
**Space systems — Adhesives — General
requirements**

Systèmes spatiaux — Adhésifs — Exigences générales

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Published in Switzerland

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 20, *Aircraft and space vehicles*, Subcommittee SC 14, *Space systems and operations*.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

The organic adhesive materials have been widely applied in most components of space systems, not only for structural adhesion but also in embedding electronic units and fixing little devices. Hence, the reliability and performance of adhesive materials is essential to the space system performance and safety. Especially for space applications, the environmental adaptability and reliability of adhesive materials is the critical factor to mission schedule and success. This document establishes primary characteristics requirements, selection criterion and procedure for helping space system designer or manufacturer select the best-fit adhesive. Manufacturing process requirements and quality assurance for adhesive materials selection are provided to confirm their compliance with the requirements of space applications. [Annex A](#) provides references for general test methods for property characterization, additional surface preparation and cleaning requirements, and verification of the adhesive lifetime.

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Space systems — Adhesives — General requirements

1 Scope

This document specifies general requirements for adhesive selection with the adhesive bonding process and quality assurance used in space systems.

This document can be applied to different types of adhesive materials in space systems, such as launch vehicles, satellites, spacecraft and space station for the following applications: bonding, components embedding (only for space application), sealing, fixing and repairing.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 14624-3, *Space systems — Safety and compatibility of materials — Part 3: Determination of offgassed products from materials and assembled articles*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <https://www.electropedia.org/>

3.1

coefficient of linear thermal expansion

reversible increase of a material per unit length per degree change in temperature

3.2

coefficient of moisture expansion

α_{CME}

$$\alpha_{\text{CME}} = \frac{\Delta l / l}{m_{\text{water}} / m_{\text{sample}}}$$

where

$\Delta l / l$ is the relative length change referred to as strain;

m_{water} is the weight of the absorbed water;

m_{sample} is the dry weight of the sample

3.3

curing

process of converting a prepolymeric or polymeric composition into a more stable, usable condition by polymerization and/or crosslinking

Note 1 to entry: With adhesives, curing results in the development of the strength properties.

[SOURCE: ISO 472:2013, 2.243, modified — The alternative preferred term "cure, noun" has been removed; the original note 1 to entry has been removed; the original note 2 to entry has become note 1 to entry.]

3.4

glass transition temperature

T_g

approximate midpoint of the temperature range over which the glass transition takes place

Note 1 to entry: The glass transition temperature varies significantly, depending upon the specific property and the test method and conditions selected to measure it.

[SOURCE: ISO 472:2013, 2.441, modified — The symbol T_g has been added.]

3.5

liner

treated sheet to cover the adhesive temporarily to facilitate handling or unrolling

[SOURCE: ISO 29862:2018, 3.6]

3.6

pot life

maximum period of time during which a multi-part adhesive can be used after mixing the components

[SOURCE: ISO 10364:2015, 3.1, modified — The alternative preferred term "working life" has been removed.]

3.7

substrate

object or semi-manufactured product (e.g. wire, extruded metallic section or plastic profile, sheet, film, paper, textile product) on which a coating or layer of another material is applied from the gas, liquid or solid phase by coating, by laminating or generated by a chemical process

Note 1 to entry: In adhesion, the term "substrate" often is a synonym of adherend.

[SOURCE: ISO 472:2013, 2.1128, modified — Note 2 to entry has been removed.]

3.8

surface preparation

physical and/or chemical treatments applied to adherends to render them suitable (or more suitable) for bonding

[SOURCE: ISO 472:2013, 2.1613, modified — The alternative preferred term "surface pretreatment" has been removed.]

3.9

thermal conductivity

proportionality coefficient that represents the relationship of heat flux and temperature gradient, where heat flux on an isothermal surface is proportional to the temperature gradient in the normal direction on the isothermal surface

Note 1 to entry: It is expressed in watt per meter kelvin (W/m*k).

[SOURCE: ISO 16525-3:2014, 3.6, modified — The symbol k has been removed.]

3.10 thermal decomposition

process whereby the action of heat or elevated temperature on an item causes changes in the chemical composition

[SOURCE: ISO 472:2013, 2.1285, modified — Note 1 to entry has been removed.]

