Ticona
Performance Driven Solutions™

Fortron® PPS
for Thermoplastic Composites

November 2012

Celanese
Ticona – A Business of Celanese

Contents

- Introduction to Ticona
- Fortron® PPS
  - Chemistry
  - Properties
  - Applications
- Fortron® PPS Composites
  - Background
  - Processing Options
  - Properties
  - Applications
- Summary

Broad Portfolio of Engineering and High-Performance Polymers

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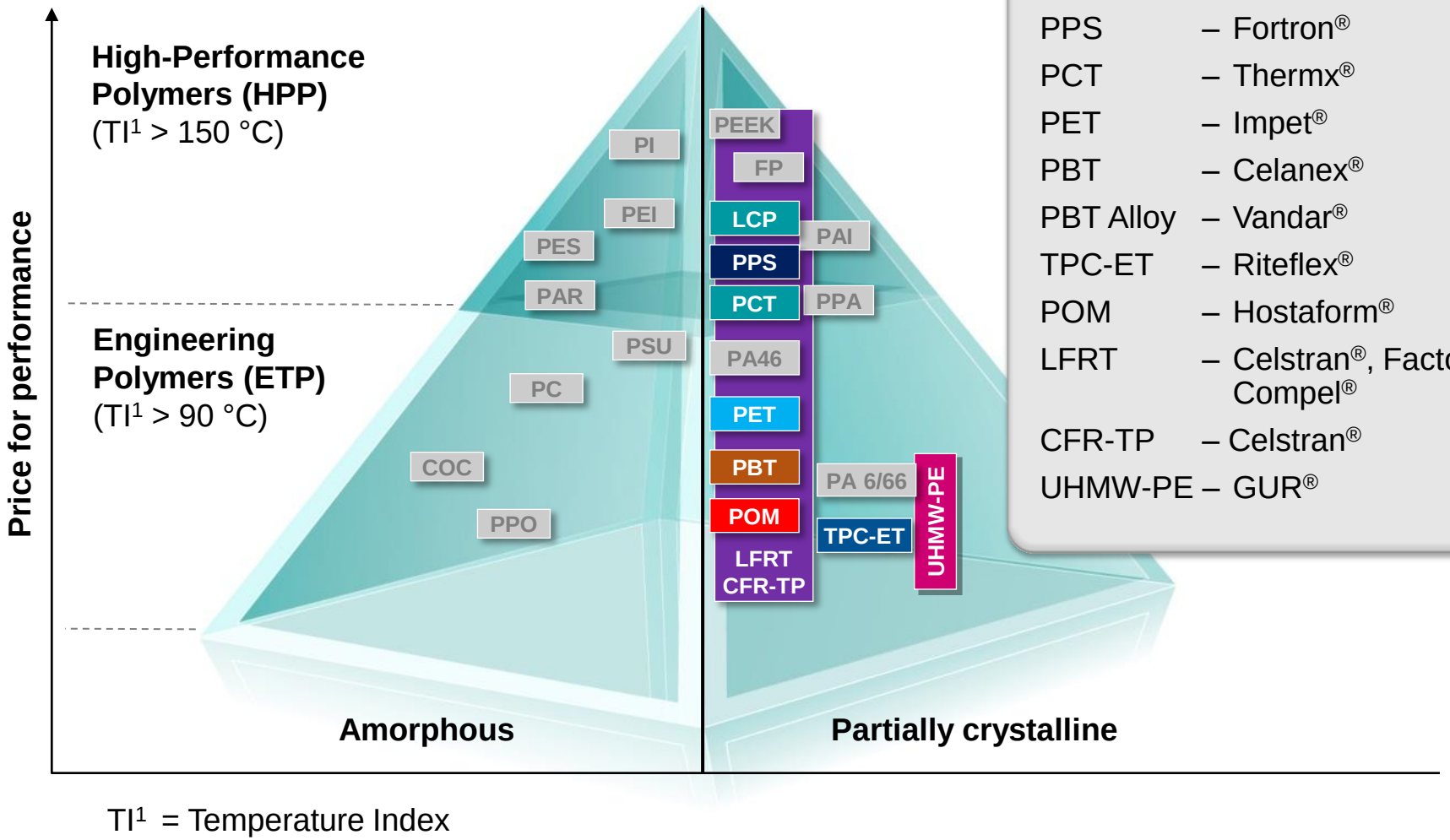

Ticona Engineering Polymers

LCP	– Vectra® /Zenite®
PPS	– Fortron®
PCT	– Thermx®
PET	– Impet®
PBT	– Celanex®
PBT Alloy	– Vandar®
TPC-ET	– Riteflex®
POM	– Hostaform®
LFRT	– Celstran®, Factor ® Compel®
CFR-TP	– Celstran®
UHMW-PE	– GUR®

TI[1] = Temperature Index

Fortron® PPS
Summary – Structure and Properties

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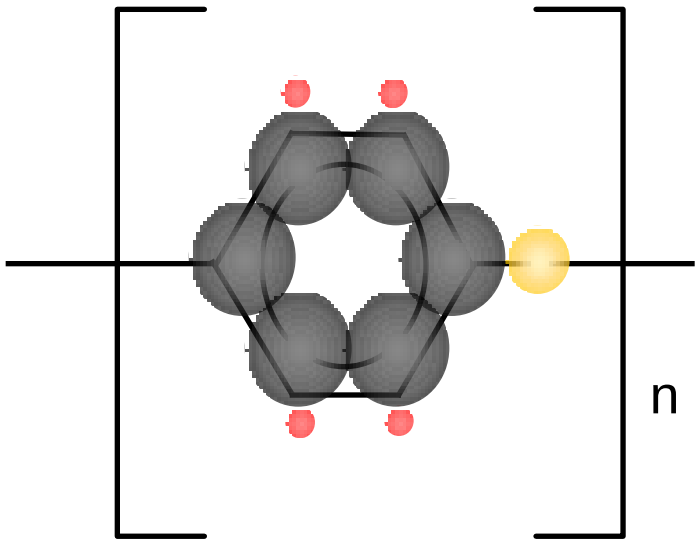

Polyphenylenesulfide (PPS)

Poly(thio – 1,4 - phenylene)

- **Semicrystalline**
  - T_g 85°C, T_M 285°C
  - Density 1.35 g/cm^3
- **Inherently Flame Retardant:**
  - UL94-V0, LOI > 45
- **Chemical Resistance – Dimensional Stability**
  - Fuels, oils, solvents
  - Water-glycol
- **Easy to Process**
  - Injection molding
  - Extrusion

Fortron® PPS

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Semi-crystalline thermoplastic polymer, perfectly suited for parts that have to withstand the high mechanical and thermal requirements which require…

- A high melting point range between 280° and 290°C
- Inherently flame resistant
- Excellent resistance to chemicals, oils and fluids
- An ideal alternative to conventional materials such as thermosetting polymers and metals
- High hardness and stiffness and superb long-term creep under load properties
- Ease to injection mold, blow mold and machine
- Weight reduction combined with high dimensional stability

Fortron® PPS Has No Known Solvent Below 200°C

- Chemical resistance with minimal attack or swelling even at elevated temperatures
  - Resists: acids/bases pH 2 to 12
  - Resists: strong bleaches
  - Resists: auto fluids – coolants, transmission & brake
  - Resists: gas & alternate fuels (methanol, ethanol)
  - Resists: hydrolysis

Fortron® PPS 0214C1 – Matrix Material for Composites

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- Linear, unmodified PPS polymer
- High molecular weight / high viscosity: 140 pa·s
  - For extrusion and injection molding applications
- Specified for aircraft applications
  - In use at Airbus and Boeing
  - VIAM qualification
  - Federal state unitary enterprise “All Russian Scientific Research Institute of Aviation Materials”
- Tested in regards to flammability, smoke density and smoke toxicity:
  - ABD0031
  - FAR/JAR 25.853
  - New: DIN 5510 and ISO 5659

