.

11.2.3.3 Test programme sequence

The specified tests are summarised in Chart 11.1. The mechanical and environmental tests which may be dependent on application and previous evaluation of similar components, are shown in a dotted box.

The initial measurements are all optical measurements and will not have any influence on the properties of the tested components. The indicated order is based on the importance of the different parameters. The optical branching efficiency is measured first to establish the basic performance of the device. The optical branching efficiency shall be measured over the wavelength range of interest. The polarization sensitivity and the dependence on the modal distribution is then measured to establish the sensitivity of the performance to the characteristics of the incoming light.

For the mechanical, environmental and endurance tests new test samples are used for each test. The test order will therefore not affect the test result and is as such of no importance. It is generally recommended to perform the easiest and least expensive tests first and the more complicated and expensive tests in the end. If the component fails during the cheap and least expensive part of the test programme, it can be stopped before large expenses have been incurred.

We suggest to do the mechanical tests first. This is a test of the component's and the package's ability to withstand mechanical loads and the package's ability to protect the optical part of the component. The strength of fibre attachment is tested first. This will be an important property during installation and handling of the component of the system. The resistance to acceleration, impact, drop, bump and crush is tested thereafter.

The environmental tests are performed after the mechanical tests. We recommend to do the temperature tests first. Testing with respect to temperature will both reveal fundamental temperature dependent properties of the optical design and temperature dependent properties of the assembly. The temperature tests include testing with respect to temperature extremes, rapid change of temperatures and condensation. The test with respect to temperature extremes shall be performed first to establish the limits for the other tests.

The tests with respect to the effects of vibration and shock are tested before the vacuum and ionizing radiation test. The materials applied in the component are, in advance, tested with respect to such material related effects. The latter tests are performed to ensure that no unexpected effects occur. The characteristics of the component when it is exposed to loads such as vibration and shock is less predictable and in addition easier and less expensive to perform.

The tests with respect to the effects of rapid depressurisation and vacuum operation are performed on the same samples. The effects of rapid depressurisation should be tested before the effects of vacuum operation. If the device fails in the rapid depressurisation test, there will be no point in proceeding to the test with respect to vacuum operation.

The effect of radiation (ionizing as well as solar and UV radiation) is tested in the end, such that only components that have passed the other tests are subjected to this test. Radiation resistance is a fundamental requirement for components in space applications. The device should be based on materials and fibres exhibiting minimal radiation effects, and the test is performed to ensure that no unexpected effects will occur.

If the resistance to solvents and contaminating fluids is of concern, this shall also be measured.

The endurance tests are ageing and optical power handling capability, if applicable. The conditions during the ageing test are determined by the test with respect to temperature extremes. The test will thus have to be started after this test. This is a long term test with measurements at regular intervals and can be performed in parallel with the other tests.

11.2.3.4 Use of control group

The use of a control group is not considered necessary in the mechanical and environmental tests. In these tests the parameters of interest are usually monitored while the test is performed. The stability of the source output and the repeatability of the measurements are ensured by a control of the output power. If the post test investigations include optical measurements not performed during the test, the measurements shall also be performed on the control group. This may include measurements of optical branching efficiency as a function of signal wavelength and measurements of transfer coefficients which nominally are zero.

A control group is used in the construction analysis to be able to compare the devices that have been exposed to environmental and mechanical loads with a "fresh" sample.

11.2.3.5 Post test investigation

The standard test procedures given in Chapter 11 Part 3 often specify that after the exposure to mechanical or environmental load is completed, some measurements should be made to look for permanent changes in one or more critical properties. In the evaluation programme there are in many cases specified additional tests to analyse the failure mechanisms, but also to reveal whether the load has induced changes not observed directly during the tests or revealed by the standard post test investigations. An example of such a test would be testing of the strength of fibre or cable entry after the test with respect to temperature extremes, to investigate whether temperature extremes have affected the materials in the fibre attachment in such a way that the strength is reduced.

11.2.4 Inspection

The purpose of the inspection is to make sure that the samples are suited for testing. All samples shall be inspected.

11.2.4.1 Visual inspection

The visual inspection shall be carried out in accordance with ESA/SCC Basic Specifications No. 20500.

11.2.4.2 Dimensions

Test method: 11.1.1

11.2.4.3 Mass

Test method: 11.1.2

11.2.4.4 Marking

All samples shall be marked in accordance with the standard procedure of the manufacturer.

11.2.5 Initial measurements

The purpose of the initial measurements is to determine the initial values of the most important optical parameters. The result from these initial measurements will be used as a basis for the evaluation of later measurements. Further, one wants to ascertain that the various samples meet the specified requirements and to get a picture of the spread in values. The spread in values will give an indication of the production control.

The initial measurements shall be performed on all samples.

11.2.5.1 Optical branching efficiency

The measurement shall be performed over the specified wavelength range.
Test method: 11.2.1

11.2.5.2 Polarization sensitivity

The test applies to single mode devices only.
Test method: 11.2.3

11.2.5.3 Modal distribution

The test applies to multimode devices only.
Test method: 11.2.2

11.2.5.4 Susceptibility to ambient light coupling

Test method: 11.2.5

11.2.6 Mechanical tests

The main mechanical properties to test are strength of attachment of fibre which includes tests for pulling, axial compression, flex and torsion. The component should also be tested with respect to mechanical loads such as crush, impact, drop and acceleration.

The optical branching efficiency is measured before and after the test. The transmission through an input/output port which are meant to transmit light, are measured during the test.

11.2.6.1 Strength of attachment of fibre

The test with respect to strength of attachment of fibre includes pulling, axial compression, flex and torsion tests. In some commercial devices input and output ports of the branching device are connectors. In such a case these connectors should be tested for mechanical strength and durability as given by Chapter 7.

11.2.6.1.1 *Pulling*

In this test the fibres constituting the input and output ports of the component is subjected to increasing load until the fibre attachment breaks. The number of samples is chosen to get a picture of the spread in values. For each component each fibre attachment shall be tested on an individual basis.

Number of samples: 2

The tensile force shall be applied smoothly and controlled, the magnitude of the force shall be increased at a specified rate. The tensile force shall be increased until the fibre breaks.
Test method: 11.3.8

11.2.6.1.2 *Axial compression*

The fibre leads of the branching device shall be subjected to axial compression to establish the ability of the retention means to withstand axial compression. The number of samples is chosen to get a picture of the spread in values. For each component each fibre attachment shall be tested on an individual basis.

Number of samples: 2

The axial compression shall be applied smooth and controlled, the magnitude of the force shall be applied with the specified rate. The axial compression shall be increased until the fibre breaks.
Test method: 11.3.8

11.2.6.1.3 *Flex*

The test is intended to determine the ability of the fibre interface and strain relief to withstand flexing. For each component each fibre attachment shall be tested on an individual basis.

Number of samples: 2
Start load: as specified
The load shall be increased in steps of 20% of the initial value until the fibre breaks.
Test method: 11.3.8

11.2.6.1.4. *Torsion*

The test is intended to determine the ability of the fibre attachment to withstand torsion of the fibre. Each fibre shall be tested on an individual basis.

Number of samples: 2

The torque shall be increased until the fibre breaks.
Test method 11.3.8

11.2.6.2 Acceleration

Number of samples: 3
Start acceleration: as specified
The acceleration shall be increased until the component has failed or has suffered physical destruction.
Test method: 11.3.3

11.2.6.3 Impact

Number of samples: 3
Start energy: as specified
The energy in the impact shall be increased in steps of 20 % of the specified value. The load shall be increased until the component has failed or suffered physical destruction.
Test method: 11.3.5

11.2.6.4 Crush resistance

Number of samples: 3
Start force: as specified
The force shall be increased in steps of 20 % of the specified value. The load shall be increased until the component has failed or suffered physical destruction.
Test method: 11.3.4

11.2.6.5 Drop

Number of samples: 3
Start height: as specified

The height shall be increased in steps of 20 % of the initial value. The load shall be increased until the component has failed or suffered physical destruction.
Test method: 11.3.6

11.2.6.6 Bump

Number of samples:	3
Number of bumps:	4000 at each level of acceleration
Start acceleration:	40 g

The acceleration shall be increased in steps of 10 g. The load shall be increased until the component has failed or suffered physical destruction.
Test method: 11.3.7

11.2.7 Environmental tests

11.2.7.1 Temperature extremes

The optical branching efficiency shall be measured in the specified wavelength range at each temperature.

Number of samples:	3, for integrated optics devices the samples shall be taken from different wafers.
Thermal cycling:	first low, then high
Low temperature:	sufficient to induce component failure, but not below - 70°C.
High temperature:	sufficient to induce component failure, but not above 150°C.
Low starting temperature:	lowest specified temperature, or - 40°C if not given.
High starting temperature:	highest specified temperature or 90°C if not given.
Step change in temperature:	10°C
Duration of stay at each temperature:	1 hour
Test method:	11.4.2

11.2.7.1.1 *Post test investigation*

The post test investigation include a repetition of the measurement of optical branching efficiency after the component has reached room temperature. A visual inspection and dimensional check shall be performed on each device to check any changes in material appearance. One of the samples used in the temperature test shall be subjected to constructional analysis. The remaining samples shall be tested with respect to fibre attachment to ensure that the materials in the fibre attachment are not influenced by temperature extremes.

Optical branching efficiency,	ref: 11.2.5.1
Visual inspection,	ref: 11.2.4.1
Dimensions,	ref: 11.2.4.2
Strength of fibre attachment, pulling strength.	ref:11.2.6.1.1
Constructional analysis	ref: 11.2.9

11.2.7.2 Rapid change of temperature

The optical branching efficiency shall be measured as a function of wavelength immediately before and after the temperature change. The insertion loss in the transmission paths were the light is meant to be transmitted shall be monitored during the change of temperature.

Number of samples:	3, for integrated optics devices the samples shall be taken from different wafers
High temperature:	10°C below high temperature limit established in 11.2.7.1
Low temperature:	10°C above low temperature limit established in 11.2.7.1
Rate of change of temperature:	as specified
Test method:	11.4.3

11.2.7.2.1 *Post test investigation*

The optical branching efficiency shall be measured when the component has reached room temperature after the test is finished. A visual inspection shall be performed on the devices. One of the samples shall be subjected to a constructional analysis to investigate whether rapid change of temperature has changed the internal structure of the device.

Optical branching efficiency,	ref: 11.2.5.1
Visual inspection	ref: 11.2.4.1
Constructional analysis	ref: 11.2.9

11.2.7.3 Condensation

The optical branching efficiency shall be measured each time the test conditions/temperature are changed.

Number of samples:	3, for integrated optics devices the samples shall be taken from different wafers
Test conditions:	as specified in IEC 68.2.38
Test method:	11.4.5

11.2.7.3.1 *Post test investigation*

The optical branching efficiency shall be measured after the component has reached room temperature. The devices shall be subjected to a visual inspection and a dimensional check to look for changes in material structure and appearance. Constructional analysis is included in the post test investigation to find out whether combined humidity/heat would change any of the internal materials. The remaining samples shall be tested with respect to strength of fibre attachment to investigate the effect on the materials in the fibre mounting.

Optical branching efficiency,	ref: 11.2.5.1
Visual inspection,	ref: 11.2.4.1
Dimensions,	ref: 11.2.4.2
Strength of fibre attachment, pulling strength,	ref: 11.2.6.1.1
Constructional analysis	ref: 11.2.9

11.2.7.4 Vibration

The insertion loss in the transmission paths were the light is meant to be transmitted shall be monitored during the test.

Number of samples:	3
Vibration frequency:	100-2000 Hz
Starting acceleration:	as specified
The increase in acceleration:	steps of 20% of specified level until the level has reached 30 g or the component has failed
Duration:	90 minutes
Test method:	11.3.1

11.2.7.4.1 *Post test investigation*

The optical branching efficiency shall be measured when the device has settled after the test. The device shall be subjected to a visual inspection to look for changes in structure or appearance. Vibration may induce mechanical fractures not possible to reveal by visual inspection and measurement of optical branching efficiency. One of the samples is therefore subjected to a condensation test. In this test condensed water may freeze in possible cracks and increase the crack. Another sample is subjected to constructional analysis to investigate whether vibration induce any changes in the internal structure of the device.

Optical branching efficiency,	ref: 11.2.5.1
Visual inspection	ref: 11.2.4.1
Condensation	ref: 11.2.7.3
Constructional analysis	ref: 11.2.9

11.2.7.5 Shock

The insertion loss in the transmission paths were the light is meant to be transmitted shall be monitored during the test.

Number of samples:	3
Pulse duration:	0.5 ms
Starting acceleration:	as specified
The increase in acceleration:	steps of 20% of specified level until the level has reached 2000 g or the component has failed.
Test method:	11.3.2

11.2.7.5.1 *Post test investigation*

The optical branching efficiency shall be measured when the device has settled after the test. The device shall be subjected to a visual inspection to look for changes in structure or appearance. Shock may induce mechanical fractures not possible to reveal by visual inspection and measurement of optical branching efficiency. One of the samples is therefore subjected to a condensation test. In this test condensed water may freeze in possible cracks and increase the crack. Another sample is subjected to constructional analysis to investigate whether shock induce any changes in the internal structure of the device.

Optical branching efficiency,	ref: 11.2.5.1
Visual inspection	ref: 11.2.4.1
Condensation	ref: 11.2.7.3
Constructional analysis	ref: 11.2.9

11.2.7.6 Rapid depressurisation

The insertion loss in the transmission paths were light is meant to be transmitted shall be measured during the rapid depressurisation.

Number of samples:	3
Test method:	11.4.15

11.2.7.6.1 *Post test investigation*

The post test investigation shall include measurement of optical branching efficiency of all ports of the tested devices as well as the control group. If any of the components fail, a failed sample shall be subjected to constructional analysis to investigate whether rapid depressurisation may have influenced the internal structure of the branching device. If all components pass the test, they shall be used in the test with respect to vacuum operation (11.2.7.7)

Optical branching efficiency,	ref: 11.2.5.1
Visual inspection,	ref: 11.2.4.1
Constructional analysis,	ref: 11.2.9

11.2.7.7 Vacuum operation

The optical branching efficiency is not measured during the vacuum test, because any changes is expected to be permanent.

Number of samples:	3
Vacuum:	10^{-3} Pa or less
Temperature:	125°C or high temperature limit established in 11.2.7.1, whichever is lower
Duration:	24 hour
Test method:	11.4.4

11.2.7.7.1 *Post test investigation*

The post test investigation shall include measurement of the optical branching efficiency of the tested samples as well as the control group. The device shall be subjected to visual inspection to look for changes in structure or appearance. One of the samples shall be subjected to constructional analysis to investigate whether vacuum operation influenced the internal structure of the device.

Optical branching efficiency,	ref: 11.2.5.1
Visual inspection	ref: 11.2.4.1
Constructional analysis	ref: 11.2.9

11.2.7.8 Ionizing radiation

The optical branching efficiency shall be measured at regular intervals during the exposure.

Number of samples:	3 samples, for integrated optics devices the samples shall be from different wafers
Temperature:	Room temperature
Optical power:	As specified

Wavelength:	As specified
Dose rate:	5 rad(Si)/s
Duration:	The irradiation shall last until the component has failed or the total dose has reached 3 Mrad.
Test method:	11.4.11

11.2.7.8.1 *Post test investigation*

The optical branching efficiency shall be measured when the exposure has been removed. One of the samples shall be subjected to constructional analysis to investigate whether ionizing radiation has influenced the internal structure.

Optical branching efficiency,	ref: 11.2.5.1
Visual inspection	ref: 11.2.4.1
Constructional analysis,	ref: 11.2.9

11.2.7.9 Solar radiation

The optical branching efficiency shall be measured at regular intervals during the test.

Number of samples:	3, for integrated optics devices the samples shall be taken from different wafers
Temperature:	Room temperature
Radiation source:	source with representative spectral output
Duration:	until the component has failed or the maximum anticipated total dose has been reached
Test method:	11.4.12

11.2.7.9.1 *Post test investigation*

The optical branching efficiency shall be measured after the test is completed. The device shall be subjected to a visual inspection to look for changes in structure or appearance. One of the samples shall be subjected to constructional analysis to check whether solar radiation has influenced the materials inside the component.

Optical branching efficiency,	ref: 11.2.5.1
Visual inspection,	ref: 11.2.4.1
Constructional analysis,	ref: 11.2.9

11.2.7.10 UV radiation

The optical branching efficiency shall be measured at regular intervals during the exposure.

Number of samples:	3, for integrated optics devices the samples shall be taken from different wafers
Temperature:	room temperature
Radiation source:	representative UV source
Duration:	until the component has failed or the maximum anticipated total dose has been reached.
Test method:	11.4.10

11.2.7.10.1 *Post test investigation*

The optical branching efficiency shall be measured after the test is completed. The device shall be subjected to a visual inspection to look for changes in structure or appearance. One of the samples shall be subjected to constructional analysis to check whether the materials inside the component has changed during exposure.

