Guidelines for the Utilization of Composite Materials in Oxygen Storage Tanks

Space travel is inherently dangerous and, currently, quite expensive. NASA has always done everything possible to minimize the risk associated with the materials chosen for space travel applications by requiring that all materials associated with NASA programs meet the strict requirements established by NASA testing standard NASA-STD-6001 *Flammability, Odor, Offgassing, and Compatibility Requirements and Test Procedures for Materials in Environments that Support Combustion.* NASA also has the need to develop lighter weight structural materials that will allow more payload weight to be carried into space. NASA is utilizing composite materials inside the orbiter to lighten the overall weight, but has not considered composite materials for oxygen tanks because of the inherent incompatibility of composite materials with atomic oxygen. This presentation will focus on how oxygen tanks can be built from composite materials. Details will be provided for the design and compatibility testing techniques that will be utilized to create a new NASA standard, NASA-HDBK-6018, which will serve as the starting point for the design of oxygen tanks made from composite materials.

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NASA-HDBK-6018

What Is It?

A document that provides some baseline guidance for choosing the best composite materials from which to produce tanks to store oxygen.

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Why Do We Need It?

The storage of oxygen is dangerous, especially when nonmetals are in contact with it. However, composite materials offer substantial weight savings.

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Why NASA?

At $10,000 per pound payload, an ounce saved in tank material is an ounce of payload that can be added.

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What Are the Benefits?

A document is needed to help tank designers select materials for their oxygen tank designs, and currently no other documents of this type exist.

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Why the Concerns with Materials Compatibility?

The primary components of composite materials are NOT compatible with oxygen, they ignite and burn quite easily.

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Why Do We Believe That It Can Be Done?

Even though composite materials are incompatible with oxygen, the tanks that we have made from composites work very well and seem completely compatible.

Short Course

Background On How NASA Selects Materials to Use As Parts of NASA Vehicles or to Use on NASA Missions

How Does NASA Select Materials To Use?

Method 1 – Test and Rate

> Perform Appropriate Testing Based Upon Application

> Rate Material for Application

> Choose Only "A-Rated" or Top-Rated Materials for NASA Missions

How Does NASA Select Materials To Use?

Method 2 – Evaluation of Materials and Their Proposed Use Conditions/Locations

> Materials Identification and Usage List (MIUL)

> Oxygen Hazards Analysis (Oxygen Compatibility Assessment)

NASA-HDBK-6018

Assumes That No "Ideal" Composite Material for Oxygen Systems Service Will Be Found Anytime Soon, (But Does Help You Identify One If You Do Find It)

NASA-HDBK-6018 – Scope

- The document will outline the most suitable test methods for composites proposed for use in either LOX or GOX applications
- The document also serves as a "roadmap" that will present guidelines for the selection of composite materials
- The document will help you on the path to "getting there"

