element

WHITE PAPER | 2021

PRODUCT QUALIFICATION TESTING FOR SPACE

SURVIVAL, CHALLENGES AND SOLUTIONS

element.com

We are the recognized leader in testing, inspection, and certification services to a diverse range of sectors where failure in service is not an option. With almost 200 years of experience and a global network of world-class laboratories, we make certain that the materials and products we test, inspect and certify for our customers are safe, quality, compliant and fit for purpose.

INTRODUCTION

Space has a reputation for being cold and unforgiving.

Without oxygen, or any other major convenience, it is quite difficult for mankind to enter the great unknown. Preparation is key to surviving the harsh climates and extremities of outer space.

Whether heat or cold, materials in spacecraft face many special challenges. You wouldn't need your car to stand up to sub-zero temperatures, or the pressure of orbit, but the importance of constant testing and product recalls in the auto industry remains imperative to the safety of drivers. Millions of cars are recalled every year to save lives and protect consumers from product defects.

During launch, materials in spacecraft experience very high temperatures and sizeable acoustic exposures. As launch vehicles ascend, they are impacted by large changes in pressure and eventually enter the vacuum of space. In orbit, materials are exposed to rapid thermal cycling as they go in and out of the Earth's shadow. They may even encounter extreme radiation and atomic oxygen.

Imagine how much more difficult it would be to have a breakdown in space! That's where it's so critical to ensure you have a comprehensive testing plan in place to get your spacecraft ready for launch. Below, we explore some important tests for safety, durability and overall performance.

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CRITICAL TESTS FOR SPACECRAFT

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Non-destructive testing is essential for quality assurance.

NON-DESTRUCTIVE TESTING

Non-destructive testing (NDT) covers a broad group of techniques used to evaluate the properties of a material, part, product, weld, or system without materially affecting the integrity of the unit being inspected or investigated under the test procedure. Performing these tests give assurance that the products, and materials we use are fit-for-purpose. NDT is essential for quality assurance; appropriate testing methods are used to gather information on a material without damaging it.

NDT is a highly effective way to detect the very smallest of imperfections or damage in aerospace materials or components throughout their operational life, without materially affecting the integrity of the item being tested. Aerospace non-destructive testing can be used to detect defects such as geometrical faults, e.g. material thickness, welding defects, bondline defects, delamination, wrinkles, porosity, dry areas, foreign objects, cracks or corrosion.

Types of Non-Destructive Testing

Conventional radiographic testing (RT): a portable method capable of revealing the most microscopic cracks in metallic materials.

Digital radiography: a highly sensitive radiographic method that produces an image in a digital format that is viewable on a computer.

Computed tomography: the most advanced radiographic testing method that uses an automated detector motion to gather thousands of images at various angles to create a 3D image.

Eddy current testing (ET): particularly helpful to evaluate heat exchangers and aircraft parts and components.

Liquid penetrant inspection (LPI): a valuable tool for evaluating non-ferromagnetic and non-metallic materials. In addition to checking for defects and cracks, it can also be used to determine other surface characteristics, such as porosity.

Magnetic particle inspection (MPI): used to check for surface and near-surface discontinuities in ferrous materials.

Ultrasonic testing (UT): utilizes sound waves to detect cracks and defects in parts and materials. It can also be used to determine a material's thickness, such as measuring the wall thickness of a pipe.

Visual inspection

Weld inspection

ASTM E595 OUTGASSING TESTING

The unique environment encountered by orbiting spacecraft necessitates a particular focus on aerospace manufacturing to safeguard against environmental factors in space. The impact of the combination of vacuum and heat on a spacecraft may cause some materials to release harmful vapors. These can condense on components within electronic equipment, causing issues such as shorted circuits and potentially impacting the clarity of sensitive optics, like telescopes and spectrometers.

Contamination control is essential for spacecraft performance because dust or environmental contamination not only affects the optical performance, but can also cause damage during launch. This is why many spacecrafts are assembled in clean rooms to mitigate dust and contamination by particulates. However, another vital form of contamination is molecular, which can also have a significant impact on the operation of spacecraft.

Outgassing testing is designed to measure molecular contamination which creates thin films of matter that settle on spacecraft parts. This might occur as a result of volatile materials diffusing out of the samples under space conditions, through desorbing or evaporating. It is much like when you see a film of contamination forming on the inside of the windshield of a new car.

This form of contamination can significantly reduce the performance of lenses and mirrors, which may not be easily cleaned once in orbit. Many spacecrafts also contain sensors that need to be maintained at a constant cold temperature; designers need to balance the thermal loads carefully during the design process.

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Heat sources can include internal electronics or absorption of solar radiation, which can require the spacecraft to be actively cooled through use of radiators. These devices are made or coated with materials that emit more energy than they absorb. Both thermal absorption and thermal emissivity are changed when materials are coated with thin films of contaminants. This can upset the delicate thermal balance of the spacecraft, so every effort is made to avoid molecular contamination occurring.

Developed by NASA and the technical community with aim of screening low outgassing materials for use in space, ASTM E595 has become the industry standard test for measuring outgassing properties in organic, polymeric and inorganic materials. Its purpose is to determine the amount of volatile content in materials when exposed to a vacuum environment.