Optical branching efficiency,	ref: 11.2.5.1
Visual inspection,	ref: 11.2.4.1
Constructional analysis,	ref: 11.2.9

11.2.7.11 Resistance to solvents and contaminating fluids

Number of samples: 3

The components shall be subjected to the appropriate solvents and fluids. Reference is made to ESA/SCC Generic Specification No 3901, paragraph 9.21. No visible changes in component appearance shall be observed. The optical branching efficiency shall be measured after the test.

Test method: 11.4.13

11.2.8 Endurance tests

11.2.8.1 Ageing

The optical branching efficiency shall be measured at regular intervals during the test.

Number of samples:	3, for integrated optics devices the samples shall be taken from different wafers
Temperature:	20°C above specified operating temperature, but at least 10°C below high temperature limit established in 11.2.7
Duration:	Until the component has failed or the test has lasted 1000 hours.
Test method:	11.4.14

11.2.8.1.1 *Post test investigation*

The optical branching efficiency shall be measured after the test. The device shall also be subjected to a visual inspection and dimensional check to look for changes in the appearance and structure of the device. One of the samples shall be subjected to a constructional analysis to investigate whether long term high temperature has introduced changes in the internal structure Another sample shall be tested with respect to fibre attachment to investigate whether long term high temperature have influenced the materials used in the fibre attachment.

Optical branching efficiency,	ref: 11.2.5.1
Visual inspection,	ref: 11.2.4.1
Dimensions,	ref: 11.2.4.2
Strength of attachment of fibre, pulling strength	ref: 11.2.6.1.1
Constructional analysis,	ref: 11.2.9

11.2.8.2 Optical power handling capability

Number of samples:	3, for integrated optics devices the samples shall be taken from different wafers
Laser source:	as specified

Input power level shall be increased in steps and measurements made of optical branching efficiency

The entrance and exit surfaces shall also be examined for visual damage. Input power level shall be increased until the component has failed or visual damage has occurred. The maximum input level will very likely be limited by the available optical source.

Test method: 11.2.6

11.2.9 Constructional analysis

A sample from the control group and samples exposed to the other tests, as noted under the post test investigation, shall be subjected to constructional analysis. This involves that the package is opened and the internal structure of the device is investigated. The constructional analysis may include investigation of any fracture surfaces. It may also include an examination of the optical path of the system by means of visible light, for example a HeNe laser.

11.3 Production testing

11.3.1 Introduction

A number of non-destructive tests can be performed on a fibre optic branching device during and after production to ensure that all adjustments and other production parameters are according to specifications. The production testing includes geometrical measurements as well as control of the mass of the component. The production control also includes control of some optical properties.

11.3.2 Production control

The optical branching efficiency shall be controlled during production. This applies both to fused devices and micro-optic devices. For fused devices optical the branching efficiency is monitored during fusion to control the characteristics of this region. For devices based on micro-optic design the branching efficiency has to be monitored during the mechanical alignment of the various components. In integrated optics devices, each wafer should be inspected for optical loss prior to dicing [14]. The branching efficiency is controlled at the specified wavelength(s).

The dimensions as well as the mass of all components shall be controlled prior to assembly. This applies to optical components as well as package.

11.3.3 Final production testing

The tests shall be performed according to Chart 11.2. Unless otherwise specified, all samples shall be tested. In addition to a final control of the dimensions and the mass of the device, the optical performance shall be tested. This includes optical branching efficiency, polarisation sensitivity and sensitivity to modal distribution, where applicable. The susceptibility to ambient light coupling is dependent on the optical and mechanical design. The optical design in this respect is not production dependent. Changes in mechanical structure which would change the susceptibility to ambient light coupling will probably be disclosed by the visual inspection. The component shall be temperature cycled and subjected to vibration tests to reveal any failures in mechanical alignment and mounting. The temperature test is performed before the vibration test. Any temperature induced changes in glue or screws should then be revealed by the succeeding vibration test.

11.3.3.1 Visual inspection

To be performed in accordance with ESA/SCC Basic Specification No. 20500.

11.3.3.2 Dimensions

The dimensions of the package as well as the length of the fibre leads shall be controlled.

Test method: 11.1.1

11.3.3.3 Mass

Test method: 11.1.2

11.3.3.4 Optical branching efficiency

The optical branching efficiency shall be measured over the wavelength range of interest. The measurement is included in the final production testing even though it is controlled in the production process to ensure that the package has no influence on the branching efficiency.

Test method: 11.2.1

11.3.3.5 Polarisation sensitivity

Test method: 11.2.3

11.3.3.6 Modal distribution

Test method: 11.2.2

11.3.3.7 Temperature extremes

The component shall be exposed to one temperature cycle. The high and low temperature shall be chosen so that according to specifications, no permanent changes are induced in the component.

Test method: 11.4.2

11.3.3.8 Vibration

Test method: 11.3.1

11.4 Burn-in

Burn-in is not relevant for optical branching devices.

11.5 Qualification testing

The qualification testing shall include all tests of relevance not included in the final production testing. The test programme will therefore not include any test for just optical characteristics since this is covered by the final production testing. The sensitivity to mechanical and environmental loads was evaluated in the evaluation test programme. Several of the characteristics of the device are dependent on design and technology rather than production parameters. It will therefore not be necessary to repeat some of the tests in the qualification test programme. This is noted, as appropriate, in the discussion of the qualification test strategy.

The qualification testing is divided in tests for endurance, mechanical and environmental properties. All samples supplied for testing shall however be exposed to a climatic sequence before it is exposed to the other tests. This climatic sequence is performed to expose mechanical mounting and glue to temperature variations and humidity before any other test is performed, which may change the properties of these components.

All samples are exposed to a condensation test at the end of the test programme. This condensation test includes humidity and temperatures below zero, which may reveal any cracks and failures induced by the mechanical/environmental test programme, but not detected by the post test investigations. A similar environmental stress sequence is also seen in other test programmes [14, 15].

The environmental tests included in the qualification testing is climatic sequence, condensation, vibration and shock. The effects of vacuum operation, rapid depressurisation, radiation (including ionizing radiation, solar and UV radiation) have all been investigated during the evaluation process. Any effects of these loads will be related to technology and design and not to production, and it will therefore not be necessary to repeat the tests in the qualification test programme.

The tests for component endurance includes the effects of long term temperature endurance (ageing).

The mechanical tests are performed to ensure that the components meet the specified mechanical requirements. The tests include strength of fibre attachment (fibre pulling, axial compression, flex and torsion) and crush resistance. Testing with respect to drop, bump and impact is not included because this is all testing of the package. These characteristics are evaluated in the evaluation phase. Production related failures will probably be revealed by the test with respect to crush resistance. Mechanical properties which may effect the internal mounting of the component, for example acceleration, are covered by the vibration and shock tests.

Each group consists of 4 branching devices, for integrated optics devices the samples shall be taken from three different wafers. The number of samples are chosen to get an indication of the spread in values. The qualification test programme uses few devices for each test, thus all samples shall meet the requirements.

11.5.2 Environmental tests

11.5.2.1 Climatic sequence

Test method: 11.4.1

11.5.2.2 Condensation

Test method: 11.4.5

11.5.2.3 Vibration

Test method: 11.3.1

11.5.2.4 Shock

Test method: 11.3.2

11.5.3 Endurance tests

11.5.3.1 Ageing

In those cases were the component is intended to be used in a humid atmosphere, the component shall be exposed to humidity at a specified level together with the high temperature level. Humidity may induce changes and failures not seen in an atmosphere of dry heat.

Test method: 11.4.14

11.5.4 Mechanical tests

11.5.4.1 Strength of attachment of fibre

Test method: 11.3.8

11.5.4.2 Crush resistance

Test method: 11.3.4

11.6 Lot acceptance testing

Lot acceptance testing (LAT) shall be performed on every lot delivered by the manufacturer. The purpose of the tests which have been included in the LAT-test programme is discussed in 11.2. The sequence of the tests in each level is discussed in 11.2 and 11.5.

LAT is divided in three levels, as discussed in Chapter 4. LA2 and LA1 are considered destructive, and the tested samples shall not form part of the delivered lot.

All tested samples shall meet specifications.

The LAT shall be carried out in accordance with Chart 11.4

11.6.1 Lot acceptance level 3 testing (LA3)

All components are subjected to a detailed final production control. Measurements performed in the LA3 testing are repetition of some of these measurements, performed by different personnel to ensure the quality of the delivered item as well as a control of the routine measurements performed in the final production control.

11.6.1.1 Visual inspection

The visual inspection shall be performed according to ESA/SCC Basic Specification No 20500.

11.6.1.2 Optical branching efficiency

The measurement shall be performed over the specified wavelength range.
Test method: 11.2.1

11.6.2 Lot acceptance level 2 testing (LA2)

In addition to the tests included in the LA3 testing, the LA2 is comprised of tests with respect to ageing and strength of fibre attachment. The tests are considered destructive. The test with respect to the strength of the fibre attachment is performed after the ageing test to reveal any ageing related defects.

11.6.2.1 Ageing

The test shall include humidity if required by the application.

Test method: 11.4.14

11.6.2.2 Strength of attachment of fibre

Test method: 11.3.8

11.6.3 Lot acceptance level 1 testing (LA1)

In addition to the tests included in the LA2 testing, the LA1 is comprised of tests with respect to mechanical and environmental properties. The tests are considered destructive. The sequence is discussed in 11.2 and 11.5.

