



# Resurrecting NASA Historical Fabrics (Which Fabrics and Why)

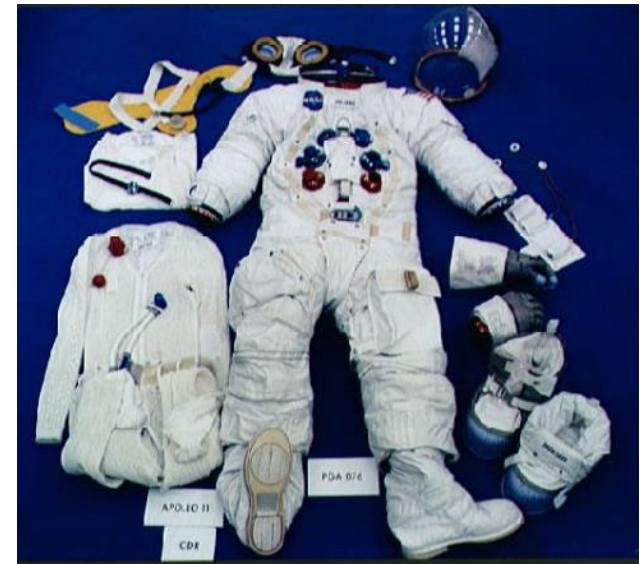
Evelyne Orndoff

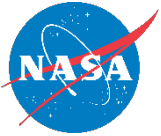
*"Trade names are used in this presentation for identification only. Their usage does not constitute an official endorsement, either expressed or implied, by the National Aeronautics and Space Administration."*

## Apollo Extravehicular (EV) Suit

*(rear entry zipper)*

- Teflon Cloth: Abrasion/flame resistance
- Beta cloth (Teflon-coated silica fiber): Fire protection (non-flammable in oxygen atmosphere)
- Aluminized gridded Kapton: Reflective insulation
- Beta marquisette (Teflon-coated silica fiber, laminated to Kapton): Spacer between reflective surfaces
- Aluminized Mylar: Reflective insulation
- Nonwoven Dacron: Spacer
- Neoprene-coated nylon: Inner liner
- Nylon: Restraint layer for pressurized bladder
- Neoprene-coated nylon: Bladder material serving as an impermeable layer containing suit-pressurization oxygen
- Neoprene convolute: Pressure-retaining flexible joints
- Knit jersey laminate: Abrasion protection
- Lightweight Nomex cloth: Comfort





## Apollo Intravehicular (IV) Suit

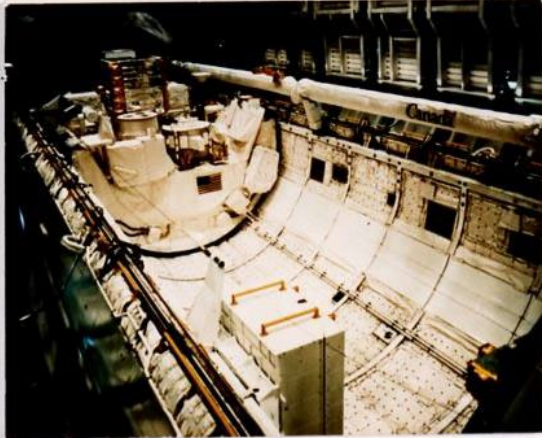
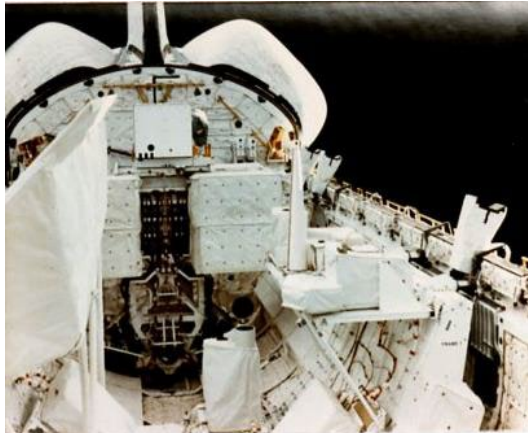
- Teflon-coated Beta cloth: Fire protection (non-flammable in oxygen atmosphere)
- Nomex cloth: Snag/fire protection
- Nylon: Restraint layer for pressurized bladder
- Neoprene-coated nylon: Bladder material serving as an impermeable layer containing suit-pressurization oxygen
- Lightweight Nomex cloth: Comfort



## Apollo Constant Wear Garment (CWG)

- Cotton: Comfort

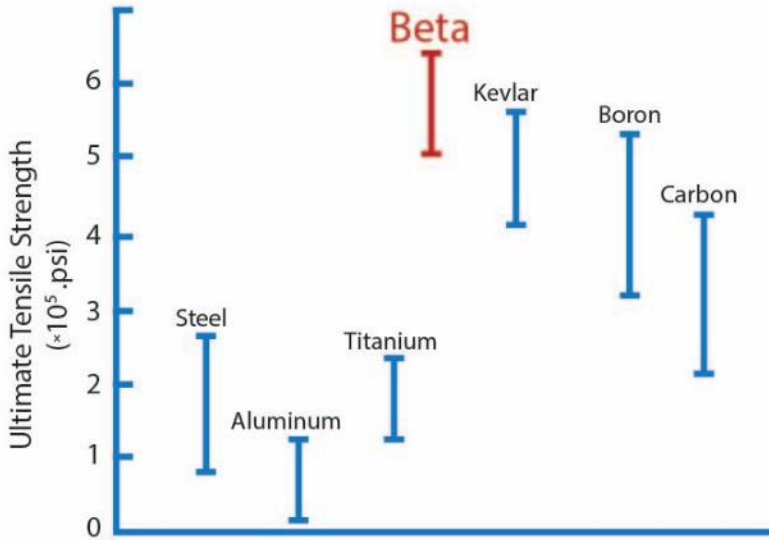




# Beta Silica Fiber

**MATERIAL SAMPLES**

- TEFLON-COATED BETA YARN WOVEN FABRIC
- TEFLON COATED BETA FABRIC
- BETA CORD



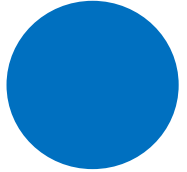
## Beta Silica Fiber

- Nonflammable in oxygen enriched environment
- Melting temperature 1,550°F
- Beta Applications
  - Flame protective layer of Apollo space suit
  - Apollo Space suit thermal insulation spacer
  - Apollo flight suit
  - Apollo Spacecraft window shade
  - Medical Kits
  - Rucksacks
  - Towel bags
  - Space accessories kit
  - Life vest assembly kit
  - PLSS covers
  - Crew provision container
  - Oxygen hose cover
  - Containers for accessories of survival equipment and crew provision items

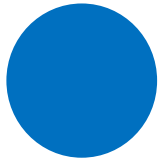
- NASA emblems
- American flags
- Name plates
- ground tape for Astros Velcro fasteners
- Astronaut's couch
- Fire protective barriers
- Heat shields
- Spacecraft insulation
- Skylab shower enclosure
- Shuttle Orbiter payload bay and door liner
- Shuttle Orbiter remote manipulator arm's cover
- IMAX camera cover



