High Performance Plastics for Spacecraft Applications

Webinar Presented by Curbell Plastics

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Agenda

- About Curbell
- CTQs for polymers in spacecraft applications
  - Thermal properties
  - Mechanical properties
  - Tribological properties (friction and wear)
- Dupont™ Vespel® polyimide - properties and spacecraft applications
- Questions and discussion

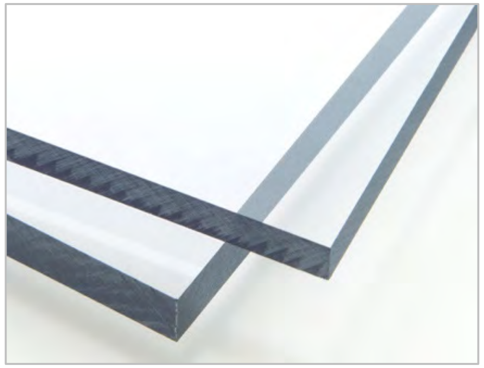
Company History

Strong History of Growth, Stability, and Values

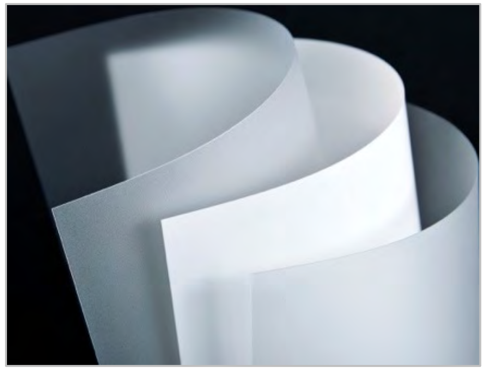
Established in Buffalo, NY in 1942

Today - 21 Locations Nationwide

Full Line of Performance Plastics


Sheet


Rod & Tube


Films


Fabricated Parts


Tapes, Fabrics & Belts

Adhesives & Sealants


Prototyping & Tooling
Materials


Tubing & Hose

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CTQs for Polymers in Spacecraft Applications

CTQs for Polymers in Spacecraft Applications

Thermal Properties

- The ability to operate reliably in a space environment with a temperature range of -150 °C to 130 degrees °C
- The ability to operate at elevated temperatures when used in rocket engine applications
- Dimensional stability including a low and consistent rate of thermal expansion and contraction
- Ductility and moderate modulus at cryogenic temperatures
- Low thermal conductivity for thermal insulators.
- High thermal conductivity to manage heat in electronics.

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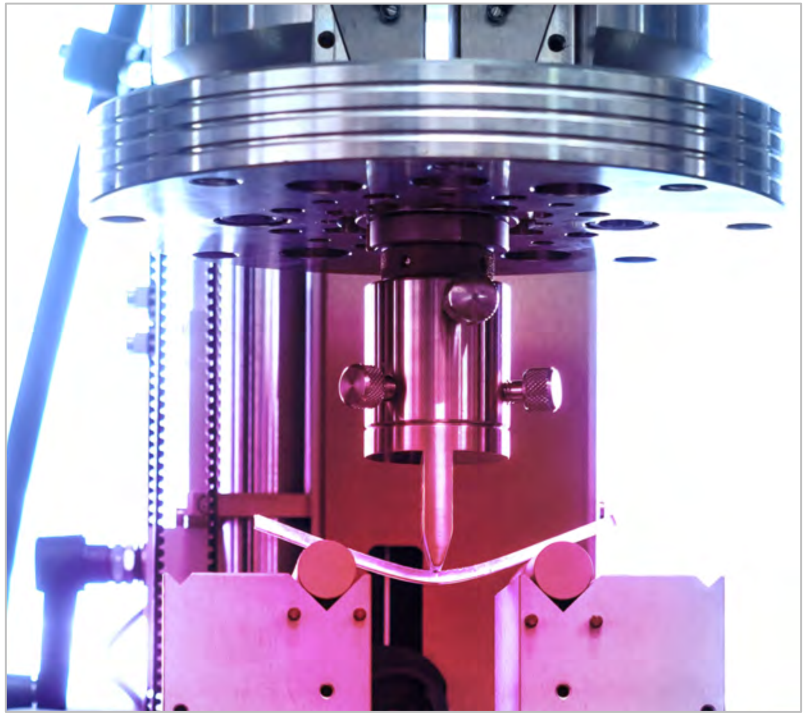
CTQs for Polymers in Spacecraft Applications

Mechanical Properties

- Sufficient mechanical strength and durability to withstand the stresses associated with launch
- Vibration damping characteristics for sensitive optics and electronics
- Good sealing characteristics
    - Moderate modulus
    - Low friction and moderate modulus for consistent actuation torque when used in spacecraft valves
    - Compressive creep resistance
    - Stress relaxation resistance



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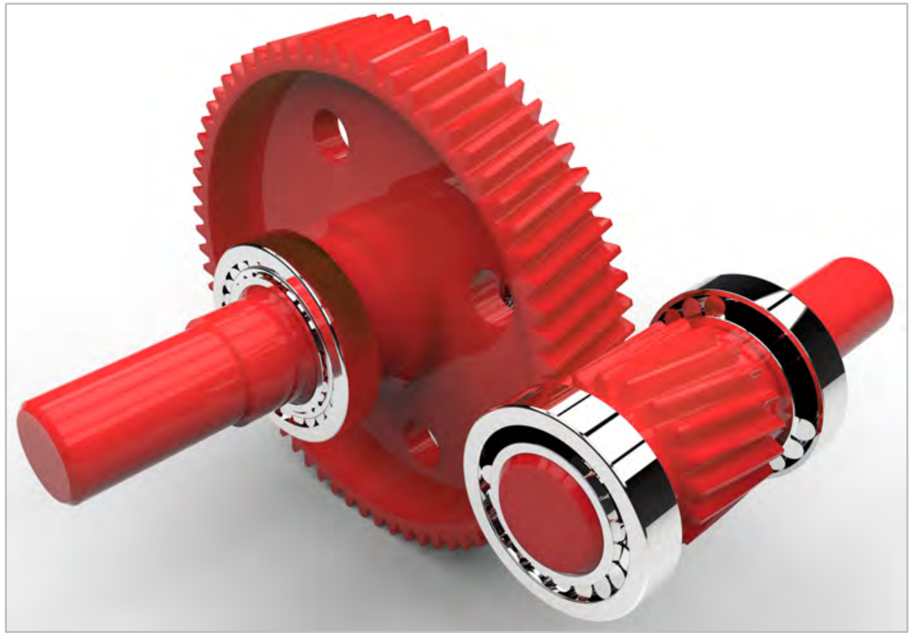
CTQs for Polymers in Spacecraft Applications

Tribological Properties (Friction and Wear)

- Low friction against a wide variety of metal counterface materials
- Long wear life
- Low wear on mating metal parts
- Low particulate generation
- Excellent friction and wear properties at elevated temperatures
- Excellent friction and wear properties at cryogenic temperatures
- Excellent friction and wear properties in vacuum conditions



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CTQs for Polymers in Spacecraft Applications

Chemical, Environmental, and Electrical Properties

- Resistance to solvents, propellants, and other corrosive chemicals
- Low outgassing in vacuum
- Resistance to radiation from sources both internal and external to the spacecraft
- Resistance to erosion from atomic oxygen
- Excellent flammability characteristics including compatibility with LOX (liquid oxygen), GOX (gaseous oxygen), and hydrogen.
- Low dielectric constant and low dissipation factor throughout a broad range of temperatures and frequencies when used for spacecraft antenna radomes
- High dielectric strength when used as an insulator

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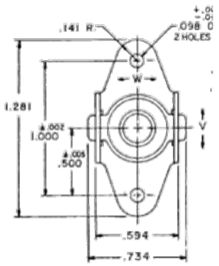
CTQs for Polymers in Spacecraft Applications

A history of successful use for spaceflight applications contributing to a high Technology Readiness Level

Source: Wood

NASA
Technical
Memorandum



NASA TM - 86456

TESTING AND EVALUATION OF VESPEL UP TO 450°F WHEN USED IN NUTS AND BOLTS AS A SELF-LOCKING ELEMENT

By Carl M. Wood

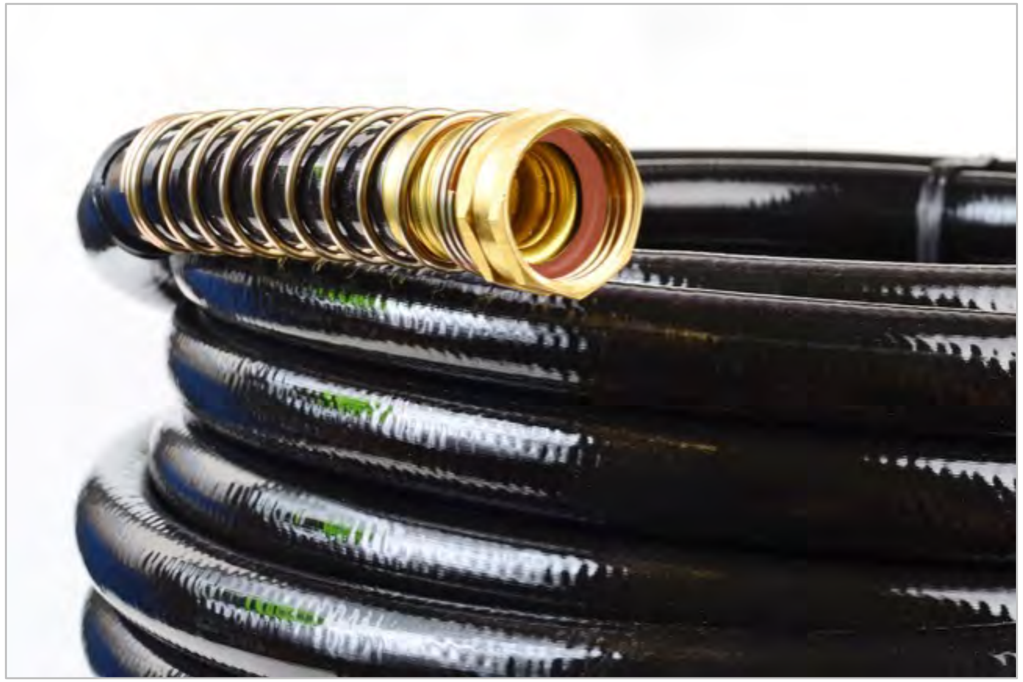
Materials and Processes Laboratory
Science and Engineering

August 1984

Thermal Properties

Operating Temperature Range

Mechanisms need to function throughout their operating temperature range



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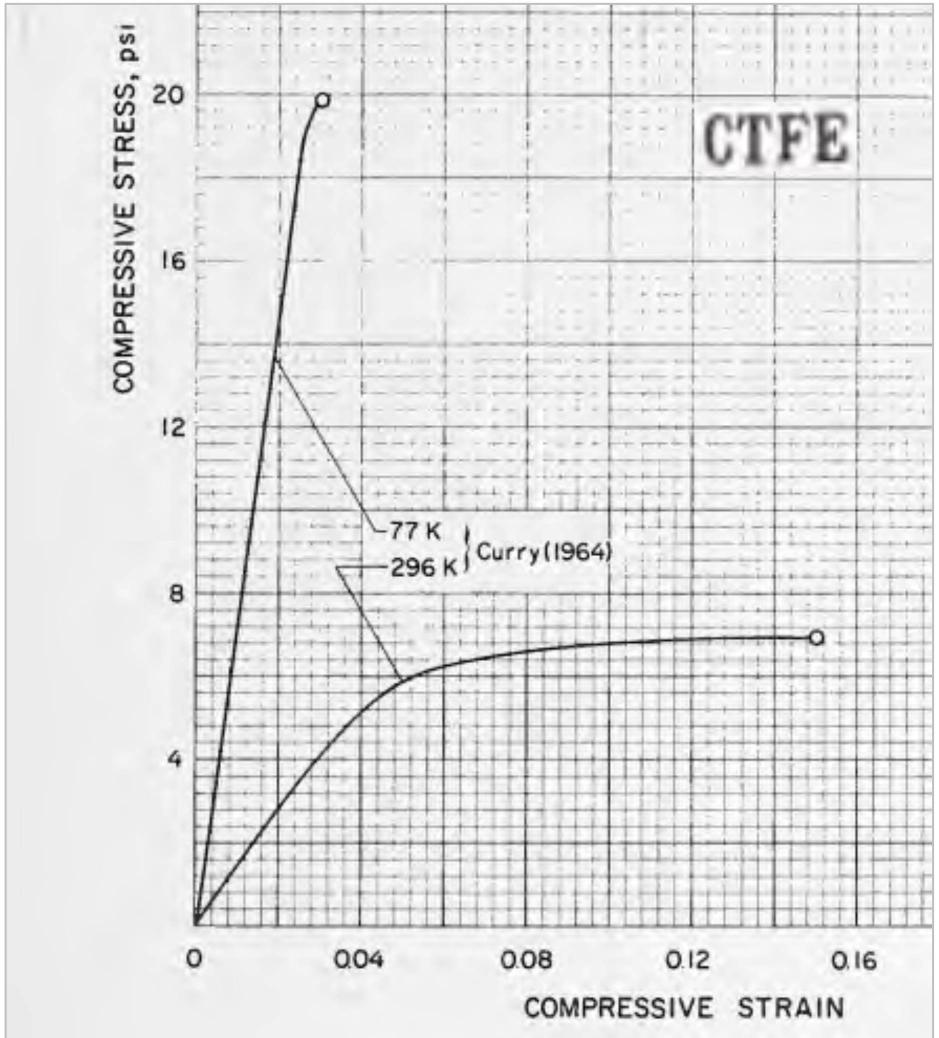
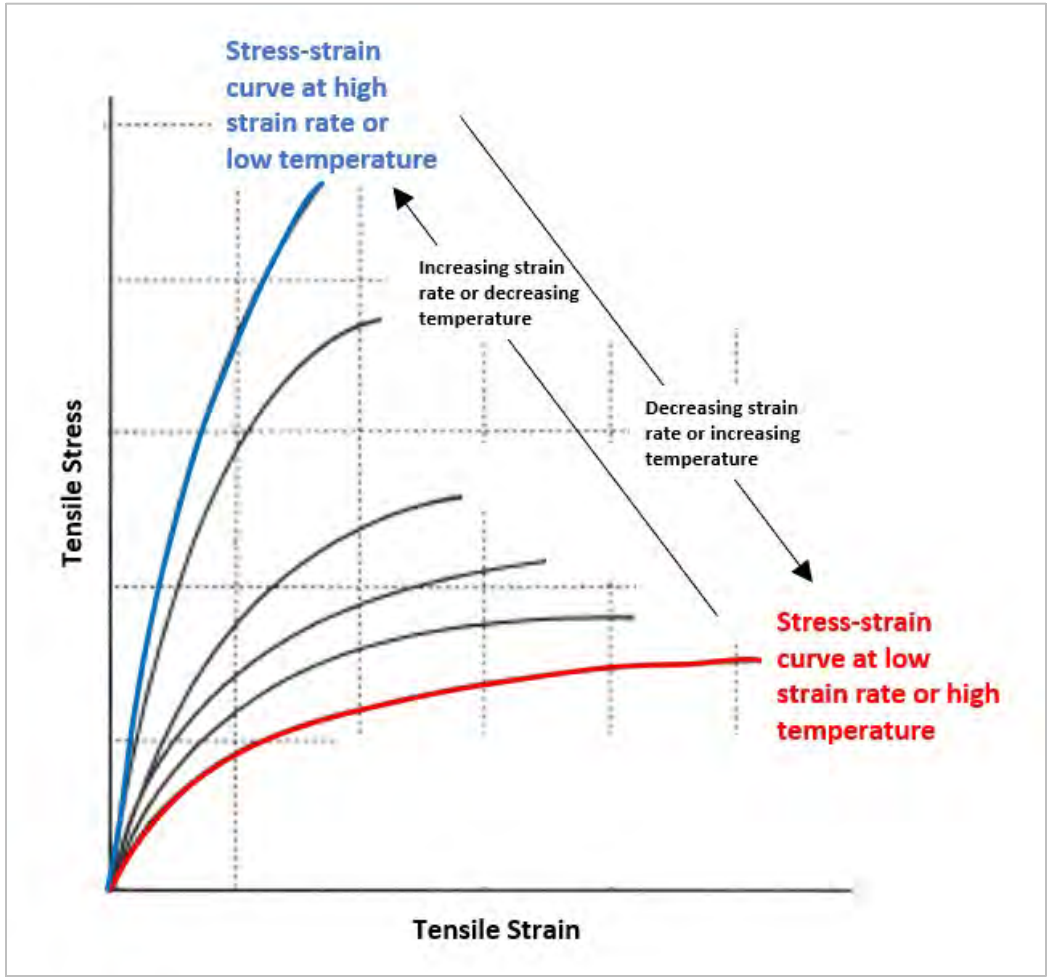
Operating Temperature

- Change in modulus
- Change in elongation / ductility
- Creep / stress relaxation behavior
- Thermal expansion and contraction
- Degradation