11.6.3.1 Temperature extremes

Test method: 11.4.2

11.6.3.2 Vibration

Test method: 11.3.1

11.6.3.3 Condensation

Test method: 11.4.5

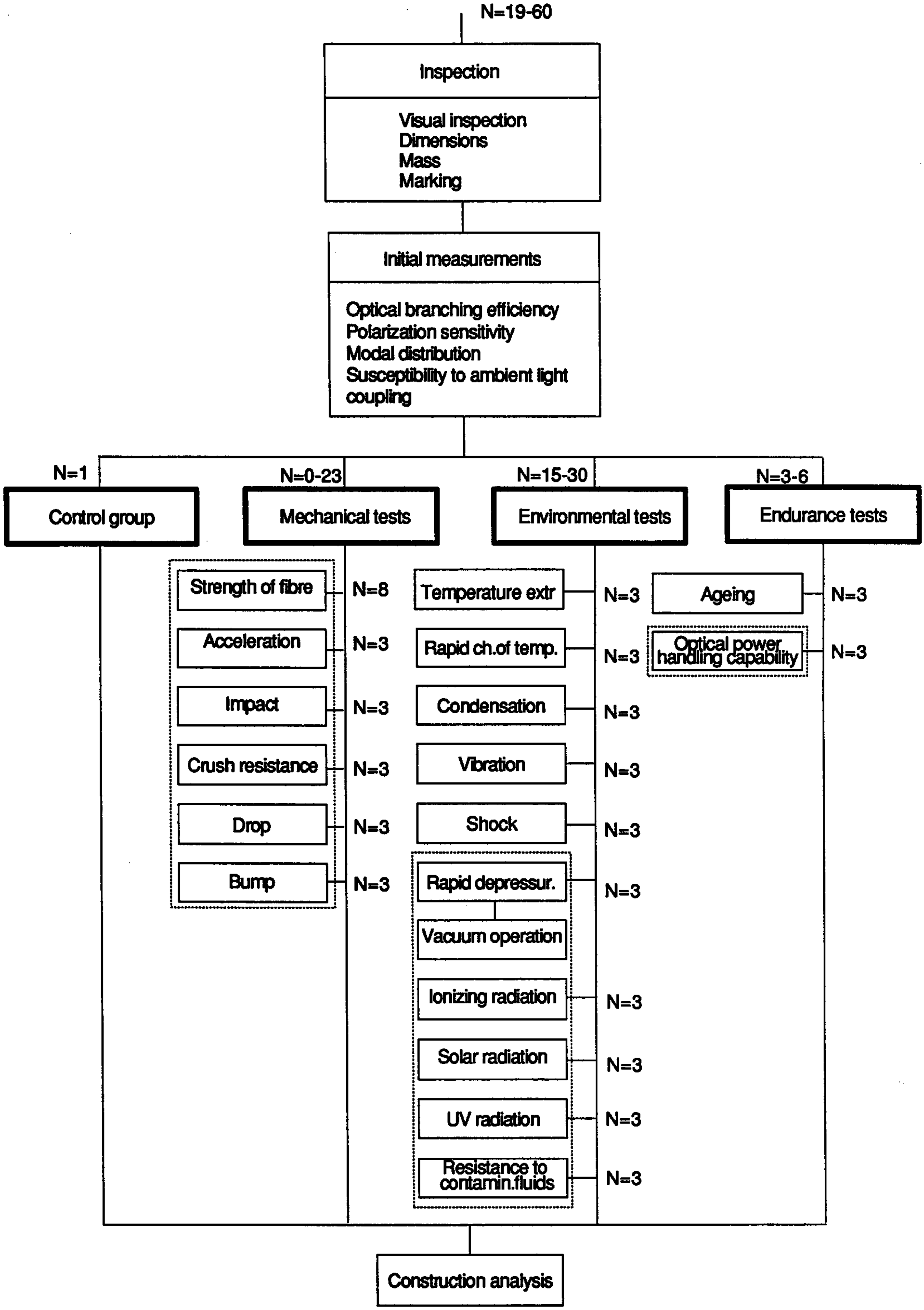

Chart 11.1 Evaluation testing for fibre optic branching devices

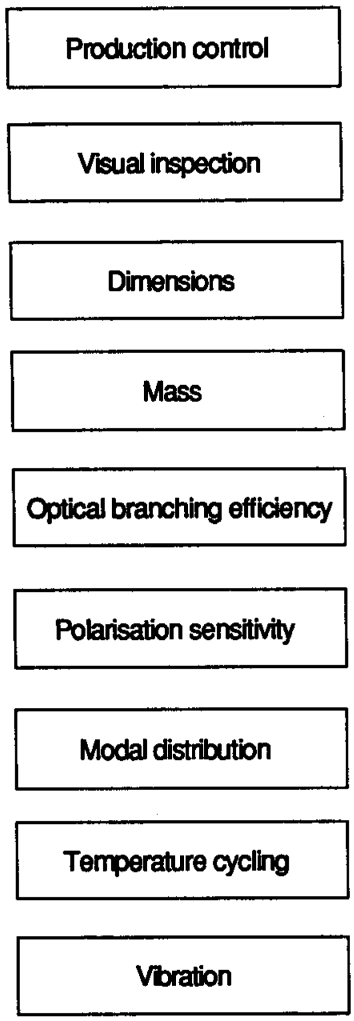

Chart 11.2 Final production testing for fibre optic branching devices

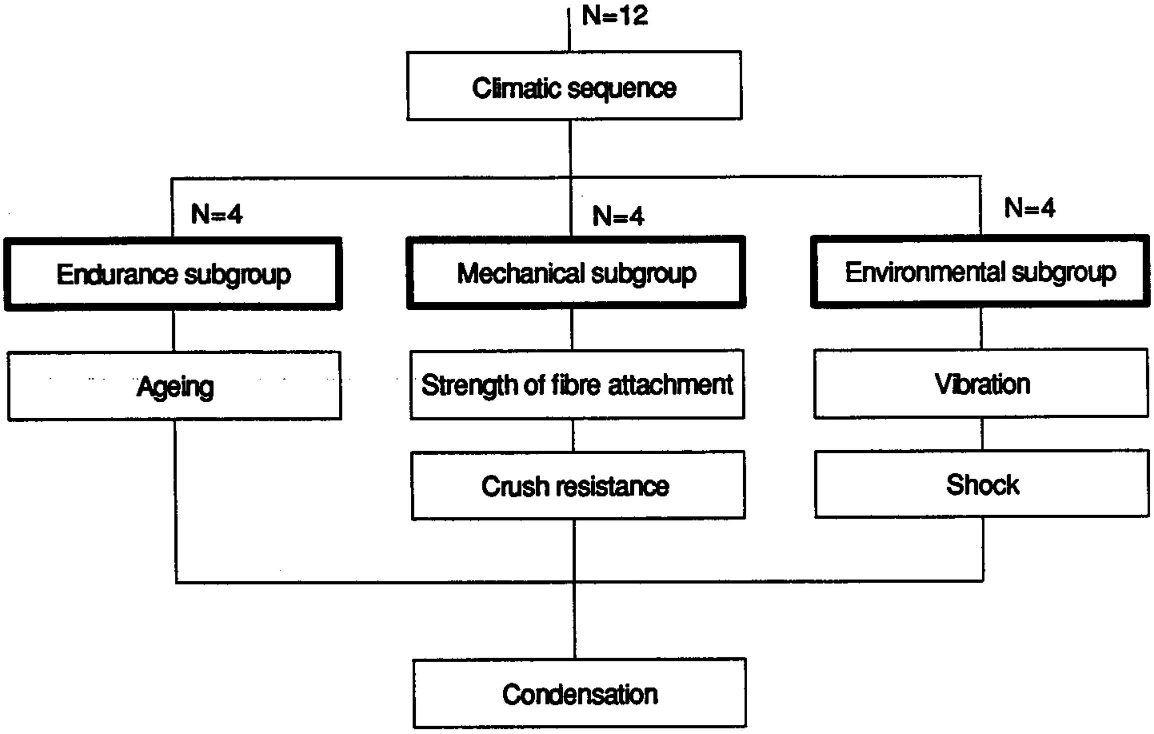

Chart 11.3 Qualification testing for fibre optic branching devices

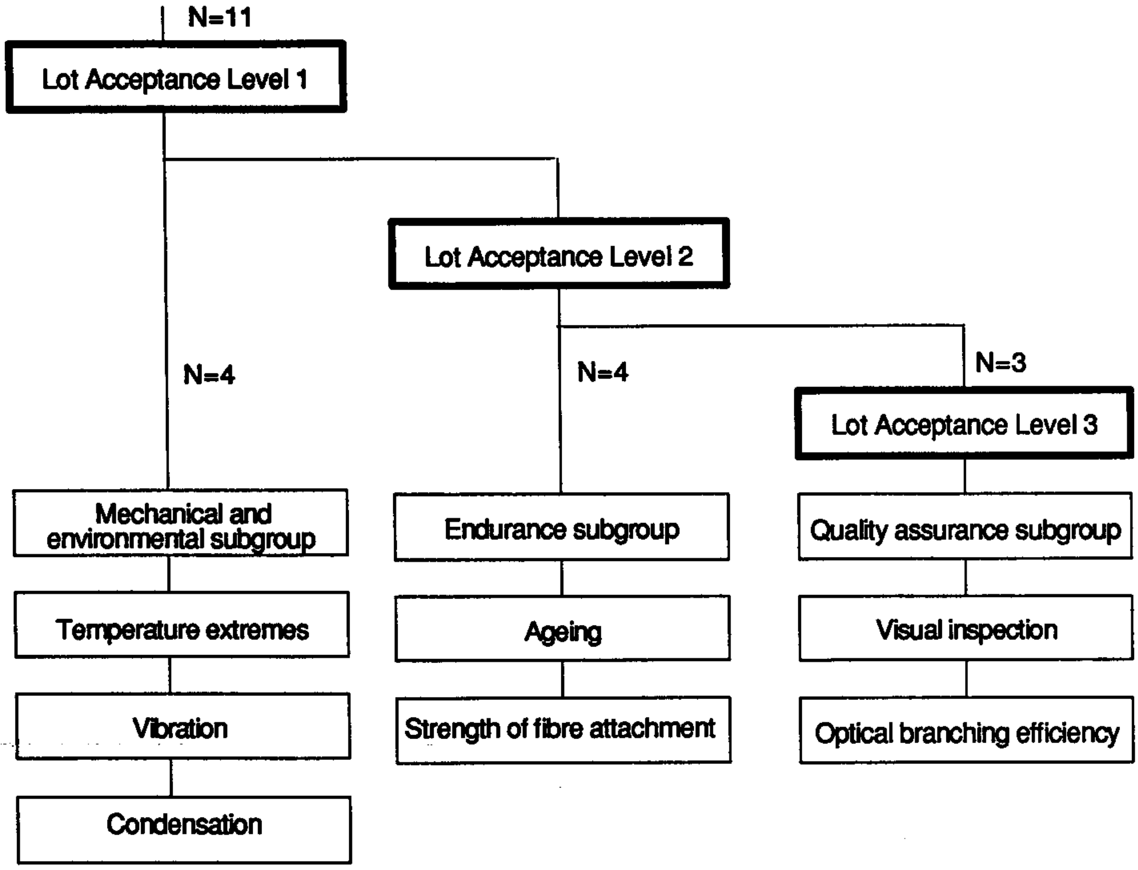

Chart 11.4 Lot acceptance testing for fibre optic branching devices

12 FIBRE OPTIC SWITCHES

12.1 Introduction

Fibre optic switches are devices that upon demand couples the input light from one output port to another. The difference between a switch and a branching device is that it is possible to choose the optical path through the component. In branching devices the paths and the transfer coefficients are constant.

Fibre optic switches are either based on mechanical alignment of optical components or waveguide technology. In switches based on mechanical alignment, the light beam or the fibre is moved from one position to another. The actuating mechanism can either be mechanical or electrical. Switches with electrical actuating mechanism may apply piezo electric elements or magnets to move mirrors, lenses etc.

Switches based on waveguide technology are made on substrates of electro-optical materials. $LiNbO_3$ is the most common material in such switches. The properties of the waveguide can be changed by applying an electric field, and in this way light is switched from one output to the other.

The sample selection will depend on the technology involved. Fused devices and micro-optics devices are manufactured on a one to one basis while integrated devices are manufactured in a more automated manner using the same mask and the same wafer for several components.

Both electrical and integrated optics switches are dependent on an electric field. They are therefore not strictly passive components. The optical transmission is, however, passive (no amplification or conversion from electrical to optical energy), and they are thus considered to belong to the group of passive fibre optic devices.

Mechanical and electrical switches will be dependent on movement of components inside the device. They will therefore be vulnerable to loads such as vibration and shock.

The characteristics of the fibre optic component is strongly dependent on the packaging. Nominally the same component, but with different packaging should therefore be tested and qualified separately.

The general test strategy is described in Chapter 4 and will also be followed here. Each test method has been given a number, and these numbers are tabulated and described in Part 3 Ch.12

12.2 Evaluation testing

12.2.1 Purpose

The purpose of the evaluation testing is to determine the operational limits of the fibre optic switch with respect to critical mechanical and environmental parameters, to overstress specific characteristics in order to identify failure modes, to demonstrate the suitability of the switch for proceeding on to qualification testing and to get information which can be of value for a detailed planning of the test programme to be used in the procurement of the component.

12.2.2 Properties to evaluate

The main properties of interest are :

- mechanical properties
- effects of high levels of vibration and shock
- effects of temperature extremes
- effects of external electromagnetic fields
- effects of rapid depressurisation and vacuum operation
- effects of ionizing radiation
- effects of solar radiation and UV radiation
- actuating mechanism
- resistance to solvents and contaminating fluids

For some special applications the optical power handling capability may be of concern.

It is expected that the fibre used in the input/output ports of the component is characterised with respect to space applications. It is thus not necessary to include tests for fibre properties such as bandwidth, coating dimensions, numerical aperture, etc. in the evaluation of the passive device. The characteristics of the fibre with respect to environmental loads such as ionizing radiation and temperature extremes should also be known.

Coatings, buffers and materials used in the packaging shall be space qualified, see Chapter 4. However, an evaluation related to their properties may be necessary to eliminate any undesired interactions between the various materials and effects of changes in the material properties on the behaviour of the device.

The flammability of the fibre optic switch is not expected to be of special concern. The materials used in the component should all undergo a test with respect to flammability in the material evaluation, see Chapter 4. These properties will not depend on the manufacturing or the assembly of component, and the test is thus not included. A test with respect to dust is not included because this is not expected to be of special concern in space applications. A test with respect to corrosive atmosphere is not included either. The materials in the component will be tested with respect to resistance to corrosion in the material evaluation, see Chapter 4, and the property is not expected to be critical to the performance of the device, as it is not meant to be mated like for instance a connector.

12.2.2.1 Mechanical properties.

The optical components as well as the packaging must withstand mechanical loads such as crush, impact, drop, bump and acceleration. In addition, the fibre attachment should be tested with respect to pulling, axial compression, flex and torsion. The largest mechanical loads are expected to occur during installation. The mechanical loads will therefore be imposed on the component before it is exposed to environmental effects. The mechanical properties such as strength of fibre attachment and resistance to crush, drop, impact and bump are determined by the package. A manufacturer of fibre optic components may apply the same mechanical design to several types of components. It will therefore not be necessary to evaluate these properties for each component type if it has previously been evaluated with another component with identical package.

The fibre optic switch should also be evaluated with respect to the electrical connections (electrical and integrated optics switches). The electrical connections are tested according to the evaluation programme for that particular type of electrical connection.

12.2.2.2 Temperature extremes

A fibre optic switch will be comprised of several materials with probably different coefficient of thermal expansion. This may lead to misalignment of the different components and increased insertion loss during temperature cycling. Thermal expansion may also induce microbend loss on the fibre within the component or put the fibres under tension. For devices based on electro-optical materials temperature variations may induce changes in the electro-optical material. This temperature dependence is inherent in the material and cannot be avoided [19]. The temperature test will not separate this effect from other temperature related effects, but the test will establish the operating temperature range of the device.

If the device is intended to be used in applications where it may be exposed to humidity, this shall be included in the evaluation test programme. Humidity and temperature extremes may induce other failure mechanisms than dry heat.

12.2.2.3 Rapid change of temperature

Rapid change of temperature may cause excessive tension as the thermal response of the component may be slower than the rate of change of temperature. Large thermal gradients across the component may therefore arise, challenging the mechanical alignment and the strength of the mounting of each part of the component. The components involved are, however, quite small which should reduce the effect of rapid change of temperature.

12.2.2.4 Rapid depressurisation

Rapid depressurisation may cause mechanical stresses because trapped air in pockets inside the component may give large pressure gradients. Fibre optic switches based on mechanical alignment involves change of positions of the components. Such switches can therefore not be made compact.

12.2.2.5 Vacuum operation

The materials used in the fibre optic switch shall all be space qualified, see Chapter 4. This means that the effects of vacuum operation (outgassing, change of material properties) should be very small. Interactions between the different media may, however, arise with deleterious effects such as misalignment of the different parts of the component and mechanical stresses.

12.2.2.6 Ionizing radiation

In space applications fibre optic components are exposed to high levels of ionizing radiation which may induce losses in the optical components as well as change the properties of the other materials in the package. Even if all the materials are space qualified, see Chapter 4, interactions may occur. Any possible interaction should be revealed during the evaluation of the component.

Switches based on mechanical alignment are usually comprised of similar components as those found in branching devices, attenuators etc. The effects of ionizing radiation should therefore be quite similar. One might suspect switches based on integrated optics to be more vulnerable to ionizing radiation. Experiments [20] have however, shown that doses in the order of 2 Mrad can be tolerated without significant reduction in device performance.

The test with respect to the effects of ionizing radiation might not be necessary if devices with identical optical design, but slightly different package (with respect to mechanical design, but not to material selection) have been previously evaluated.

12.2.2.7 Solar and UV radiation

Solar and UV radiation could affect the properties of the material in the package. If the switch is not properly designed, solar and UV radiation may also be coupled into the optical path and interfere with the signal propagation.

The test with respect to solar and UV radiation might not be necessary if devices with the identical optical design, but slightly different package (with respect to mechanical design, but not to material selection) have been previously evaluated.

12.2.2.8 Actuating mechanism

The actuating mechanism is either mechanical or electrical. Electrical actuating mechanism is most common since it is the most convenient method to control the switch. An electric actuating mechanism will require a certain power or current level applied to the switch. The actuating mechanism should therefore be tested to ensure that this level is within specification. It should also be tested to establish the tolerances to the level of this signal. The actuating mechanism will have a finite lifetime. The necessary power/current level may change during operation because of change of material properties (integrated optics devices) or mechanical wearout. In such a case it may be possible to restore the function of the switch by changing the level of the actuating signal. The component may also fail because the optical surfaces are damaged during the repetitive operations. In such a case it will not be possible to restore the function of the switch.

12.2.2.9 Resistance to solvents and contaminating fluids

During installation or service the component might be exposed to solvents and contaminating fluids. These fluids may deteriorate the materials in the component and thereby the performance.

12.2.2.10 Optical power handling capability

The power handling capability of a fibre optic switch can be limited by four different phenomena:

- heating due to absorbed power
- radiation induced colour centres which will cause loss
- various non-linear optical effects
- formation of cracks, pits, etc.

As with optical fibres, the fibre optic switch is usually operated at wavelengths with low loss and power levels in the order of 1 mW or less. The above phenomena will only be of concern in special applications were the component is used to transmit high power levels.

<u>12.2.3 Sample distribution and test programme sequence</u>

12.2.3.1 Sample distribution

The fibre optic switch shall be selected at random from a representative production lot. The size of the lot shall be 2 times to 3 times the total number of the selected samples. For electrical and mechanical switches the samples are chosen at random. For fibre optic switches based on integrated optics technology the fibre optic switch shall be selected from three different wafers.

Number of samples: 25-66, dependent on the extent of the test programme, as discussed in the text

The number of devices needed for the evaluation test programme is quite extensive. New devices are used for each test, both because each test is considered destructive and to be able to distinguish between the effects of the different parameters. The number of samples for each test is shown in Chart 12.1 (see end of Chapter). In order to get a picture of the spread in values, the number of samples of each test is 3 or larger. The evaluation test programme will give a better picture of the statistical fluctuations if more components were used for each test. A sample size of 3 will however, give an indication of the variations. If large variations are observed, the number of samples should be increased.

12.2.3.2 Test range and failure criteria

The different tests are performed on a step stress basis. This means that the load is increased in steps from a starting value. Generally, the load is increased until the component has suffered physical destruction or a substantial deterioration in performance, as appropriate. In some of the tests the upper stress limit is determined from the most severe loads expected, as listed in Chapter 4, with some margin added. If more severe loads are expected, the upper test level should be increased accordingly.

The criteria for defining a fibre optic switch as failed is chosen to be a variation in insertion loss of 2 dB.

All results shall be recorded.

12.2.3.3 Test programme sequence

The specified tests are summarised in Chart 12.1. The mechanical and environmental tests which may be dependent on application and previous evaluation of similar components, are shown in a dotted box.

The initial measurements are all optical measurements and will not have any influence on the properties of the tested components. The indicated order is based on the importance of the different parameters. The insertion loss and the crosstalk between the various optical paths will determine the performance of the switch. The stability of optical performance is tested thereafter. This will establish the repeatability of the switch. For integrated devices long term drift have been observed during constant actuating signal [19]. The polarization sensitivity and the effects of the modal distribution is then measured to establish the sensitivity of the performance to the characteristics of the incoming light. The return loss is important in systems where backreflected light may deteriorate the performance of the system or components in the system. The bandwidth will only be of interest for multimode components. A measurement to determine chattering and the speed of the switch will be performed.

For the mechanical, environmental and endurance tests new test samples are used for each test. The test order will therefore not affect the test result and is as such of no importance. It is generally recommended to perform the easiest and least expensive tests first and the more complicated and expensive test in the end. If the component fails during the cheap and least expensive part of the test programme, it can be stopped before large expenses have been incurred.

We suggest to do the mechanical tests first. This is a test of the component's and the package's ability to withstand mechanical loads and the package's ability to protect the optical part of the component. The strength of fibre attachment is tested first. This will be an important property during installation and handling of the component of the system. The resistance to acceleration, impact, drop, bump and crush is tested thereafter.

The environmental tests are performed after the mechanical tests. We recommend to do the temperature tests first. Testing with respect to temperature will both reveal fundamental temperature dependent properties of the optical design and temperature dependent properties of the assembly. The temperature tests include testing with respect to temperature extremes, rapid change of temperatures and condensation. The test with respect to temperature extremes shall be performed first to establish the limits for the other tests.

The sensitivity to external electromagnetic fields is tested thereafter. This is a fundamental property for electrical and integrated optics switches.

The tests with respect to the effects of vibration and shock are tested before the vacuum and ionizing radiation test. The materials applied in the component are, in advance, tested with respect to such material related effects. The latter tests are performed to ensure that no unexpected effects occur. The characteristics of the component when it is exposed to loads such as vibration and shock is less predictable and in addition easier and less expensive to perform.

The tests with respect to the effects of rapid depressurisation and vacuum operation are performed on the same samples. The effects of rapid depressurisation should be tested before the effects of vacuum operation. If the device fails in the rapid depressurisation test, there will be no point in proceeding to the test with respect to vacuum operation.

The effect of radiation (ionizing as well as solar and UV radiation) is tested in the end, such that only components that have passed the other tests are exposed to this test. Radiation resistance is a fundamental requirement for components in space application. The device should be based on materials and fibres exhibiting minimal radiation effects and the test is performed to ensure that no unexpected effects will occur.

If those applications where it is of concern, the resistance to solvents and contaminating fluids shall be tested.

The endurance tests are ageing, test with respect to actuating mechanism and optical power handling capability, if applicable. The conditions of the ageing test are determined by the test with respect to temperature extremes. The test will thus have to be started after this test. Since both the tests with respect to ageing and actuating mechanism are long term tests with measurements only at regular intervals these tests and can be performed in parallel with the other tests.

12.2.3.4 Use of control group

The use of a control group is not considered necessary in the mechanical and environmental tests. In these tests the parameters of interest are usually monitored while the test is performed. The stability of the source output and the repeatability of the measurements are ensured by a control of the output power. If the post test investigations include optical measurements not performed during the test procedure, the measurements shall also be performed on the control group. This may include measurements of insertion loss as a function of signal wavelength.

A control group is used in the construction analysis to be able to compare the devices that have been exposed to environmental and mechanical loads with a "fresh" sample.