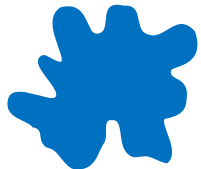
**Beta**  
¼ denier diameter  
3.8 microns



**Nylon**  
1 ½ denier  
14 microns



**Polyester**  
1 ½ denier  
12 microns



**Viscose**  
1 ½ denier  
16 microns



**Cotton**  
1 ½ denier  
16x6 microns



**Silk**  
1.2 denier  
14x8 microns



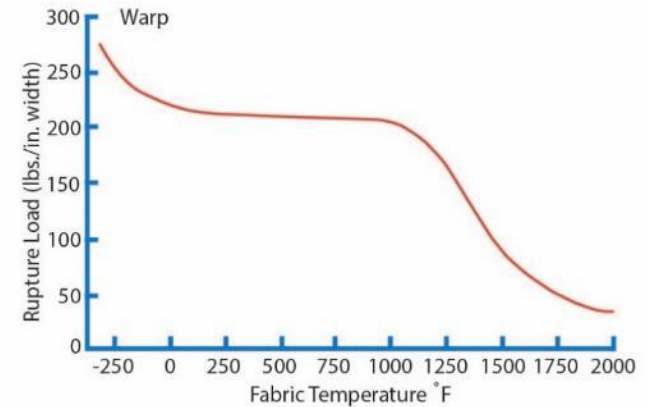
## Chromel R

- High performance metallic fiber
- Applications
  - Gemini space suit trousers (to protect astronaut from the plumes of the astronaut's maneuvering unit)
  - Apollo space suit gloves and boots
  - Apollo space suit abrasion patch

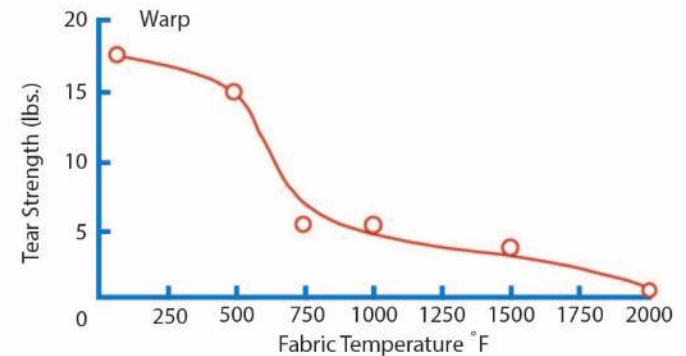
### CHROMEL R



Rupture Load vs. Temperature of Chromel R Fabric



Tear Strength vs. Temperature of Chromel R Fabric



## Chromel R



## Modified Life Raft/Life Vest Materials

- 2/2 center line reversal twill chloroprene coated nylon
- Improvements over existing life raft/life vest material
- Elimination of flotation tube distortion
- 700% higher abrasion resistance
- 200% higher breaking strength
- 50% lower permeability
- 35% lighter weight



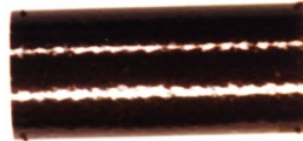
S86-35105



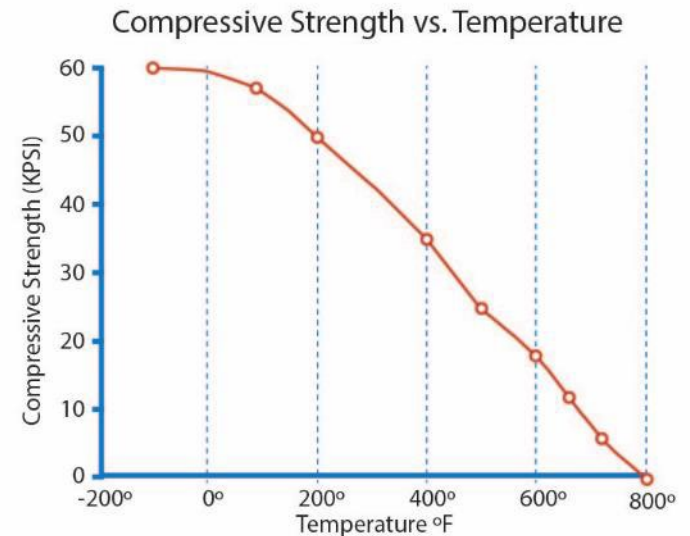
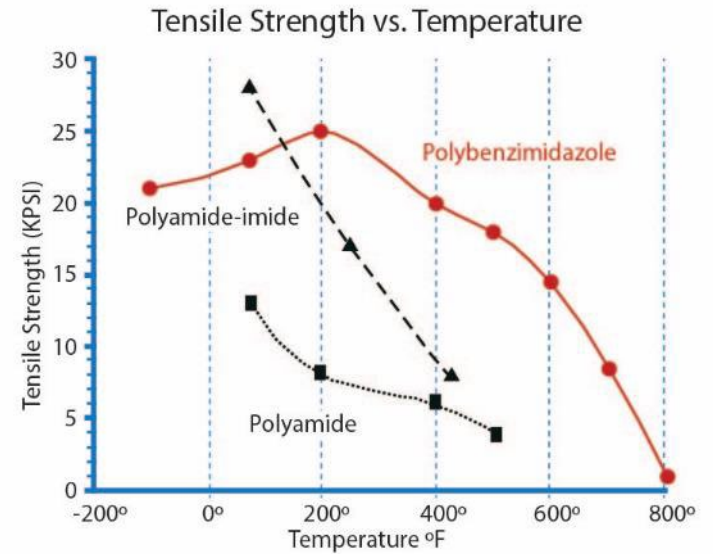
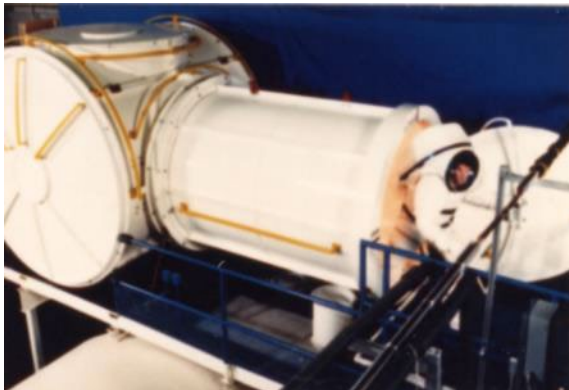


## Polybenzimidazole

- High temperature resistant
- Flame and thermal shock resistant
- Excellent stability to chemicals & hydrolysis
- Low coefficient of friction
- Typical Applications
  - CETA Carriage Housing
  - Airlock Hatch Bumper



S88-48244



## Polybenzimidazole (PBI)

- Stabilized PBI fiber high temperature and abrasion resistant
- Apollo spacecraft seat restraint
- Apollo LM seat restraint
- Apollo lunar rover seat restraint
- Apollo lunar equipment tether
- Apollo telescope mount film
- Retrieval tether (Back-up)
- Apollo inflight knitted shirt
- Skylab inflight underwear
- Skylab inflight stockings
- Skylab sleeping bag
- Skylab sleep monitoring systems
- Skylab m-171 ergometer restraint harness
- Skylab M-133 sleep monitoring cap
- Skylab oxygen Mask assembly
- Skylab feeding system canister assembly
- Skylab dual life vest
- Shuttle stowage partitions (orbiter middeck)
- Peap hose cover
- MMU restraint systems
- Thermal protection systems tie-down
- Sewing thread