Operating Temperatures



Source: Schram, 1973



Note: Strain rate mimics temperature

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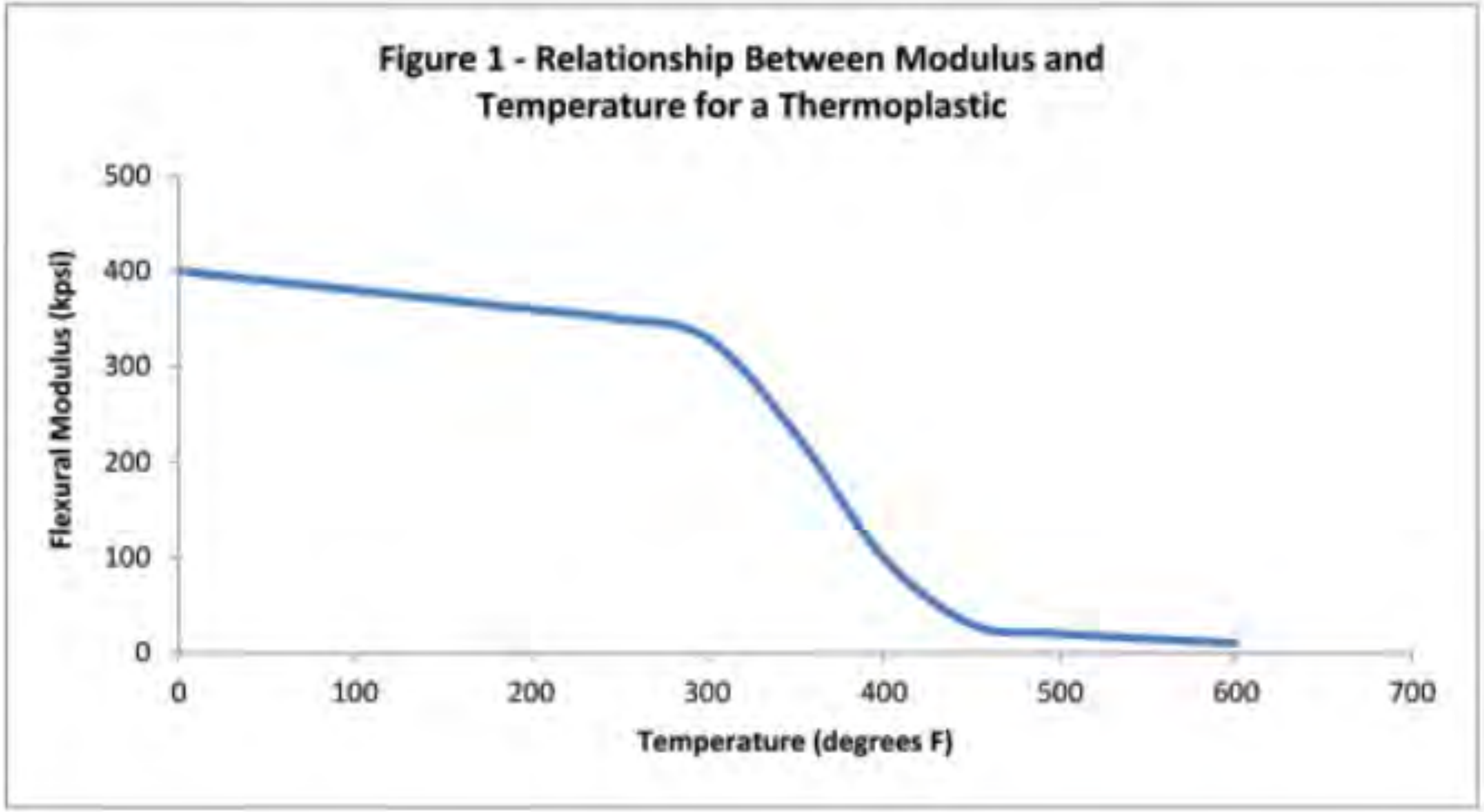
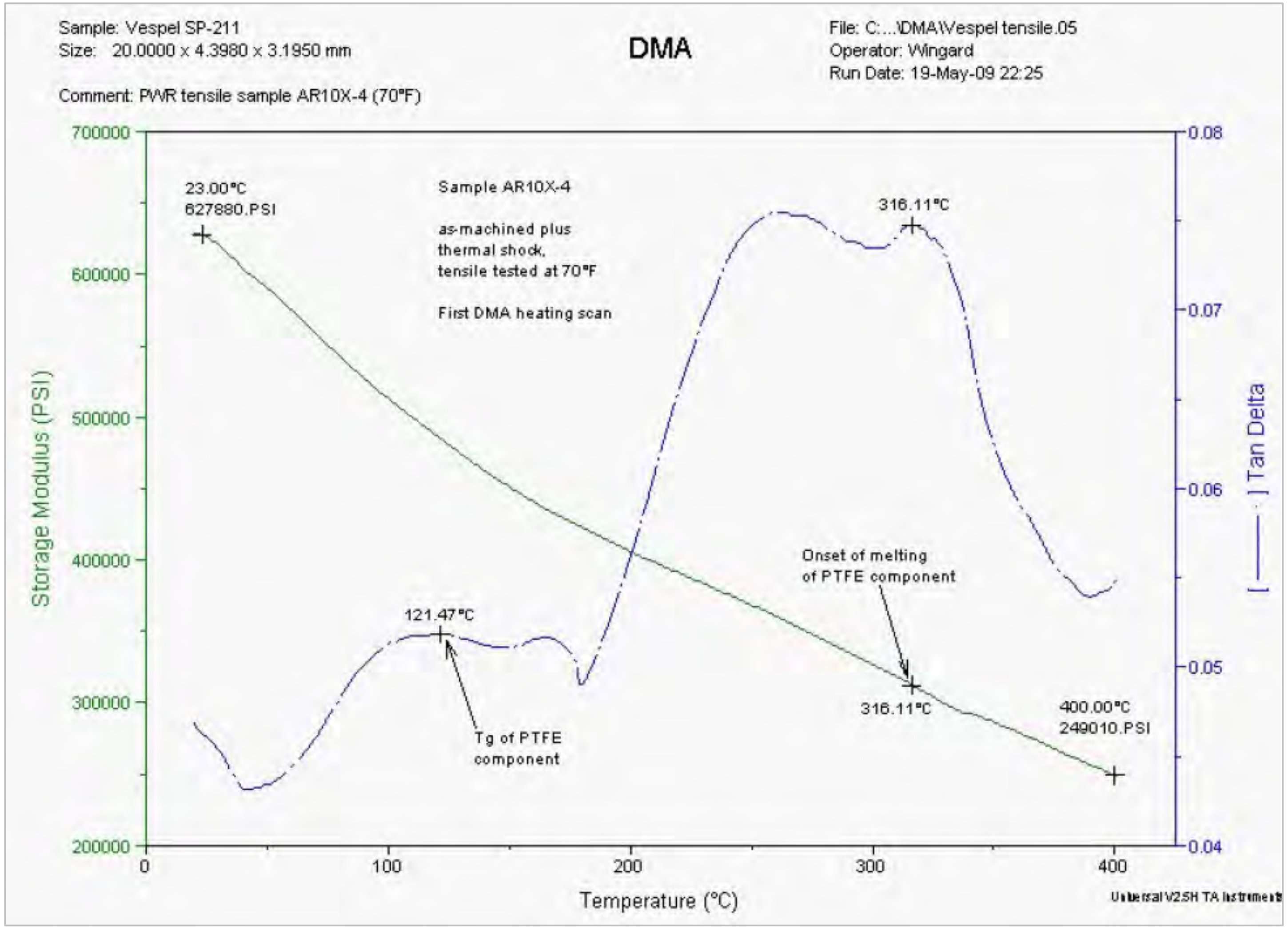
Flexural Modulus and Temperature



Source: Hechtel, 2014

Storage Modulus and Temperature – DuPont™ Vespel®



Source: Wingard, 2013

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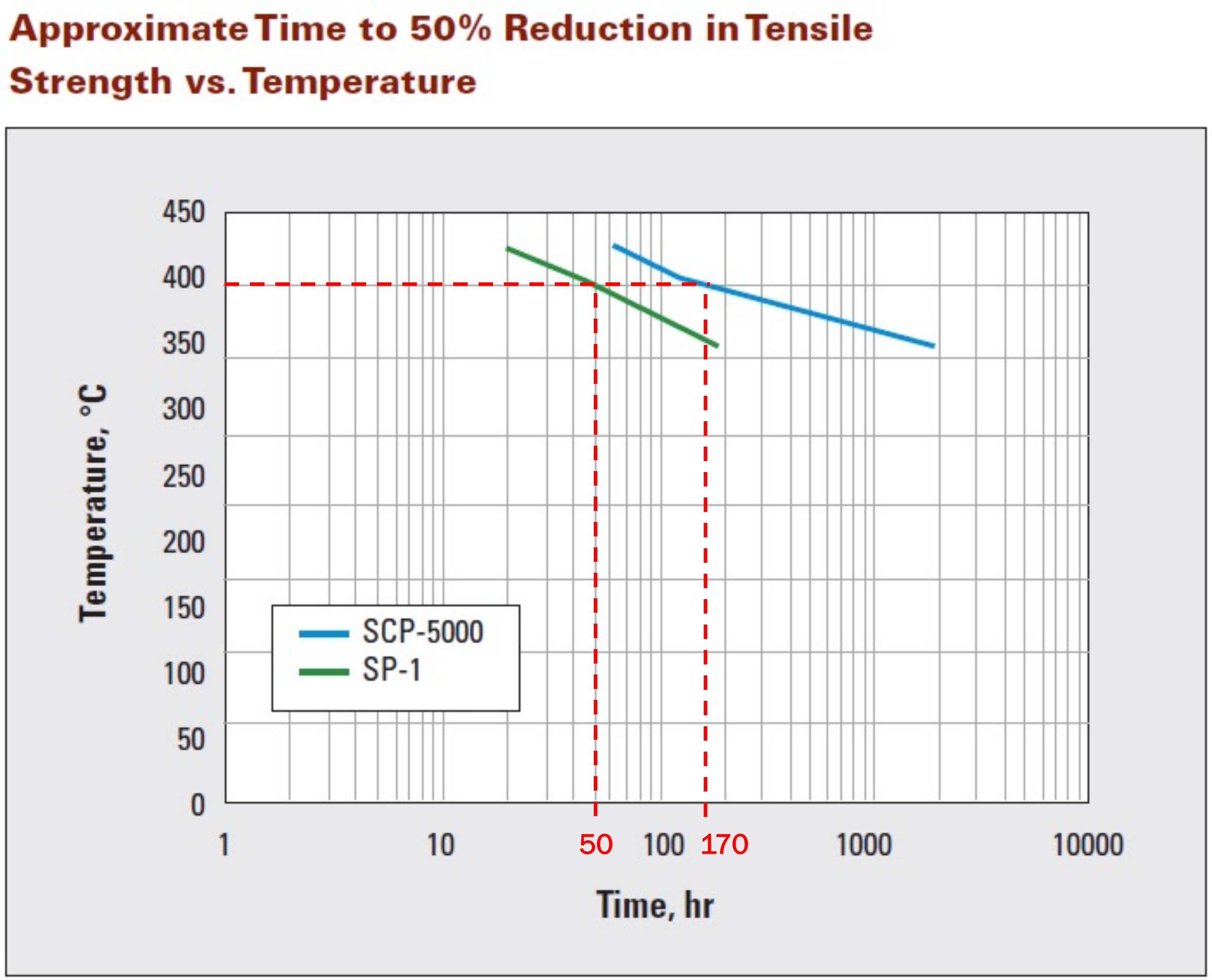
High Temperature Capability



Source: DuPont

High Temperature Capability

Dynamic Mechanical Analysis (DMA) to Help Characterize Vespel SP-211 Polyimide Material for Use as a 750°F Valve Seal on the Ares I Upper Stage J-2X Engine

Doug Wingard[1]

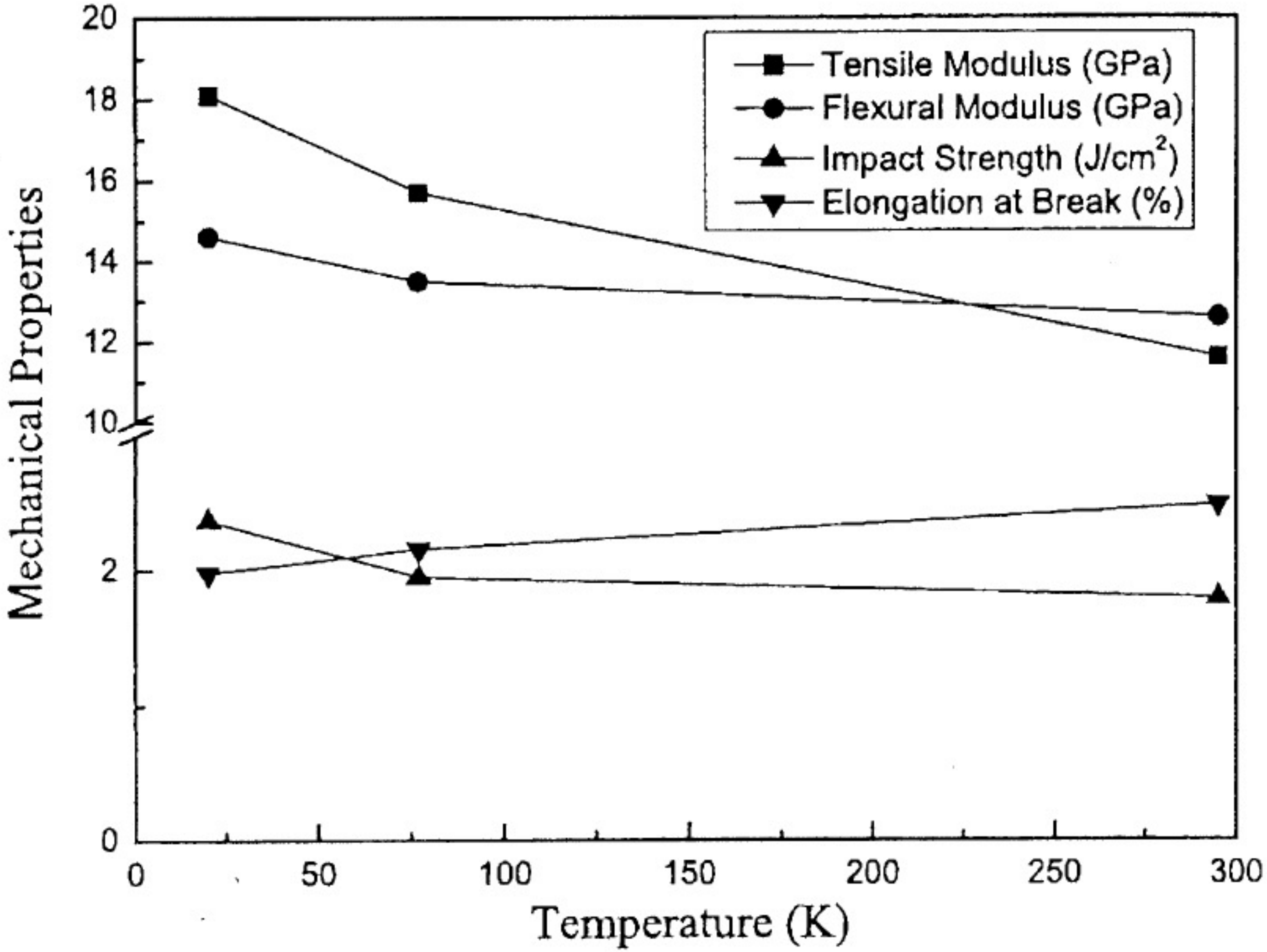
[1] NASA/Marshall Space Flight Center, Mail Code EM10, Marshall Space Flight Center, Alabama 35812, doug.wingard@nasa.gov

ABSTRACT

DuPont™ Vespel® SP-211 polyimide was selected as the top candidate seal material for use in the Oxidizer Turbine Bypass Valve (OTBV) on NASA's Ares I Upper Stage J-2X engine. In the OTBV, the seal material would get exposed to temperatures up to 750°F for ~10 minutes at a time.