NASA-HDBK-6018 – Scope

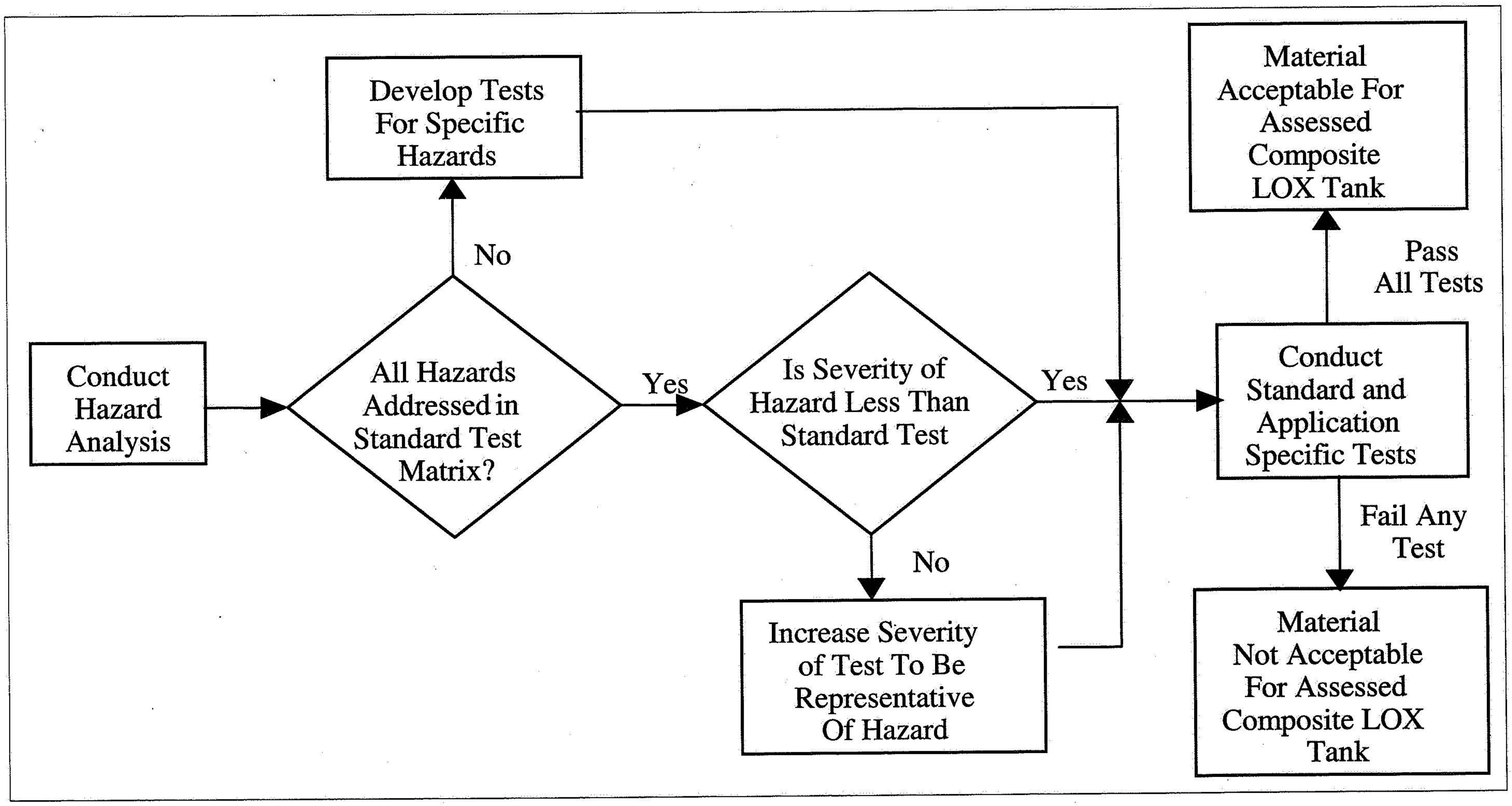
- The document will not give one specific composite to use and one specific method of using it.

- The document will not be the only information you need to create a composite oxygen tank

NASA-HDBK-6018 – Approach

- Discuss historical data sets of hazards analysis and the directions that they lead us
- Outline standardized testing for selecting materials for use in oxygen systems, as used by NASA and specified in NASA-STD-6001
- Outline any “non-standard” testing deemed appropriate by NASA Materials and Processes engineers

Approach for Approving a Material for a Composite Oxygen Tank (Assuming No "Ideal" Composite Material Exists)



Oxygen Compatibility Assessment (a.k.a. Hazards Analysis)

- Determine the worst-case operating conditions
- Assess the flammability of the oxygen-wetted materials at the use conditions
- Evaluate the presence and probability of ignition mechanisms
- Determine the kindling chain, which is the potential for a fire to breach the system
- Determine the reaction effect, which is the potential loss of life, mission, and system functionality as the result of a fire
- Document the results of the assessment

OCA Definitions

- **Worst-Case Operating Conditions**

  The analyst should determine the conditions that may exist due to single-point failures and minimize the reliance upon procedural controls to regulate the conditions within the oxygen system. In addition to environmental factors such as oxygen concentration, temperature, and pressure, the analyst should determine the worst-case cleanliness level of each component.

OCA Definitions

- **Flammability Assessment**

In general, as pressures increase, all materials become flammable in 100% oxygen. This includes metals, plastics, elastomers, lubricants, and contaminants.