BRAIDED CORD



WEBBING



WOVEN FABRIC

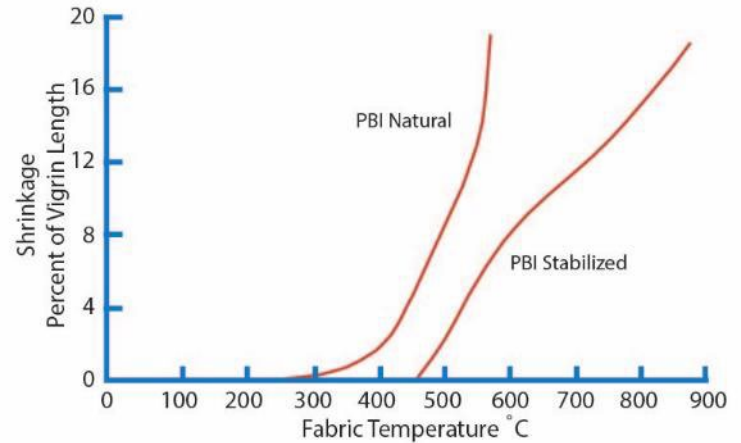


RASCHEL FABRIC

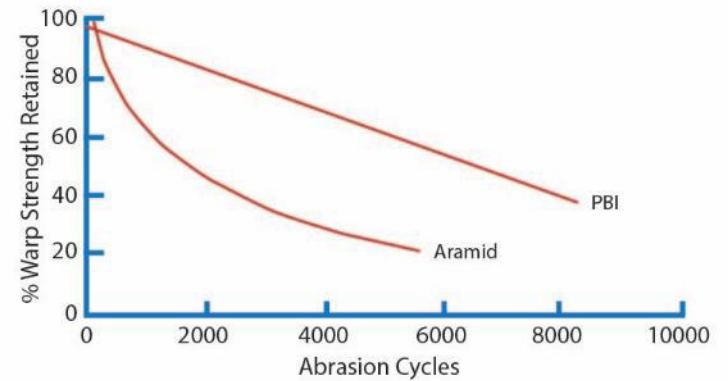


KNITTED FABRIC

### Thermal Dimensional Stability of Natural and Stabilized PBI



### Abrasion Resistance of PBI and Aramid Fabrics - Taber Abrader



## Durette – Modified Aramid

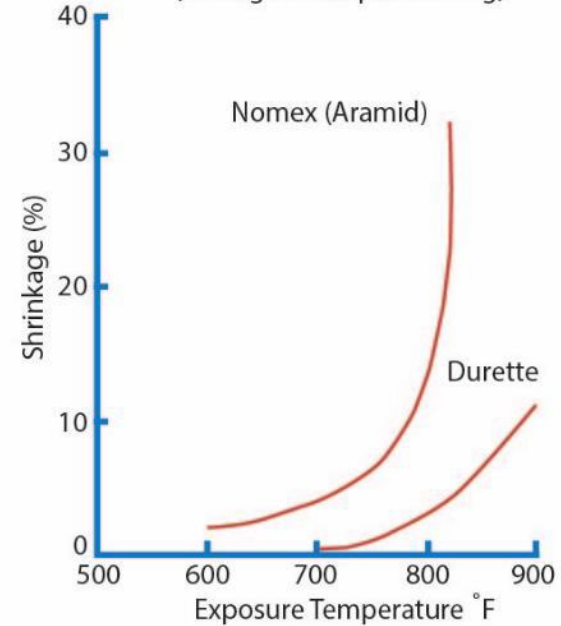
- Dimensionally stable at high temperature
- Applications
  - Skylab flight suits
  - Skylab inflight boots and gloves
  - Apollo-Soyuz inflight suit

### MATERIAL SAMPLES



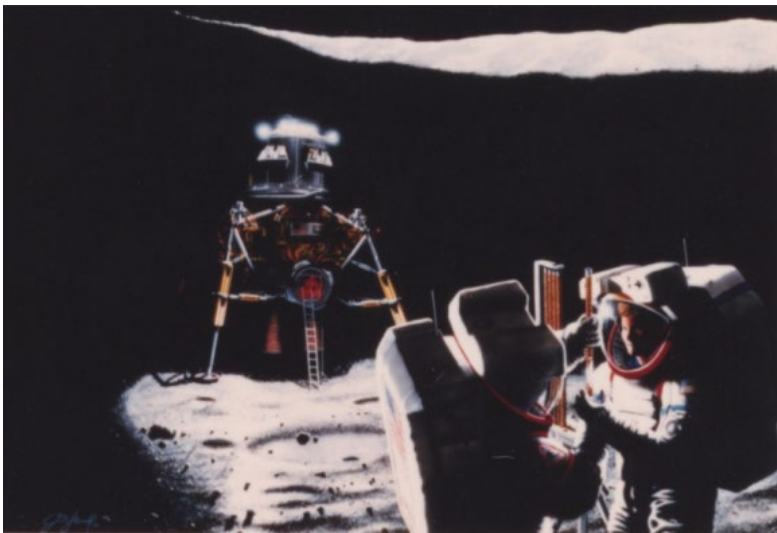
## Shrinkage of Nomex and Durette Fabrics at Elevated Temperatures

(Average of warp and filling)



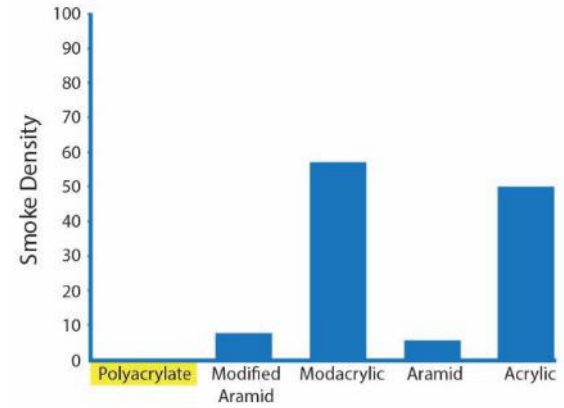
## Polyacrylate

- Excellent thermal stability
- Non-melting, minimum char
- Non-smoke generation
- Flame resistant in oxygen enriched environment