3.11 volume resistivity

electrical resistance of the isotropic electrically conductive adhesive for a given cross-sectional area or given length

Note 1 to entry: Electrical volume resistivity is converted to resistance per given cross-sectional area or given length of the isotropic electrically conductive adhesive. ISO 16525-2 specifies measurement methods for an isotropic electrically conductive adhesive, which is applied to a circuit board that is similar to the one used in practice.

Note 2 to entry: It is expressed as ohm metre ($\Omega \cdot m$).

[SOURCE: ISO 16525-2:2014, 3.2, modified — The symbol ρ has been removed.]

4 Selection requirements for adhesive materials

4.1 General requirements

4.1.1 Classification of adhesive application

The application of adhesives used in space systems includes fixing, bonding, sealing, embedding and repairing, as shown in [Figure 1](#).

- a) Fixing: using the adhesive to reinforce the joints of connected components.
- b) Bonding: state in which two materials surfaces are held together by interfacial forces formed by the adhesive.
- c) Sealing: application of the adhesive to the seam of two components, in order to keep the vacuum or decrease the inner gas releasing.
- d) Embedding: process of encasing completely a component by pouring the adhesive over it and curing.
- e) Repairing: the damage part is repaired by the adhesive.

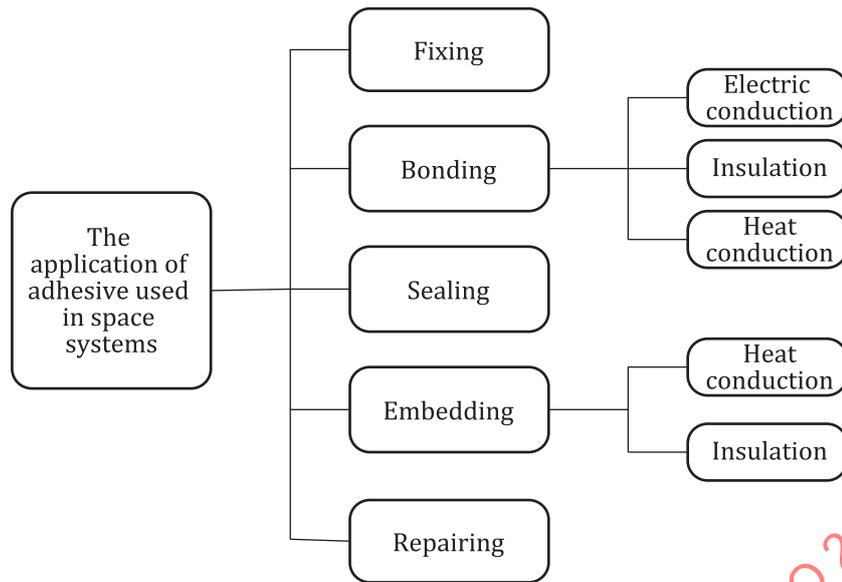


Figure 1 — Application of adhesive used in space systems

4.1.2 Selection criterion

- a) The workability of adhesive materials is highly dependent on the environmental conditions under which the spacecraft is operated. The designer shall fully consider the application environment of the space mission. Adhesive materials shall cope with the performances required during the life on-ground and during its service life.
- b) For a new mission or product, materials already qualified for other missions or products should be evaluated before the final selection. This evaluation should be based on the environmental conditions of the new mission and design requirements of the new product, the joint design, and performance requirements of the new product. If there is no available adhesive that can meet the mission requirement, the designer can start the selection of a new adhesive.
- c) For a new adhesive and process, a series of experimental qualification shall be done according to the mission requirements.
- d) Verification reports and procedures shall be approved by the designer, project manager and quality manager. When requested by the customer and agreed by contract, verification documents shall be also approved by the customer.
- e) The designer shall choose an adhesive supplier that can provide the manufacturing process data for traceability.

4.2 Selection procedure

4.2.1 Primary characteristics before selection

The selection of the adhesive is based on the knowledge of key characteristics depending on the application as described in [Figure 1](#). These characteristics are listed in [Table 1](#).