Fortron® PPS 0214C1 – Smoke Density Tested with 2 mm Plaques

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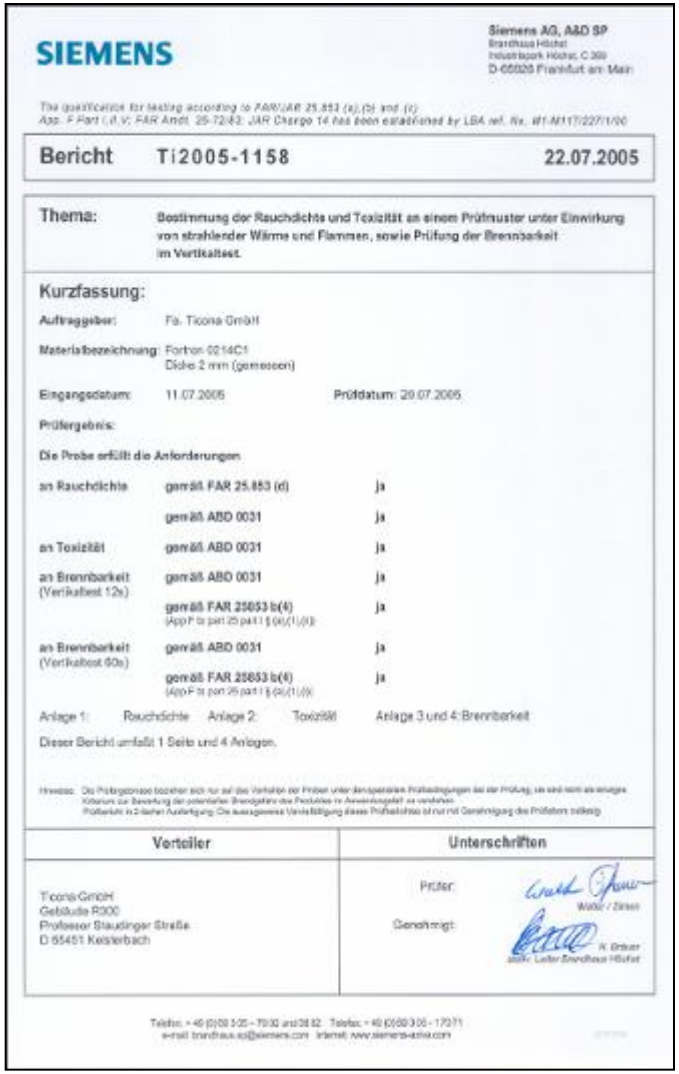
- Smoke density according to Airbus Standard ABD0031
  - Non-flaming – Max. Value: 0, Average: 0
    - DS max. @ 4 min: 0; ABD and FAR Passed
  - Flaming – Max. Value: 32 (6 min.), Average: 23 (6 min)
    - DS max. @ 4 min: 15; ABD and FAR Passed

- Tox-Test (ABD0031):

ABD / FAR passed	Value	Max. Value in ppm
– Hydrogen Cyanide HCN:	NF: 0 – F: 0	150
– Carbon Monoxide CO:	NF: 0 – F: 10	1000
– Nitrous Gases NO-NO_2:	NF: 0 – F: 0	100
– Sulfur Dioxide/ Hy. Sulfide SO_2 - H_2S:	NF: 0 – F: 10	100
– Hydrofluoric Acid HF:	NF: 0 – F: 0	100
– Hydrochloric Acid HCl:	NF: 0 – F: 0	150

Fortron® PPS 0214C1 – Flammability Tested With 2 mm Plaque

- Vertical Burning Test 12 s ABD0031
  - Total burn time: 12 s
  - Flame extinguish time: 0 s
  - No. of particles: 0
  - Ignited particles: 0
  - Total burn length: 5 mm
- Vertical Burning Test 60 s ABD0031
  - Total burn time: 60 s
  - Flame extinguish time: 0.6 s
  - No. of particles: 2.4
  - Ignited particles: 1.4
  - Total burn length: 44 mm



SIEMENS

Siemens AG, A&D SP
Brandhaus Höchst
Industriepark Höchst, C 369
D-65926 Frankfurt am Main

The qualification for testing according to FAR/JAR 25.853 (a),(b) and (c) App. F Part I,II,V; FAR Amdt. 25-72/83; JAR Change 14 has been established by LBA ref. No. 81 A117/227/1/00

Bericht Ti2005-1158 22.07.2005

Thema: Bestimmung der Rauchdichte und Toxizität an einem Prüfmuster unter Einwirkung von strahlender Wärme und Flammen, sowie Prüfung der Brennbarkeit im Vertikaltest.

Kurzfassung:

Auftraggeber: Fa. Ticona GmbH

Materialbezeichnung: Fortron 0214C1
Dicke 2 mm (gemessen)

Eingangsdatum: 11.07.2005 Prüfdatum: 20.07.2005

Prüfergebnis:

Die Probe erfüllt die Anforderungen

an Rauchdichte	gemäß FAR 25.853 (d)	ja
	gemäß ABD 0031	ja
an Toxizität	gemäß ABD 0031	ja
an Brennbarkeit (Vertikaltest 12s)	gemäß ABD 0031	ja
	gemäß FAR 25853 b(4) (App F to part 25 part I § (a)(1)(ii))	ja
an Brennbarkeit (Vertikaltest 60s)	gemäß ABD 0031	ja
	gemäß FAR 25853 b(4) (App F to part 25 part I § (a)(1)(ii))	ja

Anlage 1: Rauchdichte Anlage 2: Toxizität Anlage 3 und 4: Brennbarkeit

Dieser Bericht umfaßt 1 Seite und 4 Anlagen.

Hinweis: Die Prüfergebnisse beziehen sich nur auf das Verhalten der Prüfkörper unter den speziellen Prüfbedingungen bei der Prüfung, sie sind nicht als einziges Kriterium zur Bewertung der potentiellen Brandgefahr des Produktes im Anwendungsfall zu verstehen. Prüfbericht in Auszügen nur mit Genehmigung des Prüflabors zulässig.

Verteiler	Unterschriften
Ticona GmbH Gebäude R300 Professor Staudinger Straße D 65451 Kelsterbach	Prüfer: Walter / Zinser Genehmigt: R. Erbacher stellv. Leiter Brandhaus Höchst

Telefon: +49 (0)69 305-7930 und 3832 Telefax: +49 (0)69 305-17371
e-mail: brandhaus.sp@siemens.com Internet: www.siemens-adw.com

Internal UL Flammability Testing

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Material	Part Thickness	Unaged Sample Rating	Aged Sample Rating
Unfilled Fortron PPS Control	3.0mm (0.12”) 1/32” 1/64”	V-0* V-0 V-2	V-0* V-2 V-2
Unfilled PEEK Control	3.0mm (0.12”) 1.5mm (0.059”) 1/32” 1/64”	V-0* V-0* No V-Rating No V-Rating	V-0* V-0* V-2 No V-Rating

- Thin PEEK samples failed to achieve a V-Rating because of long burn times and cotton ignition
- Thin PPS parts have V-0 equivalent burn times but molten polymer drips can ignite the cotton = V-2 Rating