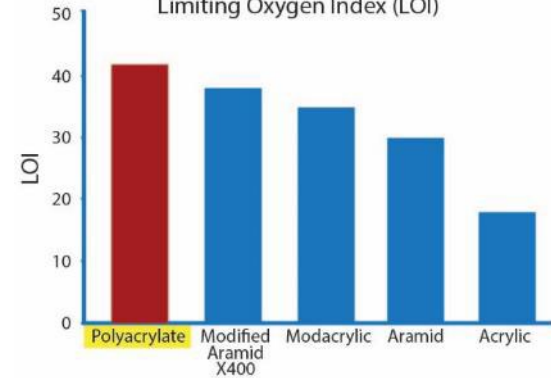


S88-48241

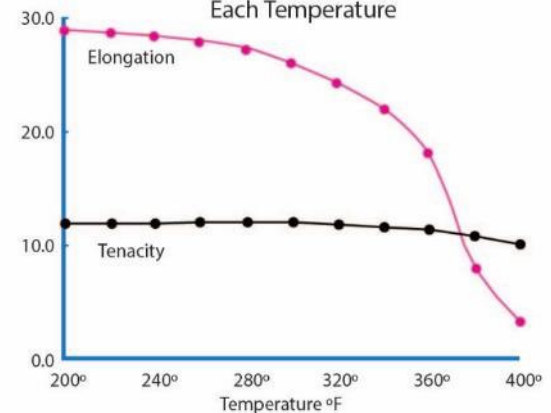
Comparison of Smoke Density



Flammability Comparison of Limiting Oxygen Index (LOI)



24-Hours Exposure at Each Temperature

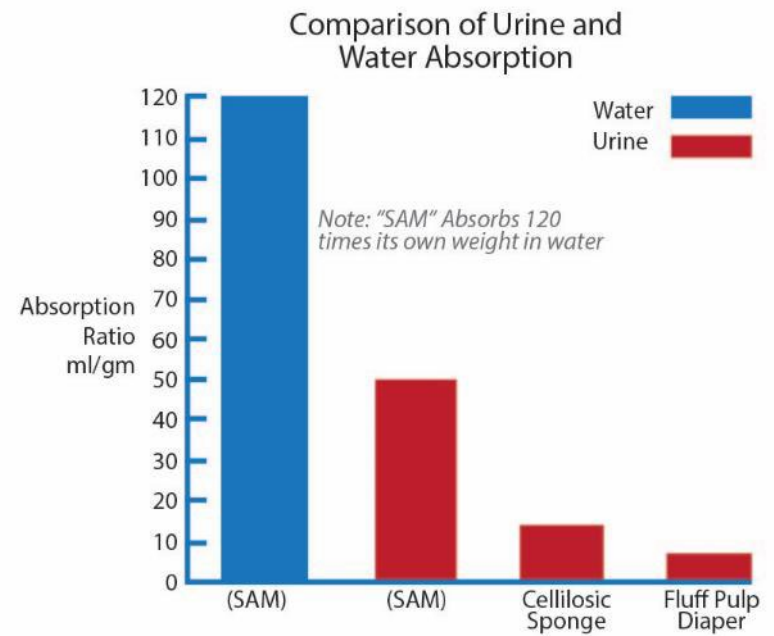


## Super Absorbent Material (SAM)

- Urine collection
- DACT – Disposable, Absorption Containment Trunk



S88-48242





## Fluoroelastomer

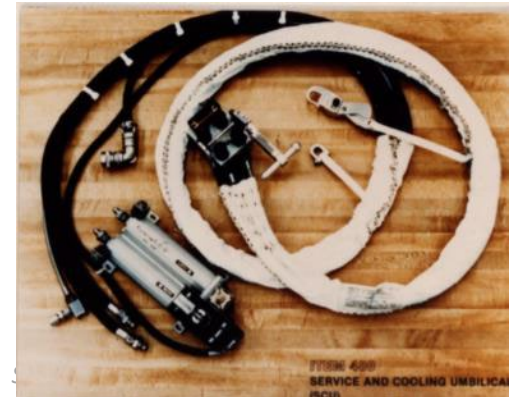
- Hexafluorpropene and vinylidene fluoride high temperature and flame resistant elastomer
- Resistance to temperature extremes 9-75°F - 600°F ) unaffected exposure at 400°F continuously 3,000 hours at 450°F
- Excellent resistance to oxidation and ultraviolet radiation
- Exceptionally good compression set values at high temperatures
- Flame resistant in oxygen enriched environment
- Outstanding resistance to oils, fuels, lubricants and chemicals

## • Applications

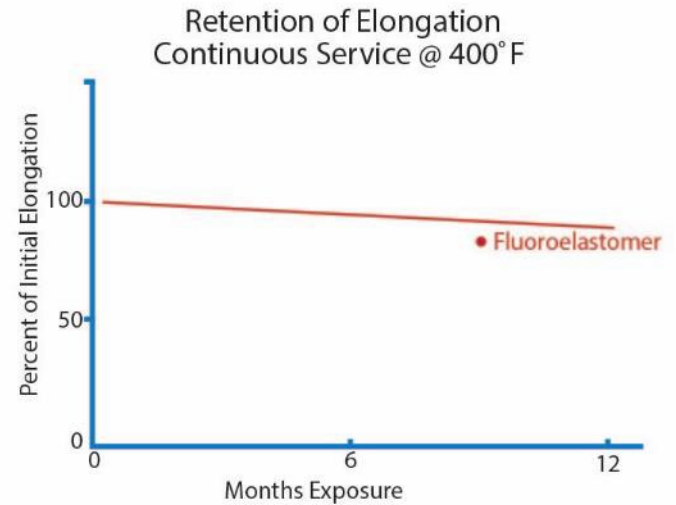
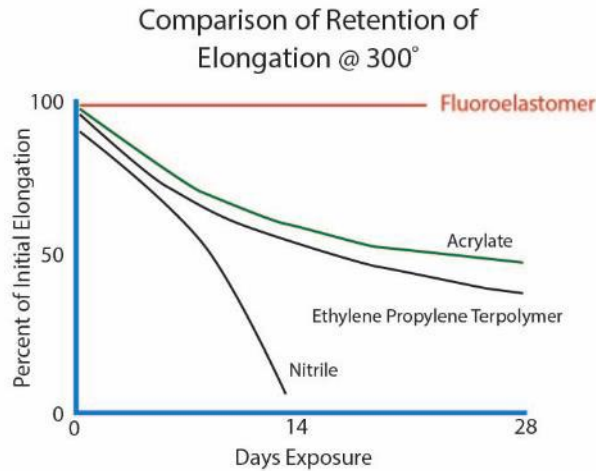
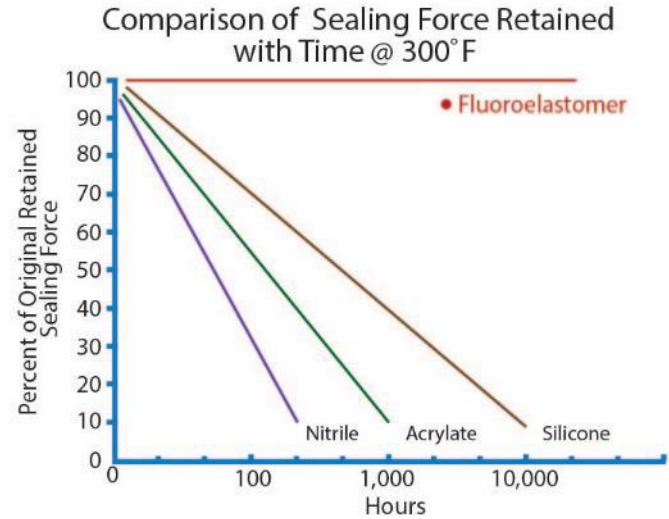
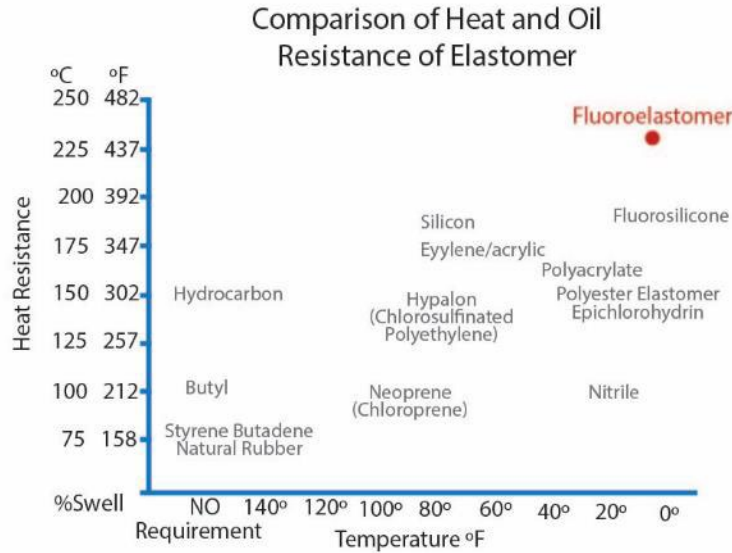
- Abrasion resistant patch
- Boot soles
- Circu9it breaker coating
- Coated harness
- Coated stainless steel fibrous structures
- Edgelock
- Fireproof coating
- Flexible magnets
- Foam – closed cell and open cell
- Gloves and Glove coating
- Headrest
- Helmet liner
- Life vest belt
- Optical glass eye piece
- Oxygen hoses
- Oxygen masks
- Oxygen umbilical hoses
- Shock absorbers
- Spacers
- Urine hoses
- Window shades

