Introduction to Aerospace Engineering

Lecture slides

Temperature & environment

Material properties & degradation

Faculty of Aerospace Engineering

22-11-2011

Learning objectives

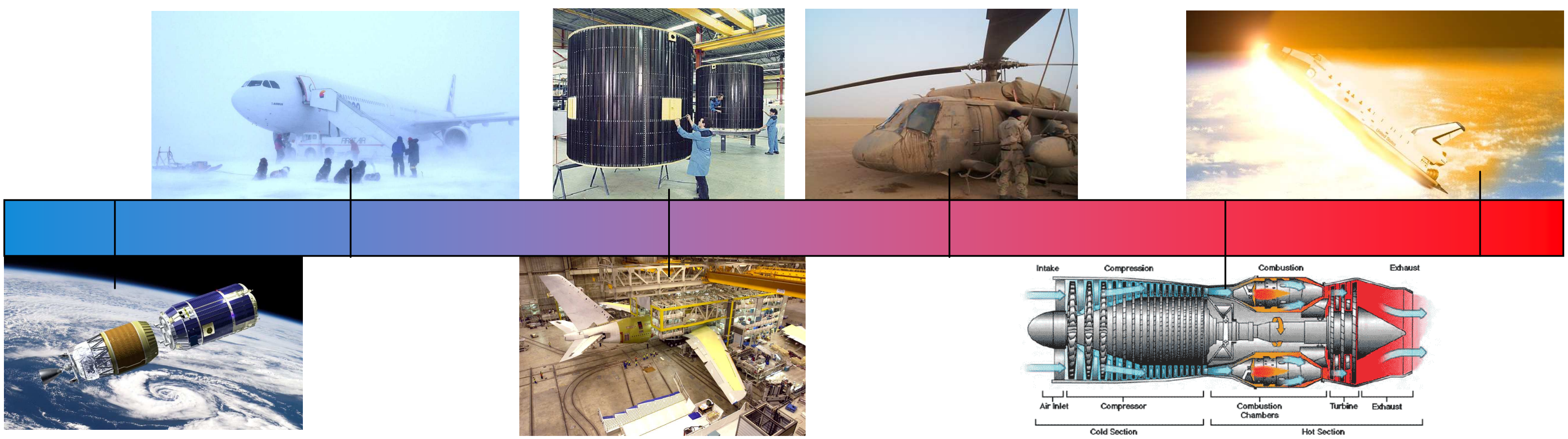
Student should be able to…

- Describe effects of low or elevated temperature on typical aerospace material properties
- Explain the significance of temperature for aircraft & spacecraft
- Explain what environments may influence the properties

Material properties

Significance of temperatures

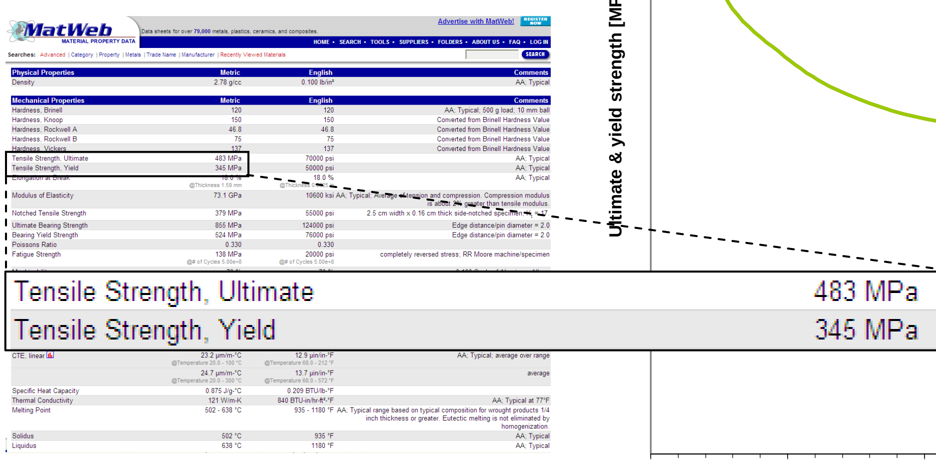
- Materials & structures are often operated at
  - Low temperatures
  - High temperatures
  - High temperature ranges
  - For a long time



Material properties

Effect of temperatures

- Material properties change with temperature (metals)
  - Ultimate strength
  - Modulus of elasticity
  - Yield strength
  - Elongation