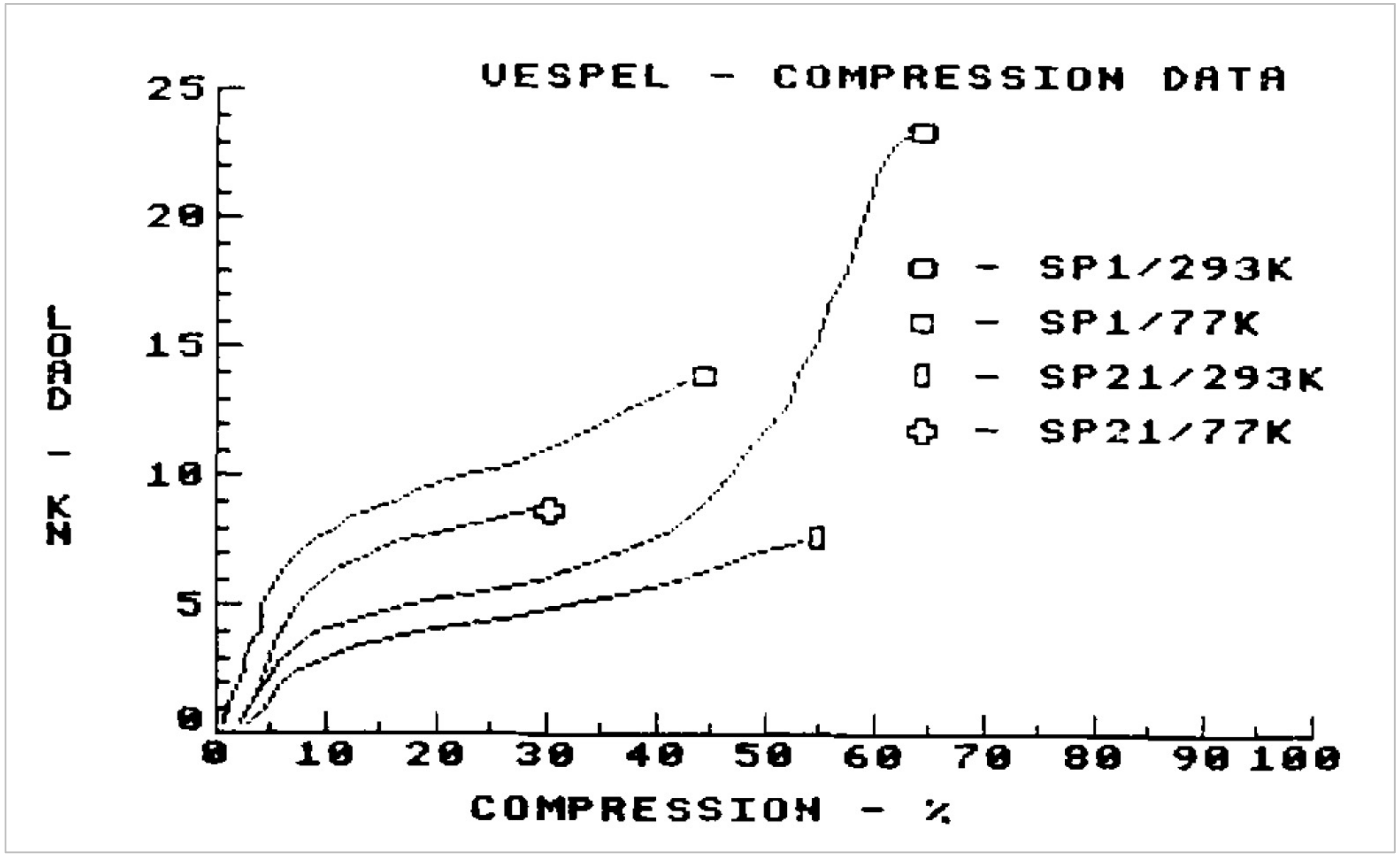
Source: Wingard, 2013

Low Temperature Ductility of 30% Glass Filled PEEK



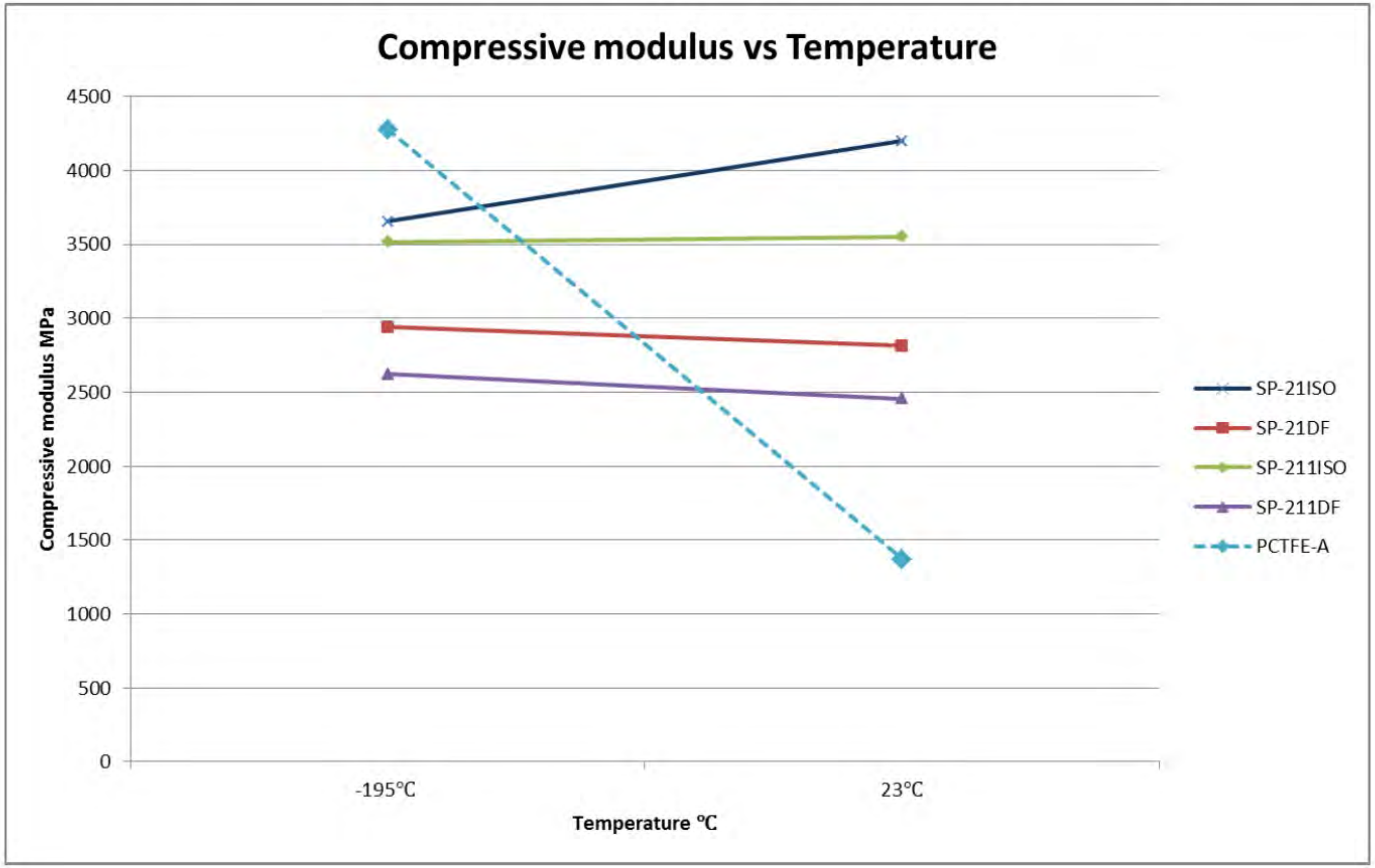
Source: Chu

Low Temperature Ductility of DuPont™ Vespel®



McDonald, P. & Rao, M. (1987). Thermal and mechanical properties of Vespel® at low temperatures. Proceedings from the International Cryogenic Materials Conference, Saint Charles, IL, 14-18 June, 1987.

Moderate Modulus of DuPont™ Vespel® at Cryogenic Temps

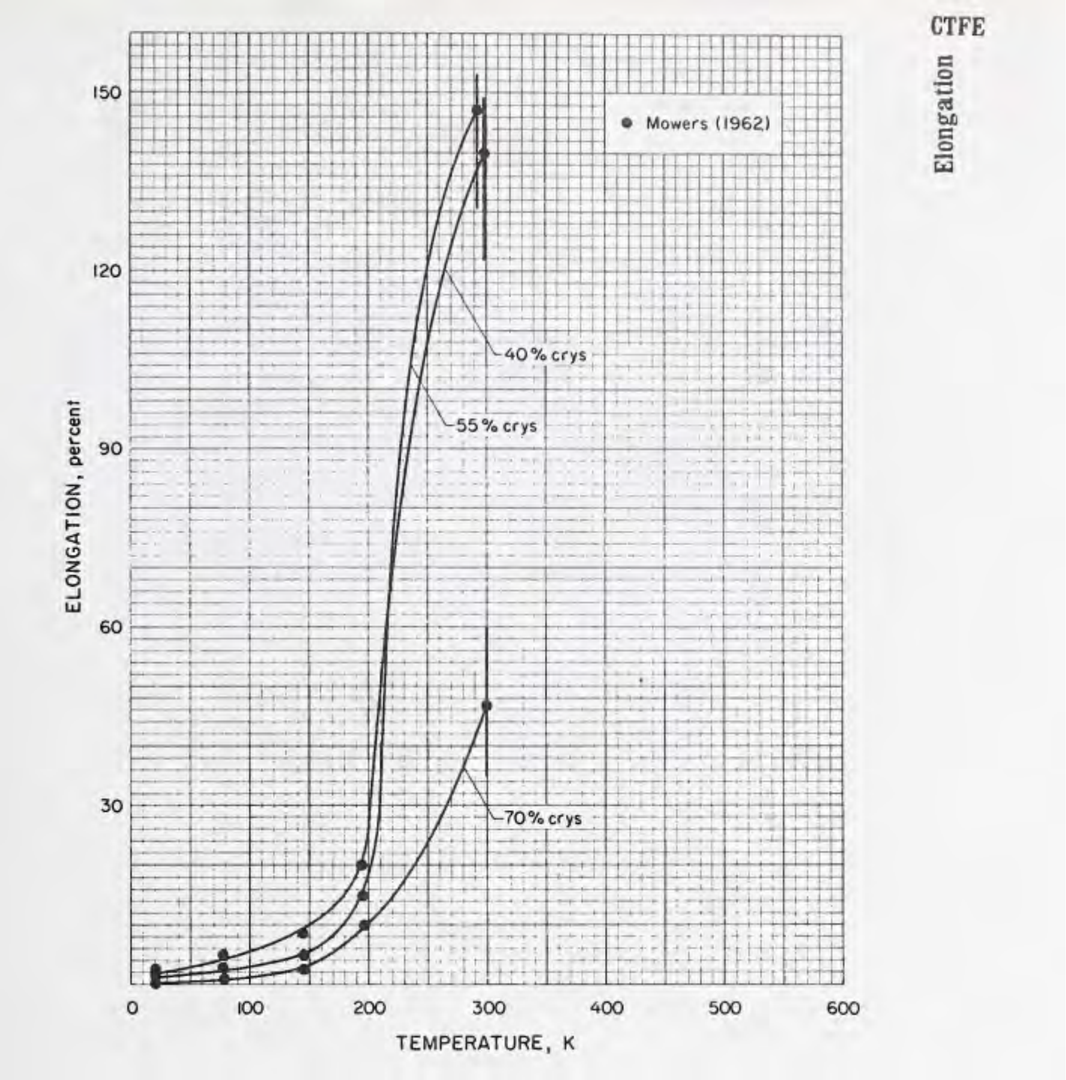


Lewis, G., Merot, P., & Matoux, J. (2015). High performance polyimide parts can help reduce actuation torque and improve sealing in cryogenics ball valves for LNG (Liquid Natural Gas) applications. Presented at the AMI International Conference on Oil & Gas Non-Metallics. London. December 8-10, 2015.

Ductility of PCTFE – Varies Depending on Processing

Processing (extrusion, compression molding, etc.) is very important

- Residual stress
- Molecular weight
- Crystallinity



Source: Schram, 1973

Combined Effect of Moderate Modulus and Low Friction on Torque to Actuate a Valve at Cryogenic Temperatures

Theoretical Example Of The Combined Effect Of Modulus And Friction

- Illustration: "Break Torque" reduction – with modest design optimisation.

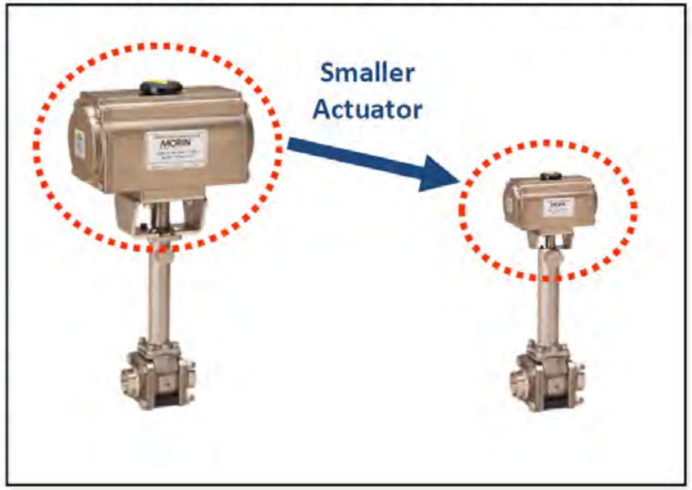
PCTFE	At -195°C
Modulus	4275 MPa
Deformation	1.20%
Stress needed	51.30 MPa
Typical seat contact area 4"	511 mm2
Force needed	26199 N
Coefficient of static friction	0.19
Linear force required	4977.8 N
Approx Torque	373.3 Nm

Vespel® SP-21	At -195°C
Modulus	2940
Deformation	1.20%
Stress needed	35.28 MPa
Typical seat contact area 4"	511 mm2
Force needed	18017 N
Coefficient of static friction	0.20
Linear force required	3603.5 N
Approx Torque	270 Nm

Torque reduction changing PCTFE to Vespel®	**28%**
Torque increase changing Vespel® to PCTFE	**38%**

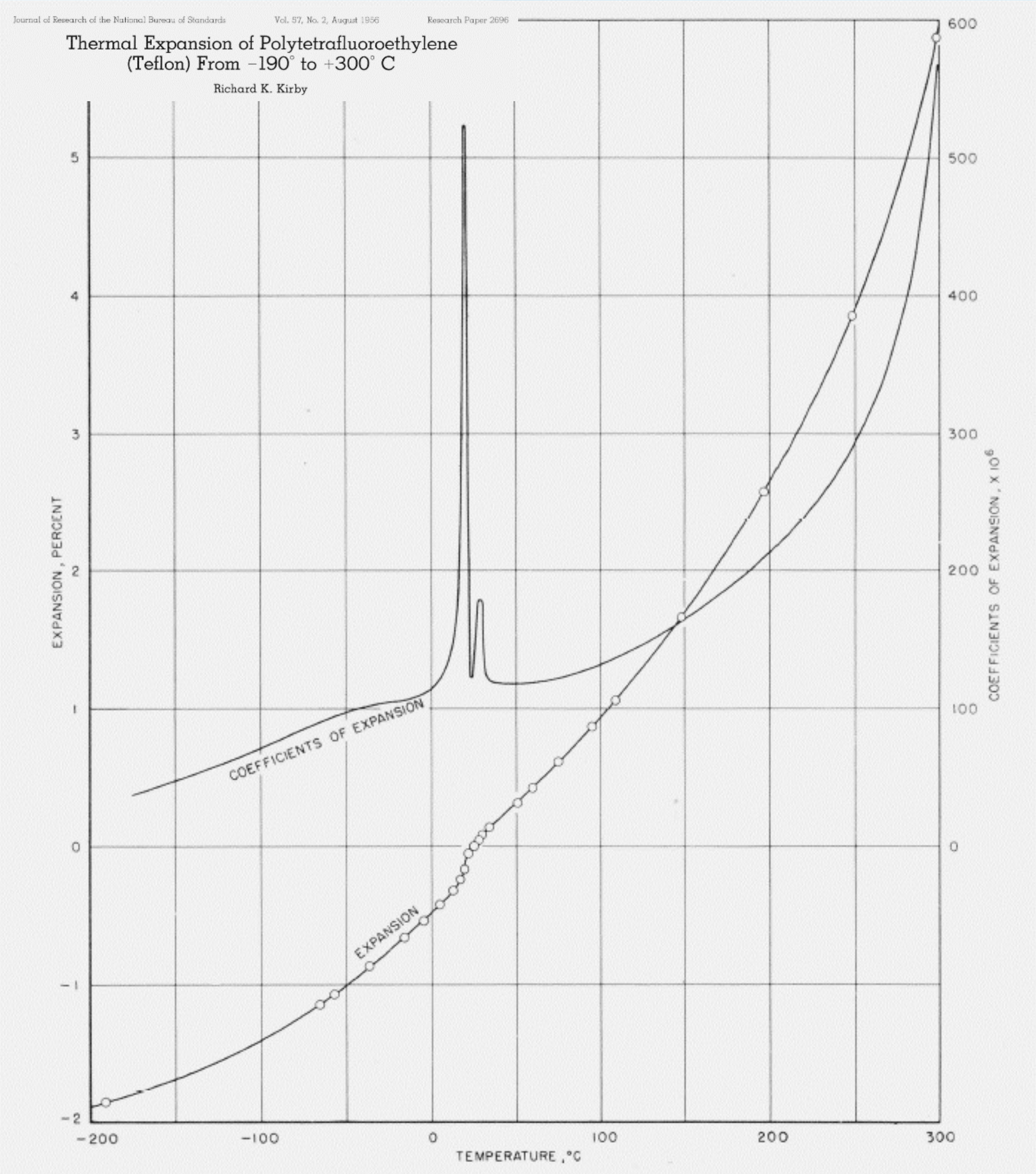
Assumptions:

- 4" Trunion ball valve sealing helium at -195C.
- 1.2% deflection needed to seal.
- Line contact ball to seat of 0.8mm radial.
- Designed contact force reduced for Vespel®



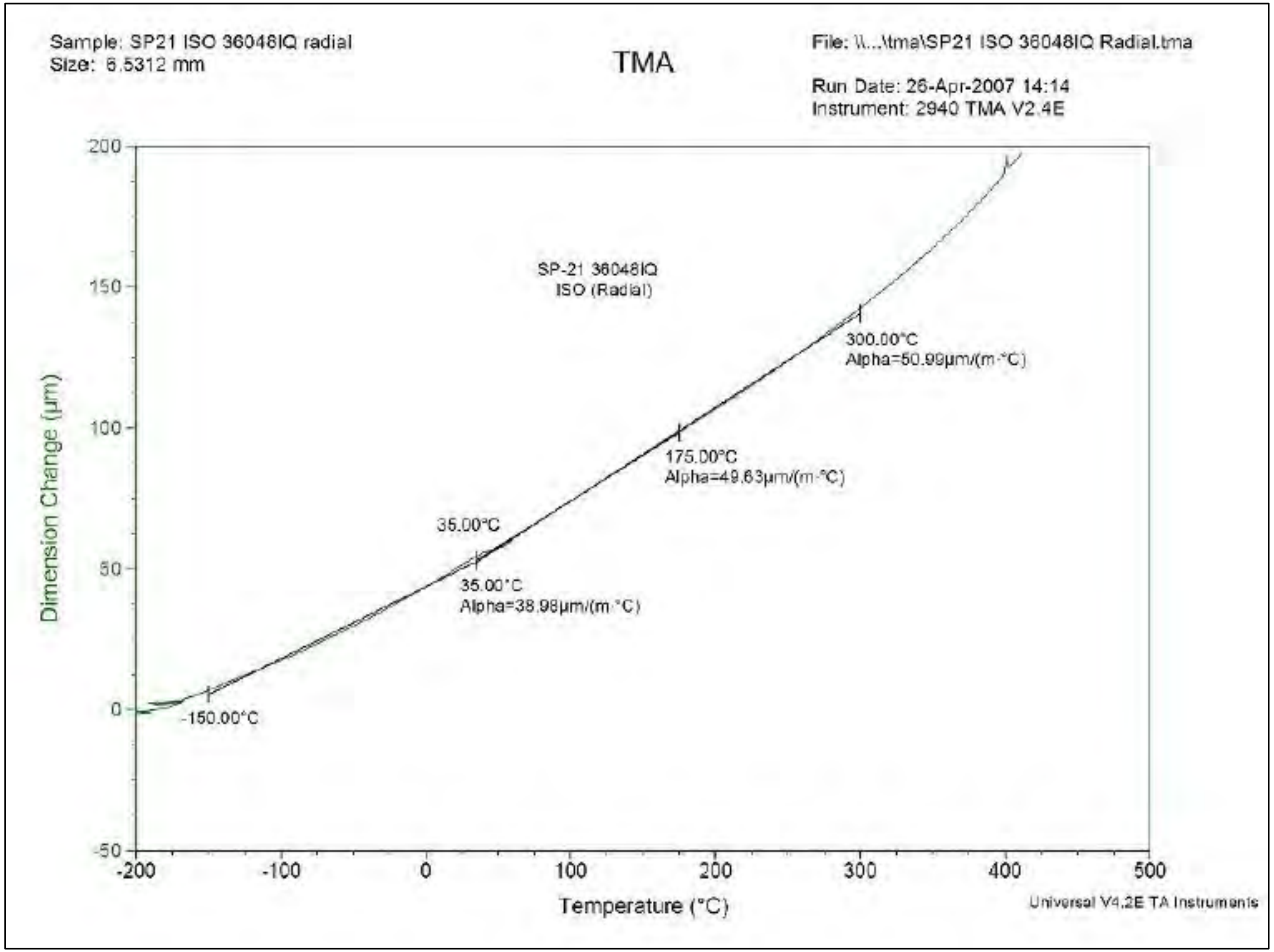
Lewis, G., Merot, P., & Matoux, J. (2015). High performance polyimide parts can help reduce actuation torque and improve sealing in cryogenics ball valves for LNG (Liquid Natural Gas) applications. Presented at the AMI International Conference on Oil & Gas Non Metallics. London. December 8-10, 2015.