12.2.3.5 Post test investigations

The standard test procedures given in Chapter 12 Part 3 often specify that after the exposure to mechanical or environmental load is completed, some measurements should be made to look for permanent changes in one or more critical properties. In the evaluation programme there are in many cases specified additional tests to analyse the failure mechanisms, but also to reveal whether the load has induced changes not observed directly during the tests or revealed by the standard post test investigations. An example of such a test would be testing of the strength of fibre or cable entry after the test with respect to temperature extremes, to investigate whether temperature extremes have affected the materials in the fibre attachment in such a way that the strength is reduced.

12.2.4 Inspection

The purpose of the inspection is to make sure that the samples are suited for testing. All samples shall be inspected.

12.2.4.1 Visual inspection

The visual inspection shall be carried out in accordance with ESA/SCC Basic Specifications No. 20500.

12.2.4.2 Dimensions

Test method: 12.1.1

12.2.4.3 Mass

Test method: 12.1.2

12.2.4.4 Marking

All samples shall be marked in accordance with the standard procedure of the manufacturer.

12.2.5 Initial measurements

The purpose of the initial measurements is to determine the initial values of the most important optical parameters. The result from these initial measurements will be used as a basis for the evaluation of later tests. Further, one wants to ascertain that the various samples meet the specified requirements and to get a picture of the spread in values. The spread in values will give an indication of the production control and be a valuable input to, for instance, the lot acceptance testing programme.

The initial measurements shall be performed on all samples.

12.2.5.1 Insertion loss

The measurement shall be performed over the specified wavelength range.

Test method: 12.2.1

12.2.5.2 Crosstalk

Test method: 12.2.2

12.2.5.3 Stability of optical performance

Test method: 12.2.8

12.2.5.4 Polarization sensitivity

The test applies to single mode devices only.
Test method: 12.2.4

12.2.5.5 Modal distribution

The test applies to multimode devices only.
Test method: 12.2.3

12.2.5.6 Return loss

Test method: 12.2.5

12.2.5.7 Switching speeds and chattering

Test method: 12.2.7

12.2.5.8 Susceptibility to ambient light coupling

Test method: 12.2.6

12.2.6 Mechanical tests

The main mechanical properties to test are strength of attachment of fibre which includes tests for pulling, axial compression, flex and torsion. The component should also be tested with respect to mechanical loads such as crush, impact, drop and acceleration.

The change in insertion loss is measured during the tests.

Any electrical connection shall be tested according to the evaluation programme for that particular connector. The test is performed on the same devices used for testing with respect to strength of fibre attachment.

12.2.6.1 Strength of attachment of fibre

The test with respect to strength of attachment of fibre includes pulling, axial compression, flex and torsion tests. In some commercial devices input and output ports of the switch are connectors. In such a case these connectors should be tested for mechanical strength and durability as given by Chapter 7.

12.2.6.1.1 *Pulling*

In this test the fibres constituting the input and output ports of the component is subjected to increasing load until the fibre attachment breaks. The number of samples is chosen to get a picture of the spread in values. For each component each fibre attachment shall be tested on an individual basis.

Number of samples: 2

The tensile force shall be applied smoothly and controlled, the magnitude of the force shall be increased at a specified rate. The tensile force shall be increased until the fibre breaks.
Test method: 12.3.8

12.2.6.1.2 *Axial compression*

The fibre leads of the switch shall be subjected to axial compression to establish the ability of the retention means to withstand axial compression. The number of samples is chosen to get a picture of the spread in values. For each component each fibre attachment shall be tested on an individual basis.

Number of samples: 2

The axial compression shall be applied smooth and controlled, the magnitude of the force shall be applied with the specified rate. The axial compression shall be increased until the fibre breaks.
Test method: 12.3.8

12.2.6.1.3 *Flex*

The test is intended to determine the ability of the fibre interface and strain relief to withstand flexing. For each component each fibre attachment shall be tested on an individual basis.

Number of samples: 2

The load shall be increased in steps until the fibre breaks.
Test method: 12.3.8

12.2.6.1.4. *Torsion*

The test is intended to determine the ability of the fibre attachment to withstand torsion of the fibre. Each fibre shall be tested on an individual basis.

Number of samples: 2

The torque shall be increased until the fibre breaks.
Test method 12.3.8

12.2.6.2 Electrical connections

The test is intended to determine the strength of the electrical connections. The evaluation test programme for that particular electrical connection shall be followed.

12.2.6.3 Acceleration

Number of samples: 3
Start acceleration: as specified

The acceleration shall be increased until the component has failed or has suffered physical destruction.

Test method: 12.3.3

12.2.6.4 Impact

Number of samples: 3
Start energy: as specified

The energy in the impact shall be increased in steps of 20 % of the specified value. The load shall be increased until the component has failed or suffered physical destruction.

Test method: 12.3.5

12.2.6.5 Crush resistance

Number of samples: 3
Start force: as specified

The force shall be increased in steps of 20 % of the specified value. The load shall be increased until the component has failed or suffered physical destruction.

Test method: 12.3.4

12.2.6.6 Drop

Number of samples: 3
Start height: as specified

The height shall be increased in steps of 20 % of the initial value. The load shall be increased until the component has failed or suffered physical destruction.

Test method: 12.3.6

12.2.6.7 Bump

Number of samples: 3
Number of bumps: 4000 at each level of acceleration
Start acceleration: 40 g

The acceleration shall be increased in steps of 10 g. The load shall be increased until the component has failed or suffered physical destruction.

Test method: 12.3.7

12.2.7 Environmental tests

12.2.7.1 Temperature extremes

The change in insertion loss shall be measured in the specified wavelength range at each temperature.

Number of samples:	3, for integrated optics devices the samples shall be taken from different wafers.
Thermal cycling:	first low, then high
Low temperature:	sufficient to induce component failure, but not below - 70°C.
High temperature:	sufficient to induce component failure, but not above 150°C.
Low starting temperature:	lowest specified temperature, or - 40°C if not given.
High starting temperature:	highest specified temperature or 90°C if not given.

Step change in temperature:	10°C
Duration of stay at each temperature:	1 hour
Test method:	12.4.2

12.2.7.1.1 *Post test investigation*

The post test investigation include a repetition of the measurement of insertion loss after the component has reached room temperature. A visual inspection and dimensional check shall be performed on each device to check any changes in material appearance. The actuating mechanism shall be tested on one of the devices to reveal any temperature induced failure. One of the samples used in the temperature test shall be subjected to constructional analysis. The remaining sample shall be tested with respect to fibre attachment to ensure that the materials in the fibre attachment are not influenced by temperature extremes.

Insertion loss,	ref: 12.2.5.1
Visual inspection,	ref: 12.2.4.1
Dimensions,	ref: 12.2.4.2
Actuating mechanism	ref: 12.2.8.2
Strength of fibre attachment, pulling strength.	ref: 12.2.6.1.1
Constructional analysis	ref: 12.2.9

12.2.7.2 Rapid change of temperature

The insertion loss shall be measured as a function of wavelength immediately before and after the temperature change. The change in insertion loss in one of the transmission paths shall be monitored during the change of temperature.

Number of samples:	3, for integrated devices the samples shall be taken from different wafers
High temperature:	10°C below high temperature limit established in 12.2.7.1
Low temperature:	10°C above low temperature limit established in 12.2.7.1
Rate of change of temperature:	as specified
Test method:	12.4.3

12.2.7.2.1 *Post test investigation*

The insertion loss shall be measured when the component has reached room temperature after the test is finished. A visual inspection shall be performed on the devices. One of the samples shall be subjected to a constructional analysis to investigate whether rapid change of temperature has influenced the internal structure.

Insertion loss,	ref: 12.2.5.1
Visual inspection	ref: 12.2.4.1
Constructional analysis	ref: 12.2.9

12.2.7.3 Condensation

The change in insertion loss shall be measured each time the test conditions/temperature are changed.

Number of samples:	3, for integrated optic devices the samples shall be taken from different wafers
Test conditions:	as specified in IEC 68.2.38
Test method:	12.4.5

12.2.7.3.1 *Post test investigation*

The insertion loss shall be measured after the component has reached room temperature. The devices shall be subjected to a visual inspection and a dimensional check to look for changes in material structure and appearance. One of the samples shall be subjected to a test for actuating mechanism to investigate whether the condensation test influenced the properties. Constructional analysis is included in the post test investigation to find out whether combined humidity/heat would change any of the internal materials. The remaining sample shall be tested with respect to strength of fibre attachment to investigate the effect on the materials in the fibre mounting.

Insertion loss	ref: 12.2.5.1
Visual inspection,	ref: 12.2.4.1
Dimensions,	ref: 12.2.4.2
Actuating mechanism test,	ref: 12.2.8.2
Strength of fibre attachment, pulling strength,	ref: 12.2.6.1.1
Constructional analysis	ref: 12.2.9

12.2.7.4 Sensitivity to external electromagnetic field

The change in insertion loss shall be measured at each step in measurement procedure.

Number of samples:	3
Starting strength of electromagnetic field:	as specified

Increase the electromagnetic field in steps of 20% of the initial value until the component has failed or the strength of the field is twice the value specified for worst case application.

Test method:	12.4.16

12.2.7.4.1 *Post test investigation*

The post test investigation shall include measurement of insertion loss after the electromagnetic field is removed.

Insertion loss,	ref: 12.2.5.1

12.2.7.5 Vibration

The change in insertion loss shall be monitored during the test.

Number of samples:	3
Vibration frequency:	100-2000 Hz
Starting acceleration:	as specified
The increase in acceleration:	steps of 20% of specified level until the level has reached 30 g or the component has failed
Duration:	90 minutes
Test method:	12.3.1

12.2.7.5.1 *Post test investigation*

The insertion loss shall be measured when the device has settled after the test. The device shall be subjected to a visual inspection to look for changes in structure or appearance. Vibration may induce mechanical fractures not possible to reveal by visual inspection and optical measurements. One of the samples is therefore subjected to a condensation test. In this test condensed water may freeze in possible cracks and increase the crack. Another sample is subjected to constructional analysis to investigate whether vibration induce any changes in the internal structure of the device. The remaining sample shall be subjected to a test for actuating mechanism to reveal whether long term vibration has induced failures.

Insertion loss	ref: 12.2.5.1
Visual inspection	ref: 12.2.4.1
Condensation	ref: 12.2.7.3
Constructional analysis	ref: 12.2.9
Actuating mechanism	ref: 12.2.8.2

12.2.7.6 Shock

The change in insertion loss shall be monitored during the test.

Number of samples:	3
Pulse duration:	0.5 ms
Starting acceleration:	as specified
The increase in acceleration:	steps of 20% of specified level until the level has reached 2000 g or the component has failed.
Test method:	12.3.2

12.2.7.6.1 *Post test investigation*

The insertion loss shall be measured when the device has settled after the test. The device shall be subjected to a visual inspection to look for changes in structure or appearance. Shock may induce mechanical fractures not possible to reveal by visual inspection and optical measurements. One of the samples is therefore subjected to a condensation test. In this test condensed water may freeze in possible cracks and increase the crack. Another sample is subjected to constructional analysis to investigate whether shock induce any changes in the internal structure of the device. The remaining sample shall be subjected to a test for actuating mechanism to reveal whether shock has induced any failures.

Insertion loss	ref: 12.2.5.1
Visual inspection	ref: 12.2.4.1
Condensation	ref: 12.2.7.3
Constructional analysis	ref: 12.2.9
Actuating mechanism	ref: 12.2.8.2

12.2.7.7 Rapid depressurisation

The change in insertion loss shall be measured during the rapid depressurisation.

Number of samples:	3
Test method:	12.4.15

12.2.7.7.1 *Post test investigation*

The post test investigation shall include measurement of insertion loss. If any of the components fail, a failed sample shall be subjected to constructional analysis to investigate whether rapid depressurisation may have influenced the internal structure of the switch. If all components pass the test, they shall be used in the test with respect to vacuum operation (12.2.7.8)

Insertion loss	ref: 12.2.5.1
Visual inspection,	ref: 12.2.4.1
Constructional analysis,	ref: 12.2.9

12.2.7.8 Vacuum operation

The insertion loss is not measured during the vacuum test, because any changes is expected to be permanent.

Number of samples:	3
Vacuum:	10^{-3} Pa or less
Temperature:	125°C or high temperature limit established in 12.2.7.1, whichever is lower.
Duration:	24 hour
Test method:	12.4.4

12.2.7.8.1 *Post test investigation*

The post test investigation shall include measurement of the insertion loss. The device shall be subjected to visual inspection to look for changes in structure or appearance. One of the samples shall be subjected to constructional analysis to investigate whether vacuum operation influenced the internal structure of the device.

Insertion loss,	ref: 12.2.5.1
Visual inspection	ref: 12.2.4.1
Constructional analysis	ref: 12.2.9

12.2.7.9 Ionizing radiation

The change in insertion loss shall be measured at regular intervals during the exposure.

Number of samples:	3 samples, for integrated optics devices the samples shall be from different wafers
Temperature:	Room temperature
Optical power:	As specified
Wavelength:	As specified
Dose rate:	5 rad(Si)/s
Duration:	The irradiation shall last until the component has failed or the total dose has reached 3 Mrad.
Test method:	12.4.11

12.2.7.9.1 *Post test investigation*

The insertion loss shall be measured when the exposure has been removed. One of the samples shall be subjected to constructional analysis to investigate whether ionizing radiation has influenced the internal structure.

Insertion loss,	ref: 12.2.5.1
Visual inspection	ref: 12.2.4.1
Constructional analysis,	ref: 12.2.9

12.2.7.10 Solar radiation

The change in insertion loss shall be measured at regular intervals during the test.

Number of samples:	3, for integrated optics devices the samples shall be taken from different wafers
Temperature:	Room temperature
Radiation source:	source with representative spectral output
Duration:	until the component has failed or the maximum anticipated total dose has been reached
Test method:	12.4.12

12.2.7.10.1 *Post test investigation*

The insertion loss shall be measured after the test procedure is completed. The device shall be subjected to a visual inspection to look for changes in structure or appearance. One of the samples shall be subjected to constructional analysis to check whether solar radiation has influenced the materials inside the component.

Insertion loss,	ref: 12.2.5.1
Visual inspection,	ref: 12.2.4.1
Constructional analysis,	ref: 12.2.9

12.2.7.11 UV radiation

The change in insertion loss shall be measured at regular intervals during the exposure.

Number of samples:	3, for integrated optics devices the samples shall be taken from different wafers
Temperature:	room temperature
Radiation source:	representative UV source
Duration:	until the component has failed or the maximum anticipated total dose has been reached.
Test method:	12.4.10

12.2.7.11.1 *Post test investigation*

The insertion loss shall be measured after the test procedure is completed. The device shall be subjected to a visual inspection to look for changes in structure or appearance. One of the samples shall be subjected to constructional analysis to check whether the materials inside the component has changed during exposure.

Insertion loss	ref: 12.2.5.1
Visual inspection,	ref: 12.2.4.1
Constructional analysis,	ref: 12.2.9

12.2.7.12 Resistance to solvents and contaminating fluids

Number of samples: 3

The components shall be subjected to the appropriate solvents and fluids. Reference is made to ESA/SCC Generic Specification No 3901, paragraph 9.21. No visible changes in component appearance shall be observed. The insertion loss shall be measured after the test.

Test method: 12.4.13

12.2.8 Endurance test

12.2.8.1 Ageing

The change in insertion loss shall be measured at regular intervals during the test.

Number of samples:	3, for integrated optics devices the samples shall be taken from different wafers
Temperature:	20°C above specified operating temperature, but at least 10°C below high temperature limit established in 12.2.7
Duration:	Until the component has failed or the test has lasted 1000 hours.
Test method:	12.4.14

12.2.8.1.1 *Post test investigation*

The insertion loss shall be measured after the test. The device shall also be subjected to a visual inspection and dimensional check to look for changes in the appearance and structure of the device. One of the samples shall be subjected to a constructional analysis to investigate whether long term high temperature has introduced changes in the internal structure. Another sample shall be tested with respect to fibre attachment to investigate whether long term high temperature have influenced the materials used in the fibre attachment.

Insertion loss	ref: 12.2.5.1
Visual inspection,	ref: 12.2.4.1
Dimensions,	ref: 12.2.4.2
Strength of attachment of fibre, pulling strength	ref: 12.2.6.1.1
Constructional analysis,	ref: 12.2.9

12.2.8.2 Actuating mechanism test

Number of samples: 3

The test is performed to investigate how an increasing number of actuations affects properties like insertion loss, switching speed, bounce time, and actuating signal. The transmitted signal for the switch path(s) under test shall be monitored as a function of number of actuations. The actuations shall be performed applying the nominal actuation signal. For every 1000 operations (or as specified) the switching speed and bounce time shall be measured. At the same time the actuation signal for engagement/disengagement shall be varied within the specified limits to determine if the specified range of actuation levels has changed. The switch should be subjected to a visual inspection at the same interval. If the insertion loss changes more than the limit for defining the component as failed, the actuating signal shall be changed to try to establish whether the requirements to actuating signal has changed. The test shall continue until the component has failed. The test condition (temperature/humidity) shall be determined by the application.