*Data as reported by Underwriters Laboratory

Fortron® PPS Dimensional Stability

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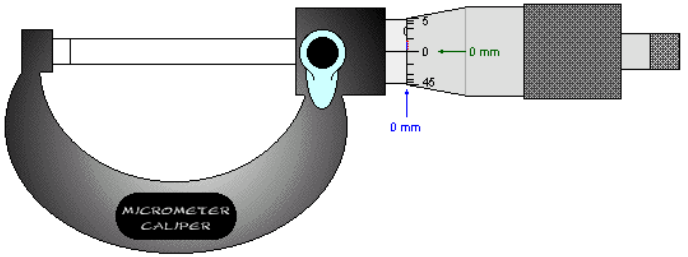
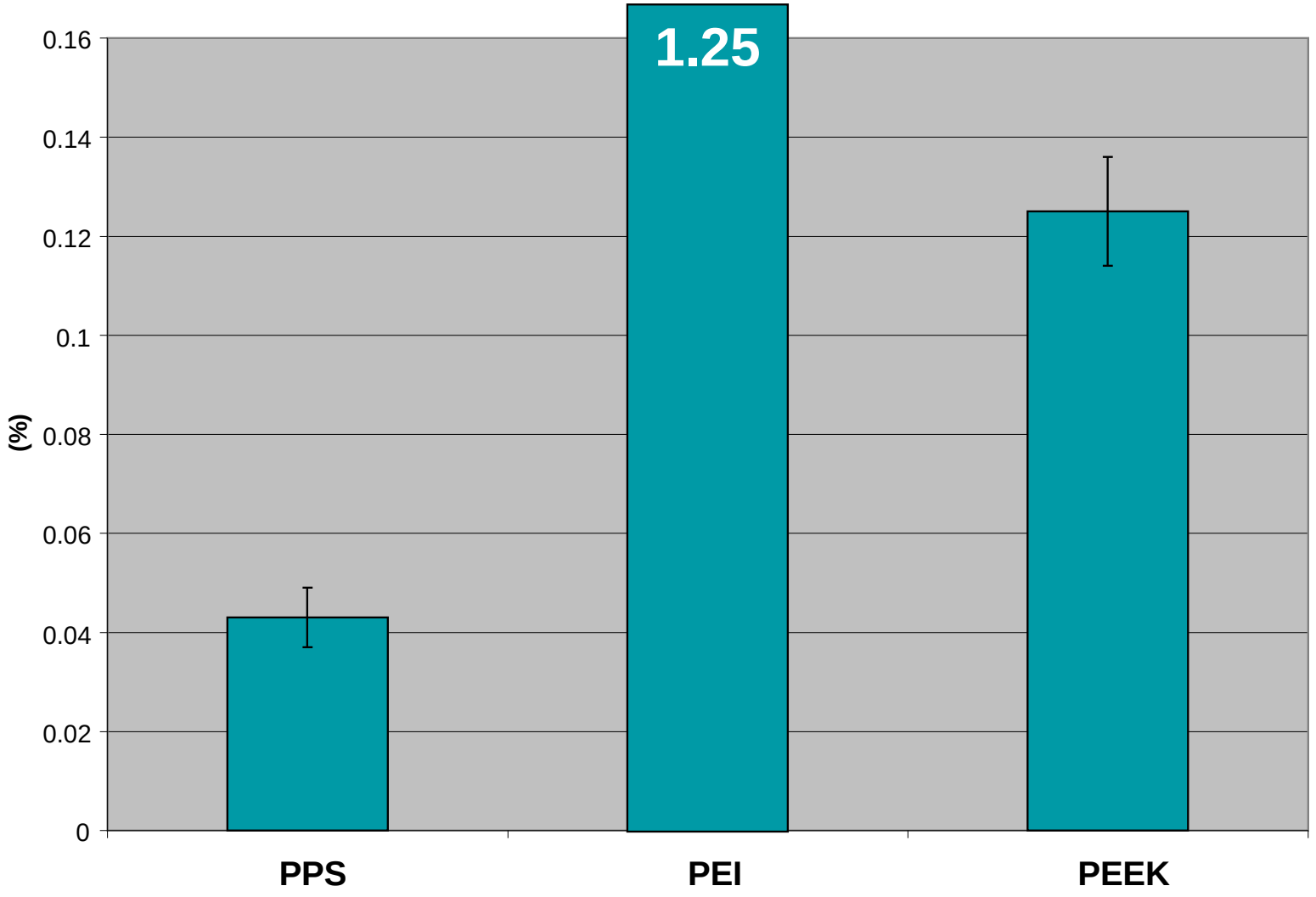
- Extremely low moisture absorption – 0.02%
- Minimal effect of temperature
- CLTE – 19 x 10^{-6} /°C (6165A4)
- Precision molding
- Low shrinkage - 0.3% (6165A4)
- Creep resistance



For Precision Parts Even at Elevated Temperatures

Low PPS Water Absorption Results in Dimensional Stability



Top Fortron® PPS Segments

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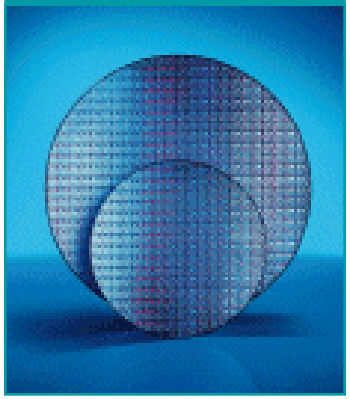
Semicon



Industrial

EE & Sensors

Fibers

Automotive

Composites

Fortron® PPS
Extrusion: Film, Fiber, Netting, etc.

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Aircraft Composite

High Tenacity Monofilament

Filter Netting

Stock Shapes

CPI Filter

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for Thermoplastic Composites

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Why Thermoplastic PPS Composites vs. Thermoset Composites?

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Improved Properties

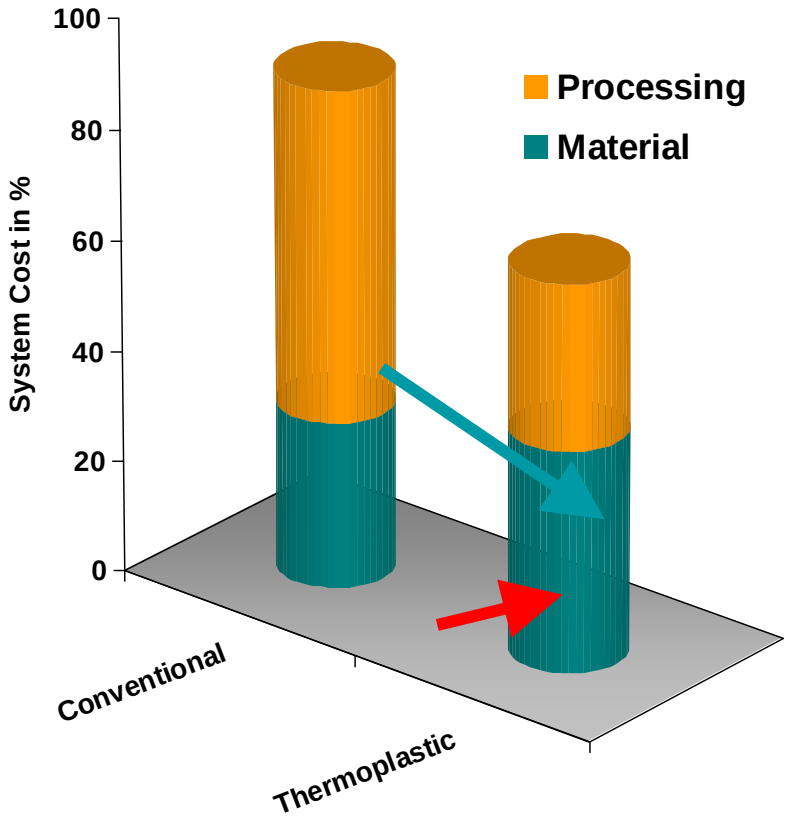
- Tougher, good fatigue performance
  - 4x tougher than toughened epoxies
- Damage tolerant
- Insensitive to moisture
- High-temperature performance
- Very low flammability, smoke, toxicity
- Low residual stress in molded parts
- Excellent chemical resistance

Improved Processing

- Eliminate bagging materials and labor
  - May also eliminate kitting and debulking steps and equipment
- Eliminate autoclave possible
  - Cost, space and bottleneck issues
- Rapid processing vs. thermosets
- Can be reformed
- Simple, longer lasting tool
- Fusion bonding eliminates fasteners and adhesives
  - Reduces cost and weight

- Green processing
  - Recyclable
  - No VOCs in processing
  - Less process scrap
  - Fewer process energy requirements

