

Guide: Space Systems — Composite Overwrapped Pressure Vessels with a Plastic Liner

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Guide: Space Systems — Composite Overwrapped Pressure Vessels with a Plastic Liner

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Abstract

This Guide assists in establishing baseline requirements for the design, analysis, fabrication, test, inspection, operation, and maintenance of composite overwrapped pressure vessels (COPVs) with a plastic non-metallic liner. These COPVs are used for pressurized, hazardous, or nonhazardous liquid or gas storage in space systems including spacecraft and launch vehicles. This Guide is applicable to COPVs constructed with a plastic liner and a carbon fiber/polymer overwrap.

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Foreword

This Guide is sponsored by the American Institute of Aeronautics and Astronautics (AIAA) as part of its Standards Program.

This Guide was developed in collaboration with manufacturers, launch site operators, range safety authorities, and individuals affiliated with universities and government entities.

The AIAA Aerospace Pressure Vessels (APV) Committee on Standards (CoS) was initially formed in March 1996 as a working group within the AIAA Structures Committee on Standards with an emphasis on inclusion of aerospace prime companies, pressure vessel suppliers, and all applicable government agencies. Deliberations focused on adapting the standard to address commercial procurement of aerospace composite pressure vessels.

The APV CoS in 2018 published: ANSI/AIAA S-080A-2018 Space Systems—Metallic Pressure Vessels, Pressurized Structures, and Pressure Components (Revision of AIAA S-080-1998) and ANSI/AIAA S-081B-2018 Space Systems—Composite Overwrapped Pressure Vessels (Revision of AIAA S-081A-2006). These two standards followed a consistent numbering; sections (requirements) that are common between the two have the same number in both documents. If one document has a section (requirement) that is not applicable (while it is relevant for the companion document) then the section is marked reserved to keep the numbering consistent. The same consistency has been followed in this Guide with respect to the two other standards.

ANSI/AIAA S-081B-2018 is applicable to COPVs constructed with a metal liner and a carbon fiber/polymer overwrap. The incorporation of a non-metallic liner changes the approach to certifying this class of COPVs and necessitates a distinct set of baseline requirements. Because the technology associated with the use of these COPVs has not been used extensively in space applications, the AIAA Aerospace Pressure Vessel Committee on Standards decided to develop this Guide in order to establish the framework for such requirements. It is hoped that this Guide will develop into a standard as the industry adopts the usage of these vessels and a consensus set of requirements emerges.

The AIAA Standards Program Procedures defines a Guide as:

technical information that supports present or future Standards or Recommended Practices and provides instruction for their application; this category includes handbooks and uses “may” statements, indicating a permissive position

In this Guide, the requirements that were retained from ANSI/AIAA S-081B-2018 are indicated with Asterisks, i.e., they are expressed as “may” statements. It is noted that ANSI/AIAA S-080A-2018 and ANSI/AIAA S-081B-2018 follow the same document structure, so this Guide matches the organization of these two standards.

The Guide includes new sections to provide guidance for establishing design and verification requirements related to the non-metallic liner.

In general, the committee chose not to update sections of the document not affected by the change of the liner material. In some areas, it was felt necessary to offer improvements based on experience. The following changes to baseline requirements are included:

- Additional clarification was provided for the use of the Environmental Correction Factor (ECF).
- Definitions were updated. Definitions were added for liner, hydrogen embrittlement, and glass transition temperature.
- Requirements for reliability were added as they appear to be an error in the previous standards.

It is anticipated that these changes might later be incorporated into future revisions of ANSI/AIAA S-080A-2018 and ANSI/AIAA S-081B-2018.

We are indebted to those authors who served on the Drafting Committee and compiled the input from a broad range of stakeholders to form the various drafts for review by the committee: Jim Harris (Editor/Chair), Jacob Fannon, Scott Forth, Vinal Goyal, and Michael Kezirian.

The current members of the AIAA APV CoS appreciate the valuable input from several original members and express their gratitude to past committee members and reviewers whose contributions over many years have resulted in an improved standard. At the time of approval of this document, members of the APV CoS were:

Michael Kezirian, Chair	University of Southern California
Nathanael Greene, Co-Chair	NASA Johnson Space Center
Alejandro Vega, Co-Chair	U.S. Air Force

Members:

Pravin Aggarwal*	Independent Consultant
Clifton Arnold	NASA OSMA
Robert Biggs	Lockheed Martin Space Systems Company
Dan Bryan	MCET Technologies
James Cannon	Axiom Space
Kevin Case	USAF, 30th Space Wing Safety
Jim Chang	Analytical Mechanics Associates
Gregory Coll	Northrop Grumman
Robert Conger	Microcosm, Inc.
Harry Conomos	Moog Inc.
Adam Cooper	NASA Kennedy Space Center
John Duke, Jr.	Virginia Polytechnic Institute and State University
Amy Engelbrecht-Wiggans*	Cornell University
Paul Fannon	Composite Technology Development, Inc.
Jacob Fannon	Blue Origin
Scott Forth	Space Exploration Technologies Corporation
Susan Gavin	Independent Technical Advisor - Engineering Contractor
Wes Geiman	Vivace Corporation
David Gillis	Airbus
Vinay Goyal	The Aerospace Corporation
Owen Greulich	Consultant
Jonathan Griffith	Marotta Controls

