NASA and ASTM – A Partnership for Oxygen System Success

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Presented to the ASTM G04 Committee

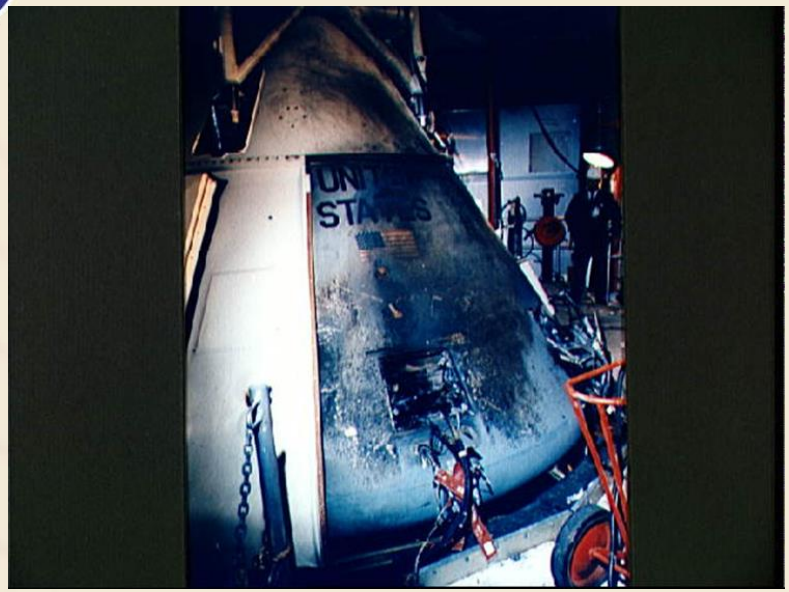
October 10, 2017

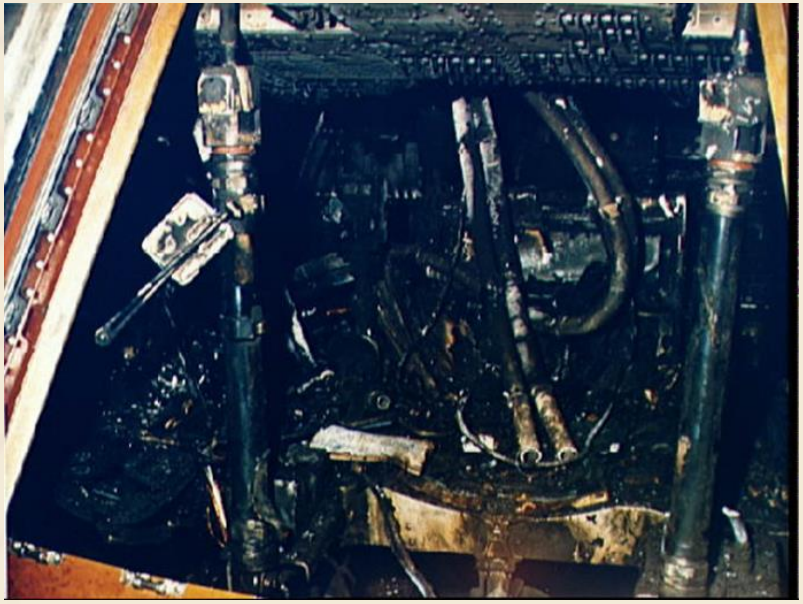
- Overview
  - NASA Oxygen Fire Problem
  - Incorporation of ASTM Standards
  - Development of ASTM Standards
    - Non-Standard test development
  - Training the next generation
  - NASA Standards to ASTM
  - Current/Future trends and needs

- "Ever since the initiation of plans for the first rockets to outer space utilizing liquid oxygen, NASA and its contractors have expended great effort in developing information on the compatibility of materials with oxygen." *Robert Neary, Keynote for first ASTM G-4 symposium, March 31st 1982*.