Table 1 — Primary characteristics considered for adhesive selection

| Properties | Application classification | | | | | Remarks on selection |
|-----------------------------------|----------------------------|---------|-----------|--------|-----------|---|
| | Bonding | Sealing | Embedding | Fixing | Repairing | |
| Shrinkage | + | + | + | + | + | The shrinkage determines the volume change in curing process; it also determines the internal stress and apparent planeness. |
| Adhesion | + | + | + | + | + | The adhesion requirement differs between structural bonding and sealing. The strength of structural bonding strongly depends on the type of the adhesive, the type of the substrate and the type of design of the joint; the test method should be chosen based on the system structure. |
| Glass transition temperature | + | + | - | - | + | For organic adhesives, the glass transition temperature should be outside of the operating temperature range for the adhesive to ensure the stability of the adhesive's properties. But with regard to cold-setting adhesives, the glass-melting temperature cannot be beyond operating temperature limits. For T_g characterization, the designer shall remove the moisture factor. T_g characterization shall be determined in wet condition for launchers. |
| Electrical volume resistivity | + | + | + | - | - | When the adhesive is used for electric conduction or electrically insulating adhesion (adhesives used in wiring, die attach of semiconductor, and surface assembly of printed circuit boards), electrical resistivity should have low sensitivity to temperature in the working temperature range. |
| Thermal conductivity | + | + | + | - | - | When a thermal conductive adhesive is used for embedding and bonding, thermal conductivity should meet the design requirement. |
| Thermal decomposition temperature | + | + | + | - | + | Thermal decomposition temperature limits the highest operating temperature of the adhesive; it also can be used to judge the change of the adhesive's molecule structure after the environment adaptability test. |
| Outgassing | + | + | + | + | + | Outgassing characters of the adhesive shall fulfil the contamination requirement of the space systems. The quantity of outgas is different depending on the adhesive molecule and the moisture structure. |
| Operating temperature | + | + | + | + | + | The minimum and maximum temperature values, at which properties of bonding, sealing embedding, fixing and repairing variate according to the designer requirement. |

Table 1 (continued)

| Properties | Application classification | | | | | Remarks on selection |
|---|----------------------------|---------|-----------|--------|-----------|---|
| | Bonding | Sealing | Embedding | Fixing | Repairing | |
| UV-resistance | + | + | - | + | + | Adhesives applied on the outer surface of a spacecraft are subject to UV rays. Thermodynamic properties and adhesion are degraded by UV. The amount of UV received by a spacecraft is determined by the orbital altitude, expected lifetime and shielding effect of the spacecraft. |
| Electrons, protons radiation resistance | + | + | + | + | + | Adhesives should withstand levels of electrons and protons radiation. Thermodynamic properties and adhesion are degraded by radiation. The dose received by a spacecraft is determined by the orbital altitude, expected lifetime and shielding effect of the spacecraft. |
| Atomic oxygen resistance | + | + | - | + | + | Adhesives applied on the outer surface of a spacecraft are exposed to a large quantity of atomic oxygen which depends on the orbital altitude. Thermodynamic properties and adhesion are affected by atomic oxygen. |
| Refractive index | + | + | + | - | - | When the adhesive is used to bond an optical device, the thermal-optical properties shall satisfy the mission requirement. |
| Thermal stress resistance | + | + | + | + | + | The adhesive shall withstand temperature cycling. The temperature cycling test of the adhesive shall be performed with substrates. |
| Corrosion resistance | + | + | + | + | + | The adhesive shall withstand chemical and biological corrosion. The physical and chemical properties of the adhesive are affected by corrosion. The corrosion test method is determined by the environment of space systems. |
| Service life | + | + | + | + | + | Accelerated environmental tests are used to estimate the life time of the adhesive. |
| Thermal expansion | + | - | + | - | + | The thermal expansion determines the volume change of the adhesive in working temperature; also it can influence the stress generated by the adhesive. The designer shall give a definition value based on the mission requirements. |

Table 1 (continued)

| Properties | Application classification | | | | | Remarks on selection |
|--------------------|----------------------------|---------|-----------|--------|-----------|---|
| | Bonding | Sealing | Embedding | Fixing | Repairing | |
| Moisture expansion | - | + | - | + | + | The hygroscopic or moisture expansion determines the volume change of adhesives due to absorption and desorption of moisture, which can influence the stress generated by the adhesive. The designer shall consider these effects in frame of the adhesive selection and joint definition based on the mission requirements of the respective configuration, for example, moisture absorption shall be considered in case of stringent requirements on dimensional stability. The coefficient of moisture expansion should be given if required by the mission or the customer. |

4.2.2 Selection steps

Selecting the right step is key to finding the best-fit adhesive efficiently. [Figure 2](#) shows a flowchart for the selection of a new adhesive.