OCA Definitions

- **Ignition Mechanism Assessment**

Ignition mechanisms in oxygen systems are simply sources of heat which, under the right conditions, can lead to ignition of the materials of construction, or ignition of the contaminants.

OCA Definitions
Ignition Mechanism Assessment

- Particle impact
- Rapid pressurization
- Flow friction
- Mechanical impact
- Friction
- External heat sources
- Static Discharge
- Electrical arc
- Chemical reaction
- Thermal runaway
- Resonance

OCA Definitions

- **Kindling Chain Assessment**

Kindling chain is defined as the ability of a fire to propagate and burn, or melt through, a component. A kindling chain begins when a material is ignited, and the material's heat of combustion is sufficient to ignite or melt the surrounding materials, leading to a burn or melt through of the component.

OCA Definitions

- **Reaction Effect Assessment**

The reaction effect assessment is performed to determine the effects of a fire on personnel, mission, and system functionality. The analyst should assign a reaction effect rating for each component, which is based upon the presence of a kindling chain and the potential consequences of a fire.

OCA Definitions

- **Document Assessment Results**

  It is strongly recommended that the results of the oxygen compatibility assessment are documented in a written report. This report can facilitate communication and dissemination of results to interested parties, and serves as a record of the findings for future reference.

OCA Definitions

Table 1: Probability Rating Logic

Rating	Code	Criteria	
		Characteristic Elements	Material Flammability
Not possible	0	Not all present	Non-Flammable
Remotely Possible	1	All present Not all present	Non-Flammable Flammable
Possible	2	All present and active	Flammable
Probable	3	All are present and all are strongly active	Flammable

OCA Definitions

Table 2: Reaction Effect Rating Logic

Rating	Code	Effect on Personnel Safety
Negligible	A	No injury to personnel
Marginal	B	Personnel-injuring factors can be controlled by automatic devices, warning devices, or special operating procedures
Critical	C	Personnel may be injured operating the system, maintaining the system, or by being in the vicinity of the system
Catastrophic	D	Personnel suffer death or multiple injuries

Testing

Test	Document	Test Site
Flammability	NASA STD 6001/Test 1 and Test 17	MSFC/WSTF
Mechanical Impact	NASA STD 6001/Test 13A ambient	MSFC/WSTF
Mechanical Impact	NASA STD 6001/Test 13B pressurized	MSFC/WSTF
Modified Impact	MSFC/WSTF SOP	MSFC/WSTF
Puncture	MSFC SOP	MSFC
Electrostatic Discharge (ESD)	MSFC SOP	MSFC

Testing

Test	Document	Test Site
Friction Heat	NASA STD 6001/Test **XX**	MSFC/WSTF
Pyrotechnic Shock	MSFC SOP	MSFC
Flow Friction	No Test Available	No Test Available
LOX Immersion	MSFC SOP	MSFC
Particle Impact	WSTF SOP	WSTF
Fluid Compatibility	MSFC SOP	MSFC
Heated GOX	MSFC/WSTF SOP	MSFC/WSTF
Lightning	MSFC/WSTF	MSFC/WSTF
Reciprocating Friction	MSFC/WSTF SOP	MSFC/WSTF
Analog/large scale Test	MSFC/WSTF	MSFC/WSTF
Structural Test Article (STA)	MSFC/WSTF	MSFC/WSTF
Chemical Analysis/ Fingerprinting	MSFC OWI	MSFC

Conclusions

- There is More to the Selection of Composite Materials Than Just the Old "Gold Standard" Test Methods for Materials in Oxygen
  - Mechanical Impact Testing
  - Promoted Ignition-Combustion Testing
- Newer Test Methods Must Be Utilized
- Oxygen Compatibility Assessments Are Important
- We Need to Share All Our Knowledge on Composites for Oxygen Service

Conclusions
NASA-STD-6018

- At This Point, This Will Not be the "Cure-All, End-All" Document
- Expected Release Date – December 2007
- Use to Organizations – Useful to Any Organization That is Concerned with Storing or Using Oxygen
- What Can We Expect – Oxygen Can Be Stored Safely in Composite Tanks