Lorie Grimes-Ledesma	NASA Jet Propulsion Laboratory
Tim Gurshin*	Lockheed Martin Space Systems Company
Ches Hall*	NASA TOSC
Joe Hamilton	Engineering Research Consulting, Inc
Jim Harris	Hexagon MasterWorks, Inc.
Luis Hernandez	Jacobs Technology
Mike Holt	Virgin Orbit
Kauser Intiaz	NASA Johnson Space Center
Srinath Iyengar	Independent Consultant
Ian Juby	NASA Johnson Space Center
Junaid Karim	Axiom Space
Michael Kelly*	Independent Consultant
Peter Kinsman	Aerojet Rocketdyne
Scott Kramer	NASA Marshall Space Flight Center
Aaron Laney	Jacobs Technology
Edward Lira	USAF, 30th Space Wing Safety
Efren Luevano	Infinite Composites Technologies
Kaushik Mallick	Verne
David McColskey	National Institute of Standards and Technology
Dan Mueller*	Independent Consultant
Cornelius Murray	General Dynamics / OTS
Norman Newhouse	Newhouse Technology LLC
Yenyih Ni	The Aerospace Corporation
Jay Nightingale	Lockheed Martin Space Systems Company
Michael Papadopoulos*	The Aerospace Corporation
James Patterson	HyPerComp Engineering
Allyssa Paul*	The Aerospace Corporation
Henry Peebles	USAF 45th Space Wing (Range Safety - KSC)
Mark Pokrywka	Vivace Corporation
Xueyong Qu	The Aerospace Corporation
Jeff Rayburn	NASA Marshall Space Flight Center
Kevin Richards	Northrop Grumman Innovation Systems

Markus Rufer	Scorpius Space Launch Company
Rick Russell*	NASA KSC
Christopher Sagrillo	The Aerospace Corporation
Laura Sargent	USAF 45th Space Wing (Range Safety - KSC)
Christian Schumacher	Naval Undersea Warfare Center
Kay Siegel	H2Safe, LLC
Gerben Sinnema	European Space Agency
Tucker Smith	HyPerComp Engineering
Kirk Sneddon	Arde, Inc.
Brett Soltz	The Aerospace Corporation
Michael Sonnen	ETC Deutschland
Brian Spencer*	Spencer Composites
Mark Stevens	MEI Technologies
Jim Sutter*	Independent Consultant
Pete Taddie*	NASA KSC
John Thesken*	NASA Glenn Research Center
Daryl Thompson	HyPerComp Engineering
Matt Villarreal	Infinite Composites Technologies
Enzo Vito	Axiom Space
Le-Son Vu Hoang-Mazière	ArianeGroup
Jake Walker	HyPerComp Engineering
Jess Waller	New Mexico State University
Daniel Wentzel*	NASA White Sands Test Facility
Jerry Widmar	NASA Johnson Space Center
Paul Wilde	Federal Aviation Administration
Rick Willardson	Raytheon Intelligence & Space
Robert Wingate*	NASA Marshall Space Flight Center
Michael Winter	ETC Deutschland
Kamil Włodarczyk	Northrop Grumman Innovation Systems
Tommy Yoder	NASA White Sands Test Facility

NOTE Names marked with an asterisk participated as Observer, nonvoting members.

The above consensus body approved this document on 16 September 2022.

The AIAA Standards Steering Committee (Paul Lambertson, Chair) accepted the document for publication on 6 December 2022.

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1 Scope

This Guide provides guidance for establishing baseline requirements for the design, analysis, manufacturing, test, and operation of composite overwrapped pressure vessels (COPV) with a plastic liner used for aerospace systems such as spacecraft and launch vehicles. This Guide is only applicable for a COPV with a plastic liner; the liner includes the metallic portions such as the bosses.

Requirements for COPVs levied from other authorities (such as Range Safety, FAA, DOT, etc.) may also be applicable. Specific applications, particularly those involving human spaceflight, may have additional requirements. There may also be additional requirements for hardware elements that are not addressed by this document, such as the presence of a propellant management device or diaphragm. The full set of these requirements may be identified before the design process begins and may be addressed through all stages of the lifecycle.

1.1 Purpose

This guidance for establishing requirements is intended to assure the safety and enhance the success of the operation of a COPV in an aerospace system.

1.2 Applicability

This Guide is applicable only to COPVs containing a plastic liner and constructed with a carbon fiber/polymer matrix overwrap. Applicable plastic liners are comprised of thermoset or thermoplastic polymer material and includes a metallic boss.

COPVs that include a fiberglass overwrap layer that serves only to protect the vessel from impact damage are permitted.

There are two companion standards to this Guide: ANSI/AIAA S-080A Space Systems—Metallic Pressure Vessels, Pressurized Structures, and Pressure Components and ANSI/AIAA S-081B-2018 Space Systems—Composite Overwrapped Pressure Vessels.

1.3 Designation of Responsibilities

This section identifies the responsibilities for the key agents: owner, procuring authority, and manufacturer.

It is noted that the owner and procuring authority may be the same entity.

The procuring authority and the manufacturer may also be the same entity, in which case additional consideration may be given regarding independent oversight.

1.3.1 Owner

The owner establishes the system level requirements. The owner develops the aerospace system incorporating the COPV to meet these system level requirements. The owner performs the system analysis on the aerospace system to identify the operational envelope, establishing the design requirements.

The owner is responsible for reviewing and approving any tailoring of requirements including the use of a document revision other than what is specified in Section 3.

The owner specifies options provided in the Guide before contracting with the manufacturer. For example, the burst factor (Section 5.2.1) and design safety factor (Section 5.2.4) are established. In addition, for the conditions established in Section 5.2.10, there may be options for the liner design and verification approach (Section 6.1).

The owner is responsible for recognizing the certification of trained COPV visual inspectors and the approval and implementation of the Inspection and Test Plan (ITP), including accept and reject criteria of necessary inspections and the creation and adherence to the Damage Control Plan (DCP).