CTE of PTFE



Source: Kirby

Low and Consistent CTE of DuPont™ Vespel® Polyimide



Source: Lewis

Thermal expansion of Dupont™ Vespel® SP-21

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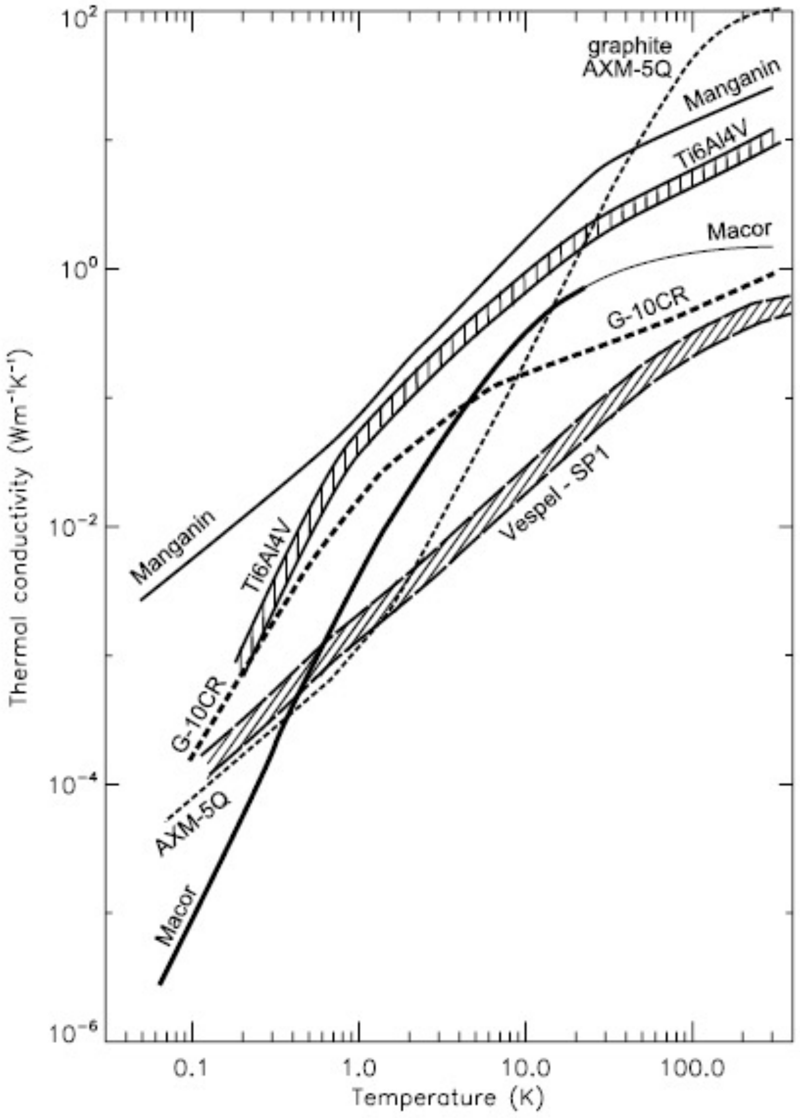
Low Thermal Conductivity at Cryogenic Temperatures

A low temperature thermal conductivity database

Adam L. Woodcraft[*,†] and Adam Gray[**]

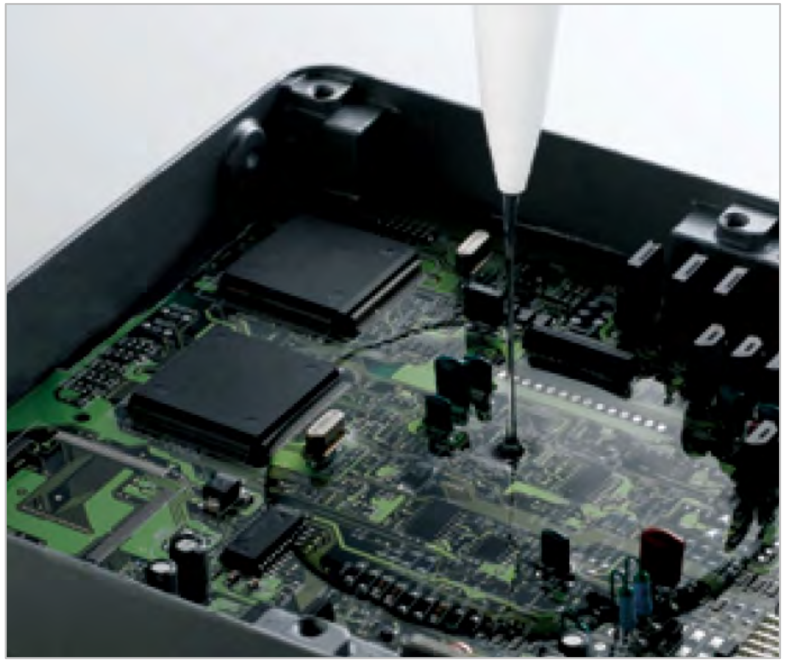
[*]SUPA, Institute for Astronomy, University of Edinburgh, Blackford Hill, Edinburgh EH9 3HJ, UK
[†]UK Astronomy Technology Centre, Blackford Hill, Edinburgh EH9 3HJ, UK
[**]School of Physics and Astronomy, University of Edinburgh, Blackford Hill, Edinburgh EH9 3HJ, UK



Source: Woodcraft

High Performance Silicones for Spacecraft Electronics

- High thermal conductivity, while retaining electrically insulative properties, to prevent excessive heat buildup in high power density devices
- Low outgassing grades for spacecraft applications
- Wide operating temperature range, from -175 °F to 500 °F continuous use
- Outstanding adhesion to a variety of substrates
- Low modulus to address thermal expansion mismatch without damaging electronic components
- Elastomeric behavior to prevent damage from vibration and fatigue
- Grades available with low dielectric constant and low dielectric loss for antenna applications
- Optically transparent grades available



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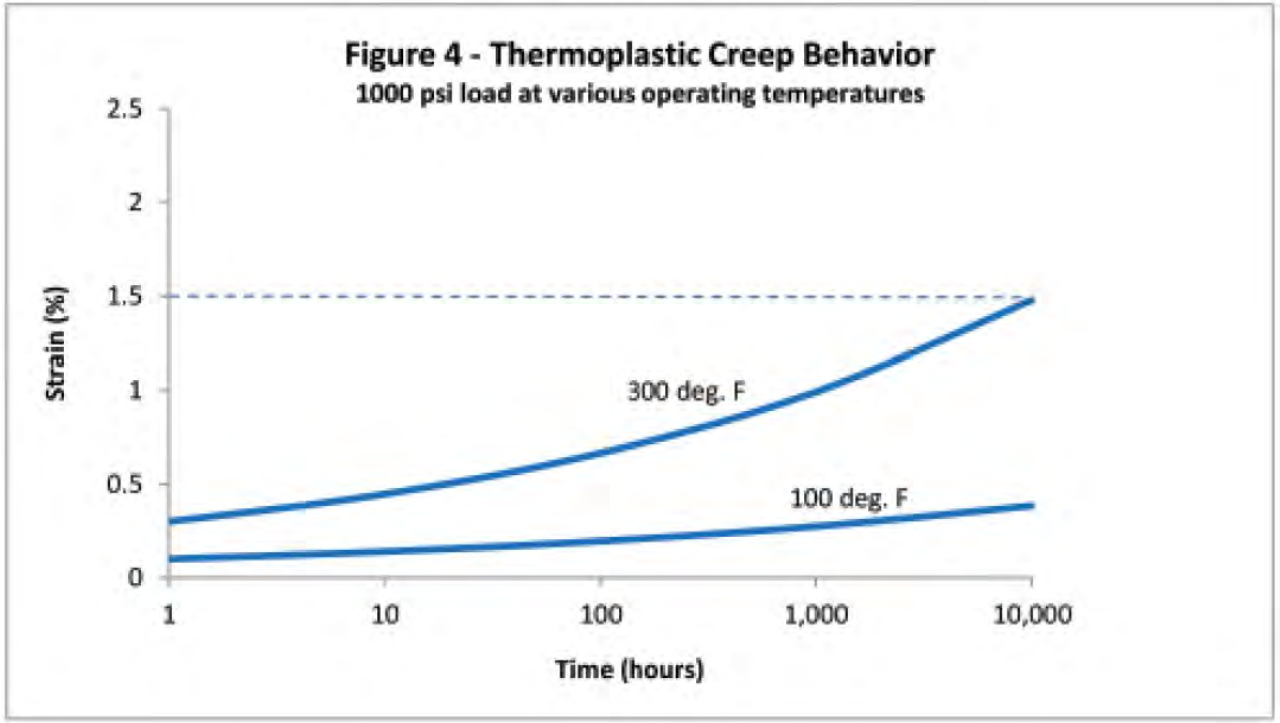
Mechanical Properties

Creep

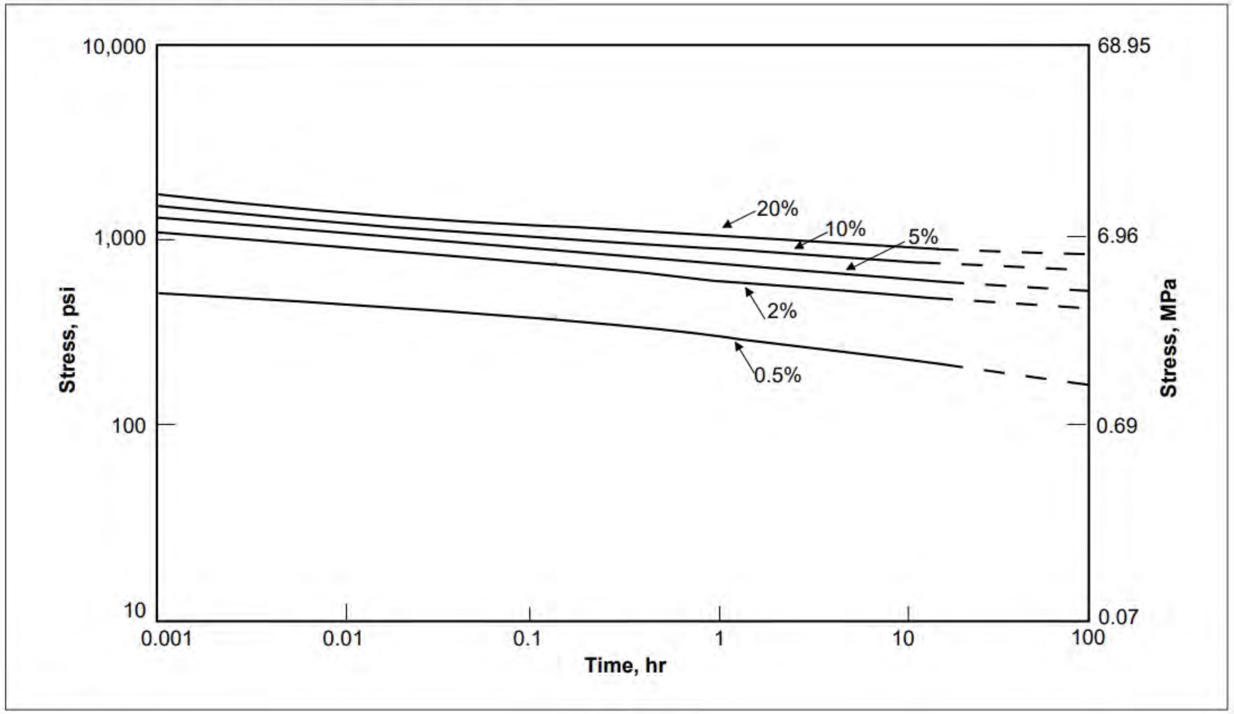


Source: Hechtel, 2014

Stress Relaxation

Tensile stress relaxation curves for PTFE held at constant strain

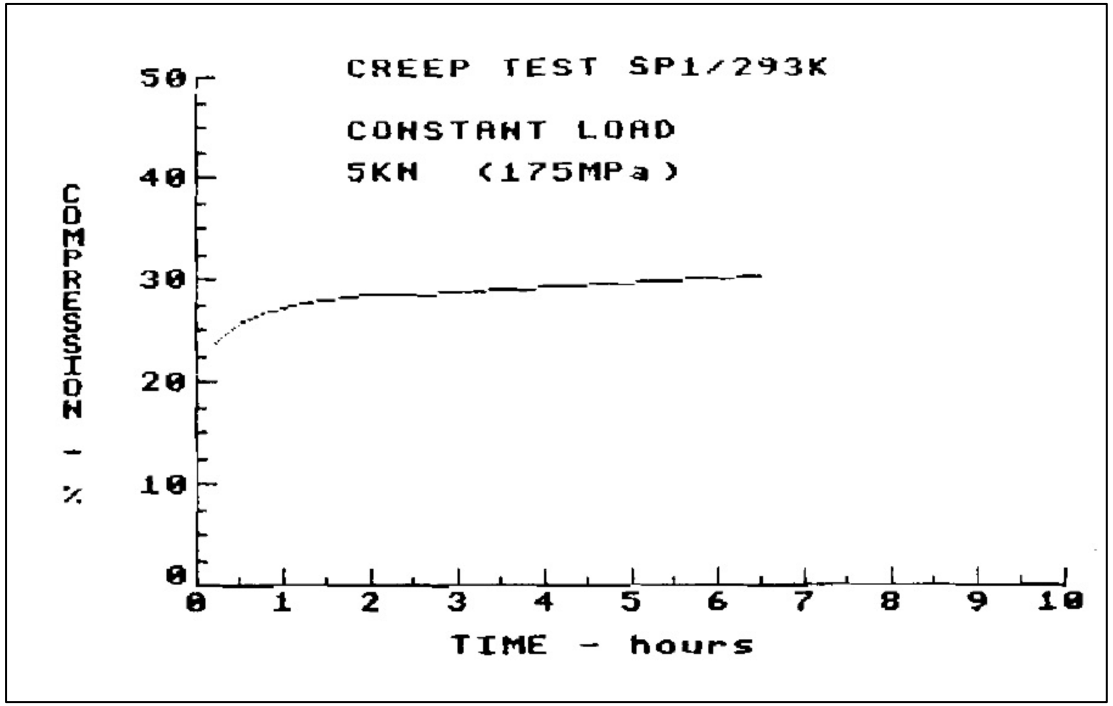
Figure 10a. Tensile Strength Relaxation at 23°C (73°F)