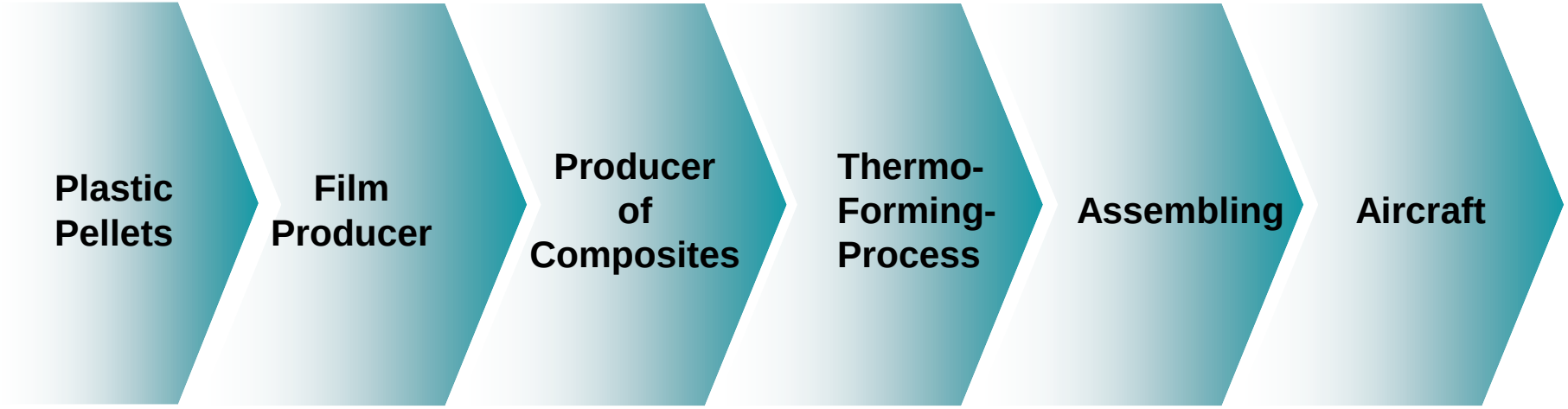
Thermoplastic Composite Matrix Cost Advantage



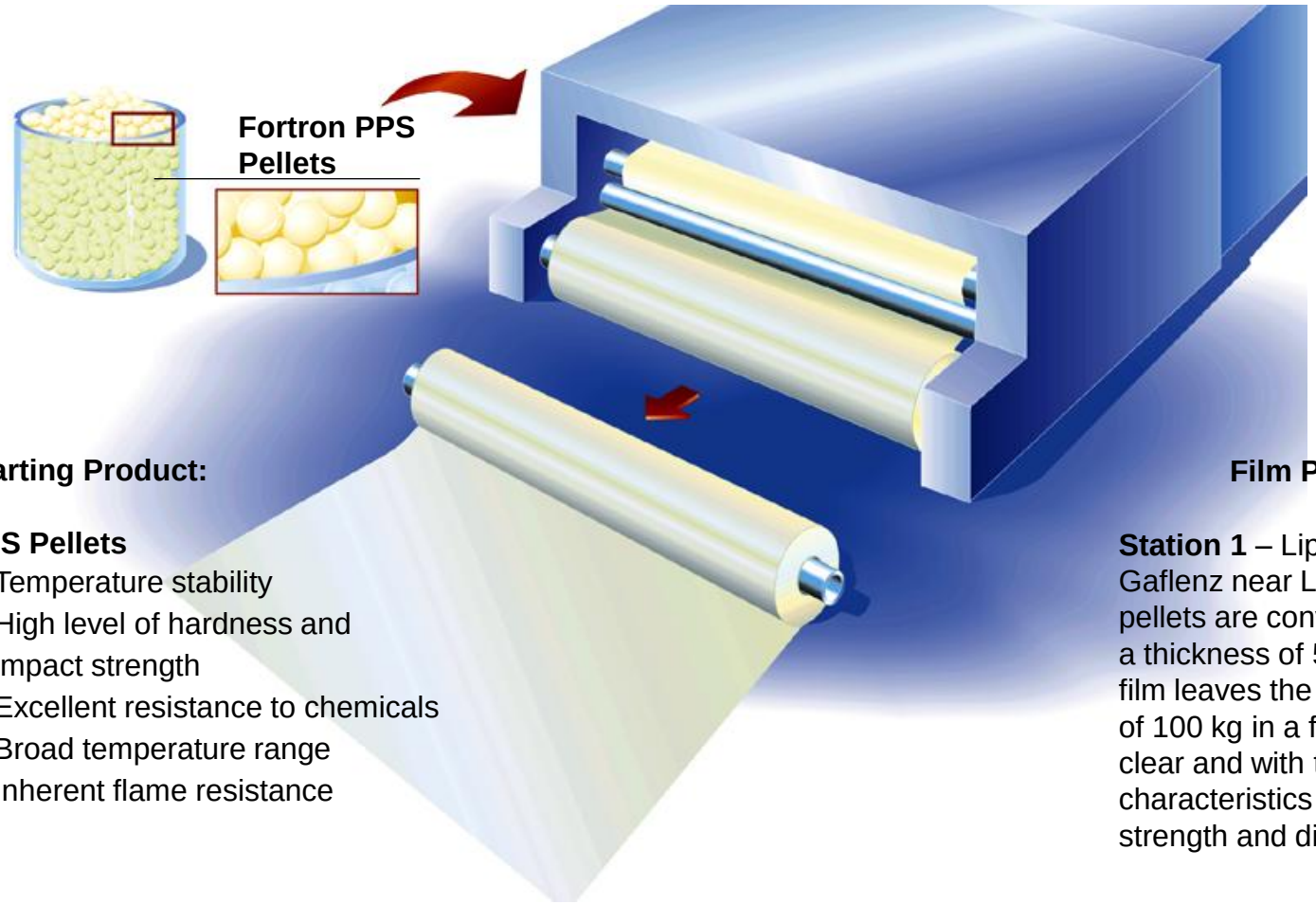
- The material cost for a thermoplastic matrix might be equal or even higher
- Lower cost for handling, processing, and assembly can lead to a substantial advantage in total cost

Even the High Cost Thermoplastic Polymers Offer Improved Cost Savings vs. Epoxy Based Composites

Example for Value Chain in Aircraft Industries



Station 1: Film Production



Starting Product:

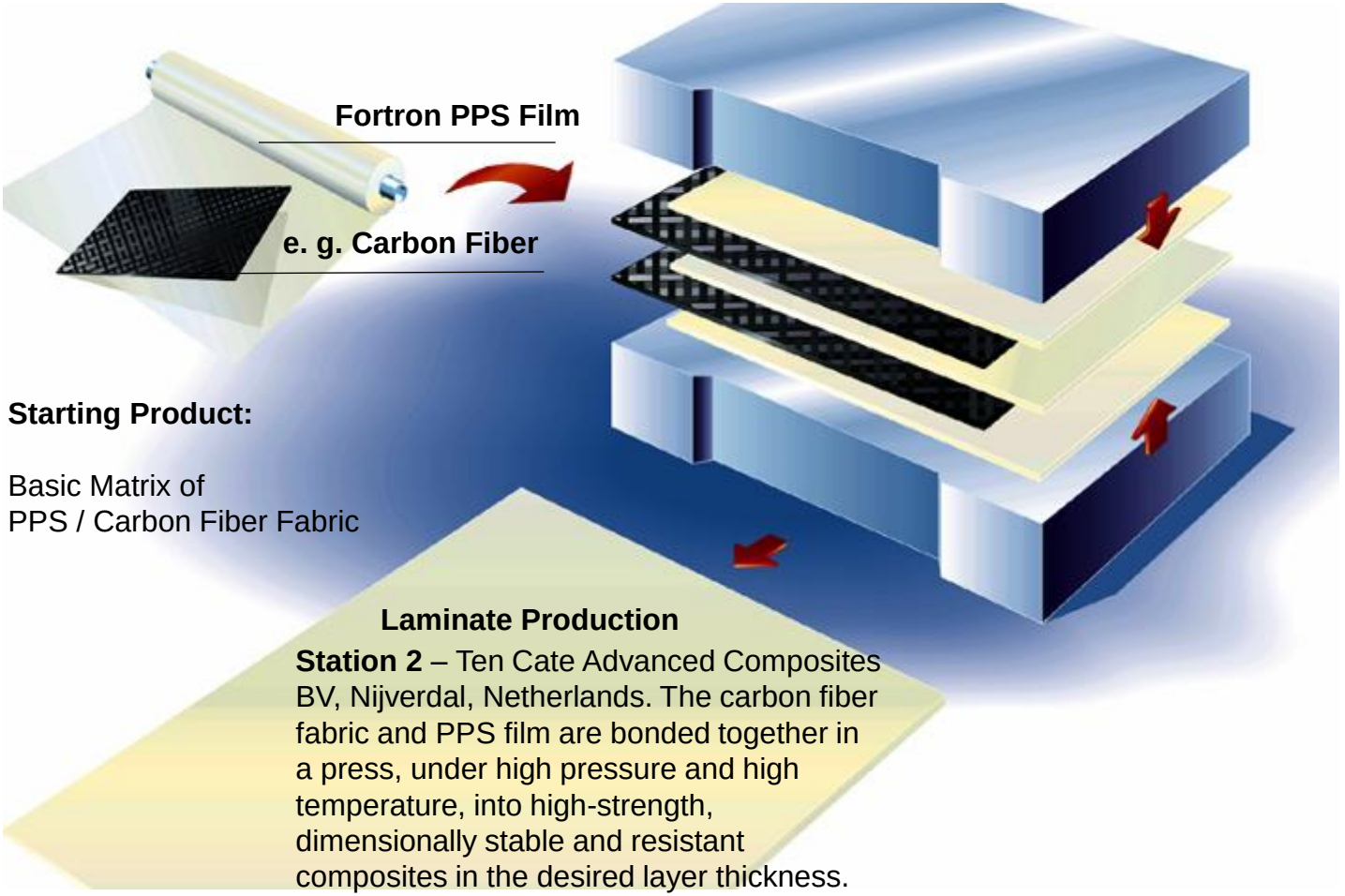
PPS Pellets

- Temperature stability
- High level of hardness and impact strength
- Excellent resistance to chemicals
- Broad temperature range
- Inherent flame resistance

Film Production

Station 1 – Lipp-Terler GmbH in Gaflenz near Linz, Austria. The pellets are converted into films with a thickness of 50 to 200 µm. The film leaves the special plant in rolls of 100 kg in a flawless state, crystal clear and with the required characteristics with regard to strength and dimensional stability.

Station 2: Composite Production



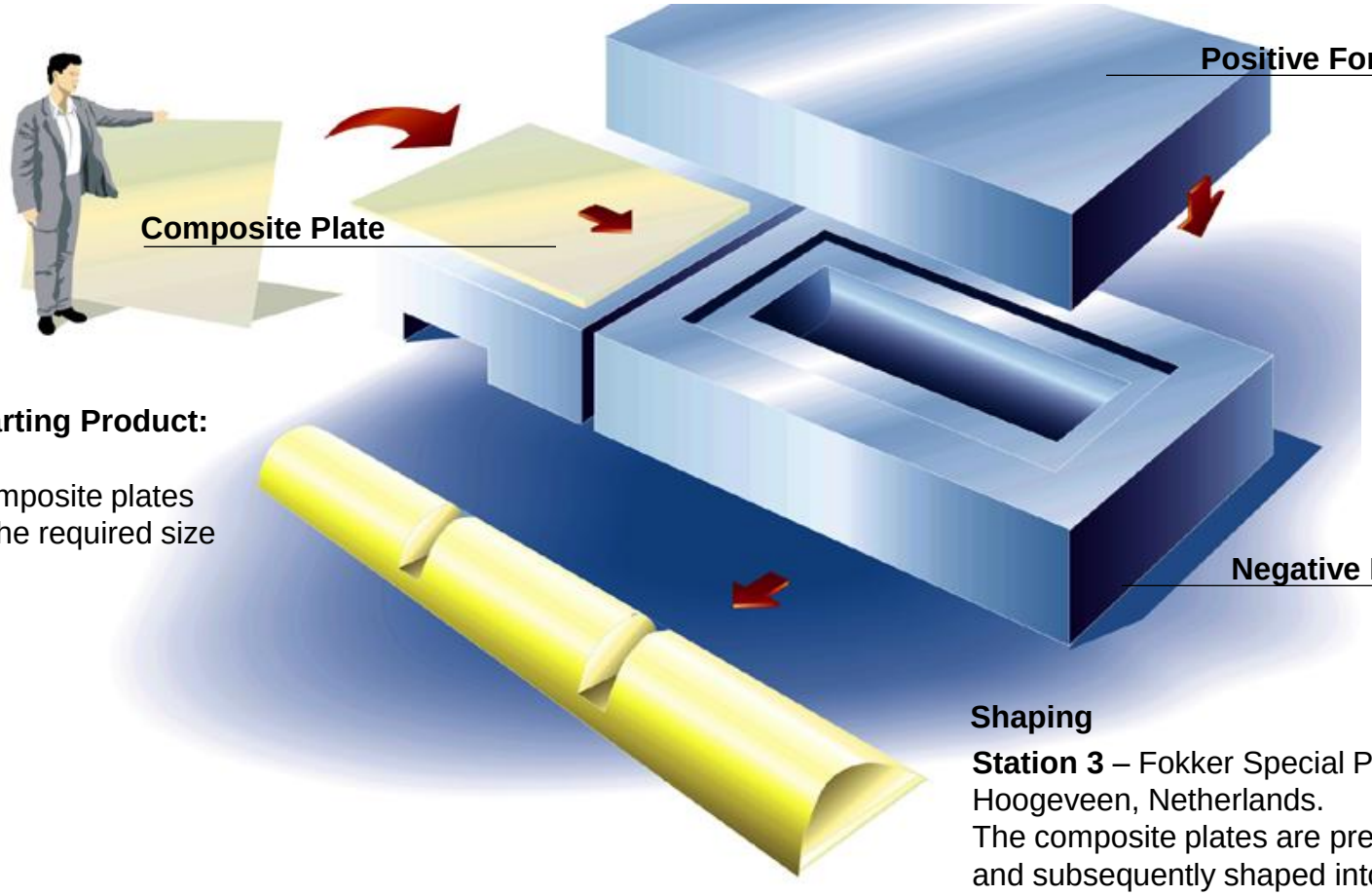
Starting Product:

Basic Matrix of
PPS / Carbon Fiber Fabric

Laminate Production

Station 2 – Ten Cate Advanced Composites BV, Nijverdal, Netherlands. The carbon fiber fabric and PPS film are bonded together in a press, under high pressure and high temperature, into high-strength, dimensionally stable and resistant composites in the desired layer thickness.