Crew of Apollo I

Apollo 1 Fire Photos

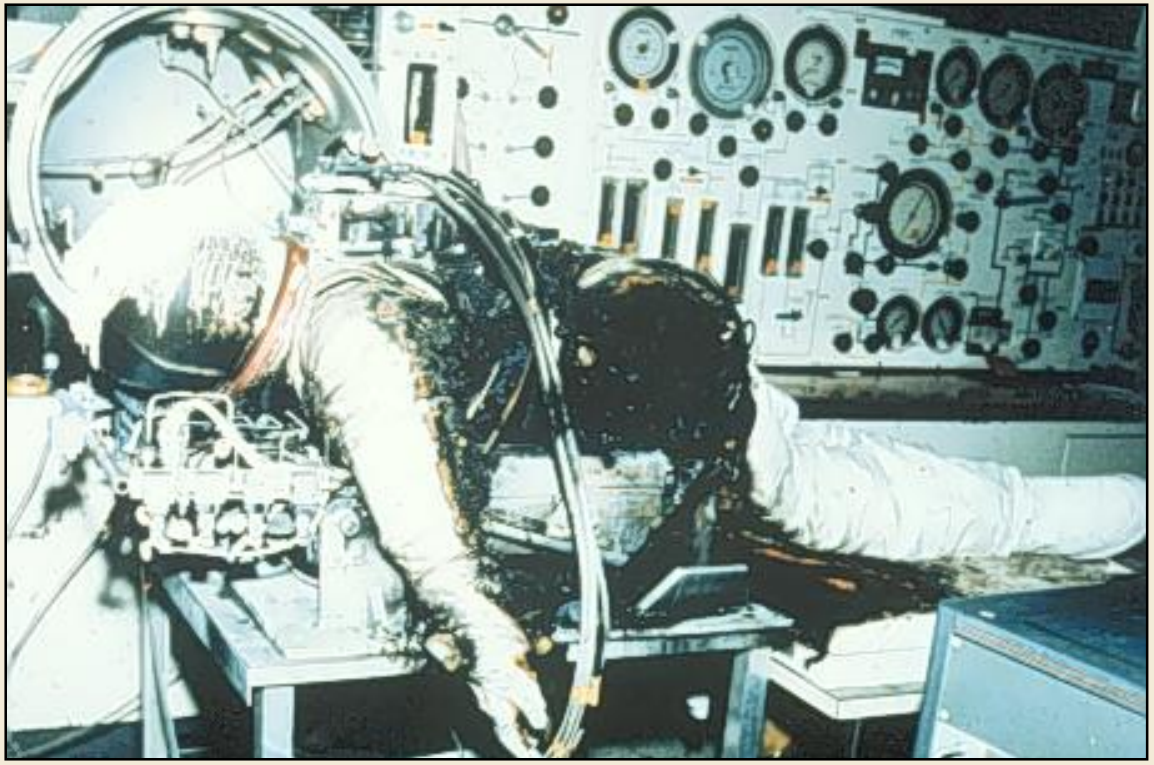




Apollo 1 Fire

- The Apollo 1 fire pointed out the following:
  - NASA lacked a consistent materials control program
  - NASA allowed unqualified materials to “creep” into the design
  - NASA did not understand the hazards
  - NASA did not understand the ignition source
- Highlighted the need to understand non-metallic flammability in gaseous oxygen
- Highlighted the need for precise ignition control
- Resulted in the establishment of NASA WSTF flammability test capability

EMU Suit Fire



EMU Suit Fire

- The EMU Suit fire highlighted the need to understand ignition and flammability of metals at high pressure
  - 10,000 diagnostic tests run using available test methods – did not replicate ignition
  - Change materials to nonflammable Monel
- Test methods needed to be developed that more realistically simulated the variety of ignition mechanisms.

Incorporation of ASTM Standards

- Early ASTM Standards
  - D2512 – Ambient LOX Mechanical Impact
    - Great screening test for non-compatible nonmetallic materials
    - Not effective at screening metals or determining flammability of metals
  - D2863 – Minimum Oxygen Concentration
    - Great for nonmetal plastics and elastomers
    - Limited applicability for fabrics, thin films and coatings

Incorporation of ASTM Standards

- Early ASTM Standards
  - D4809/D2382 – Heat of Combustion
    - Tool to assess ability of a nonmetallic material to cause damage or spread fire
  - G72 – Autogenous Ignition Temperature
    - Determine the temperature at which a nonmetallic will ignite
  - G63 – Evaluating Nonmetallic Materials for Oxygen Service
    - Develops a consistent method to evaluate and qualify system materials