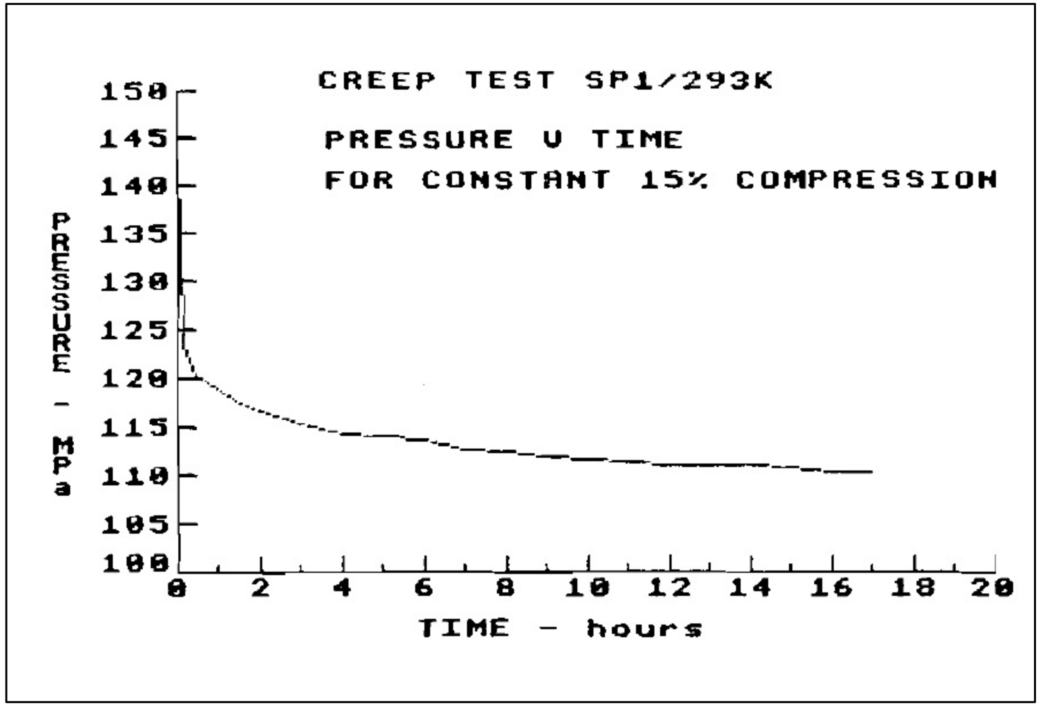
Source: DuPont

Creep and Stress Relaxation of DuPont™ Vespel® Polyimide

Creep



Stress Relaxation



Source: McDonald, 1987

Vibration Damping Characteristics

CHARACTERIZATION OF HIGH TEMPERATURE
POLYMERIC DAMPING MATERIALS

Richard P. Chartoff, Ival O. Salyer, Michael L. Drake

UNIVERSITY OF DAYTON RESEARCH INSTITUTE
300 COLLEGE PARK AVENUE
DAYTON, OHIO 45469

January 1983

MATERIALS LABORATORY
AIR FORCE WRIGHT AERONAUTICAL LABORATORIES
AIR FORCE SYSTEMS COMMAND
WRIGHT-PATTERSON AIR FORCE BASE, OHIO 45433

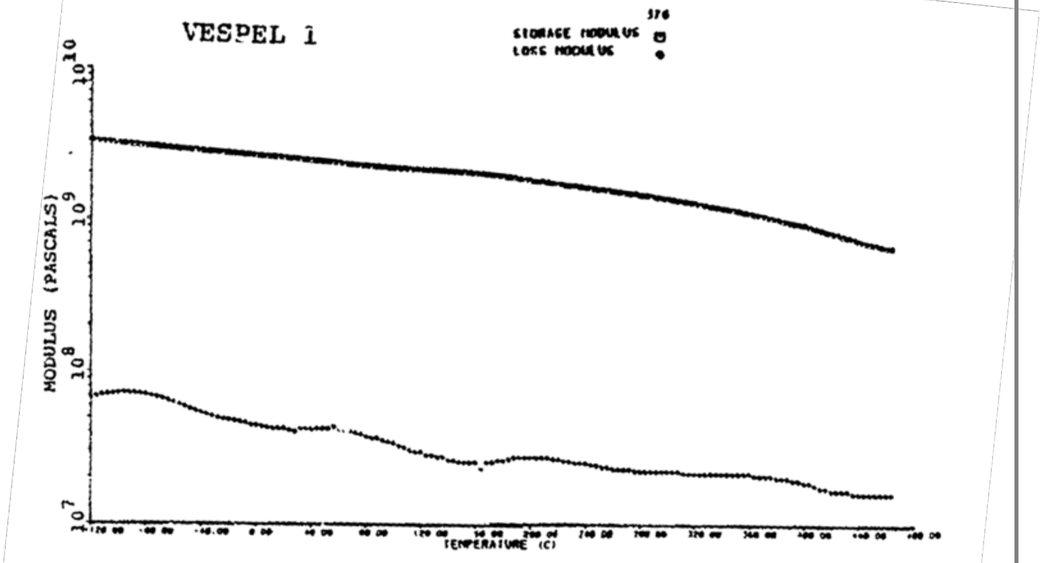


Figure 21. Vespel 1 DMA Storage and Loss Modulus Data.

of fillers, plasticizers, and polyblending. A number of polymers and polymer formulations were identified that have the potential for effective vibration damping within the temperature range 300°F (149°C) to 700°F (371°C). Further work on the application of these materials in structural damping treatments was recommended.

Source: Chartoff, 1983

Case Study – Centering Rings for Space Camera

Optomechanical Design of Nine Cameras for the Earth Observing Systems Multi-Angle Imaging Spectral Radiometer, TERRA Platform

Virginia G. Ford, Mary L. White, Eric Hochberg, and Jim McGown
Jet Propulsion Laboratory
California Institute of Technology

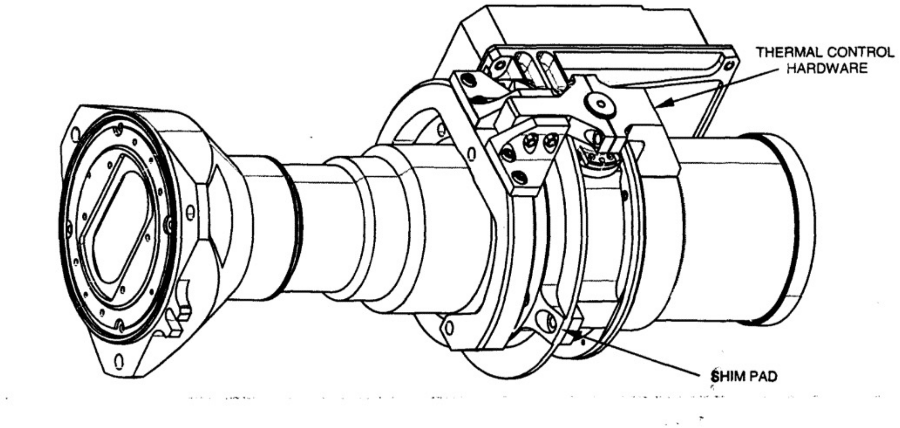
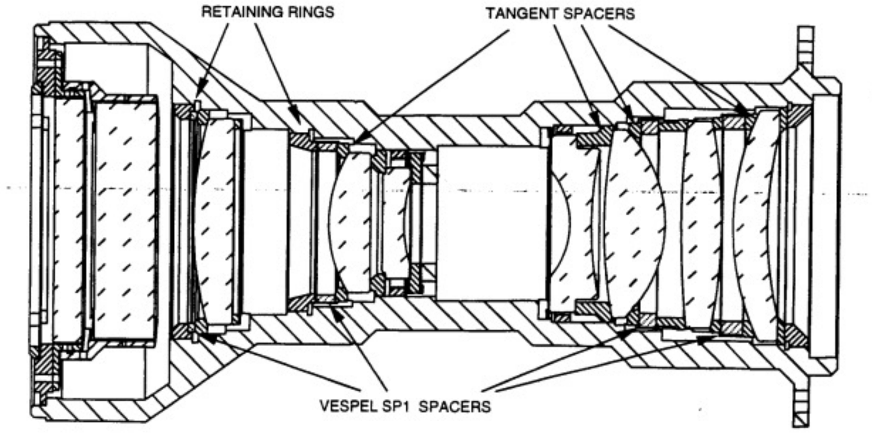


Figure 8. Assembled Camera D



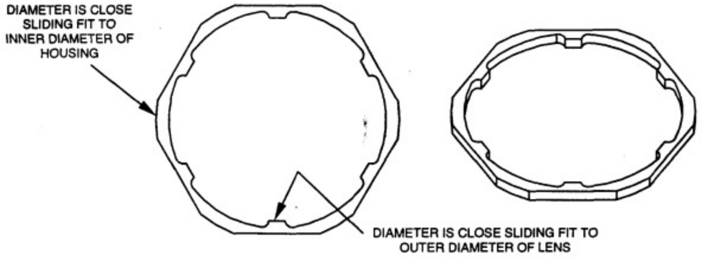


Figure 7. Vespel SP1 Centering Ring for Concave Lens Elements

Source: Ford

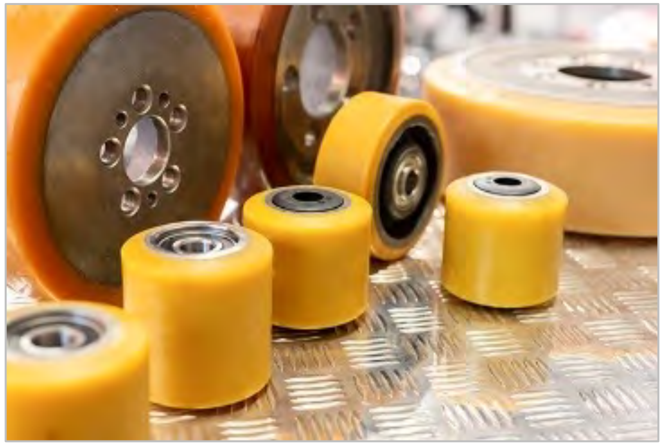
Tribological Properties (Friction and Wear)

Friction and Wear

- "Wear" is a complex behavior
- A system property, not a material property
- The COF of base polymers varies considerably
- Additives can reduce COF, improve wear, and increase limiting PV
- Vacuum changes wear characteristics
- Mating metal surface is very important
  - Chemistry
  - Hardness
  - Surface roughness

Mechanisms of Wear

Sliding Wear



Rolling Contact Fatigue

Impact Fatigue

Abrasive Wear

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Friction and Wear

NASA/TM—1998–207195

Database for the Tribological Properties of Self-Lubricating Materials

T.R. Jett and R.L. Thom
Marshall Space Flight Center, Marshall Space Flight Center, Alabama

plotted. The data are summarized and an overall ranking for lowest wear rate is shown in table 11. This table shows that the polyimide materials (Vespel SP211, Vespel SP21, and Vespel SP22) had the lowest wear rates. Chemloy 7570 (70 percent Bronze, 30 percent PTFE) also had a low wear rate. TFM and the

Table 2. Average coefficient of friction at 66 N normal load and 7.9 m/min.

TFM	0.12	Chemloy 7584	0.19
Chemloy 7586	0.12	Chemloy 7520	0.19
Rulon-J	0.16	Vespel SP3	0.20
Chemloy Q18	0.17	Chemloy 7574	0.20
Chemloy 7558	0.17	Chemloy 7570	0.22
Chemloy 7589	0.17	Vespel SP211	0.23
Chemloy 7579	0.18	Chemloy 7569	0.24
Chemloy 7519	0.18	Vespel SP22	0.32
Chemloy 7575	0.18	Vespel SP21	0.35

Source: Jett

Friction and Wear of Various Polymers Against 304 Stainless Steel at Room Temperature and at Cryogenic Temperatures

Material	Friction coefficient		
	At 4.2 K	At 77 K	At 293 K
Teflon	0.16 ± 0.01	0.09 ± 0.01	0.12 ± 0.01
UHMW	0.12 ± 0.01	0.07 ± 0.02	0.15 ± 0.01
HDPE	0.14 ± 0.02	0.11 ± 0.03	0.18 ± 0.01
Polypropylene	0.24 ± 0.01	0.21 ± 0.03	0.22 ± 0.04
Kel-F	0.21 ± 0.03	0.19 ± 0.01	0.36 ± 0.01
Nylon 101	0.10 ± 0.02	0.09 ± 0.01	0.28 ± 0.02
Lucite	0.50 ± 0.06	0.34 ± 0.01	0.30 ± 0.03
	Wear coefficient, $k(\times 10^6)^a$		
	At 4.2 K	At 77 K	At 293 K
Teflon	1.0 ± f(1.9)	0.8 ± f(2.2)	5.0 ± f(1.6)
UHMW	0.2 ± f(1.9)	0.4 ± f(1.8)	0.3 ± f(2.1)
HDPE	1.2 ± f(3.3)	2.3 ± f(1.6)	0.9 ± f(1.9)
Polypropylene	8.0 ± f(1.6)	18.0 ± f(1.4)	4.9 ± f(2.3)
Kel-F	3.4 ± f(2.8)	10.4 ± f(2.7)	5.2 ± f(2.9)
Nylon 101	0.4 ± f(1.9)	0.2 ± f(2.3)	2.2 ± f(1.4)
Lucite	220.0 ± f(1.2)	65.0 ± f(2.7)	25.0 ± f(1.5)

Source: Michael

Friction and Wear Performance in Vacuum (Vespel® SP-3)

TESTS OF CERTAIN BEARING MATERIALS IN HIGH VACUUM BY CERN

Geneva and IRCHA - Paris

The best polyimide material tested
Both in air and vacuum appeared to be
Vespel SP31 (old name for Vespel SP-3)
polyimide MoS_2 mixture.

Source: Poncet

Case Study – Rollers for a Planetary Atmosphere Occultation Spectrometer

A Low Mass Translation Mechanism for Planetary FTIR Spectrometry Using an Ultrasonic Piezo Linear Motor

Matthew Heverly*, Sean Dougherty*, Geoffrey Toon**, Alejandro Soto**, Jean-Francois Blavier**

* Alliance Spacesystems, Inc., Pasadena, CA
** Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA

Proceedings of the 37th Aerospace Mechanisms Symposium, Johnson Space Center, May 15-17, 2004

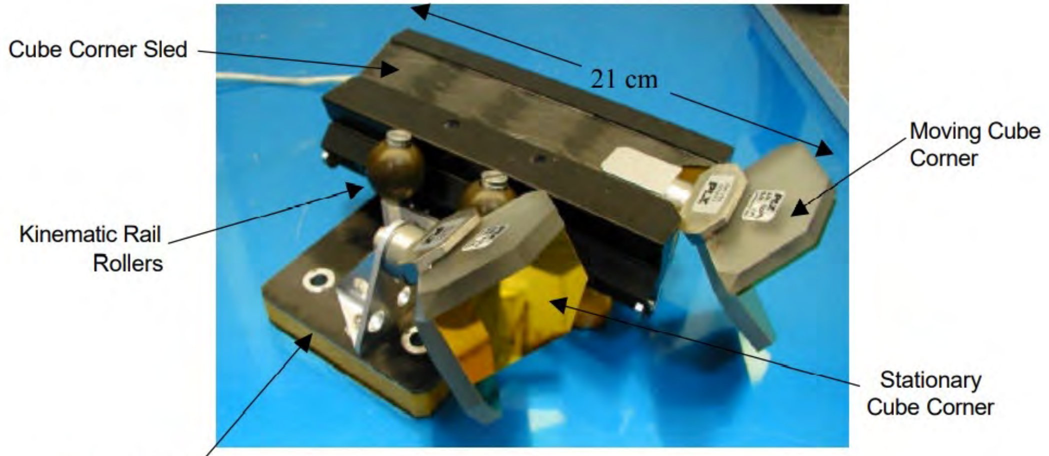

Figure 3. PAOS Prototype Mechanism

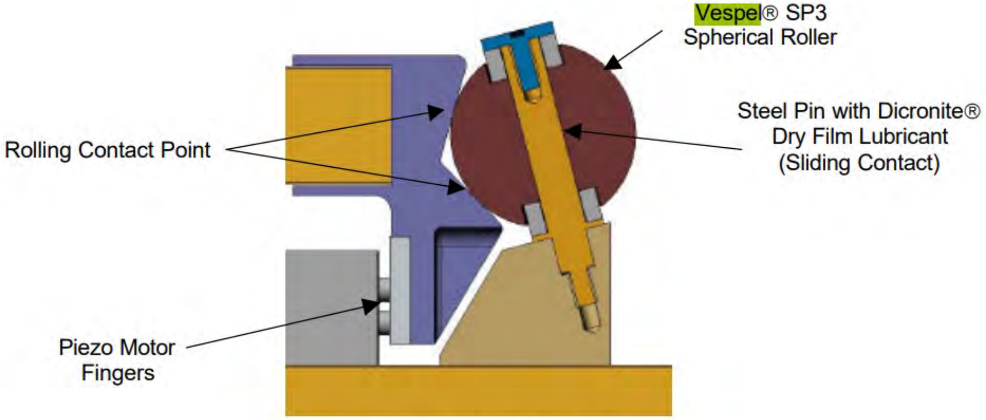

Figure 12. Spherical Roller Cross Section

All three of the spherical rollers are made from Vespel SP3. Initially, a pair of preloaded radial ball bearings was used inside each of the spherical rollers, yielding good velocity uniformity performance. Tests were then run without the ball bearings using only the Vespel rollers as bushings, sliding on steel pins coated with Dicronite® dry film lubricant as shown in Figure 12. These tests yielded similar results to the tests using bearings, but without the requirement for wet lubrication. This is advantageous because the lubrication under vacuum conditions could outgas and contaminate the optical surfaces. With the rollers acting as bushings the force necessary to move the mechanism is proportional to the preload of the piezo motor and the coefficient of friction between the sliding Vespel/Dicronite interface. Under normal ambient conditions the mechanism requires approximately 1 pound of force to move the sled. Under vacuum conditions, the coefficient of friction for Vespel SP3 reduces by a factor of 10 due to the removal of moisture on the contacting surfaces. This further reduces the power required by the system and increases the motor's force margin over stall conditions.

Conclusions

A new linear translation mechanism has been developed that will allow the PAOS instrument to offer improved performance and lower mass compared to existing spaceborne spectrometers. The low mass (< 1kg) of this mechanism is a direct result of the enabling technology represented by the ultrasonic piezo motor. These motors provide a new alternative for linear space mechanisms and offer smooth, precise motion, inherent redundancy, low mass, and simplified integration. The kinematic Vespel rail system provides a solution that is fault tolerant and insensitive to structural misalignments due to thermal distortion or manufacturing tolerances. The design can easily be adapted to provide any stroke length over a wide range of velocities. Initial testing shows consistent velocity error of less than 0.7% in a mechanism that requires no wet lubrication and is small enough to hold in a single hand.