Station 3: Thermoforming



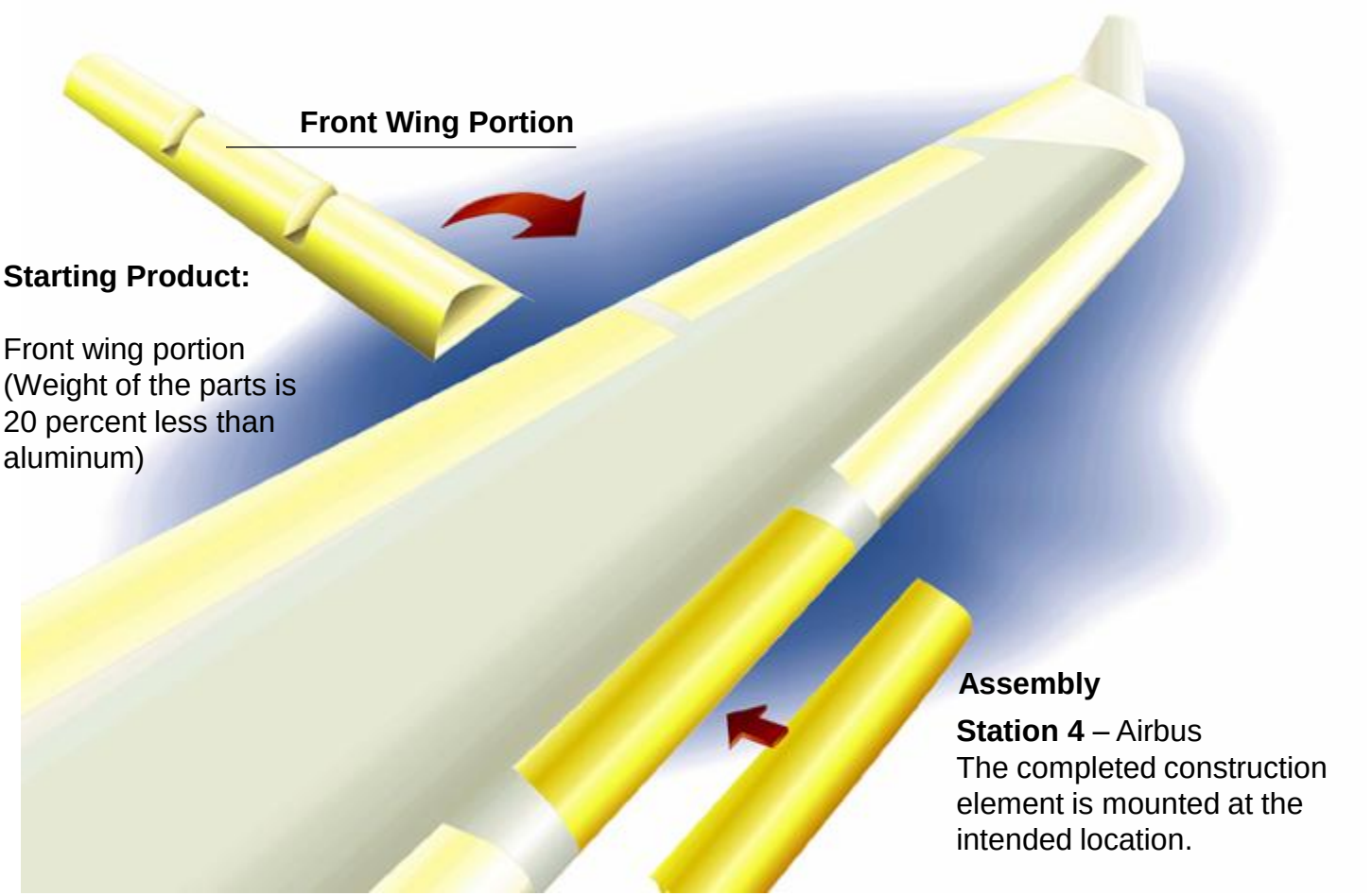
Starting Product:

Composite plates
in the required size

Shaping

Station 3 – Fokker Special Products, Hoogeveen, Netherlands.
The composite plates are pre-heated and subsequently shaped into the desired form under pressure and high temperature.

Station 4: Assembly



Starting Product:

Front wing portion (Weight of the parts is 20 percent less than aluminum)

Assembly

Station 4 – Airbus
The completed construction element is mounted at the intended location.

Technology Breakthrough: Fixed Wing Leading Edge Airbus

- Welded structure
- Low weight and low cost monolithic design

Fortron® PPS
Success in the Aviation Industry

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- Safe, efficient, environmentally friendly
- Modern design
- Licensed for aircraft construction
- New applications from Fortron® PPS

Reduced Process Energy Example for TP vs TS Composites

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Thermosets

- Assemble part in tool
- Match Mold Process Cycle (1+ hours)
- Cool, removal

Thermoplastics

- Assemble part in tool
- Stamp /Thermoform Cycle (minutes)
- Subsequent part can be stamped immediately

Energy Required Per Part can be less than a factor of 10 for TP vs TS with Match Metal Molding of Simple Parts

Additional Savings:

- No Need for Prepreg Freezers
- Reduced Facility HVAC Costs

Reduced VOC's and Toxic Products

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Thermosets

- Prepregs usually Contain Solvents (VOC's) for Tackiness
- Cure By-Products can be Complex Organic Compounds
- Halogenated Additives Are Typically Used to Reduce Flammability
  - But Toxicity is Increased

Thermoplastics

- Prepregs Do Not Contain Solvents
- No Cure By-Products
- No Halogenation Necessary for Most High Performance Thermoplastics
  - Excellent FST Performance

T300 3K Carbon Fabric/Fortron® PPS Composite Property Data*

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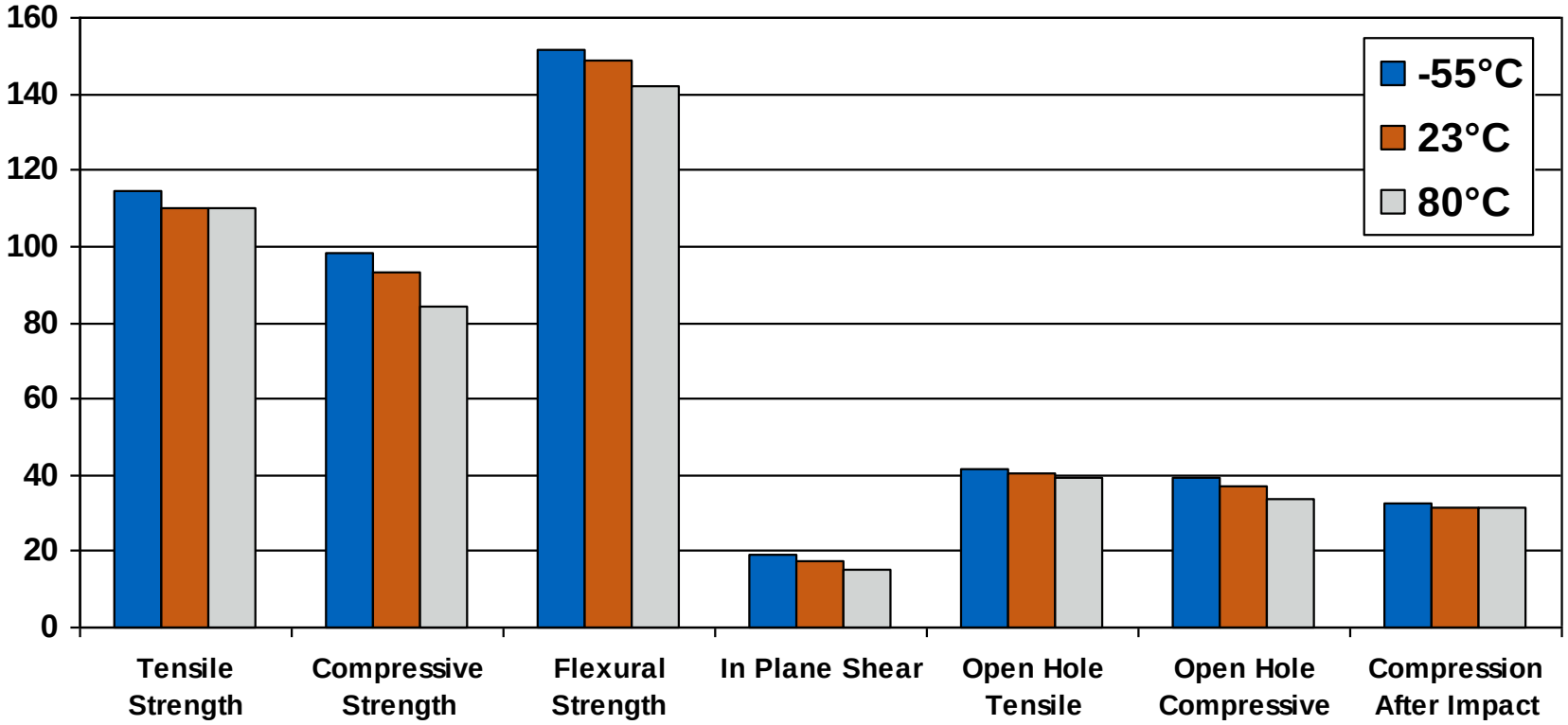