Incorporation of ASTM Standards

- Early standards were limited:
  - Nonmetallic materials
  - Two ignition mechanisms
    - Although G74 below followed quickly
  - Limited relevance to fabrics, thin films, and coatings
  - Relatively low pressure
- Standards required to address these issues
- NASA WSTF and KSC fully embrace ASTM G-4 as a partner in solving our Oxygen Issues

Development of Standards

- G74 – Ignition by Gaseous Fluid Impact of Materials
  - High pressure ignition of nonmetallic materials
  - Addresses the most common ignition mechanism for nonmetallic
  - Insensitive to small changes in materials
- G86 – Pressurized mechanical impact
  - High pressure ignition of nonmetallic materials
  - Insensitive to small changes in materials
  - Attempted to use to qualify metals but without success

Development of Standards

- G88 – Design Guide for Oxygen Systems
  - Adaptation of NASA design guide developed following Suit fire
  - Excellent training tool
- G94 – Guide for Evaluating Metals
  - Began to incorporate Oxygen Compatibility Assessment techniques
  - Metals evaluation primarily on thermal chemical properties
  - Started to utilize data coming from joint NASA and ASTM test series

Development of Standards

- G93 and other Cleaning Standards
  - G93 developed based on aerospace and industry experience in cleaning for oxygen systems
  - Several adjunct cleaning standards were also developed using NASA and industry experience to solve the issue of qualification of alternative cleaning solvents
- G124 – Promoted Combustion of Metals
  - First definitive method to assess flammability of metals over a broad pressure range
- G175 – Adiabatic Compression of Oxygen Regulators
  - Utilized NASA adiabatic compression test experience for components for high pressure oxygen systems to solve a major safety issue in the medical community
  - Full industry cooperation with WSTF and subsequent transfer of the test methodology to Industry

Non-Standard Test Development

- Component Adiabatic Compression
- Particle Impact
- Frictional Ignition
- Specialized/Configurational test methods
  - Arc/spark ignition
  - Reciprocating Friction
- Test method improvements

NASA TECHNICAL STANDARD	NASA-STD-6001B
National Aeronautics and Space Administration Washington, DC 20546-0001	Approved: 08-26-2011 Superseding: NASA-STD-6001 and NASA-STD-(I)-6001B