- a) The designer shall define the mission requirement before adhesive selection, including system or component structure, environmental conditions, the application's performance levels, etc.
- b) Adhesive selection shall be made by designers based on their concern(s) on the physical and chemical properties of the adhesive, and then the designers select the potential available adhesive for further test.
- c) The space system manufacturer shall design a reliable manufacturing process, which is achievable and controlled. The configuration, the cleaning, the application of chemical conversion coating, primers and the surface preparation of the part(s) to be sealed or glued are considered as critical parameters of the adhesive bonding process, which govern the performance of the adhesion.
- d) Standardized test methods shall be selected to assure adhesive application performance and material compatible. Accelerated environmental tests like thermal cycle, thermal acceleration and irradiation also shall be performed according to representative conditions of the mission or the product environment.
- e) After completing the first four steps, if there are several potential adhesives which meet the mission requirements, the designer shall choose the best one after considering economic, environment, safe and healthy regulations constraints. But if there are no adhesive to meet the mission requirements, the designer shall go back to step a) and re-evaluate more adhesives, or change design (adhesion structure, load pass) and service conditions (temperature, radiation dose) until finding one available adhesive.

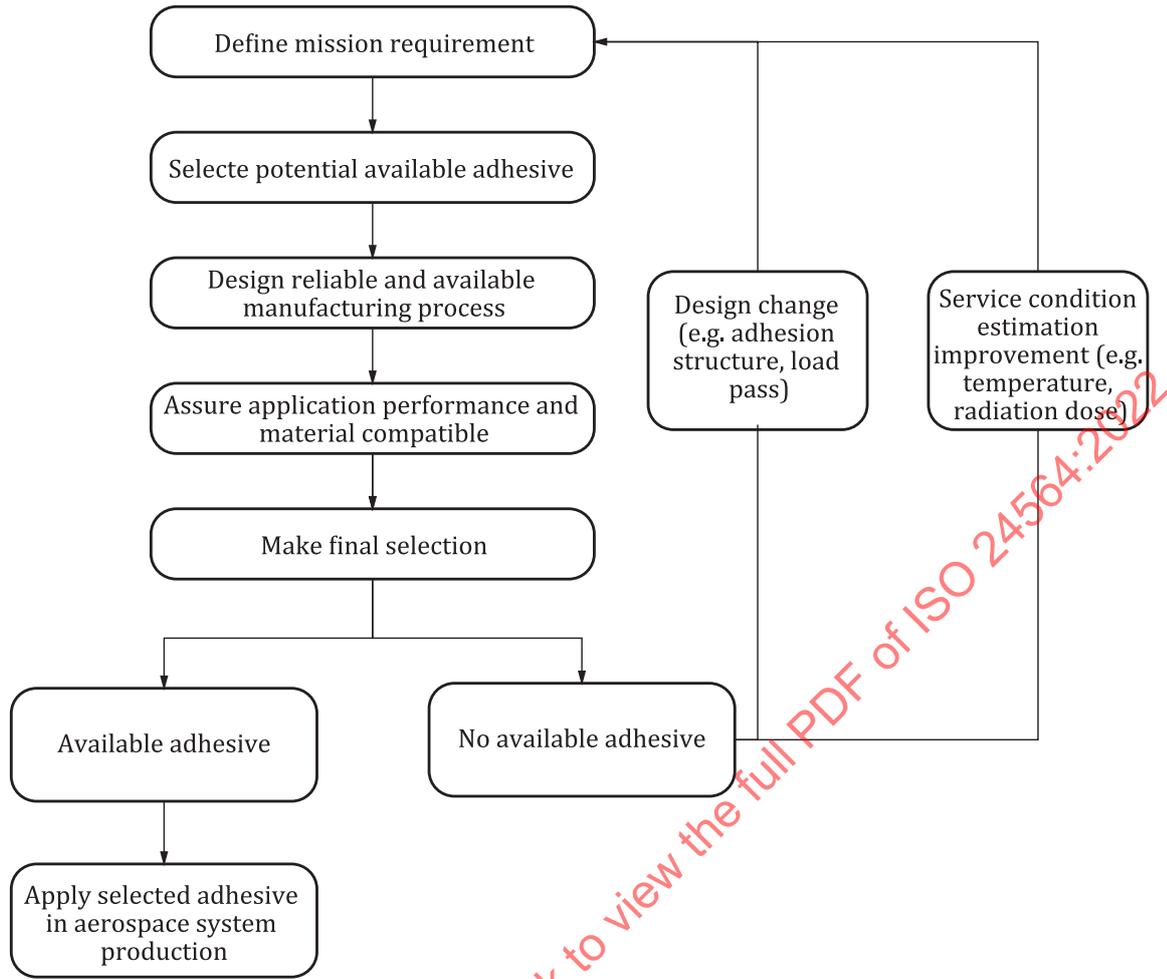


Figure 2 — The procedure of adhesive selection

5 Test methods for adhesive properties

5.1 General

The adaptability and reliability of adhesive are confirmed by testing properties. Appropriate test methods shall be selected based on the actual application; and the test plan shall be reviewed by the designer and the customer. The test report shall be approved and registered. [Table A.1](#) provides methods to perform the measurement tests for the properties specified in [5.2](#) to [5.13](#).

5.2 Shrinkage

Shrinkage characters are obtained by measuring the volume or thickness change of the adhesive before and after curing. The curing process (temperature, moisture and intensity of illumination) affects the shrinkage behaviour of the adhesive.

5.3 Adhesion

The adhesive strength is obtained by using appropriate standard methods on representative test sample of the real joint system structure (same substrate surface preparation process, cleaning process, curing process).

5.4 Glass transition temperature

The glass transition temperature of the adhesive can be obtained through measuring dynamic mechanical properties and the expansion coefficient method. The curing process of test samples shall be identical to products.