Source: Heverly, 2004

DAVE SEILER

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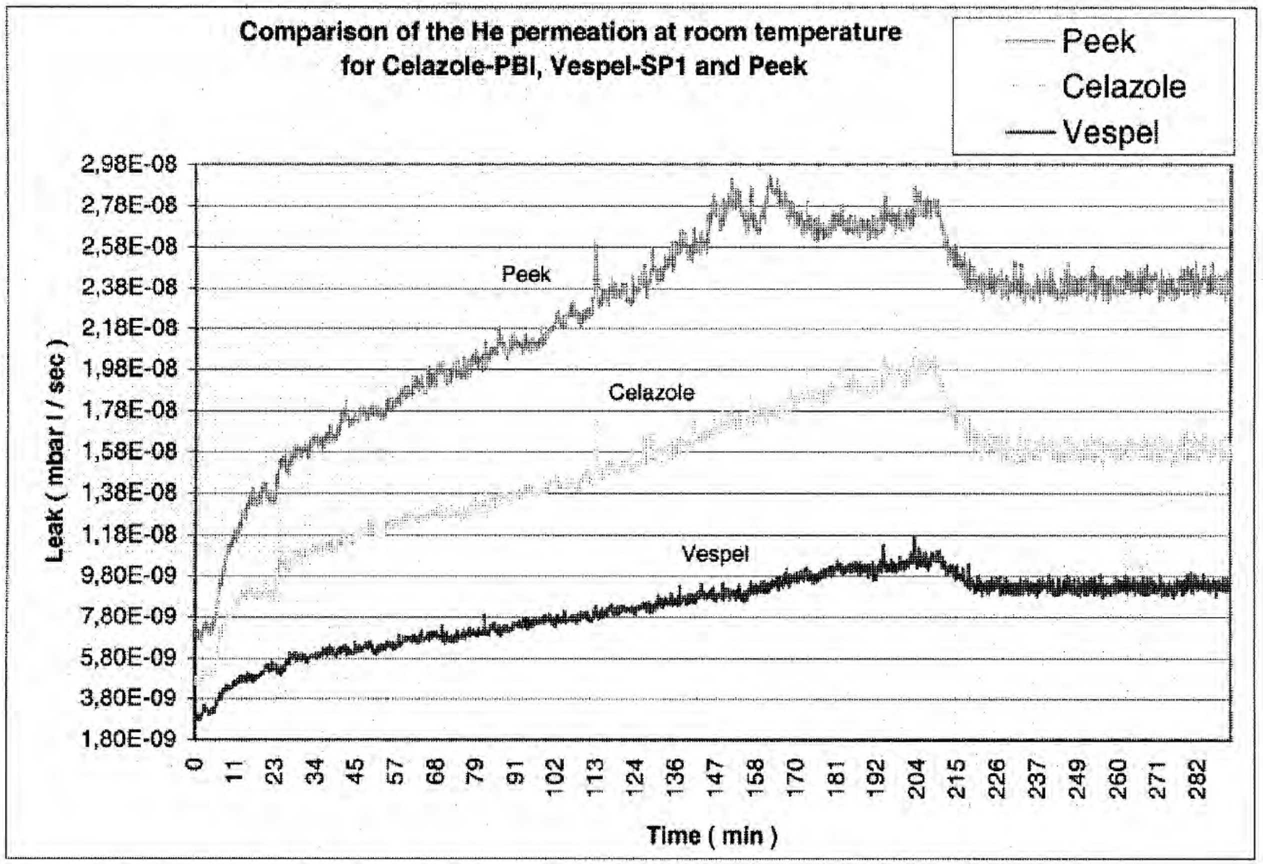
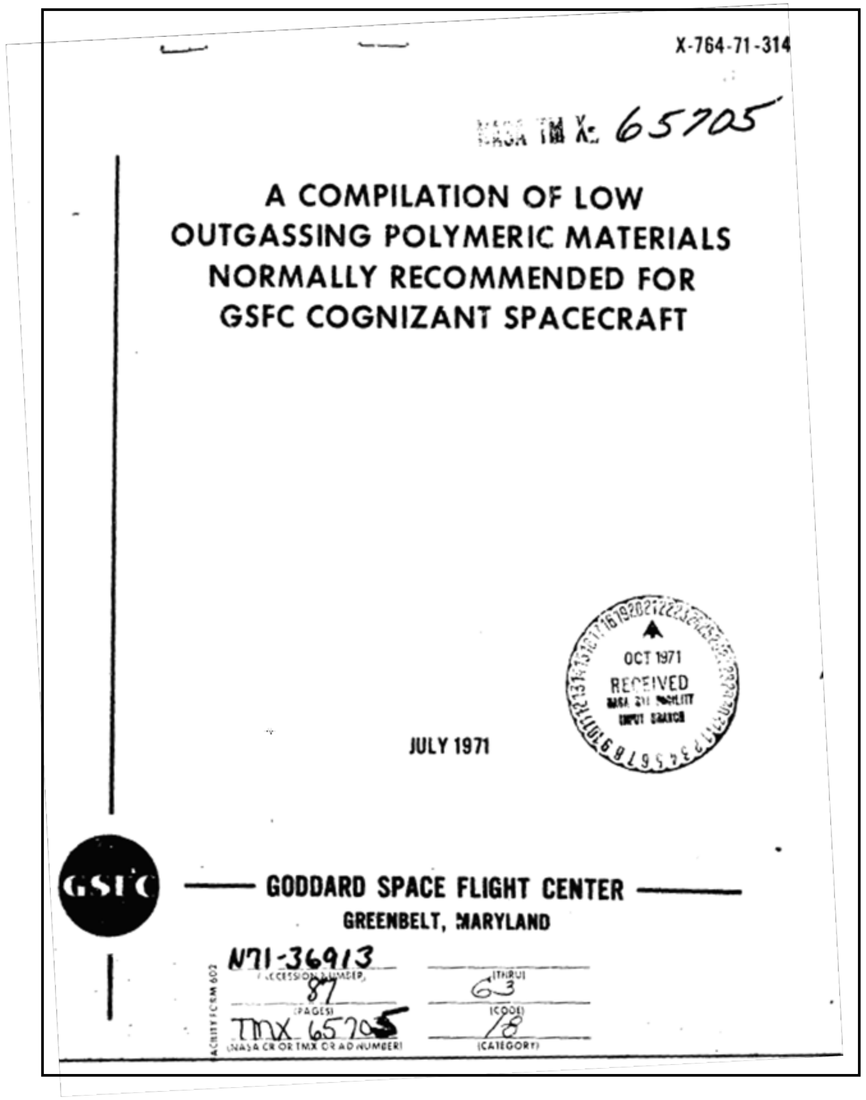
Vacuum Conditions



Notes: - Vacuum also affects friction and wear performance
- NASA Low Outgassing Database

Source: Murari and Barzon

Low Outgassing


X-764-71-314

NASA TM X- 65705

A COMPILATION OF LOW OUTGASSING POLYMERIC MATERIALS NORMALLY RECOMMENDED FOR GSFC COGNIZANT SPACECRAFT

OCT 1971 RECEIVED

JULY 1971

GSFC

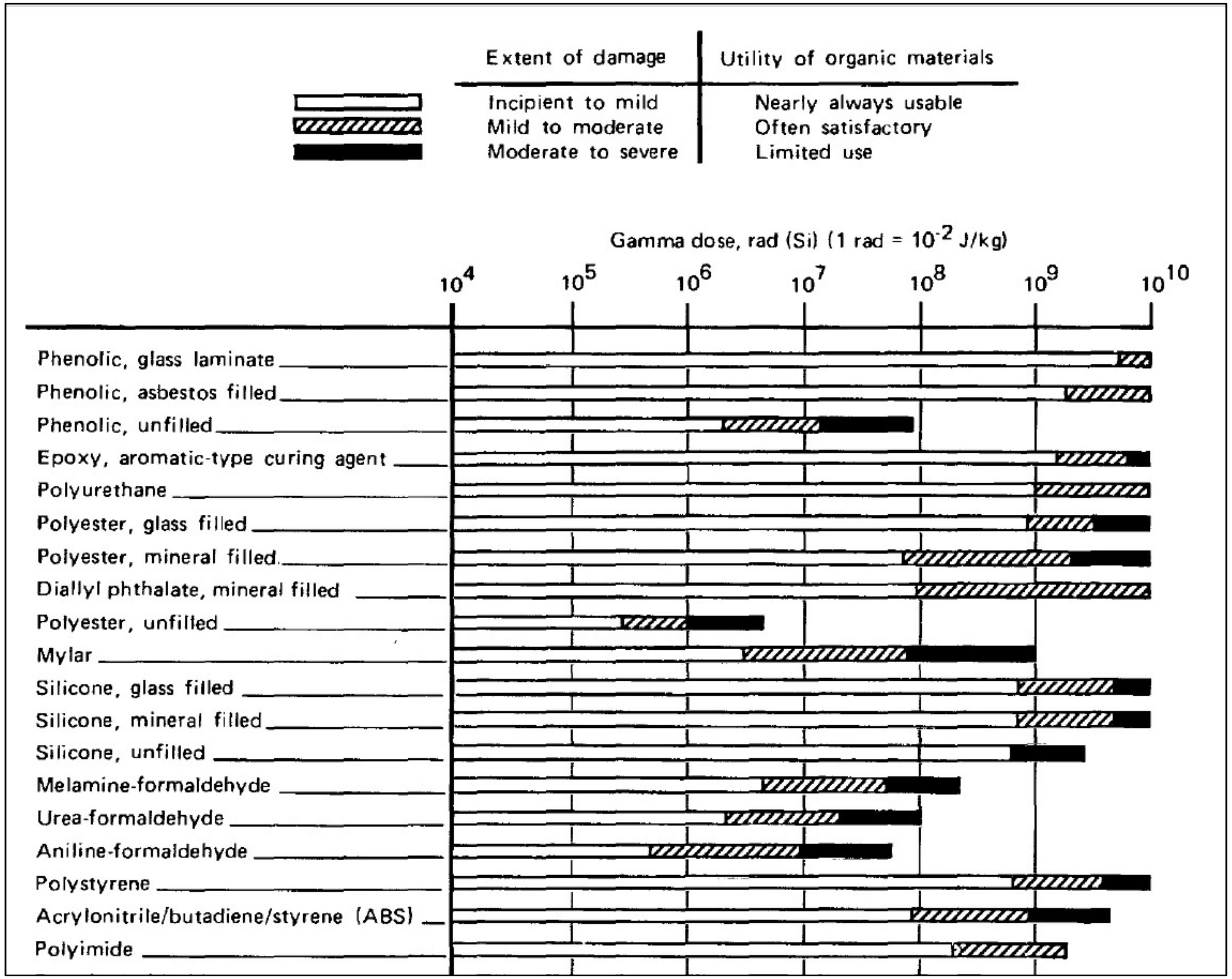
GODDARD SPACE FLIGHT CENTER
GREENBELT, MARYLAND

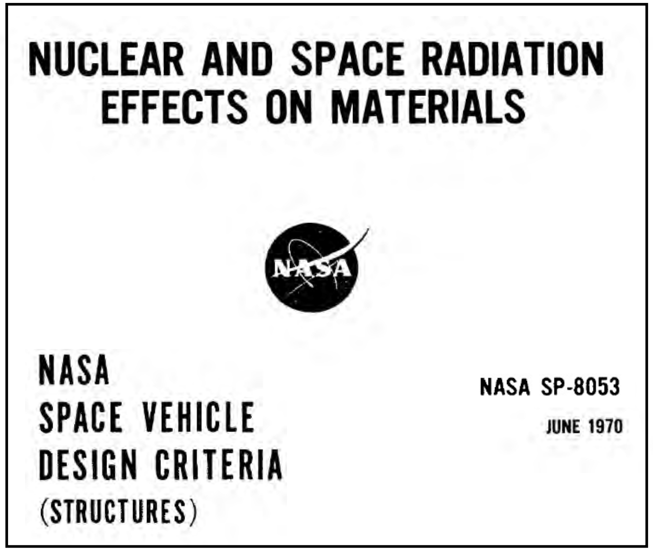
N71-36913
87
TMX 65705
63
18

Vespel has a submarginal total outgassing of 1.24%, this is primarily moisture. It may be considered for use where its excellent combination of properties, low condensables, low friction coefficient, excellent ultra violet, particulate radiation and high temperature resistance are essential to spacecraft function.

Source: Fisher

Radiation Resistance (from sources internal and external to spacecraft)





NUCLEAR AND SPACE RADIATION EFFECTS ON MATERIALS

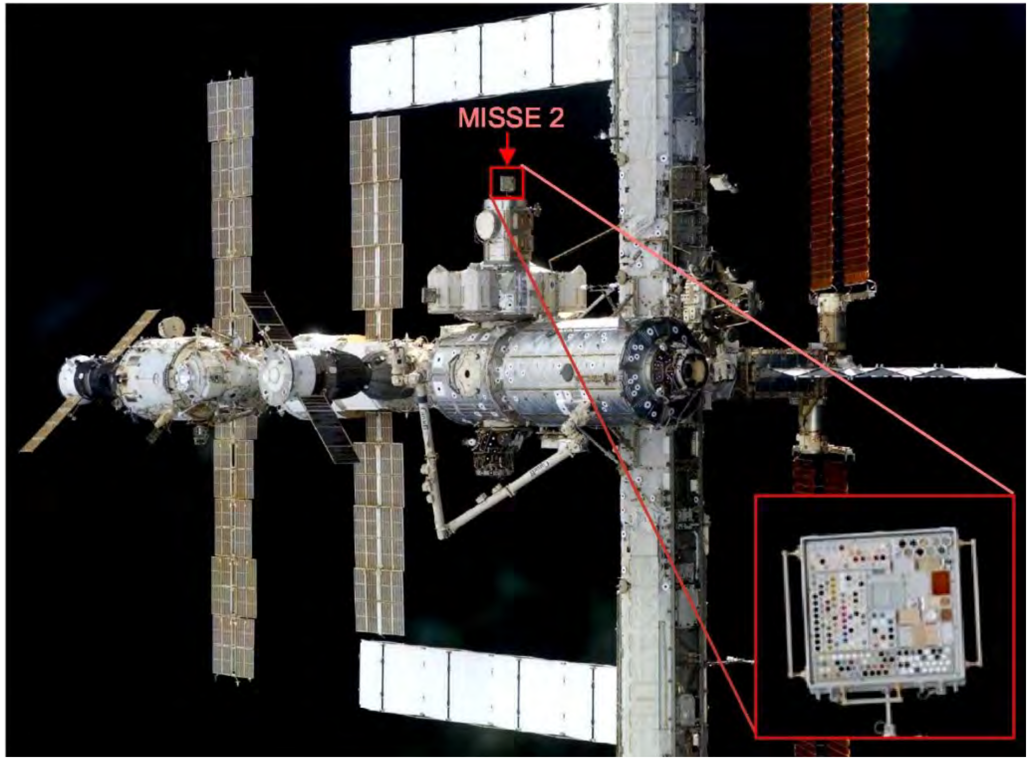
NASA
SPACE VEHICLE
DESIGN CRITERIA
(STRUCTURES)

NASA SP-8053

JUNE 1970

Source: Shulman, 1970

Resistance to Erosion from Atomic Oxygen



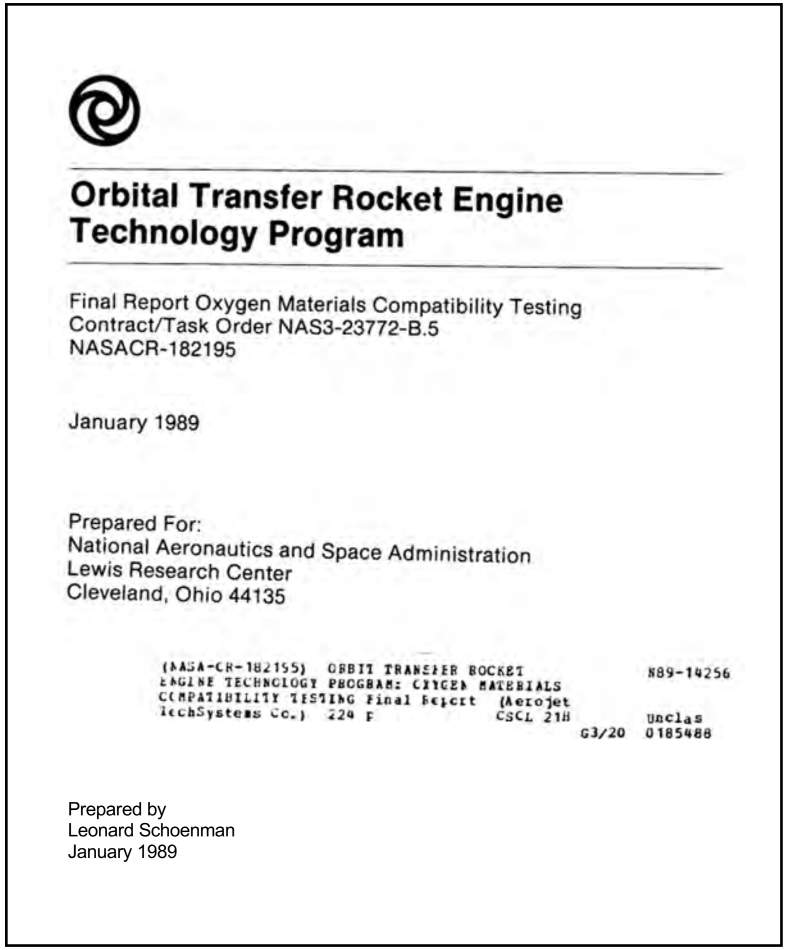
Polymer Erosion and Contamination Experiment

Figure 2.—Photograph of the MISSE 2 PEACE Polymers experiment prior to flight. The labels shown indicate the materials defined in Table I.