Test method: 12.3.9

12.2.8.3 Optical power handling capability

Number of samples: 3, for integrated optics devices the samples shall be taken from different wafers
Laser source: as specified

Input power level shall be increased in steps and measurements made of insertion loss

The entrance and exit surfaces shall also be examined for visual damage. Input power level shall be increased until the component has failed or visual damage has occurred. The maximum input level will very likely be limited by the available optical source.
Test method: 12.2.9

12.2.9 Constructional analysis

A sample from the control group and samples exposed to the other tests, as noted under the post test investigation, shall be subjected to constructional analysis. This involves that the package is opened and the internal structure of the device is investigated. The constructional analysis may include investigation of any fracture surfaces. It may also include an examination of the optical path of the system by means of visible light, for example a HeNe laser.

12.3 Production testing

12.3.1 Introduction

A number of non-destructive tests can be perfomed on a fibre optic switch during and after production to ensure that all adjustments and other production parameters are according to specifications. The production testing includes geometrical measurements as well as control of the mass of the component. The production control also includes control of some optical properties.

12.3.2 Production control

The insertion loss shall be controlled at the specified wavelength during production.

The dimensions as well as the mass of all components shall be controlled prior to assembly. This applies to optical components as well as package.

12.3.3 Final production testing

The tests shall be performed according to Chart 12.2. Unless otherwise specified, all samples shall be tested. In addition to a final control of the dimensions and the mass of the device, the optical performance shall be tested. This includes insertion loss, cross talk, polarisation sensitivity and sensitivity to modal distribution, where applicable. The susceptibility to ambient light coupling is dependent on the optical and mechanical design. The optical design in this respect is not production dependent. Changes in mechanical structure which would change the susceptibility to ambient light coupling will probably be disclosed by the visual inspection. The stability of the optical performance shall be tested. The actuating mechanism shall be tested for functionality and tolerances to the actuating signal. The component shall be temperature cycled and subjected to vibration tests to reveal any failures in mechanical alignment and mounting. The temperature test is performed before the vibration test. Any temperature induced changes in glue or screws should then be revealed by the succeeding vibration test.

12.3.3.1 Visual inspection

To be performed in accordance with ESA/SCC Basic Specification No. 20500.

12.3.3.2 Dimensions

The dimensions of the package as well as the length of the fibre leads shall be controlled.
Test method: 12.1.1

12.3.3.3 Mass

Test method: 12.1.2

12.3.3.4 Insertion loss

The insertion loss shall be measured over the wavelength range of interest. The measurement is included in the final production testing even though it is controlled in the production process to ensure that the package has no influence on the insertion loss.
Test method: 12.2.1

12.3.3.5 Cross talk

Test method: 12.2.2

12.3.3.6 Stability of optical performance

Test method: 12.2.8

12.3.3.7 Actuating mechanism

Test method: 12.3.9

12.3.3.8 Polarisation sensitivity

Test method: 12.2.4

12.3.3.9 Modal distribution

Test method: 12.2.3

12.3.3.10 Temperature extremes

The component shall be exposed to one temperature cycle. The high and low temperature shall be chosen so that, according to specifications, no permanent changes are induced in the component.
Test method: 12.4.2

12.3.3.11 Vibration

Test method: 12.3.1

12.4 Burn-in

Burn-in is not relevant for fibre optic switches.

12.5 Qualification testing

The qualification testing shall include all tests of relevance not included in the final production testing. The test programme will therefore not include any test for just optical characteristics since this is covered by the final production testing. The sensitivity to mechanical and environmental loads was evaluated in the evaluation test programme. Several of the characteristics of the device are dependent on design and technology rather than production parameters. It will therefore not be necessary to repeat some of the tests in the qualification test programme. This is noted, as appropriate, in the discussion of the qualification test strategy.

The qualification testing is divided in tests for endurance, mechanical and environmental properties. All samples supplied for testing shall however be exposed to a climatic sequence before it is subjected to the other tests. This climatic sequence is performed to expose mechanical mounting and glue to temperature variations and humidity before any other test is performed, which may change the properties of these components.

All samples are exposed to a condensation test at the end of the test programme. The condensation test includes humidity and temperatures below zero, which may reveal any cracks and failures induced by the mechanical/environmental test programme, but not detected by the post test investigations. A similar environmental stress sequence is also seen in other test programmes [14,15].

The environmental tests included in the qualification testing is climatic sequence, vibration, shock, sensitivity to external electromagnetic fields and condensation. The sensitivity to external electromagnetic fields is tested after the vibration and shock test in case these tests induced failure in the electromagnetic protection. The effects of vacuum operation, rapid depressurisation, radiation (including ionizing radiation, solar and UV radiation) have all been investigated during the evaluation process. Any effects of these loads will be related to technology and design and not to production, and it will therefore not be necessary to repeat the tests in the qualification test programme.

The tests for component endurance includes measurements of long term high temperature exposure (ageing) and actuating mechanism. The actuating mechanism test is performed in the end to reveal any ageing induced effects.

The mechanical tests are performed to ensure that the components meet the specified mechanical requirements. The tests include strength of fibre attachment (fibre pulling, axial compression, flex and torsion) and crush resistance. Testing with respect to drop, bump and impact is not included because this is all testing of the package. The characteristics are evaluated in the evaluation phase. and production related failures will probably be revealed by the test with respect to crush resistance. Mechanical properties which may effect the internal mounting of the component, for example acceleration, are covered by the vibration and shock tests.

Each group consists of 4 switches, for integrated devices the samples shall be taken from three different wafers. The number of samples are chosen to get an indication of the spread in values. The qualification test programme uses few devices for each test, thus all samples shall meet the requirements.

12.5.2 Environmental tests

12.5.2.1 Climatic sequence

Test method: 12.4.1

12.5.2.2 Condensation

Test method: 12.4.5

12.5.2.3 Vibration

Test method: 12.3.1

12.5.2.4 Shock

Test method: 12.3.2

12.5.2.5 Sensitivity to external electromagnetic fields

Test method: 12.4.16

12.5.3 Endurance tests

12.5.3.1 Ageing

In those cases were the component is intended to be used in a humid atmosphere, the component shall be exposed to humidity at a specified level together with the high temperature level during the ageing test. Humidity may induce changes and failures not seen in an atmosphere of dry heat.
Test method: 12.4.14

12.5.3.2 Actuating mechanism

Test method: 12.3.9

12.5.4 Mechanical tests

12.5.4.1 Strength of attachment of fibre

Test method: 12.3.8

12.5.4.2 Crush resistance

Test method: 12.3.4

12.6 Lot acceptance testing

Lot acceptance testing (LAT) shall be performed on every lot delivered by the manufacturer. The purpose of the tests which have been included in the LAT-test programme is discussed in 12.2. The sequence of the tests in each level is discussed in 12.2 and 12.5.

LAT is divided in three levels, as discussed in Chapter 4. LA2 and LA1 are considered destructive, and the tested samples shall not form part of the delivered lot.

All tested samples shall meet specifications.

The LAT shall be carried out in accordance with Chart 12.4

12.6.1 Lot acceptance level 3 testing (LA3)

All components are subjected to a detailed final production control. Measurements performed in the LA3 testing are repetition of some of these measurements, performed by different personnel to ensure the quality of the delivered item as well as a control of the routine measurements performed in the final production control.

12.6.1.1 Visual inspection

The visual inspection shall be performed in accordance with ESA/SCC Basic Specification No 20500.

12.6.1.2 Insertion loss

The measurement shall be performed over the specified wavelength range.
Test method: 12.2.1

12.6.2 Lot acceptance level 2 testing (LA2)

In addition to the tests included in the LA3 testing, the LA2 is comprised of tests with respect to ageing, actuating mechanism and strength of fibre attachment. The tests are considered destructive. The tests with respect to actuating mechanism and the strength of the fibre attachment are performed after the ageing test to reveal any ageing related defects.

12.6.2.1 Ageing

The test shall include humidity if required by the application.
Test method: 12.4.14

12.6.2.2 Actuating mechanism

Test method: 12.3.9

12.6.2.3 Strength of attachment of fibre

Test method: 12.3.8

12.6.3 Lot acceptance level 1 testing (LA1)

In addition to the tests included in the LA2 testing, the LA1 is comprised of tests with respect to mechanical and environmental properties. The tests are considered destructive. The sequence is discussed in 12.2 and 12.5.