FLAMMABILITY, OFFGASSING, AND COMPATIBILITY REQUIREMENTS AND TEST PROCEDURES

MEASUREMENT SYSTEM IDENTIFICATION:
METRIC/SI

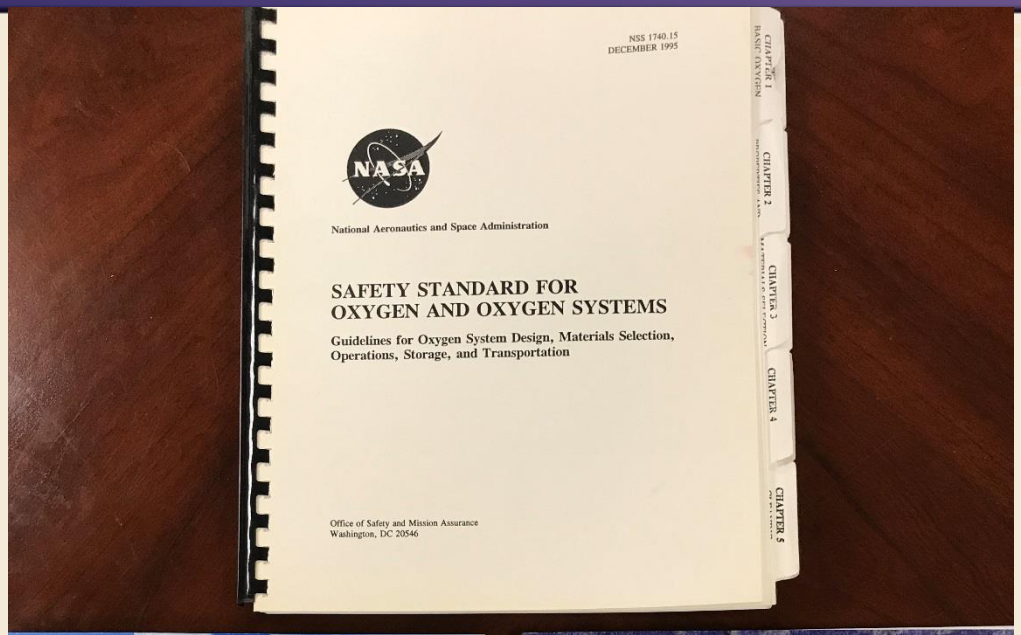
Compatibility Assessments

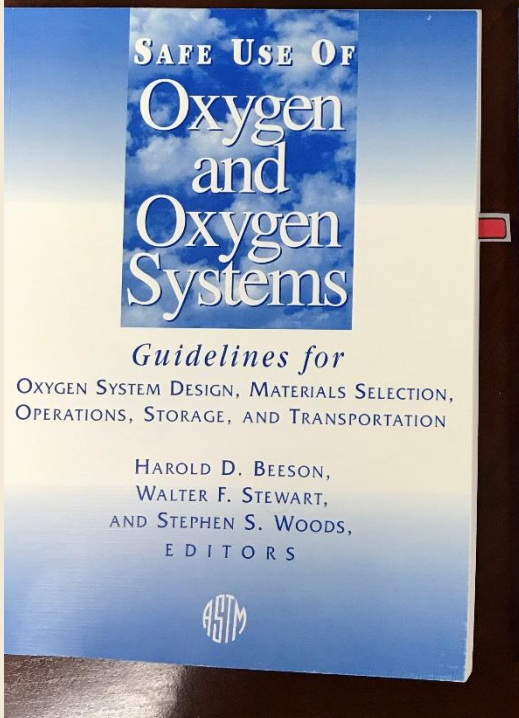
- Organizations/Standards using Oxygen Compatibility Assessment (OCA)
  - ASTM
    - ASTM G63 for evaluating nonmetals
    - ASTM G94 for evaluating metals
  - CGA and EIGA/IGC
    - G4.4-2003 (4th edition) for oxygen pipeline systems
    - IGC Document 13/02 for oxygen pipeline systems
  - NFPA
    - NFPA 53 for oxygen-enriched atmospheres
  - NASA
    - NASA-STD-6001 for space vehicles, test facilities, and GSE

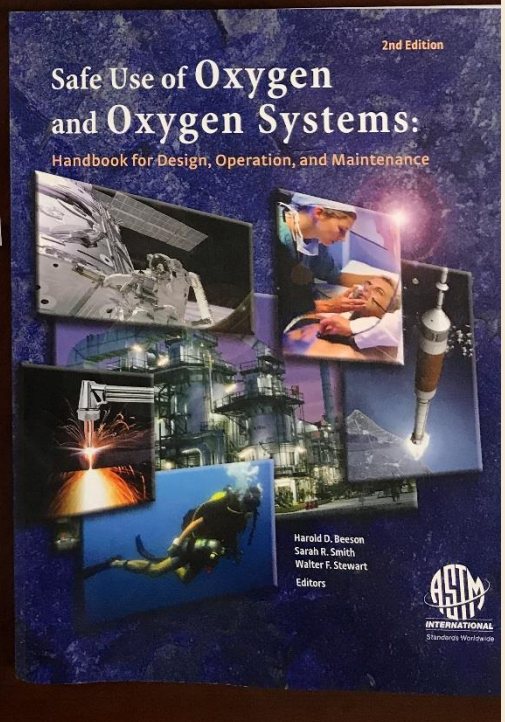
Training the Next Generation

- Technical Papers and Formal Training
  - ASTM STP's
    - This represents NASA's database of materials testing used daily by our oxygen team
  - ASTM 2-day Course
  - ASTM 4-hour Course
- NASA Adapted Training
  - Astronaut 1-hour Course
  - NASA Management Course
  - Special courses for unique applications

NASA Standard Transferred to ASTM







Current/Future

- NASA continues to support ASTM with people and test data
- Will continue to work with ASTM and our industry partners to develop the best technology to understand oxygen hazards
- Current/future test needs include
  - Tests related to composite materials
  - Tests related to additive manufactured (AM) materials

We stand on the shoulders of giants

Special thanks to the following:

- Dave Pippen
- Jack Stradling
- Joel Stoltzfus
- Cole Bryan
- Frank Benz
- Barry Newton
- Barry Werley
- Joe Slusser
- Bob Lowrie

And Many More