## • Development

- Cable coating
- Spray coating
- Dip coating
- Conformal coating
- Fluorescent coating
- Various colored paint
- Adhesives
- Caulking compound
- Molding compound
- Extrusion compound



## Fluoroelastomer

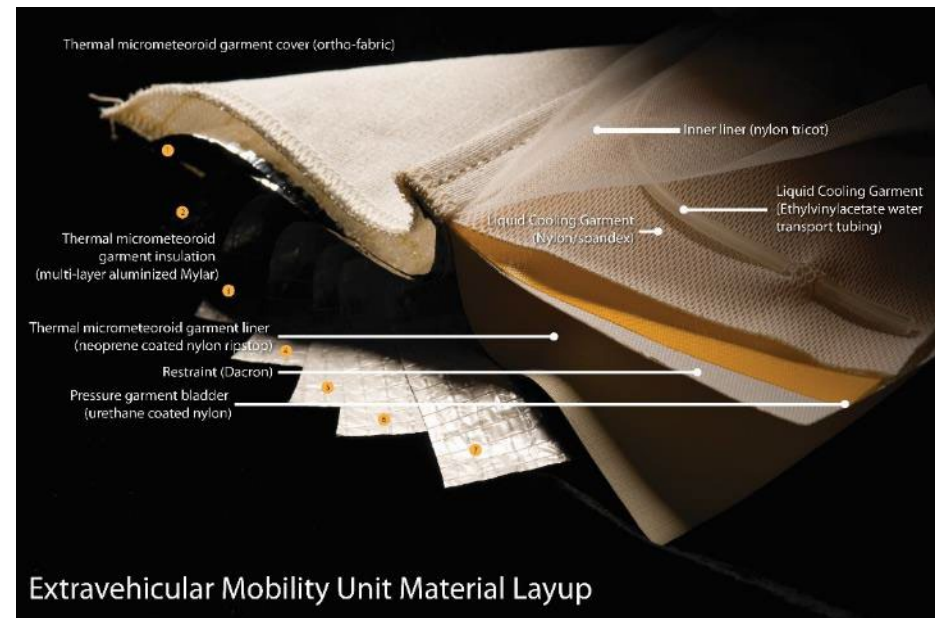




## Shuttle Extravehicular Mobility Unit (EMU) Materials

- Thermal Micrometeoroid Garment (TMG)
  - Ortho-fabric: Gore-Tex (expanded Teflon ) fibers woven together with Nomex and backed with ripstop network of Kevlar: Abrasion/flame resistance
  - Aluminized Mylar backed with unwoven Dacron: Insulation
  - Neoprene-coated nylon ripstop: Liner
- Pressure Garment Assembly (PGA)
  - Dacron Woven with primary and secondary axial lines: Restraint and control of longitudinal growth
  - Polyurethane-coated nylon: Bladder layer for pressurization
- Liquid cooling and Ventilation Garment (LCVG)
  - Nylon spandex raschel knit with woven with ethylene vinyl acetate tubing: tubing support
  - Nylon chiffon: Protection from tubing rubbing on astronaut's comfort base layer

The first nine layers are integrated with the protective, vest-like fiberglass shell to form the hard upper torso assembly (HUT). For the lower torso assembly (LTA), the materials are integrated with the body seal closure, waist bearing, legs, and boots.







## Ortho Double Face Fibrous Structures

- Excellent abrasion and wear resistance
- Flame resistant in oxygen enriched environment
- High temperature and chemical resistant
- Low temperature flexibility
- Physical/thermal radiative properties:
  - Specific gravity, gm/cc front face 2.2/back face 1.4
  - Breaking strength, lbs./in. width 230
  - Ultimate elongation, % 60
  - Emissivity (infrared) 0.77
  - Absorptance (solar) 0.18

Front face



100% Gortex fiber,  
400 Denier, 6  
harnesses split basket  
weave, fancy draw.  
Warp 52 ends X filling  
41 picks

Back face



200 Denier/2-ply filament  
Nomex, 6 harnesses split  
basket weave, fancy draw  
with 2-end repeat of 400  
denier Kevlar yarn after  
every 16 Nomex yarns in  
warp and filling directions.  
Warp 39 ends X filling 32  
picks

Typical Application:  
Extravehicular Mobility Unit outer layer





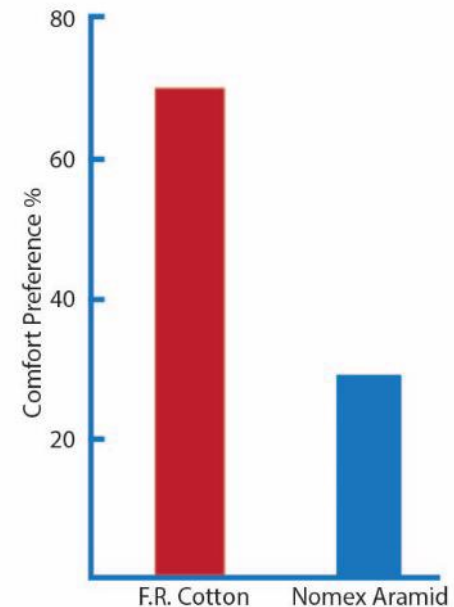
## Cotton

- Flame resistant in 30% oxygen at 10 psia
- Space Shuttle flight suit
- Space Shuttle Training suit
- Space Shuttle Sleeping pad
- Space Shuttle sleeping bag



S86-35108

Comparative Comfort  
Space Shuttle FR Cotton Flight Suit vs.  
Nomex Aramid Flight Suit