12.6.3.1 Temperature extremes

Test method: 12.4.2

12.6.3.2 Vibration

Test method: 12.3.1

12.6.3.3 Sensitivity to external electromagnetic fields

Test method: 12.4.16

12.6.3.4 Condensation

Test method: 12.4.5

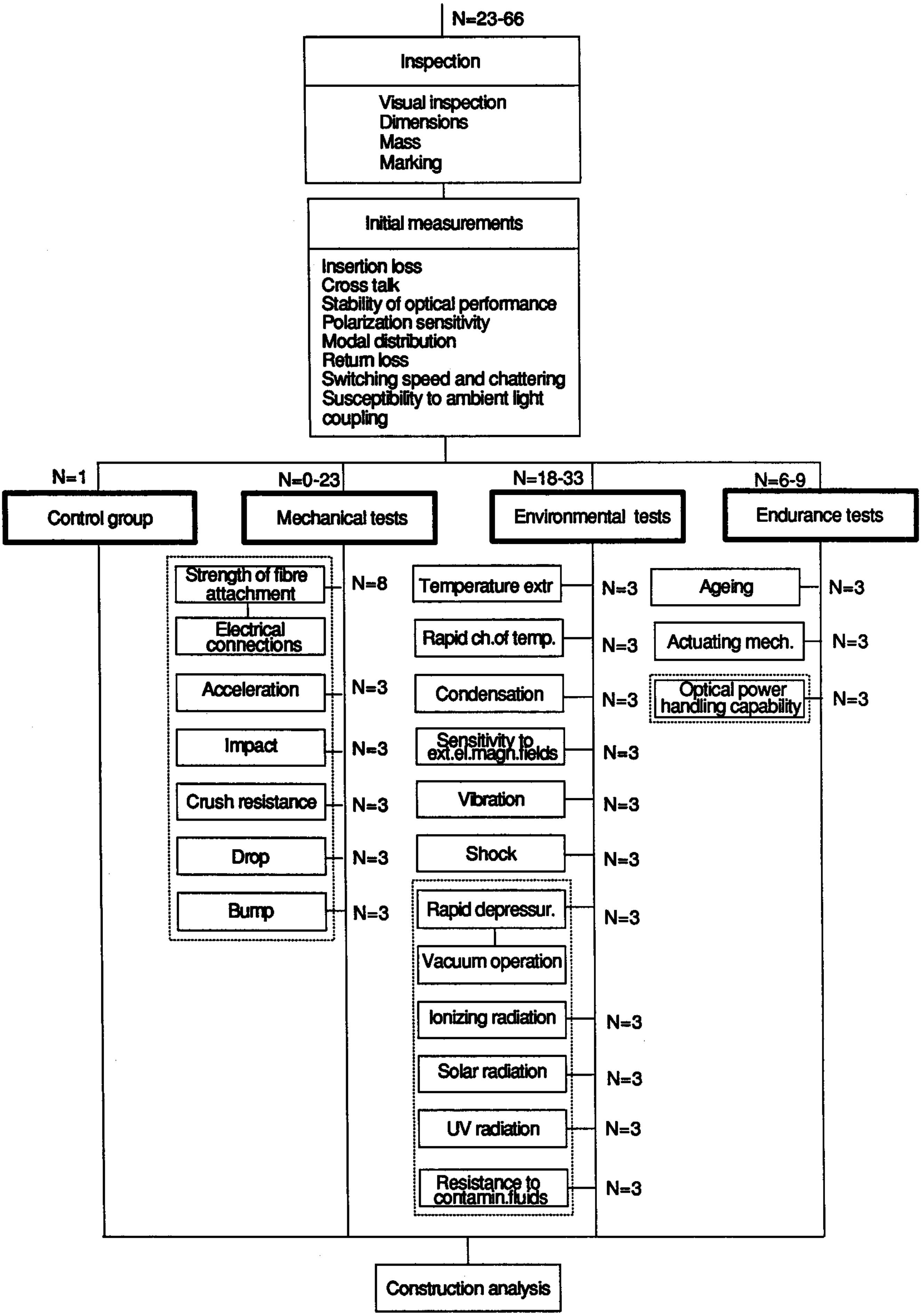

Chart 12.1 Evaluation testing for fibre optic switches

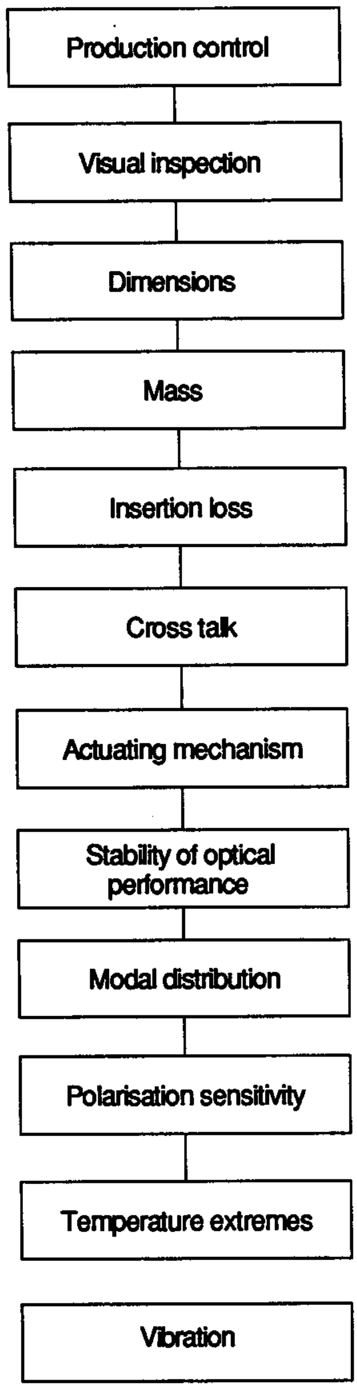

Chart 12.2 Final production testing for fibre optic switches

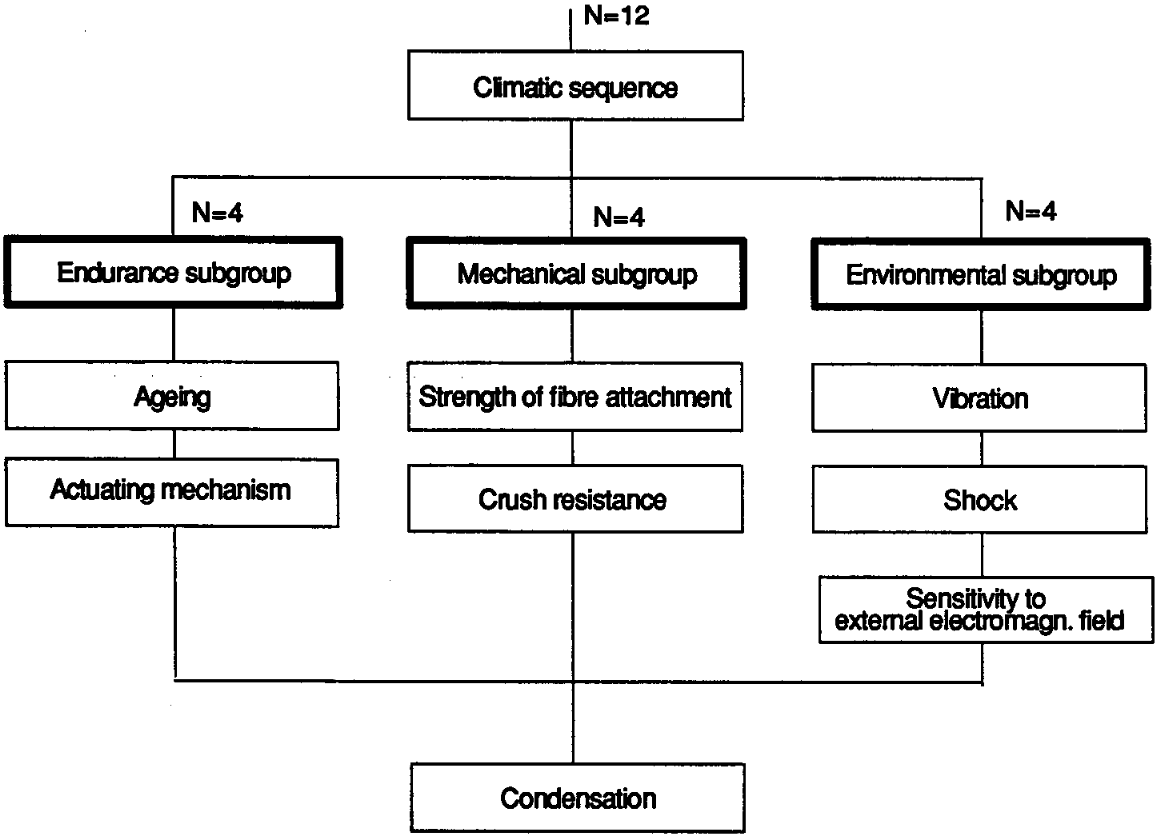

Chart 12.3 Qualification testing for fibre optic switches

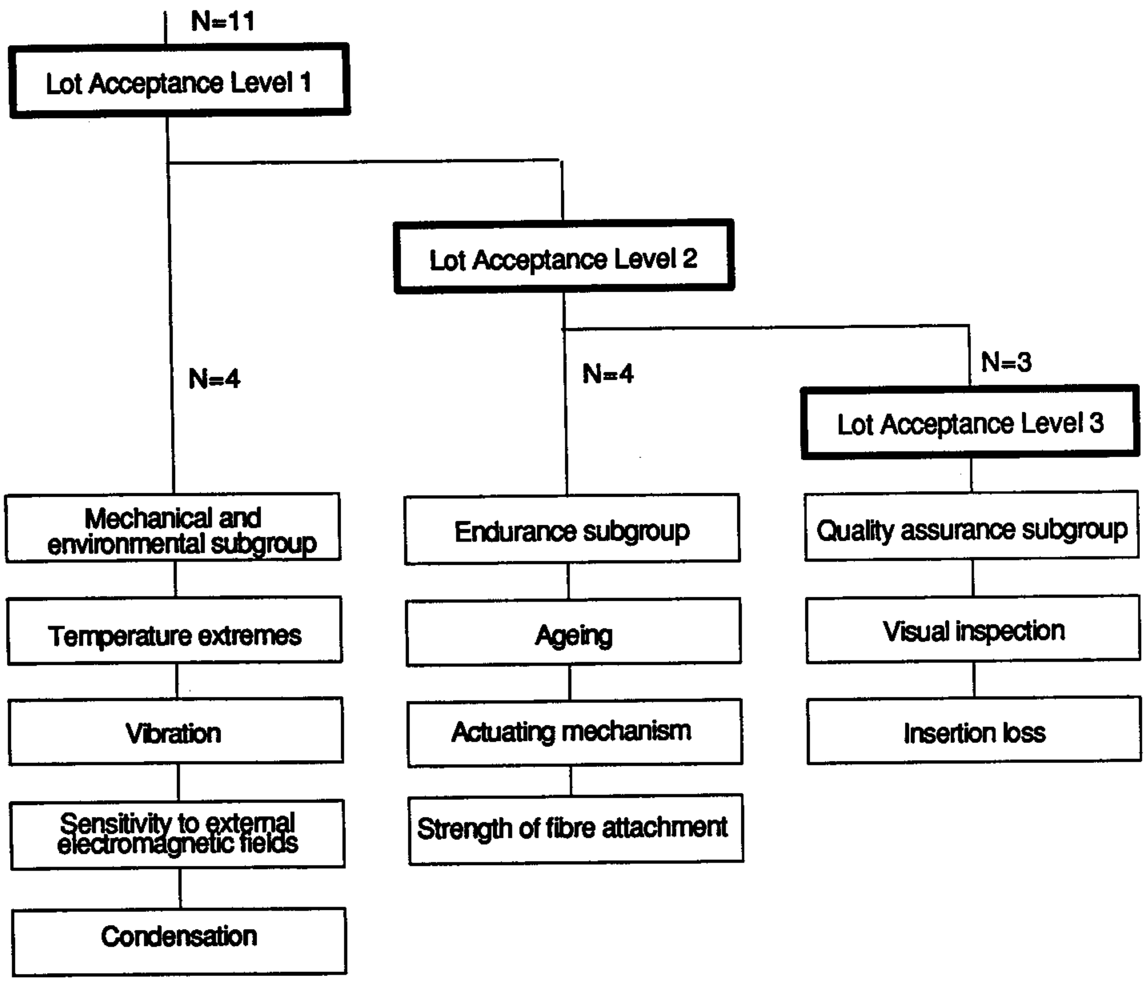

Chart 12.4 Lot acceptance testing for fibre optic switches

13 FIBRE OPTIC WAVELENGTH MULTIPLEXERS/DEMULTIPLEXERS (WDM)

13.1 Introduction

Fibre optic wavelength multiplexer/demultiplexers (WDMs) are passive components that combine or split light in such a way that the transfer coefficients between the different ports are dependent on the wavelength of the light. If an incoming light contains two signals at different wavelengths, the WDM is capable of separating the two signals. The WDM can also combine two signals at different wavelengths into one output port. WDMs are manufactured using several different technologies, i.e. fused biconical taper, micro-optics, and waveguides formed on either electro-optical materials or glass substrates (integrated optics).

In fused biconical taper devices the transfer coefficients between the different input and output ports are determined by the characteristics of the area where the fibres are fused together. The coupling ratio is measured during fusion to obtain the desired characteristics.

In micro-optics devices the coupling is achieved by using miniature versions of bulk optical devices such as lenses, mirrors, beamsplitters, filters etc. The component is strongly dependent on the mechanical alignment of the different components, which have to be screwed or glued in position.

In integrated optic devices the coupling is determined by the waveguide structure in the substrate. This structure is made by the exchange of ions and determined by a mask. The same mask can be used for several components, and several components can be made from a single wafer. The difference between a substrate made of glass and a substrate made of electro-optical material is that in devices made of the latter the waveguide properties can be changed by applying an electric field. In passive fibre optic WDMs this attribute is not necessary because the transfer coefficients are meant to be constant throughout the lifetime of the component. Electro-optical materials are used in switches.

Devices based on the different technologies will have different characteristics with respect to environmental loads such as temperature and vibration because of the different optical design. The mechanical properties will mainly be determined by the packaging and the mounting of the fibre. The sample selection will depend on the technology involved. Fused devices and micro-optic devices are manufactured on a one to one basis while the integrated devices are manufactured in a more automated manner using the same mask and the same wafers for several components.

The characteristics of the fibre optic component is strongly dependent on the packaging. Nominally the same component, but with different packaging should therefore be tested and qualified separately.

The general test strategy is described in Chapter 4 and will also be followed here. Each test method has been given a number, and these numbers are tabulated and described in Part 3 Ch.13.

13.2 Evaluation testing

13.2.1 Purpose

The purpose of the evaluation testing is to determine the operational limits of the fibre optic WDM with respect to critical mechanical and environmental parameters, to overstress specific characteristics in order to identify failure modes, to demonstrate the suitability of the WDM for proceeding on to qualification testing and to get information which can be of value for a detailed planning of the test programme to be used in the procurement of the component.

13.2.2 Properties to evaluate

The main properties of interest are :

- mechanical properties
- effects of high levels of vibration and shock
- effects of temperature extremes
- effects of rapid depressurisation and vacuum operation
- effects of ionizing radiation
- effects of solar radiation and UV radiation
- resistance to solvents and contaminating fluids

For some special applications the optical power handling capability may be of concern.

It is expected that the fibre used in the input/output ports of the component is characterised with respect to space applications. It is thus not necessary to include tests for fibre properties such as bandwidth, coating dimensions, numerical aperture, etc. in the evaluation of the passive device. The characteristics of the fibre with respect to environmental loads such as ionizing radiation and temperature extremes should also be known.

Coatings, buffers and materials used in the packaging shall be space qualified, see Chapter 4. However, an evaluation related to their properties may be necessary to eliminate any undesired interactions between the various materials and effects of changes in the material properties on the behaviour of the device.

The flammability of the WDM is not expected to be of special concern. The materials used in the component should all undergo a test with respect to flammability in the material evaluation, see Chapter 4. These properties will not depend on the manufacturing or the assembly of component, and the test is thus not included. A test with respect to dust is not included because this is not expected to be of special concern in space applications. A test with respect to corrosive atmosphere is not included either. The materials in the component will be tested with respect to resistance to corrosion in the material evaluation, see Chapter 4, and the property is not expected to be critical to the performance of the device, as it is not meant to be mated like for instance a connector.

13.2.2.1 Mechanical properties.

The optical components as well as the packaging must withstand mechanical loads such as crush, impact, drop, bump and acceleration. In addition, the fibre attachment should be tested with respect to pulling, axial compression, flex and torsion. The largest mechanical loads are expected to occur during installation. The mechanical loads will therefore be imposed on the component before it is exposed to environmental effects. The mechanical properties such as strength of fibre attachment and resistance to crush, drop, impact and bump are determined by the package. A manufacturer of fibre optic components may apply the same mechanical design to several types of components (couplers, WDMs, isolators and attenuators). It will therefore not be necessary to evaluate these properties for each component type if it has previously been evaluated with another component with identical package.

13.2.2.2 Temperature extremes

A fibre optic WDM will be comprised of several materials with probably different coefficient of thermal expansion. This may lead to misalignment of the different components and increased insertion loss during temperature cycling. Thermal expansion may also induce microbend loss on the fibres within the component. Fused fibre optic WDMs are usually made of bare fibres packed in an external protection sleeve. When the coupler is exposed to thermal variation, the bare fibres inside the package may be subjected to excessive strain due to different thermal expansion from that of the package. For devices based on waveguides the main temperature effect is expected to be related to the mounting of the fibre pigtails to the substrate.

If the device is intended to be used in applications where it may be exposed to humidity, this shall be included in the evaluation test programme. Humidity and temperature extremes may induce other failure mechanisms than dry heat [17].

13.2.2.3 Rapid change of temperature

Rapid change of temperature may cause excessive tension as the thermal response of the component may be slower than the rate of change of temperature. Large thermal gradients across the component may therefore arise, challenging the mechanical alignment and the strength of the mounting of each part of the component. The components involved are, however, quite small which should reduce the effect of rapid change of temperature.

13.2.2.4 Rapid depressurisation

Rapid depressurisation may cause mechanical stresses inside a component because trapped air in pockets inside the component may give large pressure gradients. Fibre optic WDMs can be made quite compact (integrated devices), but fused devices and devices based on micro-optics are dependent on the refractive index of the media surrounding the fused region and the optical components, respectively. The components inside the device is therefore usually filled with air [17].

The test with respect to the effect of rapid depressurisation will not be necessary if devices with a similar structure have been previously evaluated. This applies to devices with different functions (branching devices, WDM, isolators), but with nominally the same package.

13.2.2.5 Vacuum operation

The materials used in the WDM shall all be space qualified, see Chapter 4. This means that the effects of vacuum operation (outgassing, change of material properties) should be very small Interactions between the different media may, however, arise with deleterious effects such as misalignment of the different parts of the component and mechanical stresses.

The test with respect to vacuum operation might not be necessary if devices with a similar structure have been previously evaluated. This applies to devices with different functions (branching devices, WDM, isolators), but with nominally the same package.

13.2.2.6 Ionizing radiation

In space applications fibre optic components are exposed to high levels of ionizing radiation which may induce losses in the optical components as well as change the properties of the other materials in the package. Even all the materials are space qualified, see Chapter 4, interactions may occur. Any possible interaction should be revealed during the evaluation of the component.

The test with respect to the effects of ionizing radiation might not be necessary if devices with identical optical design, but slightly different package (with respect to mechanical design, but not to material selection) have been previously evaluated.

13.2.2.7 Solar and UV radiation

Solar and UV radiation could affect the properties of the material in the package. If the WDM is not properly designed, solar and UV radiation may also be coupled into the optical path and interfere with the signal propagation.

The test with respect to solar and UV radiation might not be necessary if devices with the identical optical design, but slightly different package (with respect to mechanical design, but not to material selection) have been previously evaluated.

13.2.2.8 Resistance to solvents and contaminating fluids

During installation or service the component might be exposed to solvents and contaminating fluids. These fluids may deteriorate the materials in the component and thereby the performance.

13.2.2.9 Optical power handling capability

The power handling capability of a fibre optic WDM can be limited by four different phenomena:

- heating due to absorbed power
- radiation induced colour centres which will cause loss
- various non-linear optical effects
- formation of cracks, pits, etc.

As with optical fibres, the fibre optic WDM is usually operated at wavelengths with low loss and power levels in the order of 1 mW or less. The above phenomena will only be of concern in special applications were the component is used to transmit high power levels.

13.2.3 Sample distribution and test programme sequence

13.2.3.1 Sample distribution

The fibre optic WDM shall be selected at random from a representative production lot. The size of the lot shall be 2 times to 3 times the total number of the selected samples. For fibre optic WDMs based on fused technology and micro-optics, the WDMs are selected at random. For fibre optic WDMs based on planar waveguide technology the samples shall be selected from three different wafers.

Number of samples: 19-60, dependent on the extent of the test programme, as discussed in the text

The number of devices needed for the evaluation test programme is quite extensive. New devices are used for each test, both because each test is considered destructive and to be able to distinguish between the effects of the different parameters. The number of samples for each test is shown in Chart 13.1 (see end of Chapter). In order to get a picture of the spread in values, the number of samples of each test is 3 or larger. The evaluation test programme will give a better picture of the statistical fluctuations if more components were used for each test. A sample size of 3 will however, give an indication of the variations. If large variations are observed, the number of samples should be increased.

13.2.3.2 Test range and failure criteria

The different tests are performed on a step stress basis. This means that the load is increased in steps from a starting value. Generally, the load is increased until the component has suffered physical destruction or a substantial deterioration in performance, as appropriate. In some of the tests the upper stress limit is determined from the most severe loads expected, as listed in Chapter 4, with some margin added. If more severe loads are expected, the upper test level should be increased accordingly.

The criteria for defining the component as failed is chosen to be a variation in optical branching efficiency of 2 dB for those transmission paths where the signal is meant to be transmitted. For transmission paths where the transfer coefficient nominally is zero, the criteria for failure is that the transfer coefficient shall not exceed the specified value.

All results shall be recorded.

13.2.3.3 Test programme sequence

The specified tests are summarised in Chart 13.1. The mechanical and environmental tests which may be dependent on application and previous evaluation of similar components, are shown in a dotted box.

The initial measurements are all optical measurements and will not have any influence on the properties of the tested components. The indicated order is based on the importance of the different parameters. The optical branching efficiency is measured first to establish the basic performance of the device. The optical branching efficiency shall be measured over the wavelength range of interest. The polarization sensitivity and the dependence on modal distribution is then measured to establish the sensitivity of the performance to the characteristics of the incoming light.

For the mechanical, environmental and endurance tests new test samples are used for each test. The test order will therefore not affect the test result and is as such of no importance. It is generally recommended to perform the easiest and least expensive tests first and the more complicated and expensive tests in the end. If the component fails during the cheap and least expensive part of the test programme, it can be stopped before large expenses have been incurred.

We suggest to do the mechanical tests first. This is a test of the component's and the package's ability to withstand mechanical loads and the package's ability to protect the optical part of the component. The strength of fibre attachment is tested first. This will be an important property during installation and handling of the component of the system. The resistance to acceleration, impact, drop, bump and crush is tested thereafter.

The environmental tests are performed after the mechanical tests. We recommend to do the temperature tests first. Testing with respect to temperature will both reveal fundamental temperature dependent properties of the optical design and temperature dependent properties of the assembly. The temperature tests include testing with respect to temperature extremes, rapid change of temperatures and condensation. The test with respect to temperature extremes shall be performed first to establish the limits for the other tests.

The tests with respect to the effects of vibration and shock are tested before the vacuum and ionizing radiation test. The materials applied in the component are, in advance, tested with respect to such material related effects. The latter tests are performed to ensure that no unexpected effects occur. The characteristics of the component when it is exposed to loads such as vibration and shock is less predictable and in addition easier and less expensive to perform.

The tests with respect to the effects of rapid depressurisation and vacuum operation are performed on the same samples. The effects of rapid depressurisation should be tested before the effects of vacuum operation. If the device fails in the rapid depressurisation test, there will be no point in proceeding to the test with respect to vacuum operation.

The effect of radiation (ionizing as well as solar and UV radiation) is tested in the end, such that only components that have passed the other tests are subjected to this test. Radiation resistance is a fundamental requirement for components in space applications. The device should be based on materials and fibres exhibiting minimal radiation effects, and the test is performed to ensure that no unexpected effects will occur.

If it is of concern the resistance to solvents and contaminating fluids shall be tested.

The endurance tests are ageing and optical power handling capability, if applicable. The conditions during the ageing test are determined by the test with respect to temperature extremes. The test will thus have to be started after this test. This is a long term test with measurements at regular intervals and can be performed in parallel with the other tests.

13.2.3.4 Use of control group

The use of a control group is not considered necessary in the mechanical and environmental tests. In these tests the parameters of interest are usually monitored while the test is performed. The stability of the source output and the repeatability of the measurements are ensured by a control of the output power. If the post test investigations include optical measurements not performed during the test, the measurements shall also be performed on the control group. This may include measurements of optical branching efficiency as a function of signal wavelength and measurements of transfer coefficients which nominally are zero.

A control group is used in the construction analysis to be able to compare the devices that have been exposed to environmental and mechanical loads with a "fresh" sample.

13.2.3.5 Post test investigations

The standard test procedures given in Chapter 7 Part 13 often specify that after the exposure to mechanical or environmental load is completed, some measurements should be made to look for permanent changes in one or more critical properties. In the evaluation programme there are in many cases specified additional tests to analyse the failure mechanisms, but also to reveal whether the load has induced changes not observed directly during the tests or revealed by the standard post test investigations. An example of such a test would be testing of the strength of fibre or cable entry after the test with respect to temperature extremes, to investigate whether temperature extremes have affected the materials in the fibre attachment in such a way that the strength is reduced.