Figure 3.—Photograph of the MISSE 2 PEACE Polymers experiment post-flight.

Source: Banks, 2009

Flammability/Oxygen Compatibility



Orbital Transfer Rocket Engine Technology Program

Final Report Oxygen Materials Compatibility Testing
Contract/Task Order NAS3-23772-B.5
NASACR-182195

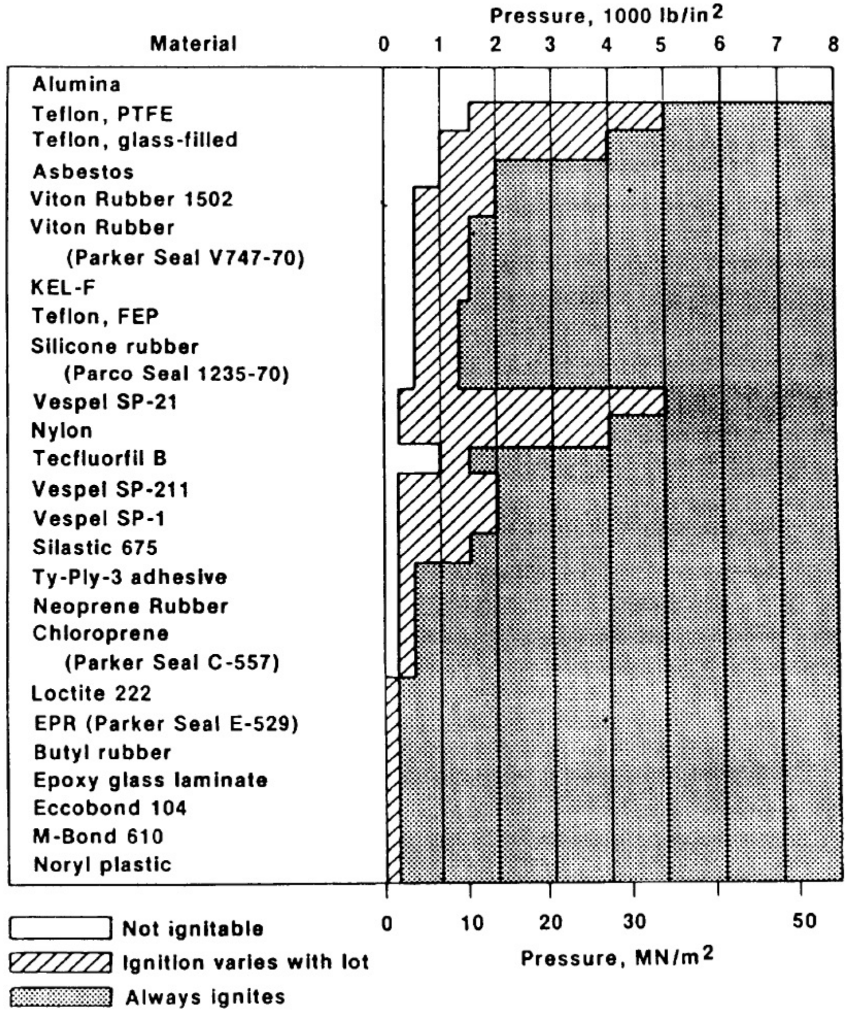
January 1989

Prepared For:
National Aeronautics and Space Administration
Lewis Research Center
Cleveland, Ohio 44135

(NASA-CR-182195) ORBIT TRANSFER ROCKET ENGINE TECHNOLOGY PROGRAM: OXYGEN MATERIALS COMPATIBILITY TESTING Final Report (Aerojet TechSystems Co.) 224 p CSCL 21H N89-14256 Unclas G3/20 0185488

Prepared by
Leonard Schoenman
January 1989

Source: Schoenman, 1989



Reference NASA Publication 1113

Figure 9. Range of Ignitability for Nonmetallics

Oxygen Compatibility/Flammability

Table 1: Bomb test results

Materials	Auto ignition temperature (°C)
Polyethylene	201
PVC	259
Nylon 66	202
Nylon 66 + 30 % glass fibres	272
Polyacetal DELRIN 100AF	209
Polyacetal DELRIN 500CL	196
PFA	458
PTFCE	429
PTFCE 302	440
Polyimide VESPEL SP-3	366
Polyimide VESPEL SP-21	366
Bronze sintered PTFE	>500

4TH EUROPEAN CONFERENCE FOR AEROSPACE SCIENCES

- SP-21 has been tested by the National Aeronautics and Space Administration and meets MSFCSPEC-106B, “Testing Compatibility of Materials for Liquid Oxygen Systems”. At present time this approval is on a selected-lot basis.

- Similarly, SP-21 was tested by the Naval Air Engineering Center, Department of the Navy, and was found compatible according to MIL-V-5027C, “Non-Metallic Materials Compatible with Oxygen”.

Table 2: Impact test results

Materials	Amount of ignition / amount of impact						
Polyamide-imide TORLON 4203	5/20						
PTFCE	0/20	0/20	1/40	4/20			
PTFCE 302	0/20	3/20	0/20	4/20	1/20	4/20	3/20
	7/20	5/20	0/39	1/40	0/20	4/20	2/20
	0/20	7/20	3/20	0/20	0/20	0/20	1/40
	1/40	0/20	3/20	1/40	1/40	3/20	0/20
	0/20	0/20	1/20	0/20	0/20	0/20	0/20
	0/20	0/20	0/20	0/20	0/20	0/20	2/27
	0/20	0/20	0/20	0/20			
VESPEL SP-21	0/20	0/20	1/40	0/20	0/20	0/20	0/20
	0/20						
PTFE	0/20	0/20	0/20	0/20	0/20	0/20	0/20
Bronze sintered PTFE	0/20						

Remark: TORLON is a trademark of Solvay

“Impact tests clearly state that polyimide Vespel SP-21 is compatible in liquid oxygen. The conclusion is the same for PTFE. As for PTFCE,…the conclusion…is less straightforward.”

Source: Bozet, 2011

Hydrogen Compatibility

Sponsored by
U.S. Department of Energy
Assistant Secretary for Energy Technology
Division of Energy Storage Systems
Washington, D.C. 20545

August 1978

Proceedings of the DOE Chemical/Hydrogen Energy Systems Contractor Review

MASTER

Held November 16-17, 1977
Hunt Valley, Maryland

Proceedings prepared by
Jet Propulsion Laboratory
California Institute of Technology
Pasadena, California 91109

DEPARTMENT OF ENERGY · UNITED STATES OF AMERICA

Rocketdyne International — Space Division

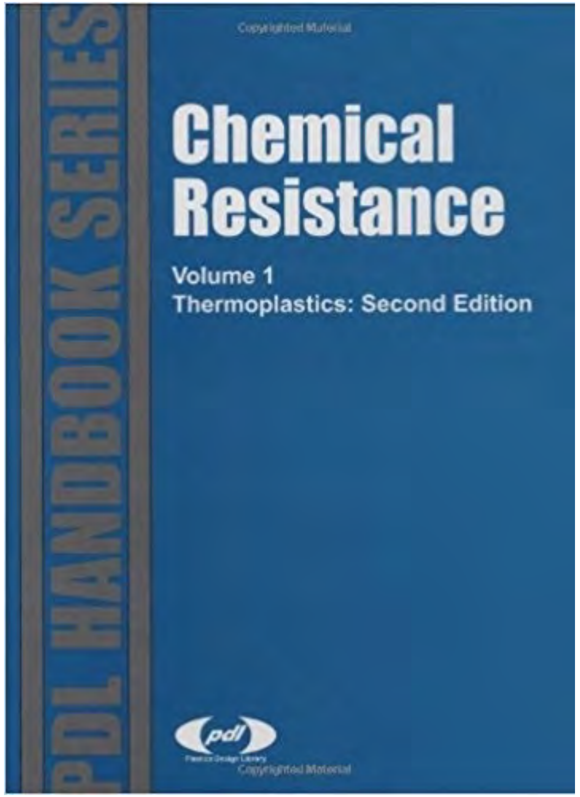
Two space division GH_2 facilities were visited; the Control Components Test laboratory in Downey, California, and the Main Propulsion Test facility at the National Space Technology Laboratory in Bay St. Louis, Mississippi.

The test facility in Downey has the capability to operate with GH_2 at pressures up to 2500 psig and at temperatures from -420 to +100°F. Manifolds range from 0.25 to one inch OD and are constructed from aluminum or conventional CRES using mechanical fittings and flanges.

Space Division has had significant experience with conventional components in gaseous hydrogen service which indicates that the major precautions necessary with the use of aerospace-quality components involve safety considerations for the high-pressure and the flamability limits. Two secondary precautions require the use of austenitic CRES for highly-stressed membranes and bellows and the minimum use of elastomers when permeability is a concern. Acceptable elastomers for hydrogen service include Buna "N", Neoprene, Viton, Teflon and Vespel. The use of metal (copper, aluminum, CRES, nickel, etc.) is preferred when possible.

Source: Kelley, 1978

Chemical Resistance and ESC



Weighted Value	Weight Change*	Diameter; length* Change	Thickness* Change	Volume Change*	Mechanical** Property Retained	Visual / Observed *** Change
10	0-0.25	0-0.1	0-0.25	0-2.5	>=97	no change
9	>).25-0.5	>0.1-0.2	>0.25-0.5	>2.5-5.0	94-<97	
8	>0.5-0.75	>0.2-0.3	>0.5-0.75	>5.0-10.0	90-<94	
7	>0.75-1.0	>0.3-0.4	>0.75-1.0	>10.0-20.0	85-<90	slightly discolored slightly bleached
6	>1.0-1.5	>0.4-0.5	>1.0-1.5	>20.0-30.0	80-<85	discolored yellows slightly flexible
5	>1.5-2.0	>0.5-0.75	>1.5-2.0	>30.0-40.0	75-<80	possible stress crack agent flexible possible oxidizing agent slightly crazed
4	>2.0-3.0	>0.75-1.0	>2.0-3.0	>40.0-50.0	70-<75	dostorted, warped softemed slight swelling blistered known stress crack agent
3	>3.0-4.0	>1.0-1.5	>3.0-4.0	>50.0-70.0	60-<70	cracking, crazing brittle plasticizer oxidizer softened swelling surface hardened
2	>4.0-6.0	>1.5-2.0	>4.0-6.0	>60.9-90.0	50-<60	severe distortion oxidizer and plasti-cizer deteriorated
1	>6.0	>2.0	>6.0	>90.0	>0-<50	decomposed
					0	solvent dissolved disintegrated

Source: PDL Staff, 1994

Note: The academic literature has articles on resistance to rocket propellants, solvents, lubricants, etc.

CURBELL PLASTICS

DuPont™ Vespel® Polyimide

Properties and Spacecraft Applications

DuPont™ Vespel® Polyimide Shapes

DuPont™ Vespel® Polyimide Shapes

Vespel® SP-1
For physical and electrical properties

SP-1 has high purity and provides physical strength, elongation and toughness, along with electrical and thermal insulation properties. Semiconductor manufacturers often find components fabricated from Vespel® SP-1 shapes useful in production processes.

Vespel® SP-21
For balanced low wear and physical properties

SP-21 is ideal for low wear and friction in applications. SP-21 has physical strength, elongation, and toughness.

Vespel® SP-22
For low wear and dimensional stability

SP-22 provides enhanced resistance to wear and friction as well as improved dimensional and oxidative stability.

Vespel® SP-211
For low coefficient of friction and unlubricated wear

SP-211 provides the lowest coefficient of friction over a wide range of operating conditions. It offers excellent wear resistance up to 300°F (149°C).

Vespel® SP-3
For unlubricated sealing and low wear in vacuum or dry environments

SP-3 provides lubrication for seals and bearings in vacuum or dry environments. SP-3 provides maximum wear and friction resistance in vacuum and other moisture-free environments, where graphite becomes abrasive.

Vespel® SCP-5000
For strength, hardness, and chemical resistance over a broad temperature range

SCP-5000 is ideal for demanding applications that require toughness, thermal and dimensional stability, chemical resistance, and stable dielectric performance across a broad temperature range.

Vespel® SCP-5009
For high wear and friction applications under high operating pressure and elevated temperature environments

SCP-5009 shapes have a low coefficient of thermal expansion and provide good sealing as well as outstanding mechanical properties like high compressive strength and low creep, even in extreme conditions.

Vespel® SCP-5050
For high temperature, wear resistance, and exceptional coefficient of thermal expansion

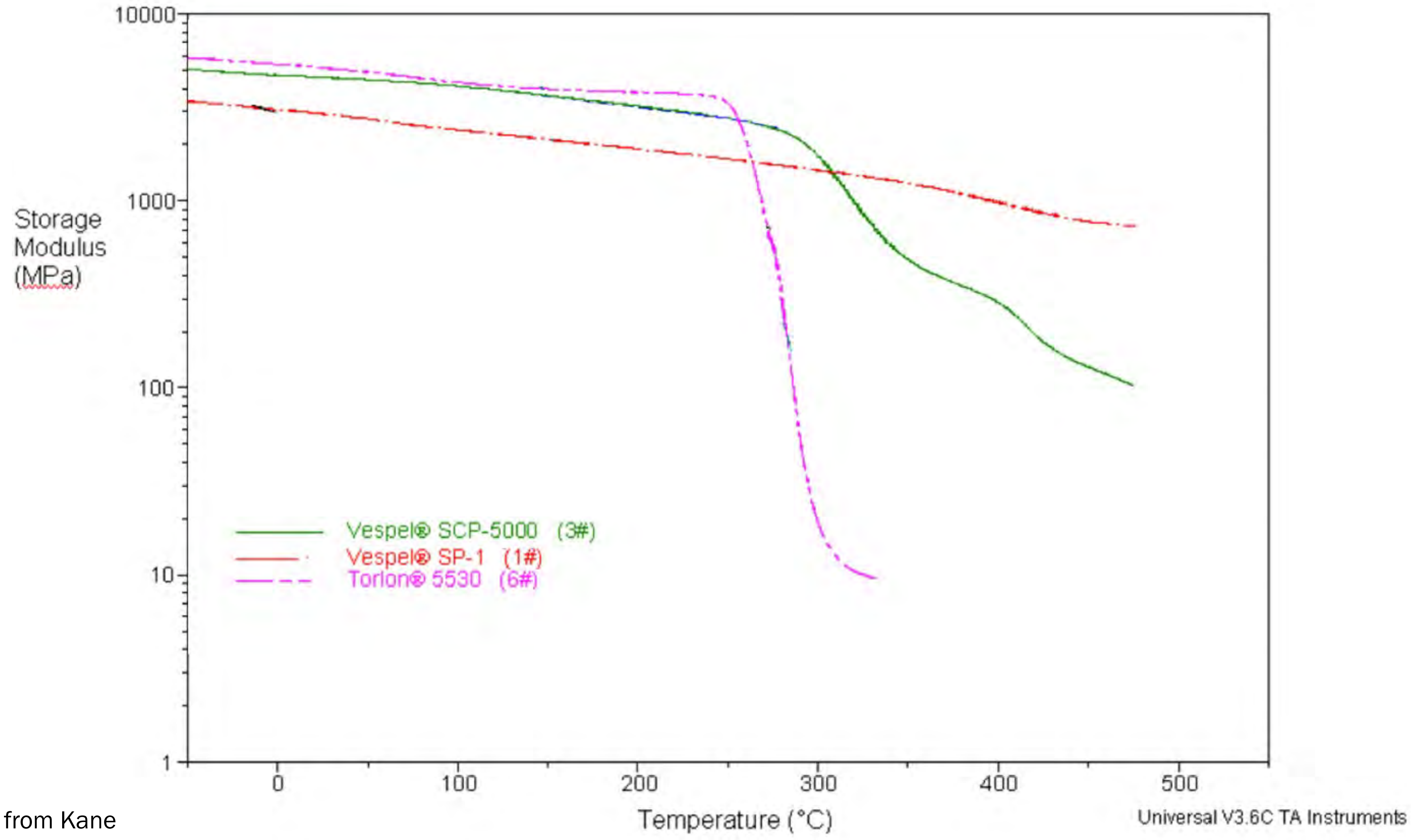
SCP-5050 is a new and innovative polyimide composition. SCP-5050 has improved high temperature and wear resistance compared to conventional polyimides allowing replacement of metal and graphite in more applications. Its proprietary composition is designed to offer a coefficient of thermal expansion (CTE) close to the CTE of metals.

Vespel® SCP-50094
For high temperature and wear resistance

SCP-50094 is a proprietary polymer designed for demanding applications that require high strength, high temperature, and wear resistance.