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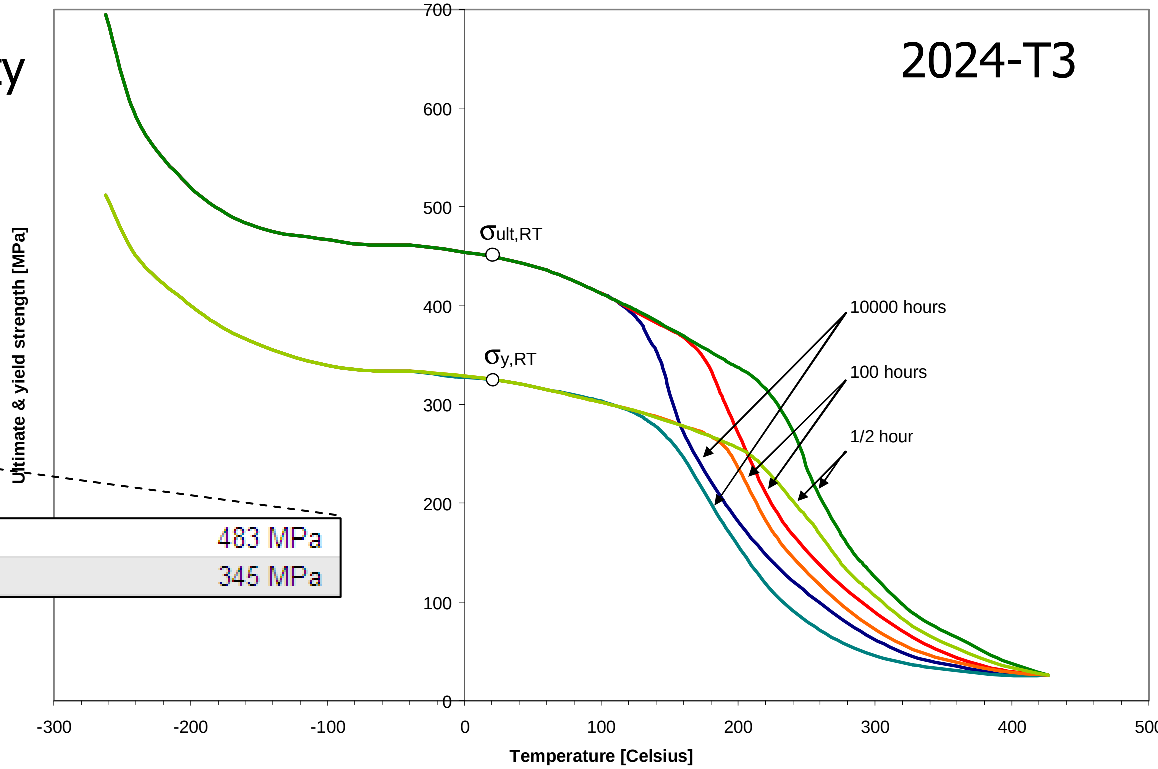
Physical Properties	Metric	English	Comments
Density	2.78 g/cc	0.100 lb/in³	AA; Typical

Mechanical Properties	Metric	English	Comments
Hardness, Brinell	120	120	AA; Typical; 500 g load; 10 mm ball
Hardness, Knoop	150	150	Converted from Brinell Hardness Value
Hardness, Rockwell A	46.8	46.8	Converted from Brinell Hardness Value
Hardness, Rockwell B	75	75	Converted from Brinell Hardness Value
Hardness, Vickers	137	137	Converted from Brinell Hardness Value
Tensile Strength, Ultimate	483 MPa	70000 psi	AA; Typical
Tensile Strength, Yield	345 MPa	50000 psi	AA; Typical
Elongation at Break	18.0 % @Thickness 1.59 mm	18.0 % @Thickness [illegible]	AA; Typical
Modulus of Elasticity	73.1 GPa	10600 ksi	AA; Typical; Average of tension and compression. Compression modulus is about 2% greater than tensile modulus.
Notched Tensile Strength	379 MPa	55000 psi	2.5 cm width x 0.16 cm thick side-notched specimen, K_t = 17.
Ultimate Bearing Strength	855 MPa	124000 psi	Edge distance/pin diameter = 2.0
Bearing Yield Strength	524 MPa	76000 psi	Edge distance/pin diameter = 2.0
Poissons Ratio	0.330	0.330	
Fatigue Strength	138 MPa @# of Cycles 5.00e+8	20000 psi @# of Cycles 5.00e+8	completely reversed stress; RR Moore machine/specimen