MATERIAL SAMPLES





# Cotton



NOMEX  
14.3 PSIA  
25.9% OXYGEN

## FLAME RESISTANCE TEST

COTTON  
10.4 PSIA  
30% OXYGEN

S86-35108



## Astro-Velcro Fastener

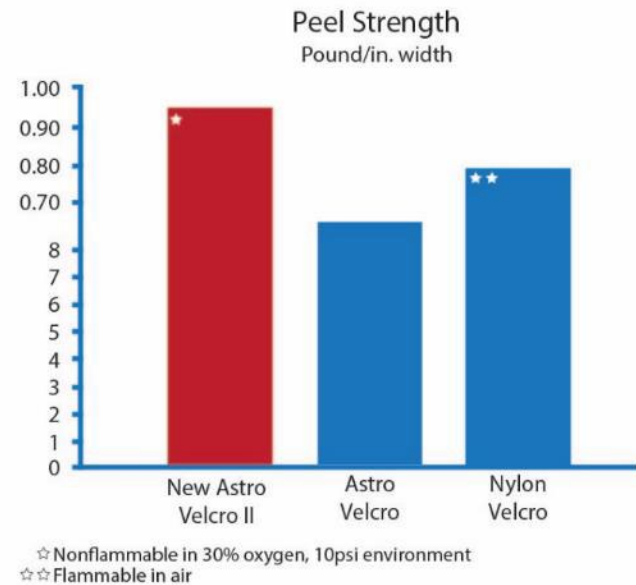
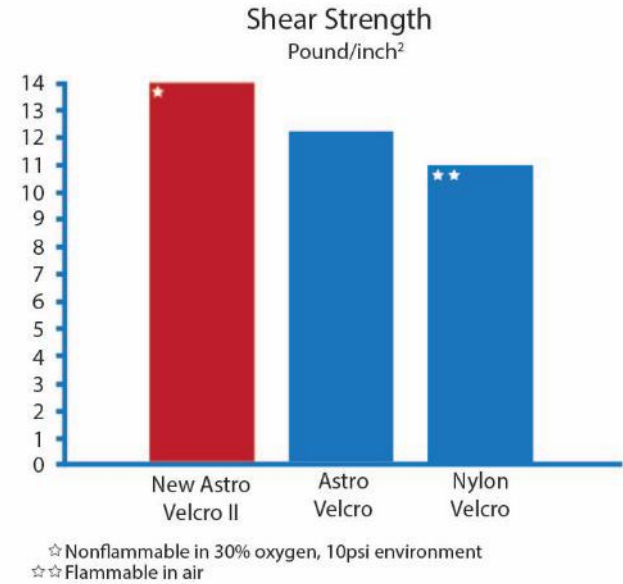
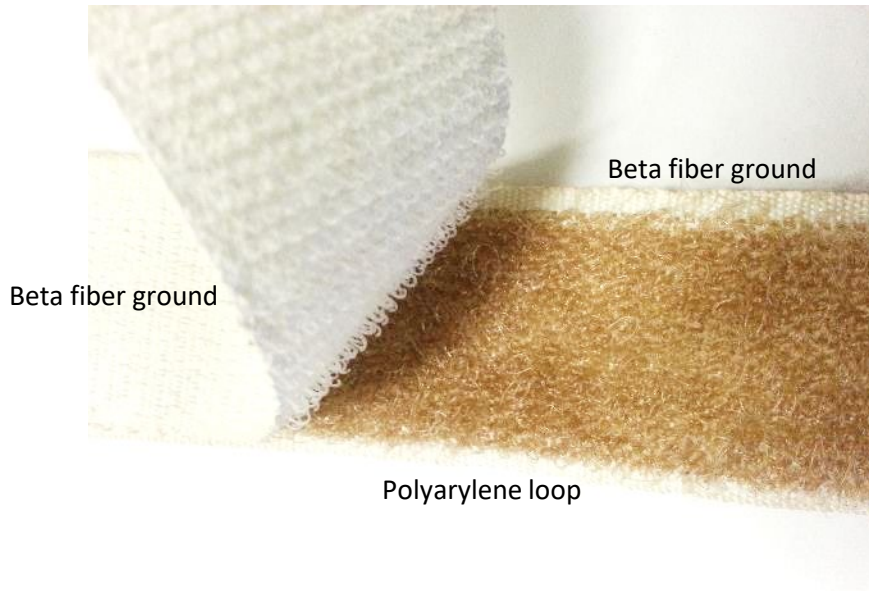
- This closure was designed for manned space flight where the crew cabin environment is oxygen enriched. It was introduced into the Apollo program and has been used in Skylab and all Shuttle flights. It is made of polyester hooks and Teflon loops woven in Beta glass ground tapes.



## Astro Velcro II

- Comparison with Astro Velcro
  - Higher peel and shear strength
  - Resilient hook structure
  - Better endurance cycle life
  - Flame Resistant in oxygen enriched environment

Polyarylene hook



## Hi-Garde Fastener

- Steel wires are woven into Type 304 corrosion resistance steel yarns to form a closure capable of withstanding temperatures up to 800°F for extended duration. This product is often used around rocket engine exhausts to secure protective thermal insulation blankets. It has been used on the Shuttles for such purposes.



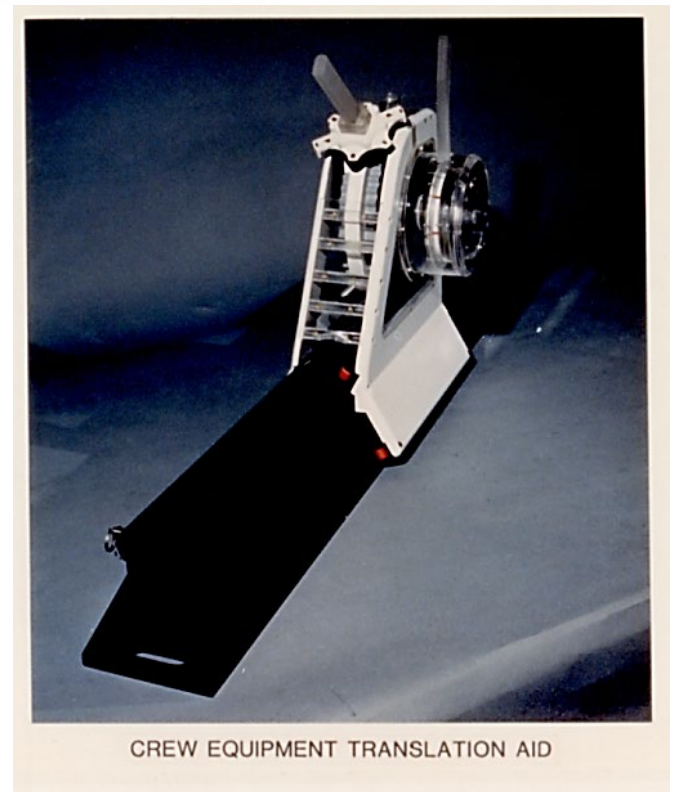
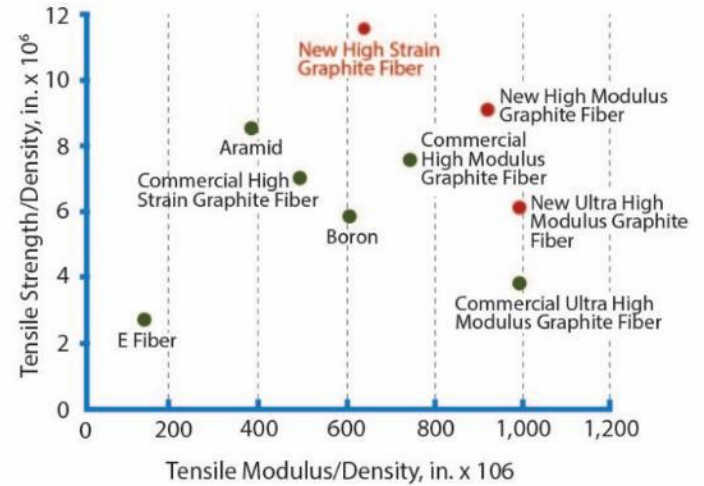
## High-Strain Graphite Composite