DMA Data – DuPont™ Vespel® and PAI

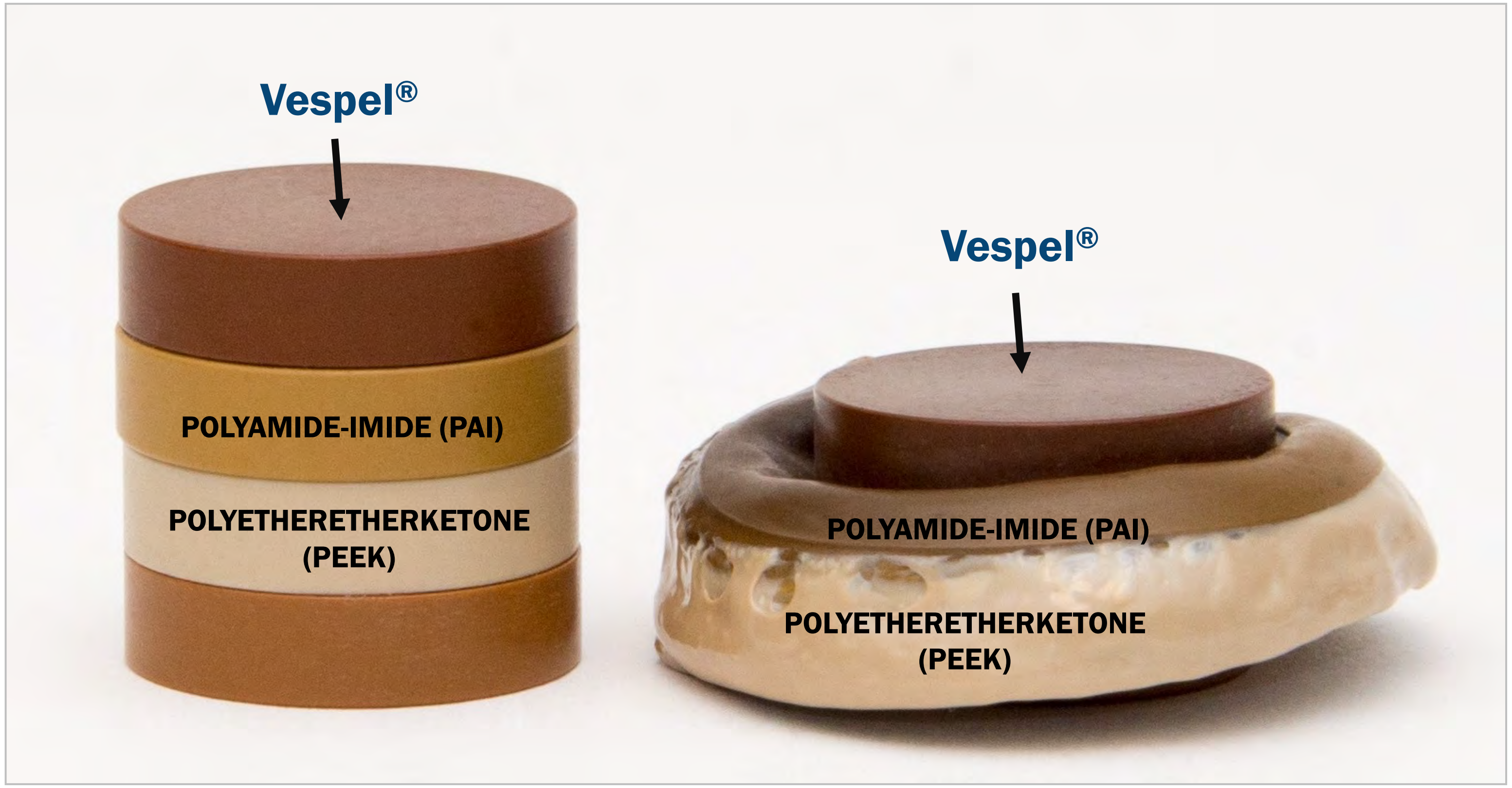
Storage Modulus by Dynamic Mechanical Analysis - DuPont™ Vespel® SP-1 and SCP-5000, and PAI



Source: Adapted from Kane

Compressive Strength at Temperature

DuPont™ Vespel® Polyimide, PAI, and PEEK

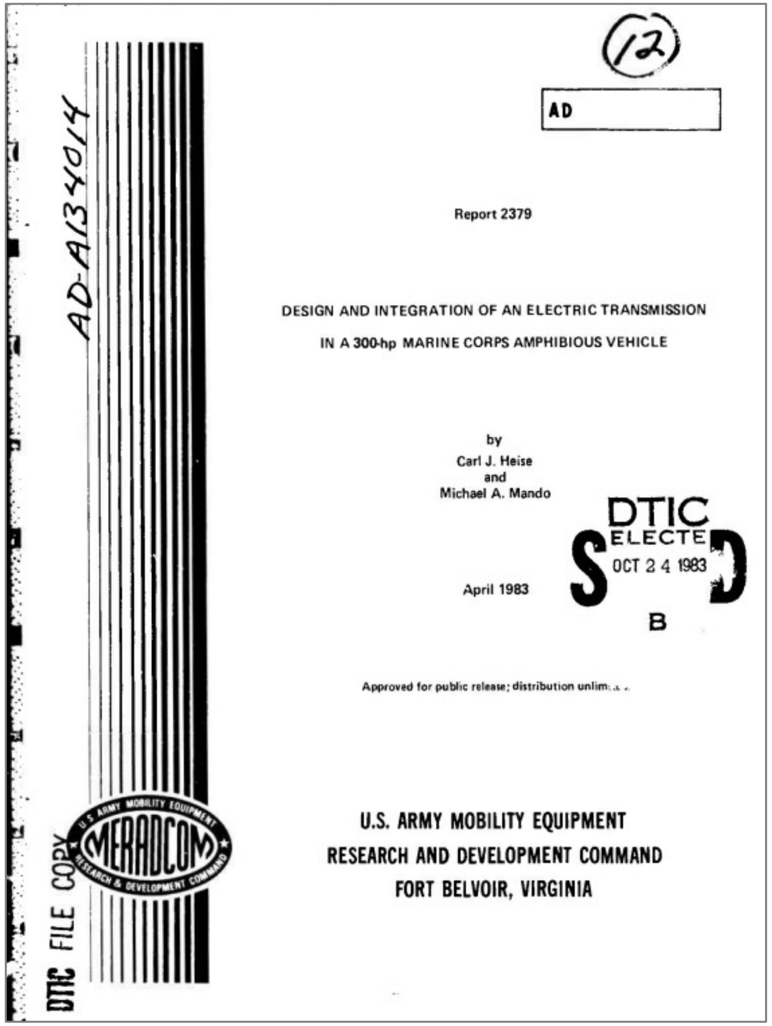


BEFORE

AFTER
Compressive Load, 700 °F

Source: Dupont

Case Study – Spline Couplings for Military Vehicles



(12)

AD

AD-A134014

Report 2379

DESIGN AND INTEGRATION OF AN ELECTRIC TRANSMISSION IN A 300-hp MARINE CORPS AMPHIBIOUS VEHICLE

by
Carl J. Heise
and
Michael A. Mando

DTIC ELECTE OCT 24 1983 S D B

April 1983

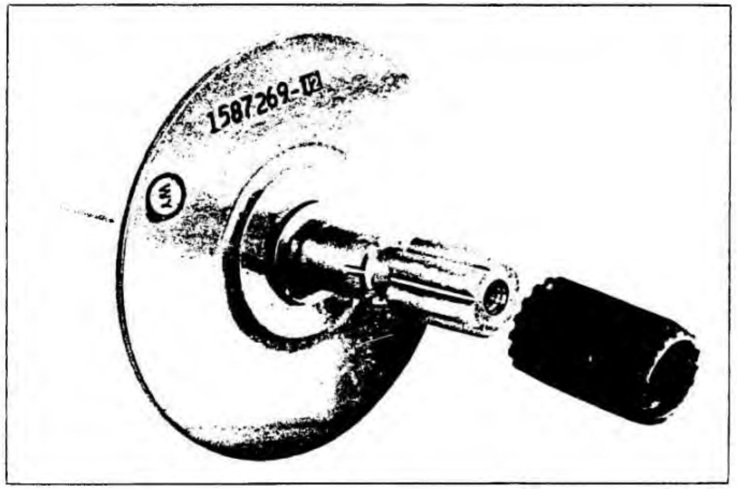
Approved for public release; distribution unlim...

U.S. ARMY MOBILITY EQUIPMENT RESEARCH & DEVELOPMENT COMMAND MERADCOM

U.S. ARMY MOBILITY EQUIPMENT
RESEARCH AND DEVELOPMENT COMMAND
FORT BELVOIR, VIRGINIA

DTIC FILE COPY

Source: Heise, 1983

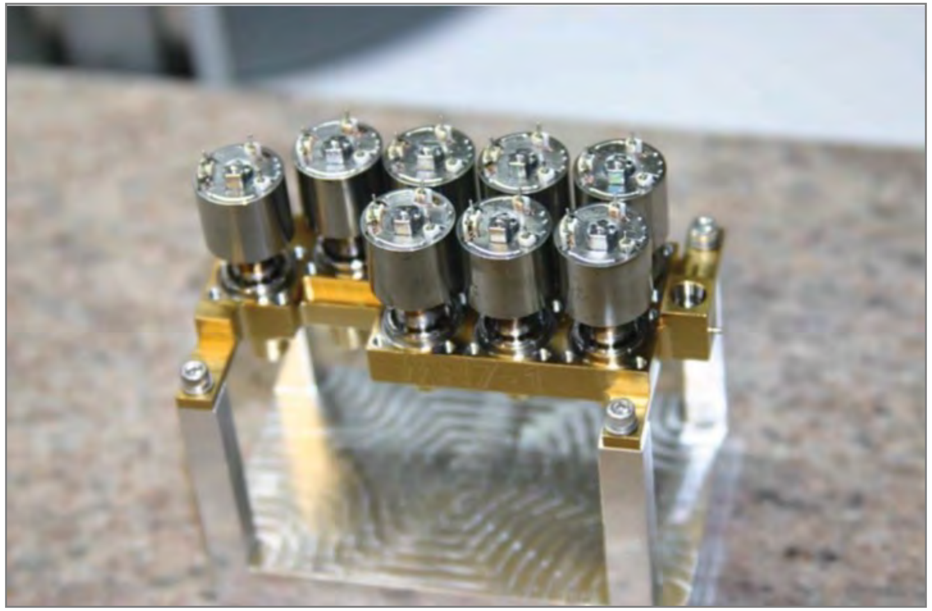


Case Study – Valve on Mars Rover

Design and Development of a Miniaturized Double Latching Solenoid Valve for the Sample Analysis at Mars Instrument Suite

James T. Smith*

Flight Microwaves Welded into a Flight Manifold



Source: Smith, 2008

*NASA/Goddard Space Flight Center, Greenbelt, MD

Proceedings of the 39th Aerospace Mechanisms Symposium, NASA Marshall Space Flight Center, May 7-9, 2008

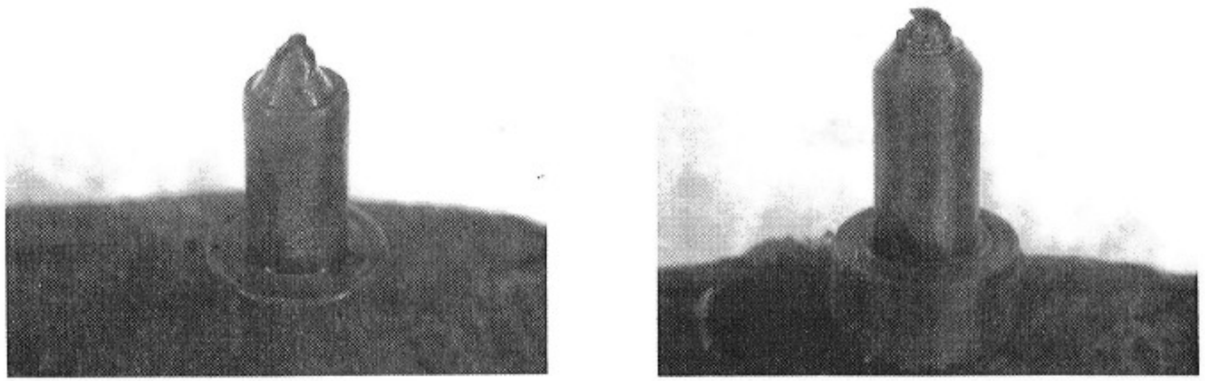
Case Study – Poppet and Seat Materials

NASA Technical Memorandum 81522

DURABILITY TESTS OF SOLENOID VALVES FOR DIGITAL ACTUATORS

A. N. Baez
Lewis Research Center

Figure 8. - Vespel Poppets.



(a) (b)

Six different poppet materials and two seat materials were considered. Each material was tested for over 100 million cycles. Serious damage was found in four kinds of poppet materials tested. Less damage was evident in an aluminum poppet and in a graphite composite poppet. The graphite composite poppet in combination with a Vespel seat was considered the most promising combination for use in digital electronic controls for gas turbine engines.

Source: Baez

Case Study – Spacecraft Valve

The Design, Development and Testing of a Propulsion System for the SNAP-1 Nanosatellite

Fill Valve

In order to meet time and cost constraints the Fill Valve is based on an existing Polyflex design as used on SSTL's UoSAT-12 spacecraft. The valve is constructed from stainless steel and incorporates a spring loaded Vespel seal.

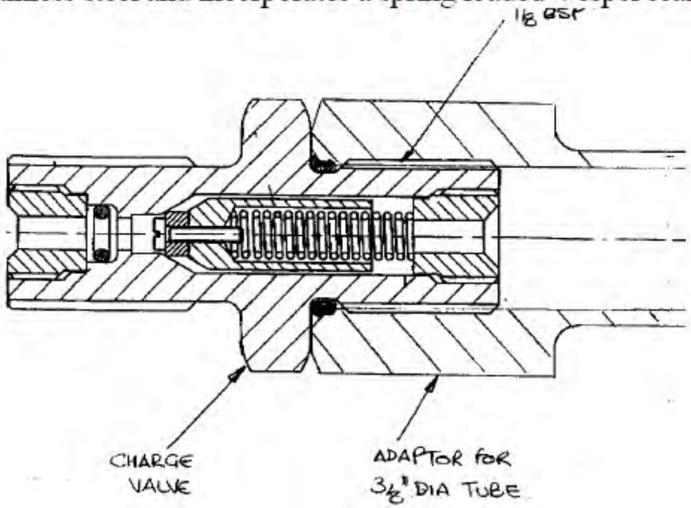


Figure 5 : Section view of the Fill Valve

The valve was subjected to a qualification programme to verify cleanliness and leakage performance in accordance with typical space requirements. The valve successfully met these requirements

Figure 8 : SNAP-1 in flight configuration

Source: Gibbon

Case Study – Locking Fasteners

NASA
Technical
Memorandum

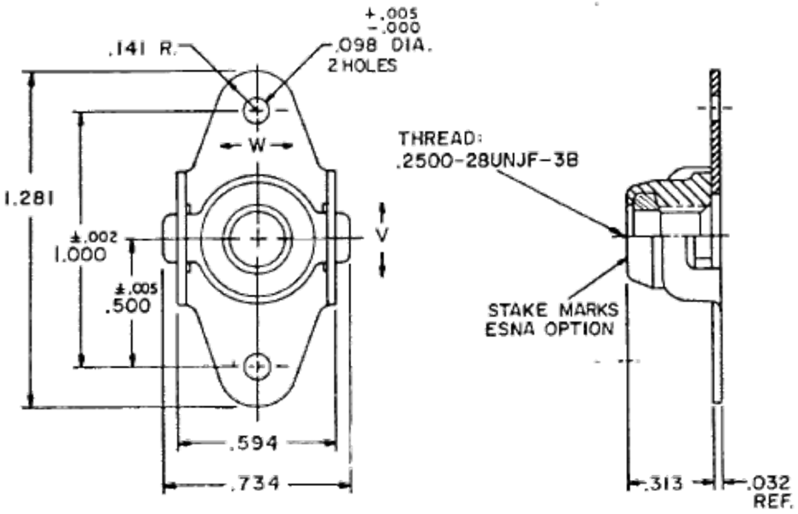
NASA TM - 86456

TESTING AND EVALUATION OF VESPEL UP TO 450°F
WHEN USED IN NUTS AND BOLTS AS A SELF-LOCKING
ELEMENT

By Carl M. Wood

Materials and Processes Laboratory
Science and Engineering

August 1984



MATERIAL: NUT - A286, AMS 5732 OR AMS 5737
BASKET - STAINLESS STEEL, TYPE 321, AMS 5510

FINISH: NUT - DRY FILM LUBRICATED
BASKET - UNPLATED (PASSIVATED)

LOCKING INSERT: DUPONT POLYMER VESPEL SP-1

Conclusions
This test program has demonstrated the acceptability of a fully reusable self-locking fastener system, employing Vespel® (SP-1 polyimide) elements in lieu of crimped nuts, for SRB application. The torque tests performed on fasteners installed with three different configurations of Vespel® self-locking element confirm that Vespel® has properties which can be used in threaded fasteners at temperatures to 450° F.

Source: Wood, 1984

Identification and Certifications

of Authentic DuPont™ Vespel® Polyimide

CERTIFICATE OF CONFORMANCE

From: **E.I. du Pont de Nemours and Company**
Engineering Polymers
DuPont™ Vespel® parts & shapes
350 Bellevue Road
Newark, DE 19713

To:

DuPont™ and Vespel® are trademarks or registered trademarks of E.I. du Pont de Nemours and Company.

Date: **07 Aug 2006**

Customer Order Number:
DuPont Order:
Description:
Delivery Number:

Item Number: 000000

Part Number: **D10967678**
Quantity:

...stome... **164**
...anuf. Date

...omer R...erence:

We ... mate... minim... phys... d che... al prop... es.

SAMPLE

Material Grade	:	**SP-21D**
Resin Lot No.	:	**PDJ2507**
Batch Number	:	**PDJ2429**
Tensile Strength (psi)	:	**8,805**
Elongation (%)	:	**4.70**
Specific Gravity (g/cm³)	:	**1,433**

This is to certify that the product or services listed above are of the quality specified and conform in all respects with the contract requirements, including specifications, drawings, preservation, packaging, marking requirements, physical and chemical properties, and are in the quantity shown on this document.

The required test reports for the items in this shipment and for the materials used in this order are on file and available for examination.

This certificate has been produced electronically and therefore does not require a signature.

Quality Assurance Representative

Qwendolyn B. Webster

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Thank you for your time today! Questions?

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