13.2.4 Inspection

The purpose of the inspection is to make sure that the samples are suited for testing. All samples shall be inspected.

13.2.4.1 Visual inspection

The visual inspection shall be carried out in accordance with ESA/SCC Basic Specifications No. 20500.

13.2.4.2 Dimensions

Test method: 13.1.1

13.2.4.3 Mass

Test method: 13.1.2

13.2.4.4 Marking

All samples shall be marked in accordance with the standard procedure of the manufacturer.

13.2.5 Initial measurements

The purpose of the initial measurements is to determine the initial values of the most important optical parameters. The result from these initial measurements will be used as a basis for the evaluation of later measurements. Further, one wants to ascertain that the various samples meet the specified requirements and to get a picture of the spread in values. The spread in values will give an indication of the production control.

The initial measurements shall be performed on all samples.

13.2.5.1 Optical branching efficiency

The measurement shall be performed over the specified wavelength range.
Test method: 13.2.1

13.2.5.2 Polarization sensitivity

The test applies to single mode devices only.
Test method: 13.2.3

13.2.5.3 Modal distribution

The test applies to multimode devices only.
Test method: 13.2.2

13.2.5.4 Susceptibility to ambient light coupling

Test method: 13.2.5

13.2.6 Mechanical tests

The main mechanical properties to test are strength of attachment of fibre which includes tests for pulling, axial compression, flex and torsion. The component should also be tested with respect to mechanical loads such as crush, impact, drop and acceleration.

The optical branching efficiency is measured before and after the test. The transmission through an input/output port which are meant to transmit light, are measured during the test.

13.2.6.1 Strength of attachment of fibre

The test with respect to strength of attachment of fibre includes pulling, axial compression, flex and torsion tests. In some commercial devices input and output ports of the WDM are connectors. In such a case these connectors should be tested for mechanical strength and durability as given by Chapter 7.

13.2.6.1.1 *Pulling*

In this test the fibres constituting the input and output ports of the component is subjected to increasing load until the fibre attachment breaks. The number of samples is chosen to get a picture of the spread in values. For each component each fibre attachment shall be tested on an individual basis.

Number of samples: 2

The tensile force shall be applied smoothly and controlled, the magnitude of the force shall be increased at a specified rate. The tensile force shall be increased until the fibre breaks.
Test method: 13.3.8

13.2.6.1.2 *Axial compression*

The fibre leads of the WDM shall be subjected to axial compression to establish the ability of the retention means to withstand axial compression. The number of samples is chosen to get a picture of the spread in values. For each component each fibre attachment shall be tested on an individual basis.

Number of samples: 2

The axial compression shall be applied smooth and controlled, the magnitude of the force shall be applied with the specified rate. The axial compression shall be increased until the fibre breaks.
Test method: 13.3.8

13.2.6.1.3 *Flex*

The test is intended to determine the ability of the fibre interface and strain relief to withstand flexing. For each component each fibre attachment shall be tested on an individual basis.

Number of samples: 2
Start load: as specified
The load shall be increased in steps of 20% of the initial value until the fibre breaks.
Test method: 13.3.8

13.2.6.1.4. *Torsion*

The test is intended to determine the ability of the fibre attachment to withstand torsion of the fibre. Each fibre shall be tested on an individual basis.

Number of samples: 2

The torque shall be increased until the fibre breaks.
Test method 13.3.8

13.2.6.2 Acceleration

Number of samples: 3
Start acceleration: as specified
The acceleration shall be increased until the component has failed or has suffered physical destruction.
Test method: 13.3.3

13.2.6.3 Impact

Number of samples: 3
Start energy: as specified
The energy in the impact shall be increased in steps of 20 % of the specified value. The load shall be increased until the component has failed or suffered physical destruction.
Test method: 13.3.5

13.2.6.4 Crush resistance

Number of samples: 3
Start force: as specified
The force shall be increased in steps of 20 % of the specified value. The load shall be increased until the component has failed or suffered physical destruction.
Test method: 13.3.4

13.2.6.5 Drop

Number of samples: 3

Start height: as specified
The height shall be increased in steps of 20 % of the initial value. The load shall be increased until the component has failed or suffered physical destruction.
Test method: 13.3.6

13.2.6.6 Bump

Number of samples: 3
Number of bumps: 4000 at each level of acceleration
Start acceleration: 40 g

The acceleration shall be increased in steps of 10 g. The load shall be increased until the component has failed or suffered physical destruction.
Test method: 13.3.7

13.2.7 Environmental tests

13.2.7.1 Temperature extremes

The optical branching efficiency shall be measured in the specified wavelength range at each temperature.

Number of samples:	3, for integrated optics devices the samples shall be taken from different wafers.
Thermal cycling:	first low, then high
Low temperature:	sufficient to induce component failure, but not below - 70°C.
High temperature:	sufficient to induce component failure, but not above 150°C.
Low starting temperature:	lowest specified temperature, or - 40°C if not given.
High starting temperature:	highest specified temperature or 90°C if not given.
Step change in temperature:	10°C
Duration of stay at each temperature:	1 hour
Test method:	13.4.2

13.2.7.1.1 *Post test investigation*

The post test investigation include a repetition of the measurement of optical branching efficiency after the component has reached room temperature. A visual inspection and dimensional check shall be performed on each device to check any changes in material appearance. One of the samples used in the temperature test shall be subjected to constructional analysis. The remaining samples shall be tested with respect to fibre attachment to ensure that the materials in the fibre attachment are not influenced by temperature extremes.

Optical branching efficiency,	ref: 13.2.5.1
Visual inspection,	ref: 13.2.4.1
Dimensions,	ref: 13.2.4.2
Strength of fibre attachment, pulling strength.	ref:13.2.6.1.1
Constructional analysis	ref: 13.2.9

13.2.7.2 Rapid change of temperature

The optical branching efficiency shall be measured as a function of wavelength immediately before and after the temperature change. The insertion loss in the transmission paths were the light is meant to be transmitted shall be monitored during the change of temperature.

Number of samples:	3, for integrated devices the samples shall be taken from different wafers
High temperature:	10°C below high temperature limit established in 13.2.7.1
Low temperature:	10°C above low temperature limit established in 13.2.7.1
Rate of change of temperature:	as specified
Test method:	13.4.3

13.2.7.2.1 *Post test investigation*

The optical branching efficiency shall be measured when the component has reached room temperature after the test is finished. A visual inspection shall be performed on the devices. One of the samples shall be subjected to a constructional analysis to investigate whether rapid change of temperature has changed the internal structure of the device.

Optical branching efficiency,	ref: 13.2.5.1
Visual inspection	ref: 13.2.4.1
Constructional analysis	ref: 13.2.9

13.2.7.3 Condensation

The optical branching efficiency shall be measured each time the test conditions/temperature are changed.

Number of samples:	3, for integrated optics devices the samples shall be taken from different wafers
Test conditions:	as specified in IEC 68.2.38
Test method:	13.4.5

13.2.7.3.1 *Post test investigation*

The optical branching efficiency shall be measured after the component has reached room temperature. The devices shall be subjected to a visual inspection and a dimensional check to look for changes in material structure and appearance. Constructional analysis is included in the post test investigation to find out whether combined humidity/heat would change any of the internal materials. The remaining samples shall be tested with respect to strength of fibre attachment to investigate the effect on the materials in the fibre mounting.

Optical branching efficiency,	ref: 13.2.5.1
Visual inspection,	ref: 13.2.4.1
Dimensions,	ref: 13.2.4.2
Strength of fibre attachment, pulling strength,	ref: 13.2.6.1.1
Constructional analysis	ref: 13.2.9

13.2.7.4 Vibration

The insertion loss in the transmission paths were the light is meant to be transmitted shall be monitored during the test.

Number of samples:	3
Vibration frequency:	100-2000 Hz
Starting acceleration:	as specified
The increase in acceleration:	steps of 20% of specified level until the level has reached 30 g or the component has failed
Duration:	90 minutes
Test method:	13.3.1

13.2.7.4.1 *Post test investigation*

The optical branching efficiency shall be measured when the device has settled after the test. The device shall be subjected to a visual inspection to look for changes in structure or appearance. Vibration may induce mechanical fractures not possible to reveal by visual inspection and measurement of optical branching efficiency. One of the samples is therefore subjected to a condensation test. In this test condensed water may freeze in possible cracks and increase the crack. Another sample is subjected to constructional analysis to investigate whether vibration induce any changes in the internal structure of the device.

Optical branching efficiency,	ref: 13.2.5.1
Visual inspection	ref: 13.2.4.1
Condensation	ref: 13.2.7.3
Constructional analysis	ref: 13.2.9

13.2.7.5 Shock

The insertion loss in the transmission paths were the light is meant to be transmitted shall be monitored during the test.

Number of samples:	3
Pulse duration:	0.5 ms
Starting acceleration:	as specified
The increase in acceleration:	steps of 20% of specified level until the level has reached 2000 g or the component has failed.
Test method:	13.3.2

13.2.7.5.1 *Post test investigation*

The optical branching efficiency shall be measured when the device has settled after the test. The device shall be subjected to a visual inspection to look for changes in structure or appearance. Shock may induce mechanical fractures not possible to reveal by visual inspection and measurement of optical branching efficiency. One of the samples is therefore subjected to a condensation test. In this test condensed water may freeze in possible cracks and increase the crack. Another sample is subjected to constructional analysis to investigate whether shock induce any changes in the internal structure of the device.

Optical branching efficiency,	ref: 13.2.5.1
Visual inspection	ref: 13.2.4.1
Condensation	ref: 13.2.7.3
Constructional analysis	ref: 13.2.9

13.2.7.6 Rapid depressurisation

The insertion loss in the transmission paths were light is meant to be transmitted shall be measured during the rapid depressurisation.

Number of samples:	3
Test method:	13.4.15

13.2.7.6.1 *Post test investigation*

The post test investigation shall include measurement of optical branching efficiency of all ports of the tested devices as well as the control group. If any of the components fail, a failed sample shall be subjected to constructional analysis to investigate whether rapid depressurisation may have influenced the internal structure of the WDM. If all components pass the test, they shall be used in the test with respect to vacuum operation (13.2.7.7)

Optical branching efficiency,	ref: 13.2.5.1
Visual inspection,	ref: 13.2.4.1
Constructional analysis,	ref: 13.2.9

13.2.7.7 Vacuum operation

The optical branching efficiency is not measured during the vacuum test, because any changes is expected to be permanent.

Number of samples:	3
Vacuum:	10^{-3} Pa less
Temperature:	125°C or high temperature limit established in 13.2.7.1, whichever is lower
Duration:	24 hour
Test method:	13.4.4

13.2.7.7.1 *Post test investigation*

The post test investigation shall include measurement of the optical branching efficiency of the tested samples as well as the control group. The device shall be subjected to visual inspection to look for changes in structure or appearance. One of the samples shall be subjected to constructional analysis to investigate whether vacuum operation influenced the internal structure of the device.

Optical branching efficiency,	ref: 13.2.5.1
Visual inspection	ref: 13.2.4.1
Constructional analysis	ref: 13.2.9

13.2.7.8 Ionizing radiation

The optical branching efficiency shall be measured at regular intervals during the exposure.

Number of samples:	3 samples, for integrated optics devices the samples shall be from different wafers
Temperature:	Room temperature
Optical power:	As specified
Wavelength:	As specified
Dose rate:	5 rad(Si)/s
Duration:	The irradiation shall last until the component has failed or the total dose has reached 3 Mrad.
Test method:	13.4.11

13.2.7.8.1 *Post test investigation*

The optical branching efficiency shall be measured when the exposure has been removed. One of the samples shall be subjected to constructional analysis to investigate whether ionizing radiation has influenced the internal structure.

Optical branching efficiency,	ref: 13.2.5.1
Visual inspection	ref: 13.2.4.1
Constructional analysis,	ref: 13.2.9

13.2.7.9 Solar radiation

The optical branching efficiency shall be measured at regular intervals during the test.

Number of samples:	3, for integrated optics devices the samples shall be taken from different wafers
Temperature:	Room temperature
Radiation source:	source with representative spectral output
Duration:	until the component has failed or the maximum anticipated total dose has been reached
Test method:	13.4.12

13.2.7.9.1 *Post test investigation*

The optical branching efficiency shall be measured after the test is completed. The device shall be subjected to a visual inspection to look for changes in structure or appearance. One of the samples shall be subjected to constructional analysis to check whether solar radiation has influenced the materials inside the component.

Optical branching efficiency,	ref: 13.2.5.1
Visual inspection,	ref: 13.2.4.1
Constructional analysis,	ref: 13.2.9

13.2.7.10 UV radiation

The optical branching efficiency shall be measured at regular intervals during the test.

Number of samples:	3, for integrated optics devices the samples shall be taken from different wafers
Temperature:	room temperature
Radiation source:	representative UV source
Duration:	until the component has failed or the maximum anticipated total dose has been reached.
Test method:	13.4.10

13.2.7.10.1 *Post test investigation*

The optical branching efficiency shall be measured after the test is completed. The device shall be subjected to a visual inspection to look for changes in structure or appearance. One of the samples shall be subjected to constructional analysis to check whether the materials inside the component has changed during exposure.

Optical branching efficiency,	ref: 13.2.5.1
Visual inspection,	ref: 13.2.4.1
Constructional analysis,	ref: 13.2.9

13.2.7.11 Resistance to solvents and contaminating fluids

Number of samples: 3

The components shall be subjected to the appropriate solvents and fluids. Reference is made to ESA/SCC Generic Specification No 3901, paragraph 9.21. No visible changes in component appearance shall be observed. The optical branching efficiency shall be measured after the test.

Test method:	13.4.13

13.2.8 Endurance tests

13.2.8.1 Ageing

The optical branching efficiency shall be measured at regular intervals during the test.

Number of samples:	3, for integrated optics devices the samples shall be taken from different wafers
Temperature:	20°C above specified operating temperature, but at least 10°C below high temperature limit established in 13.2.7
Duration:	Until the component has failed or the test has lasted 1000 hours.
Test method:	13.4.14

13.2.8.1.1 *Post test investigation*

The optical branching efficiency shall be measured after the test. The device shall also be subjected to a visual inspection and dimensional check to look for changes in the appearance and structure of the device. One of the samples shall be subjected to a constructional analysis to investigate whether long term high temperature has introduced changes in the internal structure. Another sample shall be tested with respect to fibre attachment to investigate whether long term high temperature have influenced the materials used in the fibre attachment.

Optical branching efficiency,	ref: 13.2.5.1
Visual inspection,	ref: 13.2.4.1
Dimensions,	ref: 13.2.4.2
Strength of attachment of fibre, pulling strength	ref: 13.2.6.1.1
Constructional analysis,	ref: 13.2.9

13.2.8.2 Optical power handling capability

Number of samples:	3, for integrated optics devices the samples shall be taken from different wafers
Laser source:	as specified

Input power level shall be increased in steps and measurements made of optical branching efficiency

The entrance and exit surfaces shall also be examined for visual damage. Input power level shall be increased until the component has failed or visual damage has occurred. The maximum input level will very likely be limited by the available optical source.

Test method:	13.2.6

13.2.9 Constructional analysis

A sample from the control group and samples exposed to the other tests, as noted under the post test investigation, shall be subjected to constructional analysis. This involves that the package is opened and the internal structure of the device is investigated. The constructional analysis may include investigation of any fracture surfaces. It may also include an examination of the optical path of the system by means of visible light, for example a HeNe laser.

13.3 Production testing

13.3.1 Introduction

A number of non-destructive tests can be performed on a fibre optic WDM during and after production to ensure that all adjustments and other production parameters are according to specifications. The production testing includes geometrical measurements as well as control of the mass of the component. The production control also includes control of some optical properties.

13.3.2 Production control

The optical branching efficiency shall be controlled during production. This applies both to fused devices and micro-optic devices. For fused devices the optical branching efficiency is monitored during fusion to control the characteristics of this region. For devices based on micro-optic design the branching efficiency has to be monitored during the mechanical alignment of the various components. In integrated optics devices each wafer should be inspected for optical loss prior to dicing [17]. The branching efficiency is controlled at the specified wavelength(s).

The dimensions as well as the mass of all components shall be controlled prior to assembly. This applies to optical components as well as package.

13.3.3 Final production testing

The tests shall be performed according to Chart 13.2. Unless otherwise specified, all samples shall be tested. In addition to a final control of the dimensions and the mass of the device, the optical performance shall be tested. This includes optical branching efficiency, polarisation sensitivity and sensitivity to modal distribution, where applicable. The susceptibility to ambient light coupling is dependent on the optical and mechanical design. The optical design in this respect is not production dependent. Changes in mechanical structure which would change the susceptibility to ambient light coupling will probably be disclosed by the visual inspection. The component shall be temperature cycled and exposed to vibration tests to reveal any failures in mechanical alignment and mounting. The temperature test is performed before the vibration test. Any temperature induced changes in glue or screws should then be revealed by the succeeding vibration test.