- Outstanding combined tensile strength and modulus values
- Withstand severe thermal and mechanical stress
- Dimensional stability under temperature extremes



S88-48237

### Comparison of Specific Properties With Other Reinforcement Materials



CREW EQUIPMENT TRANSLATION AID

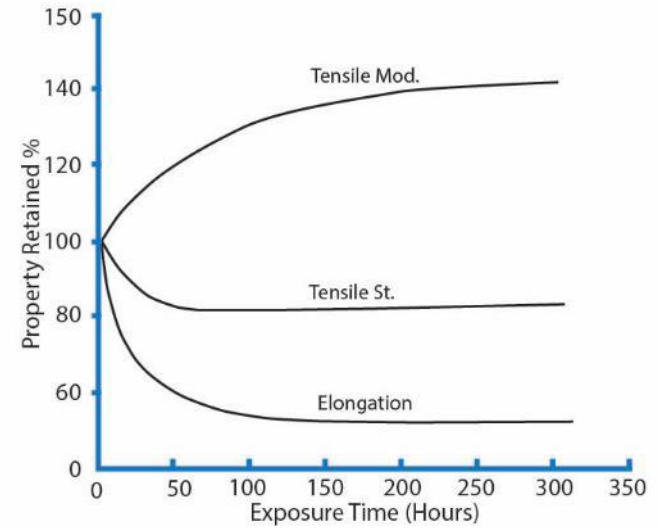
## Polyimide

- Ultraviolet radiation stable fiber
- Shuttle orbiter thermal protection system tie-down cord