- Values are in ksi
- Warp direction data
- Average values - Tested per Mil-R-17

Steady and Stable Across Use Temperature

*TenCate CETEX Data

T300 3K Carbon Fabric/ Fortron® PPS Composite Property Data*

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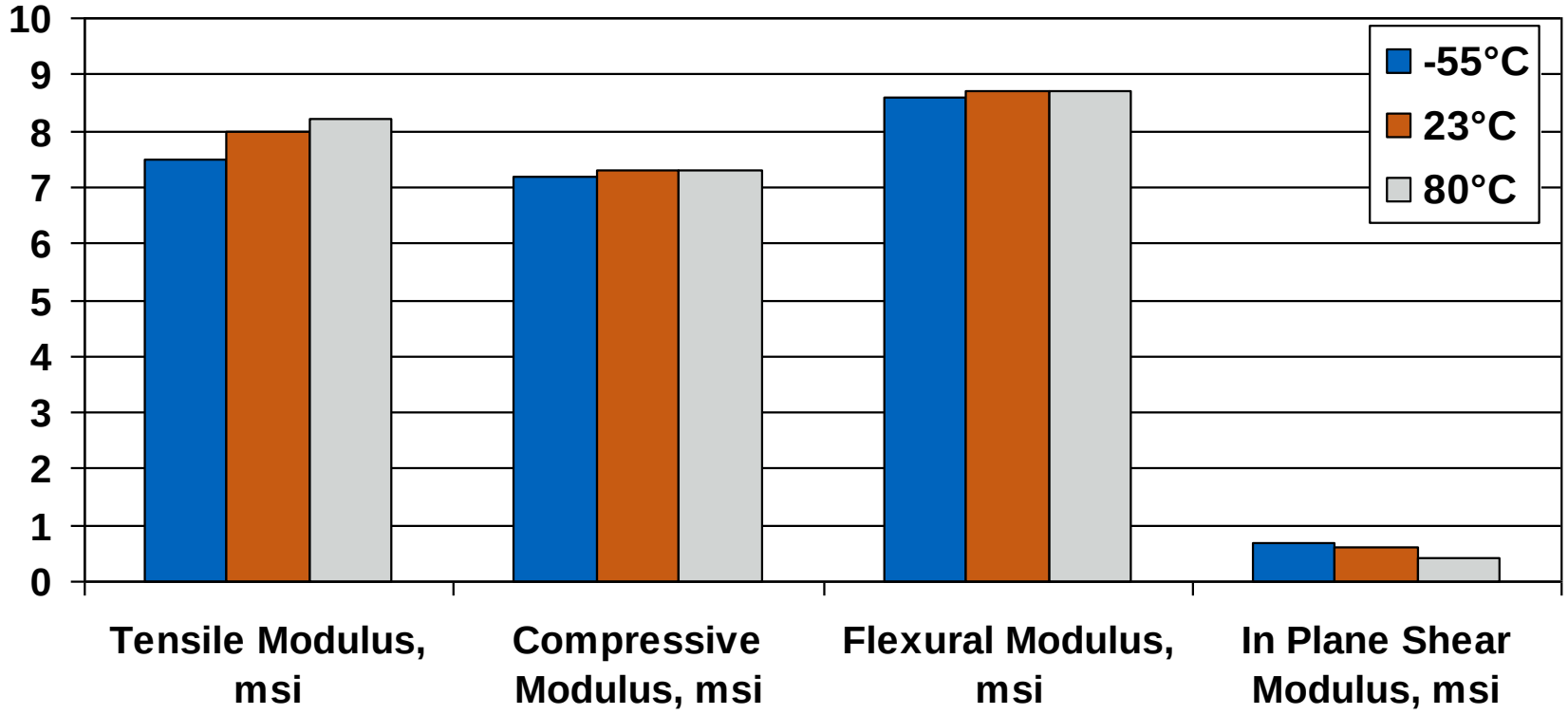

- Values are in msi
- Warp direction data
- Average values - Tested per Mil-R-17

Steady and Stable Across Use Temperature

*TenCate CETEX Data

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Working Together in the Aviation Industry

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Technology Validation – Carbon/PPS: Fokker 50 Undercarriage Door

- Final step in a dedicated 10-year program
- Press-formed ribs and spars
- Welded assembly
- Qualified carbon / PPS material
- Certified by the Airworthiness Authorities
- Flown on a KLM aircraft for 3.5 years

Technology Breakthrough: Fixed Wing Leading Edge Airbus A340-500/600

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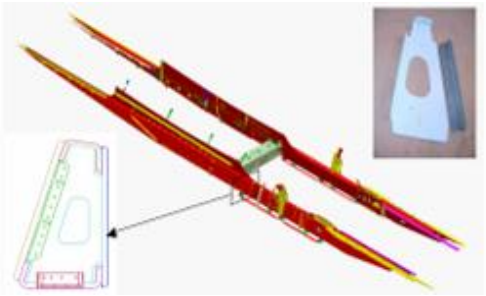
- Welded structure
- Low weight and low cost monolithic design
- Strong partnering with Airbus UK and TenCate
- Technology is now state of the art
  - current application Airbus A380

Keel Beam Application

Metal Substitution with Linear PPS Composite Resulted in 20–50% Lighter Components

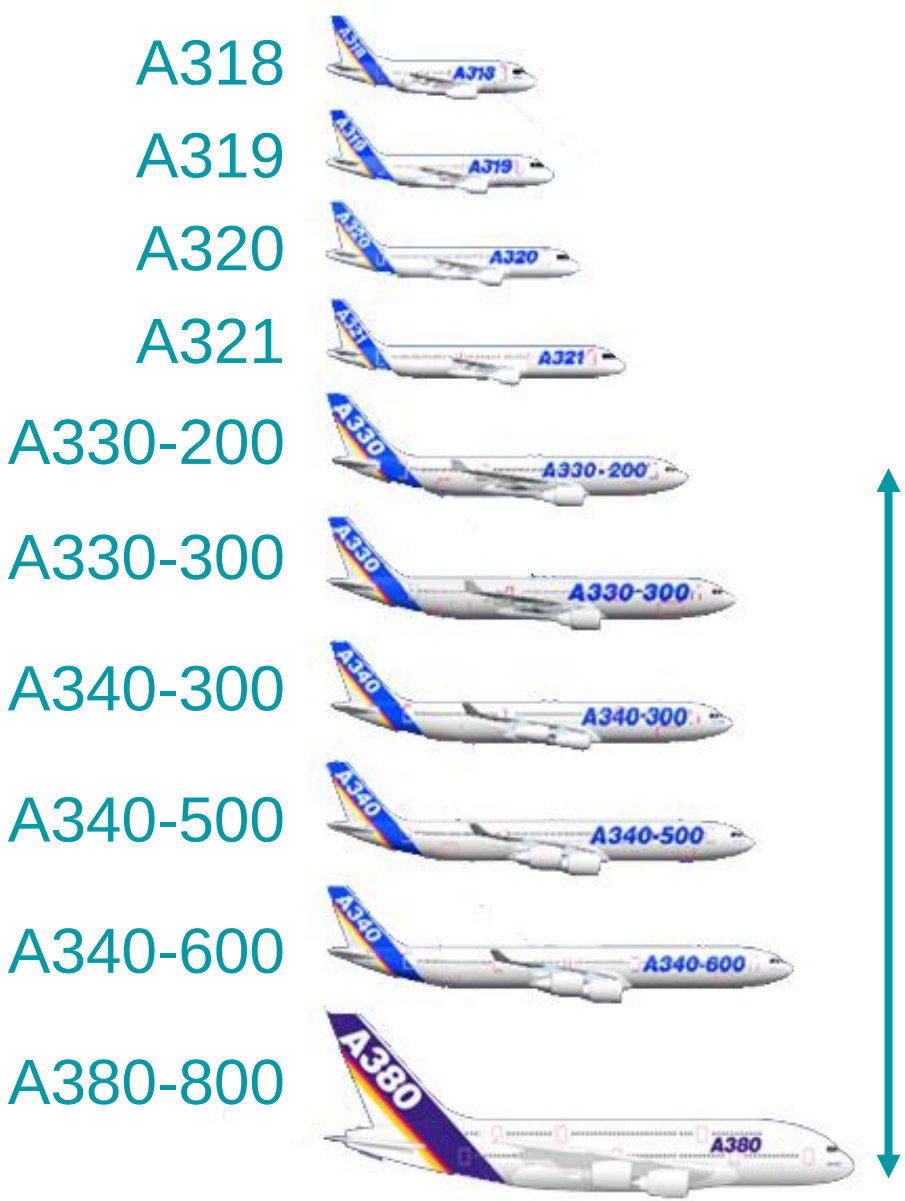


KB WP: 18m, 2.5 tons

Main Ribs (L&R)