5.5 Electrical volume resistivity

The electrical volume resistivity of the adhesive is obtained using the measuring probes and an appropriate voltage or resistance meter.

The measuring devices shall have the required accuracy and smooth regulation of the applied test voltage. The humidity, temperature, pressure, etc. of measurement shall be recorded.

5.6 Thermal decomposition temperature

The thermal decomposition temperature of the adhesive can be determined by the method of thermogravimetric analysis under inert gas atmosphere. The samples for thermal decomposition temperature test shall have the same preparation process with products.

5.7 Thermal conductivity

The thermal conductivity of the adhesive can be obtained through steady-state heat flow meter apparatus and the pulsed laser flash method. Dimensions of the samples shall be selected by reference to the requirements of the applied test method. The samples shall have identical thickness and smooth surfaces to decrease test errors.

For the pulsed laser flash method, the density and heat capacity shall be known to calculate the thermal conductivity. For the thick bulk adhesive where pores are generated, thermal conductivity should be measured via the indirect method of coupling substrates whose thermal conductivity is known and which are adhesive.

5.8 Thermal expansion

The coefficient of linear thermal expansion of the adhesive can be obtained by using push-rod dilatometers. The material shall exhibit sufficient rigidity under the stresses imposed by instrumentation.

5.9 Ground environment durability

The environmental conditions at the launch site, especially the temperature and humidity, have an effect on the durability of adhesives. The service life of the adhesive changes under the influence of on-ground environment conditions.

5.10 Outgassing

The outgassing character of the adhesive shall fulfil the contamination and moisture ingress requirement of the spacecraft.

5.11 UV-resistance

The expected lifetime, attitude, geometry of the spacecraft and potential artificial UV light sources determine the amount of UV fluence that the space system receives.

Changes in the adhesion of the tested specimen and thermodynamic properties including glass transition temperature and thermal decomposition temperature shall be evaluated.

5.12 Radiation resistance

The expected lifetime, shielding effect of the space system, and attitude determine the dose that the space system receives.

Changes in thermodynamic properties and adhesion of the tested specimen shall be evaluated.

5.13 Atomic oxygen resistance

The expected lifetime, attitude, and geometry of the spacecraft determine the amount of atomic oxygen that the space system receives.

Changes in the adhesion of the tested specimen and mass shall be evaluated.