13.3.3.1 Visual inspection

To be performed in accordance with ESA/SCC Basic Specification No. 20500.

13.3.3.2 Dimensions

The dimensions of the package as well as the length of the fibre leads shall be controlled.
Test method: 13.1.1

13.3.3.3 Mass

Test method: 13.1.2

13.3.3.4 Optical branching efficiency

The optical branching efficiency shall be measured over the wavelength range of interest. The measurement is included in the final production testing even though it is controlled in the production process to ensure that the package has no influence on the branching efficiency.
Test method: 13.2.1

13.3.3.5 Polarisation sensitivity

Test method: 13.2.3

13.3.3.6 Modal distribution

Test method: 13.2.2

13.3.3.7 Temperature extremes

The component shall be exposed to one temperature cycle. The high and low temperature shall be chosen so that, according to specifications, no permanent changes are induced in the component.
Test method: 13.4.2

13.3.3.8 Vibration

Test method: 13.3.1

13.4 Burn-in

Burn-in is not relevant for optical WDMs,

13.5 Qualification testing

The qualification testing shall include all tests of relevance not included in the final production testing. The test programme will therefore not just include optical characteristics since this is covered by the final production testing. The sensitivity to mechanical and environmental loads was evaluated in the evaluation test programme. Several of the characteristics of the device are dependent on design and technology rather than production parameters. It will therefore not be necessary to repeat some of the tests in the qualification test programme. This is noted, as appropriate, in the discussion of the qualification test strategy.

The qualification testing is divided in tests for endurance, mechanical and environmental properties. All samples supplied for testing shall however be exposed to a climatic sequence before it is subjected to the other tests. This climatic sequence is performed to expose mechanical mounting and glue to temperature variations and humidity before any other test is performed, which may change the properties of these components.

All samples are exposed to a condensation test at the end of the test programme. This condensation test includes humidity and temperatures below zero, which may reveal any cracks and failures induced by the mechanical/environmental test programme, but not detected by the post test investigations. A similar environmental stress sequence is also seen in other test programmes [14,15].

The environmental tests included in the qualification testing is climatic sequence, condensation, vibration and shock. The effects of vacuum operation, rapid depressurisation, radiation (including ionizing radiation, solar and UV radiation) have all been investigated during the evaluation process. Any effects of these loads will be related to technology and design and not to production, and it will therefore not be necessary to repeat the tests in the qualification test programme.

The test for component endurance includes the effects of long term temperature endurance (ageing).

The mechanical tests are performed to ensure that the components meet the specified mechanical requirements. The tests include strength of fibre attachment (fibre pulling, axial compression, flex and torsion) and crush resistance. Testing with respect to drop, bump and impact is not included because this is all testing of the package. These characteristics are evaluated in the evaluation phase. Production related failures will probably be revealed by the test with respect to crush resistance. Mechanical properties which may effect the internal mounting of the component, for example acceleration, are covered by the vibration and shock tests.

Each group consists of 4 WDMs, for integrated optics devices the samples shall be taken from three different wafers. The number of samples are chosen to get an indication of the spread in values. The qualification test programme uses few devices for each test, thus all samples shall meet the requirements.

13.5.2 Environmental tests

13.5.2.1 Climatic sequence

Test method: 13.4.1

13.5.2.2 Condensation

Test method: 13.4.5

13.5.2.3 Vibration

Test method: 13.3.1

13.5.2.4 Shock

Test method: 13.3.2

13.5.3 Endurance tests

13.5.3.1 Ageing

In those cases were the component is intended to be used in a humid atmosphere, the component shall be exposed to humidity at a specified level together with the high temperature level. Humidity may induce changes and failures not seen in an atmosphere of dry heat.
Test method: 13.4.14

13.5.4 Mechanical tests

13.5.4.1 Strength of attachment of fibre

Test method: 13.3.8

13.5.4.2 Crush resistance

Test method: 13.3.4

13.6 Lot acceptance testing

Lot acceptance testing (LAT) shall be performed on every lot delivered by the manufacturer. The purpose of the tests which have been included in the LAT-test programme is discussed in 13.2. The sequence of the tests in each level is discussed in 13.2 and 13.5.

LAT is divided in three levels, as discussed in Chapter 4. LA2 and LA1 are considered destructive, and the tested samples shall not form part of the delivered lot.

All tested samples shall meet specifications.

The LAT shall be carried out in accordance with Chart 13.4

13.6.1 Lot acceptance level 3 testing (LA3)

All components are subjected to a detailed final production control. Measurements performed in the LA3 testing are repetition of some of these measurements, performed by different personnel to ensure the quality of the delivered item as well as a control of the routine measurements performed in the final production control.

13.6.1.1 Visual inspection

The visual inspection shall be performed according to ESA/SCC Basic Specification No 20500.

13.6.1.2 Optical branching efficiency

The measurement shall be performed over the specified wavelength range.
Test method: 13.2.1

13.6.2 Lot acceptance level 2 testing (LA2)

In addition to the tests included in the LA3 testing, the LA2 is comprised of tests with respect to ageing and strength of fibre attachment. The tests are considered destructive. The test with respect to the strength of the fibre attachment is performed after the ageing test to reveal any ageing related defects.

13.6.2.1 Ageing

The test shall include humidity if required by the application.
Test method: 13.4.14

13.6.2.2 Strength of attachment of fibre

Test method: 13.3.8

13.6.3 Lot acceptance level 1 testing (LA1)

In addition to the tests included in the LA2 testing, the LA1 is comprised of tests with respect to mechanical and environmental properties. The tests are considered destructive. The sequence is discussed in 13.2 and 13.5.

13.6.3.1 Temperature extremes

Test method: 13.4.2

13.6.3.2 Vibration

Test method: 13.3.1

13.6.3.3 Condensation

Test method: 13.4.5

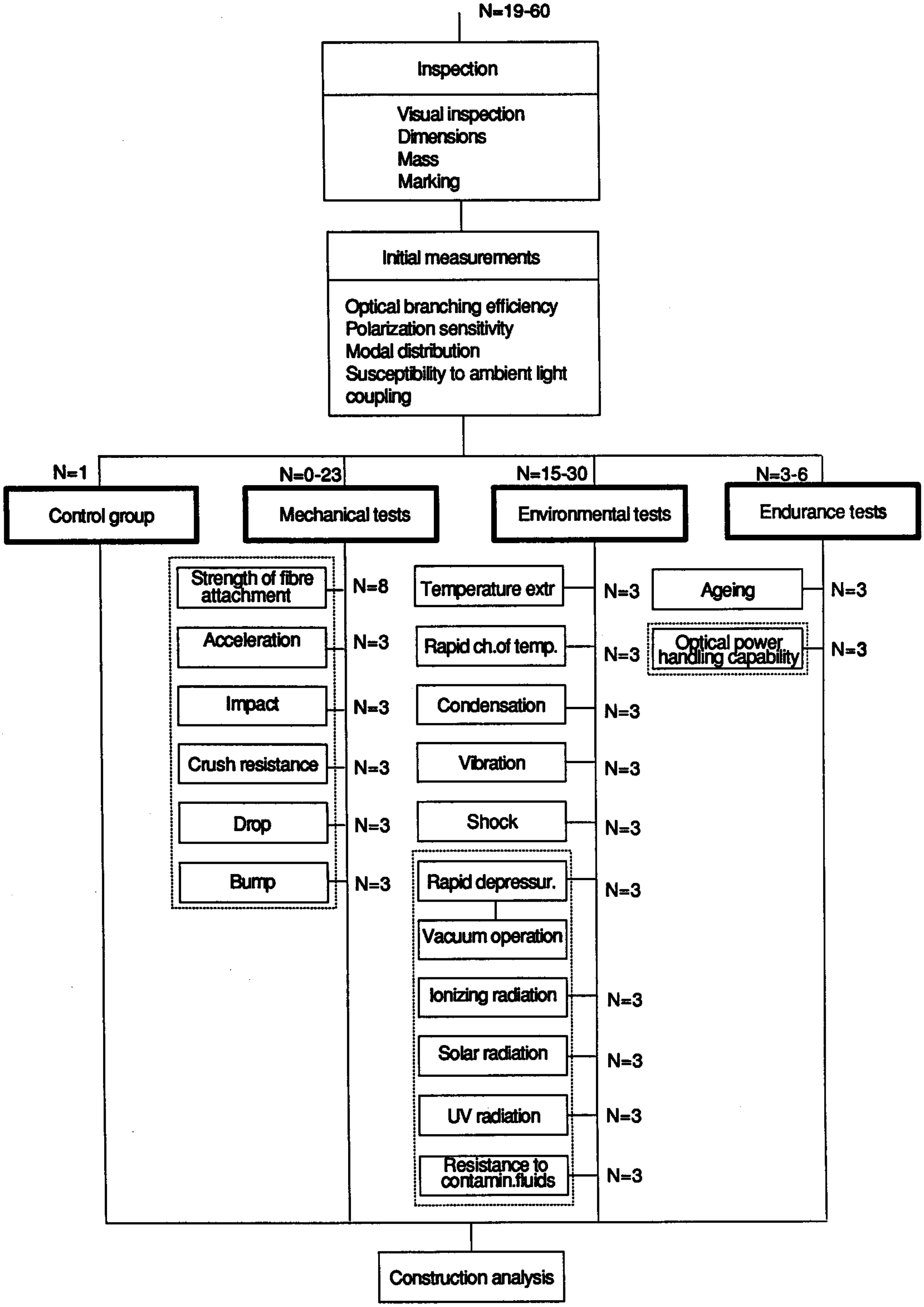

Chart 13.1 Evaluation testing for fibre optic WDMs.

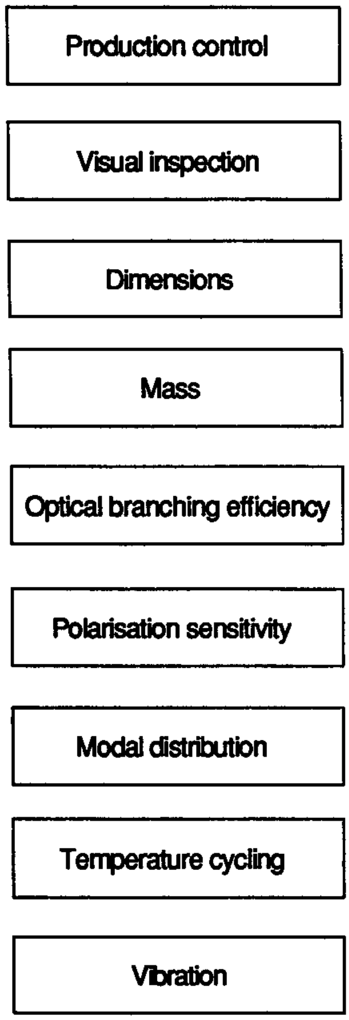

Chart 13.2 Final production testing for fibre optic WDMs.

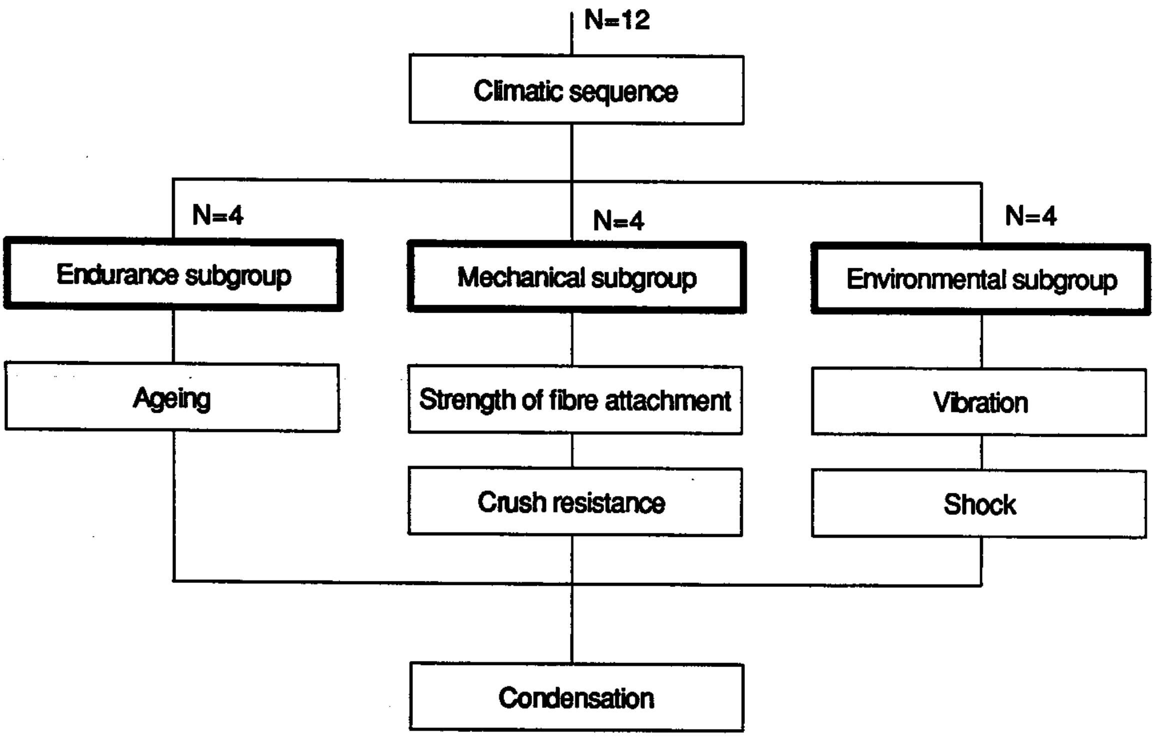

Chart 13.3 Qualification testing for fibre optic WDMs

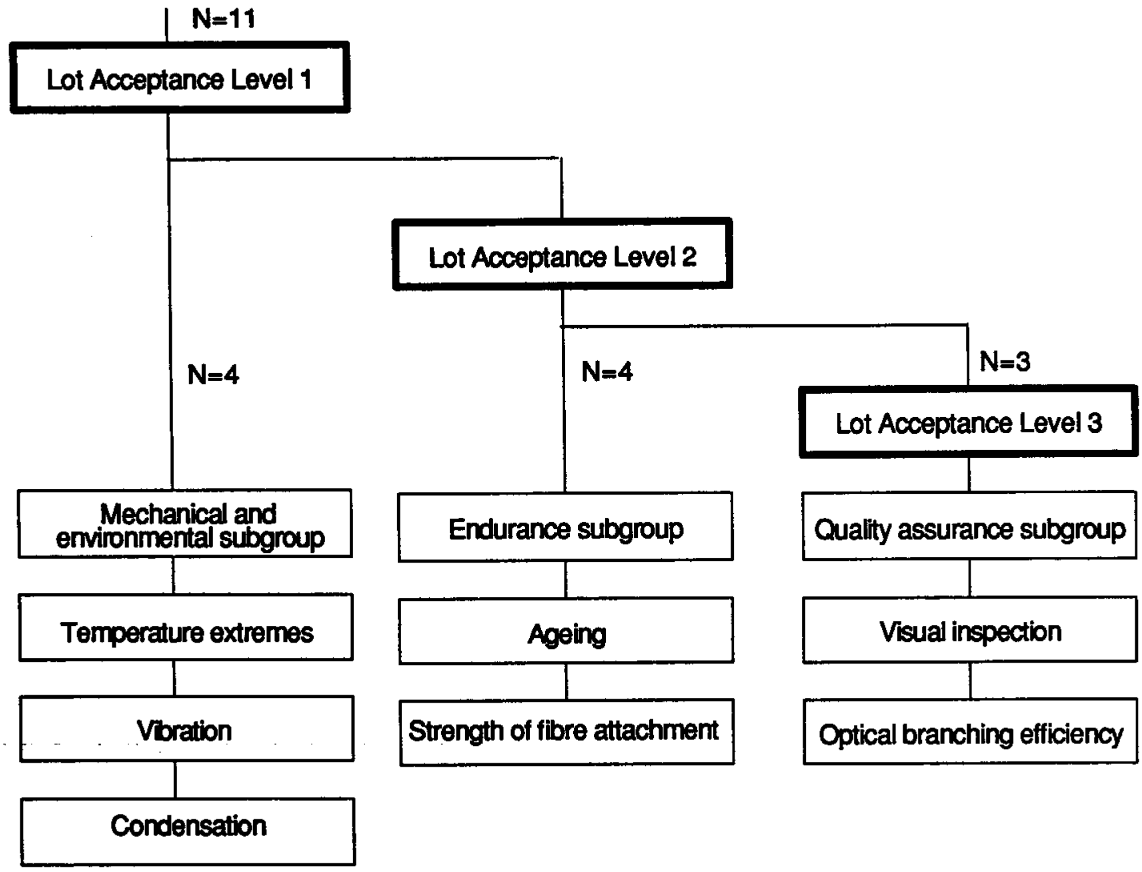

Chart 13.4 Lot acceptance testing for fibre optic WDMs.