Actual contamination depends on geometry, temperatures and other factors and ASTM E595 provides a method of reproduction to provide material screening. Samples are subjected to 125°C and less than 10^{-5} Torr. While this vacuum level is not as low as space, it is practical and sufficient that the average free path of the molecules is longer that the chamber cell dimensions. The exposure is performed in a standard configuration chamber with collection plates maintained at 25°C.

Weight loss of the samples and amount of material collected are measured, with the weight loss referred to as Total Mass Loss (TML) and normally expected to be less than 1%. The weight gain of the collector plate is referred to as CVCM. After exposure, material is conditioned at 25C and 50% RH to determine how much of the weight loss can be assumed to be moisture, known as water vapor regained (WVR).

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In performing the test, material samples such as elastomers, coated parts, seals or composites are placed in a clean standard container. The samples are typically 2mm cubes, but other sizes may be used depending on the material being tested (the minimum size is typically 200 mg).

Throughout the testing process, care is taken to avoid contamination by fingerprints or other laboratory materials. The container and sample are exposed to 23C and 50% RH for 24 hours, after which the sample and boat are re-weighed and then placed in the outgassing chamber. The contents are arranged on a heating bar that can be maintained at 125°C in the geometry specified.

Each container has a weighed condensation plate at a specified distance and is masked by separator plates to prevent cross-contamination. Once installed the vacuum is applied and once the pressure is below the 5 X 10^{-5} Torr target, the heater bar is heated to 125°C and the test then runs for 24 hours.

Three specimen compartments are run without samples to provide a control test. After the exposures, samples are weighed, exposed to 23°C, 50% RH and then weighed again.

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THERMAL VACUUM TESTING

Thermal vacuum testing is an important aspect of qualification testing for a wide variety of space flight components, sub-assemblies, and mission-critical equipment. Thermal vacuum testing allows for the simulation of space and upper atmosphere conditions including temperature and altitude.

Testing components for space applications requires a unique set of capabilities. In addition to the already rigorous standards used in the aerospace industry, space qualification requires even more extreme temperatures, higher pressures, and more drastic environmental simulation.

Thermal vacuum testing simulates a space environment, by removing air and pressure and cycling very high and very low temperatures. By testing in an environment that simulates real world conditions as closely as possible, thermal vacuum exposure can identify design issues before components are integrated into larger systems, saving time and money.

Along with testing sub-assemblies and mission-critical equipment, thermal vacuum chambers are also sought after for evaluating seals and rings, High Pressure-High Temperature (HPHT) programs, vacuum bakeout testing, and any project that requires a sterilized test environment.

FATIGUE AND SHOCK TESTING

Fracture Toughness and Fatigue Testing

Fatigue testing is a useful method for characterizing material or component behavior during cycling and loading. Understanding fatigue properties is one of the most crucial elements of research and development, product safety, and material verification programs.