6 Lifetime verification and failure

6.1 Lifetime verification

The lifetime verification can be achieved by thermal acceleration experiments, thermal cycle, corrosion and exposure of moisture, temperature and load based on real conditions. The test plan shall be fully justified and approved by the user. The test sample shall be assessed by the assembly test with adhered substrates to guarantee the test reliability. [Table A.3](#) provides reference standards to verify the adhesive lifetime.

NOTE Lifetime verification of the adhesive can be calculated under one setting parameter like temperature or moisture. As there is no exact model to predict the lifetime for now, the prediction value of accelerated aging is only for reference.

6.2 Failure

6.2.1 Failure mode

The failure modes of the adhesive are different according to the application as specified in ISO 10365. Adhesive materials failure is complex owing to different actual applications; it generally includes adhesion joint debonding or failure of the substrate, surface crack of the adhesive (embedding, repairing application). For the primer application process, lack of adhesion between the primer and the adhesive or the primer with substrate can also lead to adhesive bonding failures. All these failures are considered unacceptable and indicate bad adhesion structure or the lack of chemical bonding between the substrate and adhesive materials. But for elastomer material or composites bonding, the rupture in the interphase adhesive/substrate can be accepted because of the inter-diffusion phenomena.

When the application of the adhesive is in a low temperature environment, the failure mode may change due to higher elastic modulus of the adhesive and stress created by CTE mismatch, even if the adhesive has excellent performance at room temperature. In this case, the modification of failure can be accepted if the mechanism of adhesion is well performed at room temperature.

6.2.2 General failure analysis and preventive measures

Inappropriate failures are caused by uncertain environmental conditions during all the life cycles, inappropriate surface preparation, inappropriate adhesive selection, insufficient quality control of gluing process with insufficient training of operators and inappropriate design of the adhesive bond. An analysis shall be performed in order to find the root cause of the failure. The analysis shall cover the whole manufacturing process and application condition, including the raw material supplier, adhesive bonding and transport process, worker training, and environmental effect which may cause a degradation or failure to occur. Preventive measures are necessary to remove the cause of the failure by means of a different material selection, or a change to one or more of the processing steps, in order to satisfy the mission requirements.

7 Adhesive bonding process design, safety and environmental protection requirements

7.1 General requirements

The space system manufacturer shall prove that adhesion is well mastered. A well-detailed application procedure and a reliable control plan which gathers all the key parameters to monitor during all the steps of the process (workshop environment, glue preparation, surface preparation of the substrates, surface cleaning, and adhesive bonding process) shall be available. Demonstration of repeatability of the performance of adhesive joints shall be done before manufacturing flight products. The design of the adhesive bonding process should be in accordance with the flowchart showed in [Figure 3](#).