Tensile Strength, Ultimate	483 MPa
Tensile Strength, Yield	345 MPa

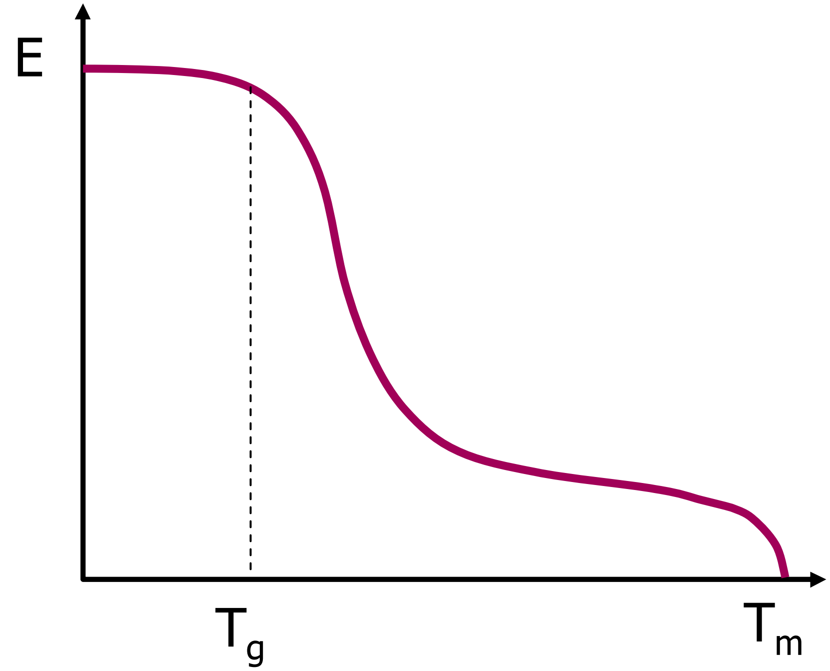
CTE, linear	23.2 µm/m-°C @Temperature 20.0 - 100 °C	12.9 µin/in-°F @Temperature 68.0 - 212 °F	AA; Typical; average over range
	24.7 µm/m-°C @Temperature 20.0 - 300 °C	13.7 µin/in-°F @Temperature 68.0 - 572 °F	average
Specific Heat Capacity	0.875 J/g-°C	0.209 BTU/lb-°F	
Thermal Conductivity	121 W/m-K	840 BTU-in/hr-ft²-°F	AA; Typical at 77°F
Melting Point	502 - 638 °C	935 - 1180 °F	AA; Typical range based on typical composition for wrought products 1/4 inch thickness or greater. Eutectic melting is not eliminated by homogenization.
Solidus	502 °C	935 °F	AA; Typical
Liquidus	638 °C	1180 °F	AA; Typical



Material properties

Effect of temperatures

- Material properties change with temperature (polymers)
  - Modulus of elasticity
  - Elongation



- "glass transition temperature"