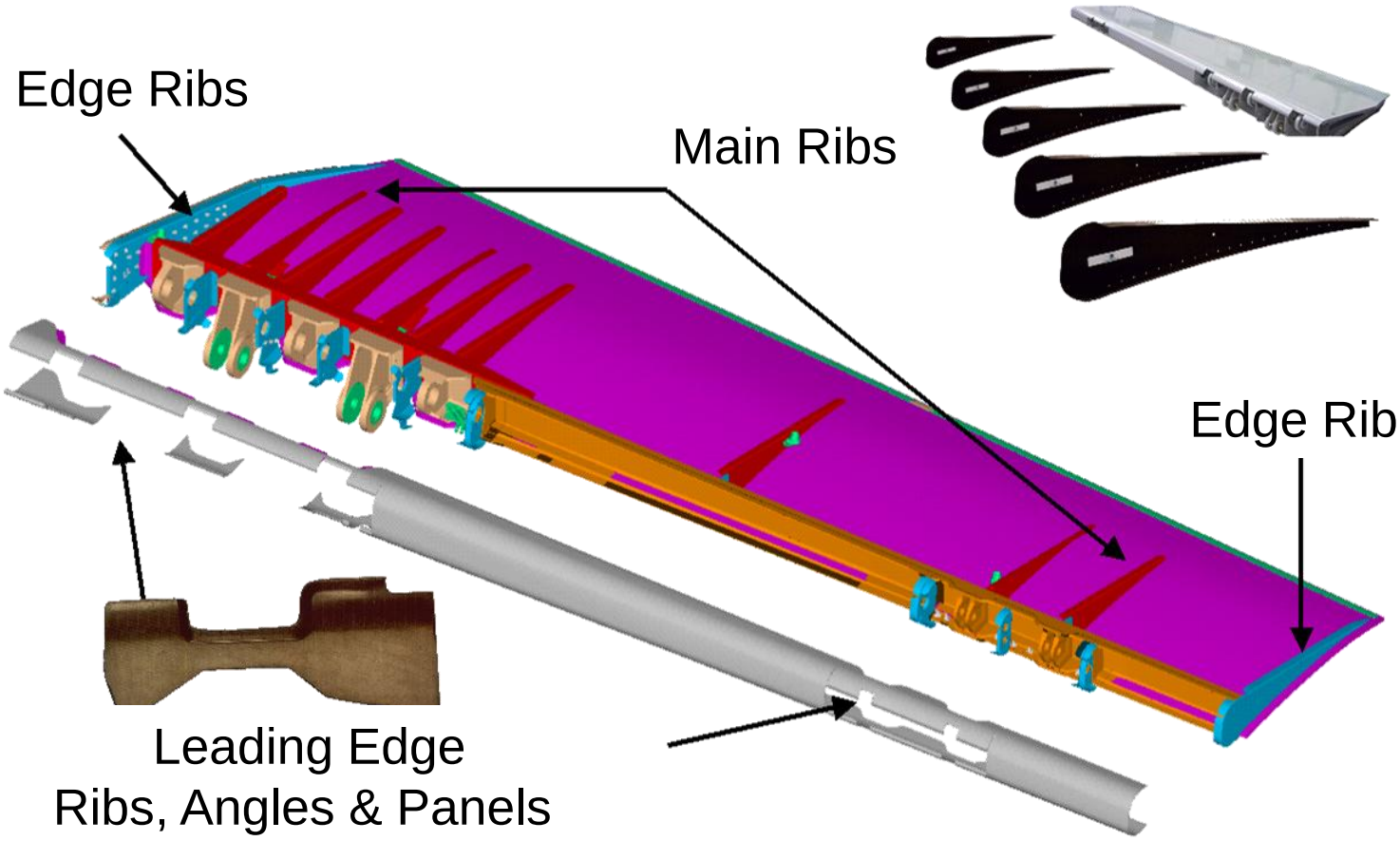
- Multi-technology concept
  - Panels and spars
- Thermoset Prepreg lay-up
  - TP ribs and angles
  - Aluminum and titanium brackets

A330/340 Family: Common Aileron



240 Parts per Airframe

Airbus A340 500/600 Aileron
Thermoplastic Composite Parts

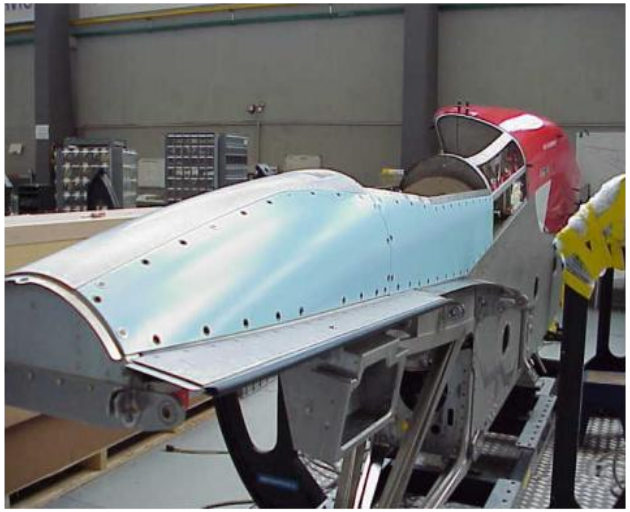


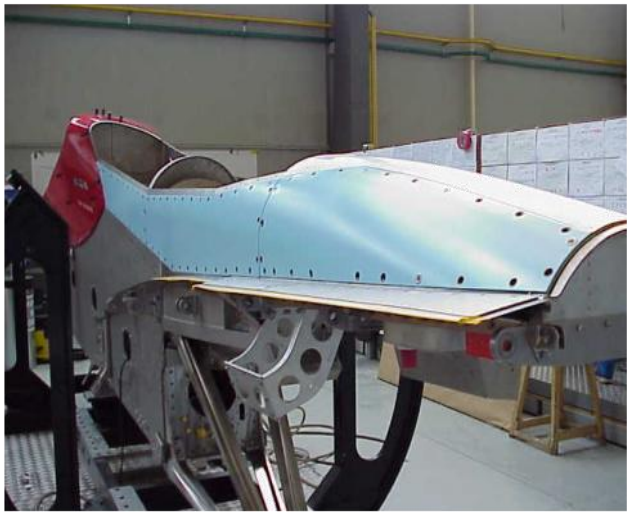
Airbus A340 500/600
Thermoplastic Composite Components

Part Description: Panel of the Pylon Forward Second Structure – 22 per Aircraft

Dimensions:
L = 700 – 1400 mm
W = 200 – 400 mm
Thickness 2.8 mm
Double-Curvature Shape

Material:
PPS / Carbon Fiber
Bronze Mesh Top-layer for EMI Shielding





Leading Edge Airbus A380

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- 8 assemblies / wing
- Wing length: 26 meters
- 16 segments, 52-meter length
- 400 kg total weight

Weight Reduction – The Vision
Fortron® PPS in Aircraft Interior

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Product innovations for Composites

46% Lighter Seat Parts Due to Metal Substitution

Aluminum	280 g
Fortron	150 g

Weight Reduction – The Vision
Linear PPS for Aircraft Interiors

- Fortron® PPS is the prime candidate for several aircraft interior efforts
- Applications include seat frames, brackets, beams, ducts
- Lower cost vs. PEI and PEKK

240 CETEX® Parts in Ailerons

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Common Aileron for
A330-340 Family

Summary

- Fortron® PPS is a demonstrated, producible, low-cost, high-performance thermoplastic for composite applications
  - Aircraft interior and exterior applications
  - Down hole applications
  - Corrosion resistant environments
  - High-temperature usage
  - The low-cost, green alternative
- Industrial thermoplastics composites manufacturing is a demonstrated production process
  - Proven success in aerospace
- Ticona technical personnel will work with you to meet your composites needs

Fortron® PPS
for Thermoplastic Composites

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For more information on Ticona Performance Driven Solutions.™

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