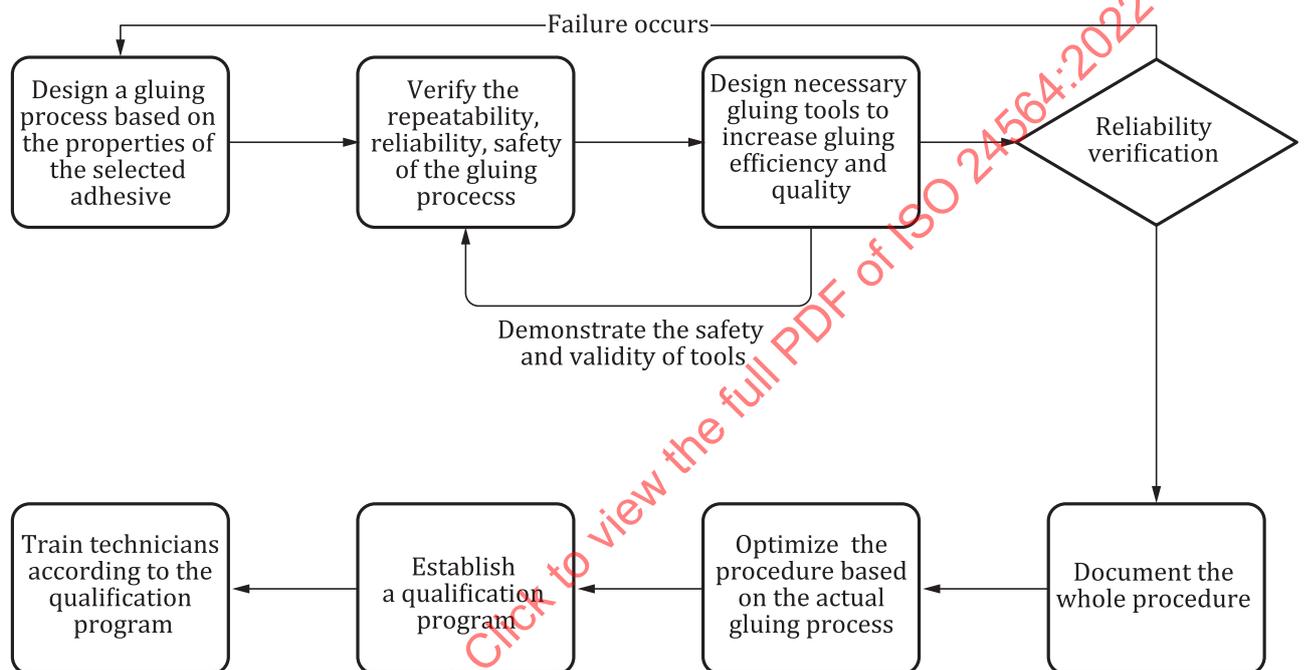


Figure 3 — The flowchart of adhesive bonding process design

7.2 Process technology and tool design requirements

- The adhesive container shall be labelled with the name, production date and expiration date. The adhesive shall be stored according to the supplier's requirements and isolated from fire and heat.
- As for a multicomponent adhesive, blend all the components thoroughly according to the proportion, and apply the blended adhesive in the pot life.
- The adhesion procedure is qualified and documented to be used in production after demonstrating repeatable and reliable processing steps. The characterization outside the process limits is also documented by the space system manufacturers, material and process department to ensure process robustness.
- The material and process department shall establish available surface preparation processes, to ensure that the substrate surface is properly prepared according to the type of bonding material. [Table A.2](#) provides additional surface preparation and cleaning requirements.
- The material and process department and space system manufacturer shall define the appropriated means to overcome gluing operation difficulties met in real operative conditions.
- The designer shall give the bond line thickness; and the manufacturer shall give the amount of adhesive.

- g) The gluing materials primarily prepared in terms of chemical and physical state shall introduce no pollution.
- h) For hot curing adhesive and radiation curing, including visible (blue) light, UV and infrared (IR), the curing process shall not influence other parts close to the gluing part.
- i) The cure conditions including temperature, applied pressure, time, moisture and contamination shall be controlled efficiently according to the material and process department and space system manufacturer requirements.
- j) The designers shall control the adhesive joint parts dimensional tolerance and pressure to ensure the performance of the adhesive.
- k) The material and process department and space system manufacturer shall give a definite requirement to avoid the contamination to products by the adhesive in the adhesive bonding process.
- l) When the substrate with film adhesives needs to be transported during the manufacturing process, the liner shall be used to avoid damage and contamination.

7.3 Safety and environmental protection requirements

- a) The adhesive materials shall be environmentally compatible; and the properties variation under temperature, irradiation and thermal vacuum conditions shall meet the environmental protection requirements.

NOTE It is presupposed that the local safety regulations are considered.

- b) The effused pollutant shall meet environmental protection requirements, which shall not set off a chemical reaction with the surrounding gas composition to generate toxic substance or inflammable, explosive, or toxic secondary dangerous compounds.
- c) The adhesive materials used inside the manned pressurized cabin shall be inspected by fire retardancy test, combustion production test, and toxic off-gassing test. The adhesive materials used outside the pressurized cabin shall be inspected by the material outgassing test.
- d) For adhesives used inside the manned spacecraft, the toxic off-gassing character shall meet the requirements of ISO 14624-3.

8 Quality assurance requirements

8.1 General requirements

- a) The requirements for the adhesive bonding process and raw materials shall be documented for training workers and inspectors.
- b) The space system manufacturer should identify the production process, raw materials and actions that influence the properties of the adhesive and should also provide adequate monitoring of the production process, raw materials and actions.
- c) The designers shall define the design key characteristics related to the quality of adhesive bonds; and the space system manufacturer shall define the production key characteristics with process control parameters.