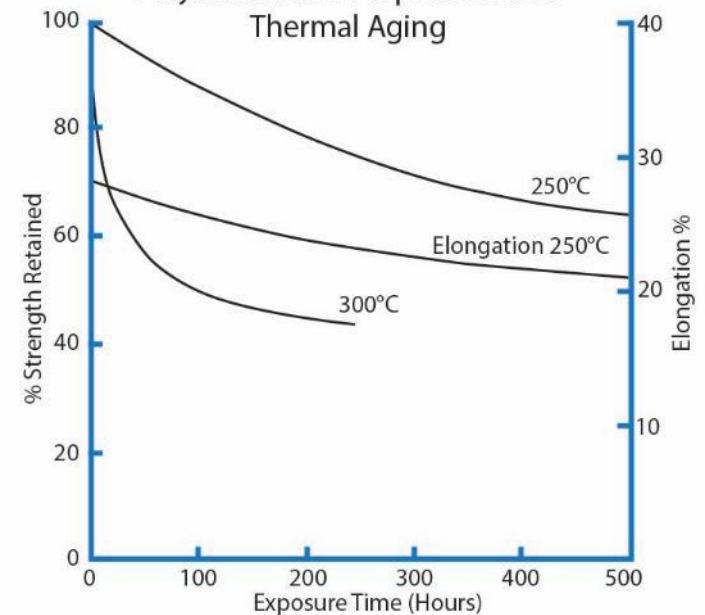


S86-35103

### U.V. Stability of Polyimide Fiber

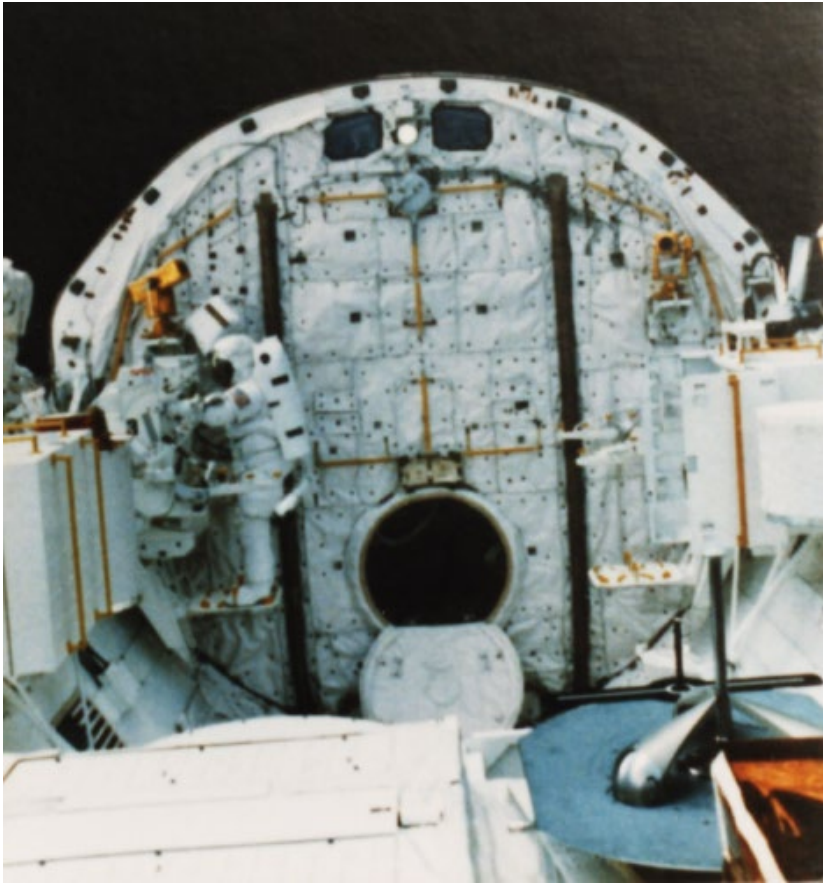


### Polyimide Fiber Properties After Thermal Aging

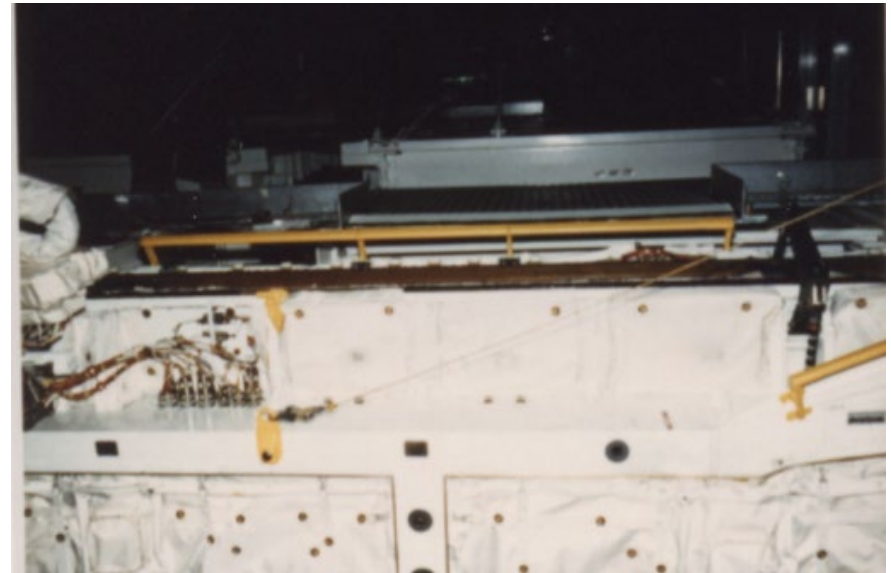
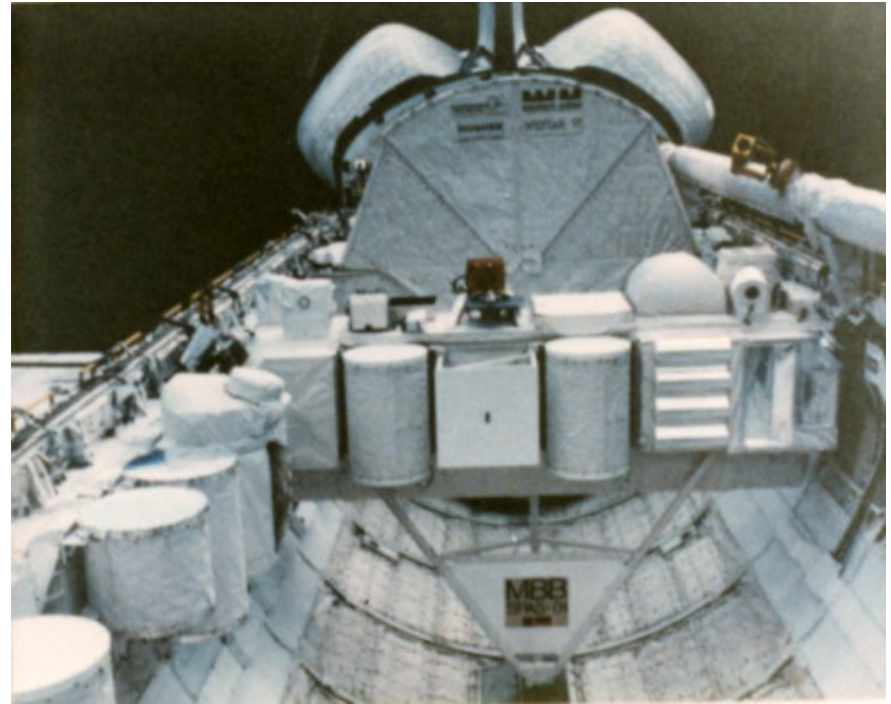




## Polyimide

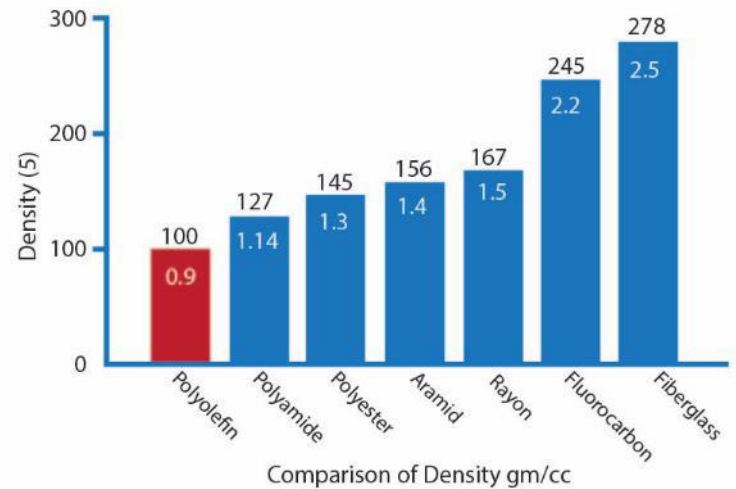
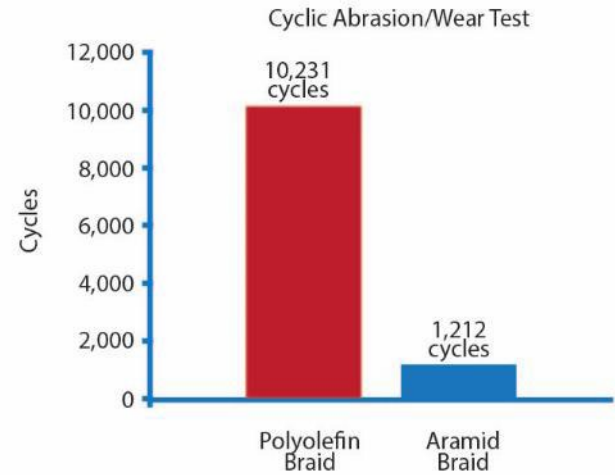
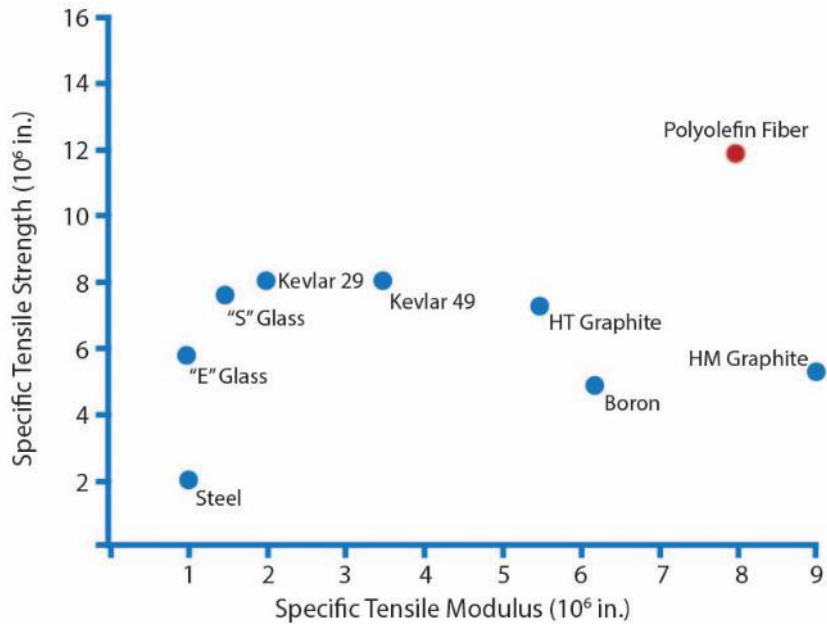


S86-35103



## Polyolefin Fibrous Structures

- Ultra high tensile strength
- High abrasion resistance
- High specific tensile modulus
- Lightest weight



## Polyolefin Fibrous Structures



S88-48247