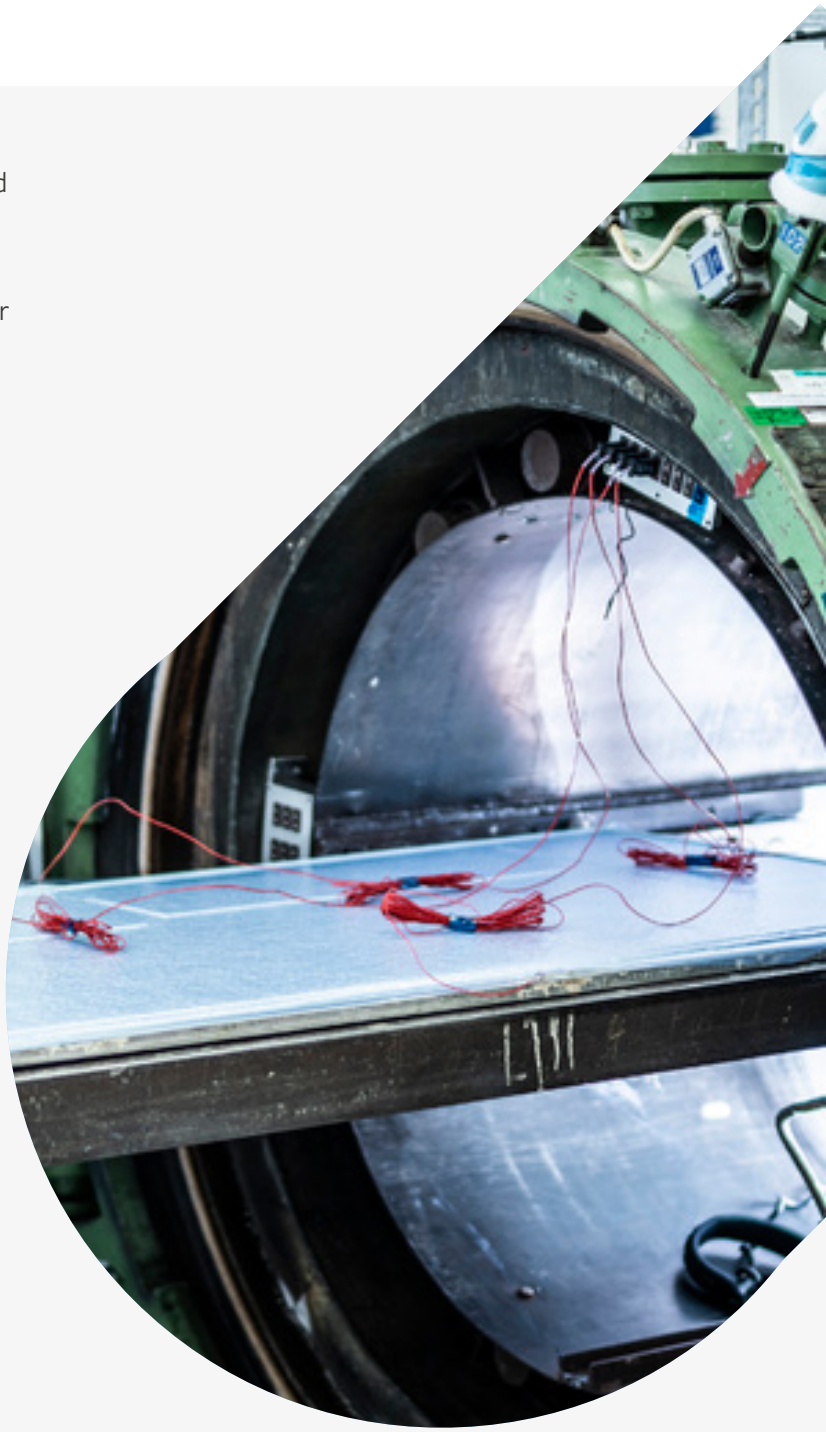
Shock Testing

Shock testing includes shock response spectrum (SRS), half sine, terminal peak saw tooth, pyro shock simulation, and ballistic testing, all of which prepare products for harsh industrial, transportation and military environments. By measuring the impact of sudden acceleration caused by drop or collision, shock testing is able to ensure a product can meet a variety of industrial and military standards, including RTCA DO-160, MIL-STD-810, DEF STAN 00-35 and EN 60068.

TESTING FOR COMPOSITE MATERIALS

Polymer based composite materials are uniquely suited for many space applications. The mechanical strength and stiffness may be designed with directional properties. Maintaining a low coefficient of thermal expansion may also be an important attribute. Some interesting applications include cryogenic tanks for propellants, other launch vehicle structure, satellite busses, and antennas. The value of a lightweight material and design is far greater than on an analogous aircraft structure in space.

Element performs qualification and allowables testing so designers may utilize these materials optimally. These tests include “building block” tests on lamina and laminates for properties such as tensile, compression and shear; they are performed at high and low temperatures and after environmental conditioning. Further up the design pyramid, Element tests sub-elements and components. Ceramic matrix composite materials have become popular in rocket engine components due to their very high resistance to temperature.



OTHER KEY TESTS

High level acoustic noise testing

Carried out in specialized reverberant chambers, high level acoustic noise tests simulate high level airborne induced vibration. Aerospace and other industrial components are exposed to these intense levels of sound pressure, helping to meet military acoustic testing specifications, such as MIL-STD-810, Method 515.

Natural and induced environmental simulation

Climatic testing services include temperature, humidity, altitude, salt spray and corrosion, and weather effects including hail, snow, wind, ice, and rain, to verify that a product can endure harsh environmental conditions.

Radiated aging and effects

Accelerated aging and shelf life tests can help determine how environmental conditions including, temperature, humidity and light will affect the lifespan and integrity of your product. Element also has radiated aging tests to find determine the impact of radiation in space.

HOW ELEMENT CAN HELP

For more information, please visit **element.com**

HOW ELEMENT CAN HELP

WHY CHOOSE ELEMENT?

Element's space simulation testing laboratories provide materials testing and product qualification services for the aviation, missile, satellite, and space industries. From electronic components to complete assemblies, our experts provide test programs for the United States Department of Defense, NASA, US armed forces, and more. Element is making space travel safer through product and material testing. Contact us to request a quote today.

We specialize in evaluating materials, components, and systems in terms of how they will behave in the extreme and hazardous environments that exist during launch, flight, and re-entry for both unmanned and manned space vehicles.

From materials characterization to electronic components to complete assemblies, our experts have many years' experience in providing comprehensive test programs designed to comply with the RTCA DO-160, EUROCAE ED14, MIL-STD-810 and MIL-STD-461 standards.

OUR TESTING SERVICES

- Fracture Toughness and Fatigue Materials Testing
- Metallic, Non-Metallic and Composite Materials Testing
- ASTM E595 Outgassing
- Non-Destructive Testing
- Clean Room Access
- Thermal Vacuum Testing
- Simulated and Ordinance Induced Pyro Shock
- High Level Reverberant Acoustic Noise
- Hydraulic, Pneumatic & Fuel Copmonent/System Natural and Induced Environmental Simulation
- Radiated Aging and Effects

Contact.us@element.com

Europe: +44 (0) 808 234 1667 Germany: +49 800 000 5137 Americas: +1 888 786 7555

www.element.com