8.2 Inspection

- a) The space system manufacturer shall perform an incoming inspection on all materials and components used in the adhesive bonding process.

- b) Inspection items shall be based on the specifications by the space system manufacturer; and inspection results of every batch shall be recorded.
- c) The adhesive materials that passed the inspection test shall be used in the required shelf life indicated in the specification or the contract.
- d) If the first inspection fails and the adhesive supplier doesn't accept the result, a generally accepted third party shall be introduced to arbitrate; and the arbitration result is the final conclusion.
- e) For adhesive materials that are sensitive to storage conditions, periodic inspection (visual, physical, mechanical tests) shall be conducted.
- f) For the adhesive beyond shelf life, follow the specification requirements if the specification declares decisively that it can be used after passing the re-inspection with specified test items and the period of validity for the re-inspection result.
- g) The space system manufacturer shall ensure all gluing system and tooling has no detrimental effect on the manufacturing process; all gluing devices and tools shall be calibrated periodically.

8.3 Traceability

- a) When the designer gives sample preservation requirements, the space system manufacturer shall preserve the adhesive sample (film of adhesive, mechanical test samples or other samples required by the designer) of every batch production for re-inspection test. The batch information of samples shall be labelled definitely.

NOTE The preservation condition and time is documented by the designer.

- b) When one or more requirements for the adhesive bonding process need to be changed, the change initiator shall issue an exception document to be approved by the designer and responsible program manager. The material and process department shall investigate the consequence of any modification of the adhesive bonding process.
- c) The permissive document shall be issued to the material and process department; and related training should be done with the support of the designer and quality manager if necessary.
- d) All changes and revisions shall be registered, including the date of change, the designation of confirmatory document and the numbers of pages (changed, new and annulled).

8.4 Worker and inspector training

The enterprise shall establish a systematic training system. Every new worker and inspector for the adhesive bonding process shall be trained and qualified before performing adhesive bonding processes. The establishment of the training system should be in accordance with the flowchart showed in [Figure 4](#). If the customer requires training in an external school, the space system manufacturer should send the worker to the external school approved by the customer to be trained and qualified.

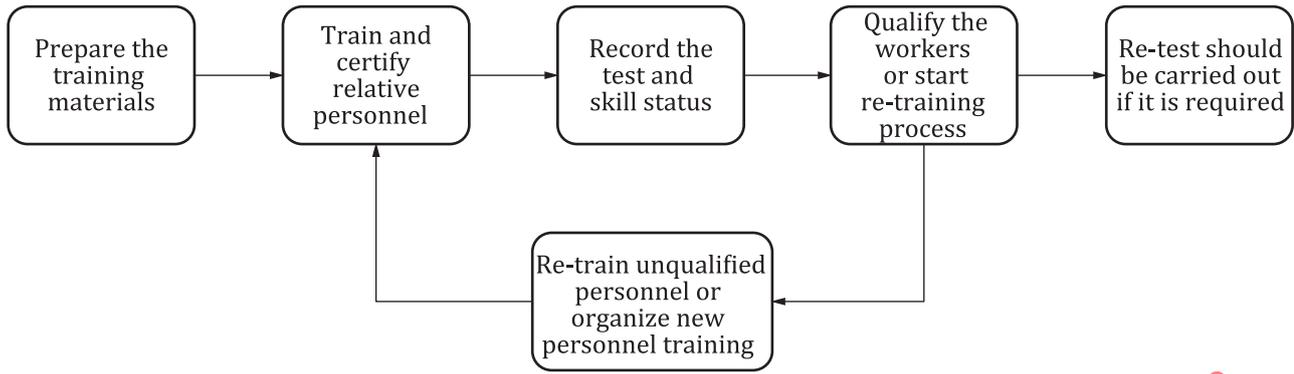


Figure 4 — The flowchart of training system

- a) The space system manufacturer shall document all training materials, including process requirements, test paper, practical assessment and inspection standards.
- b) The process management organize training and assessment for workers and inspectors systematically.
- c) The test and skill status of all workers and inspectors should be recorded and traced in human resource management.
- d) For unqualified personnel, re-training should be carried out or new personnel training should be organized.
- e) Re-test should be carried out after a period of time if it is necessary according to the designer requirement.
- f) The designer shall examine the training process to determine whether it is well done and appropriate.

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