Material properties

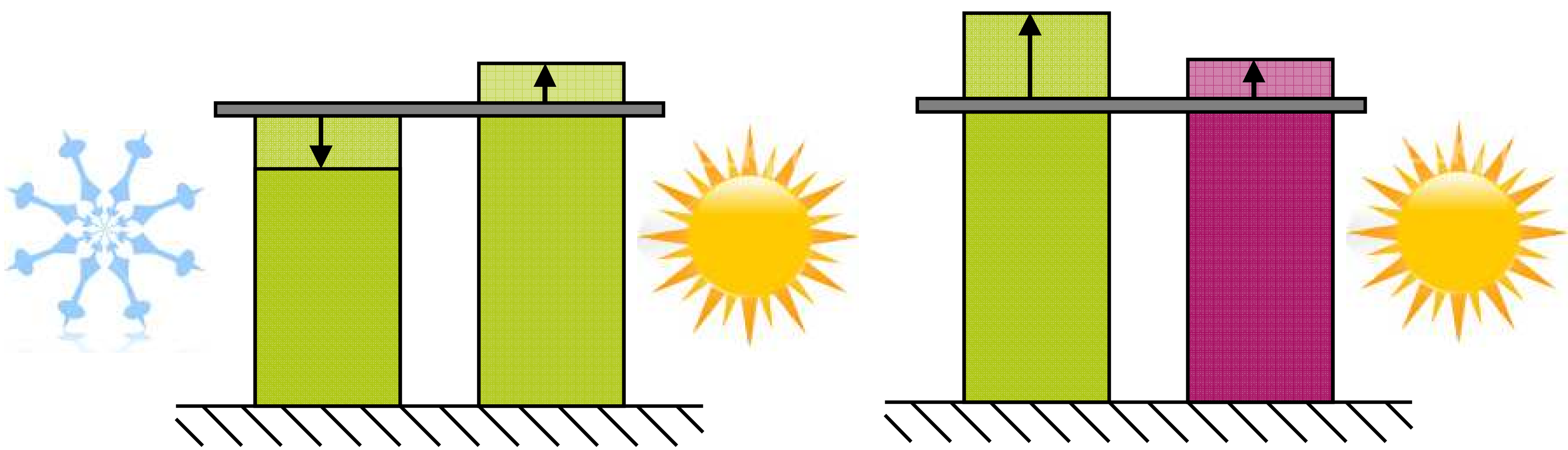
Effect of high temperatures

Material properties

Effect of high temperatures

- Thermal stress
  - Coefficient of thermal expansion

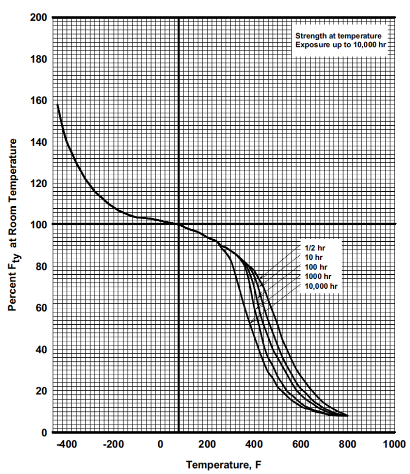
$$\alpha = \frac{1}{V}\frac{dV}{dT}$$

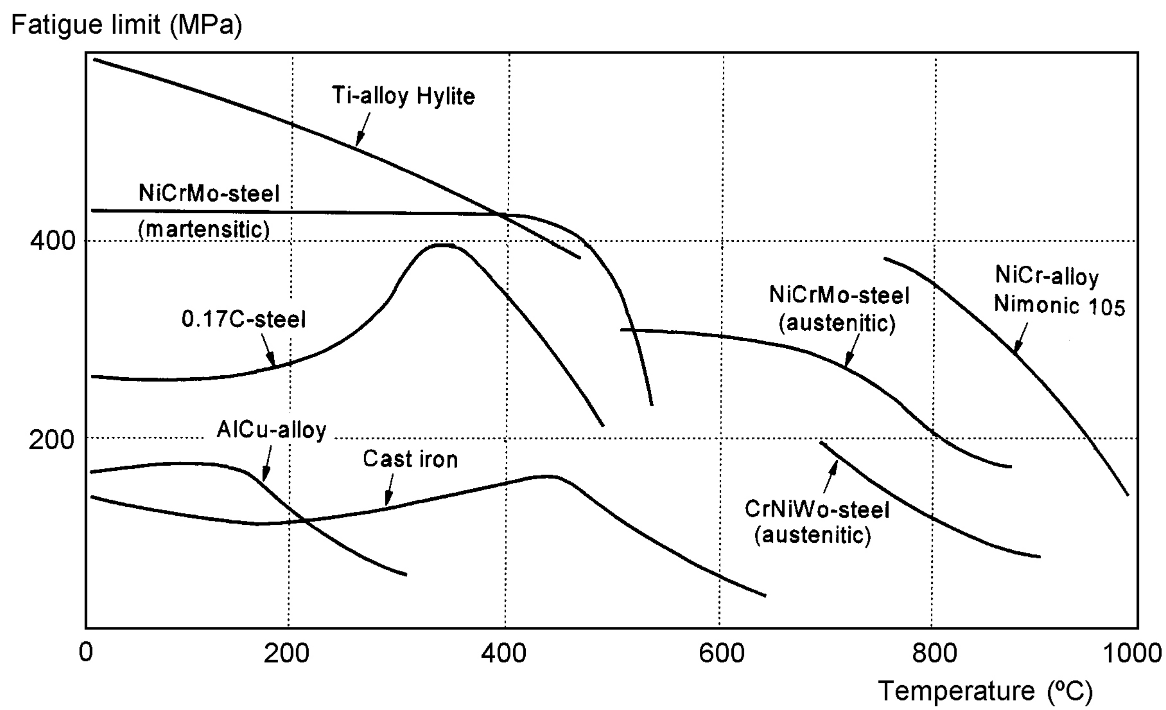


Material properties

Effect of high temperatures

Mechanical properties ⇓
Fatigue properties ⇓
Thermal stresses ⇑

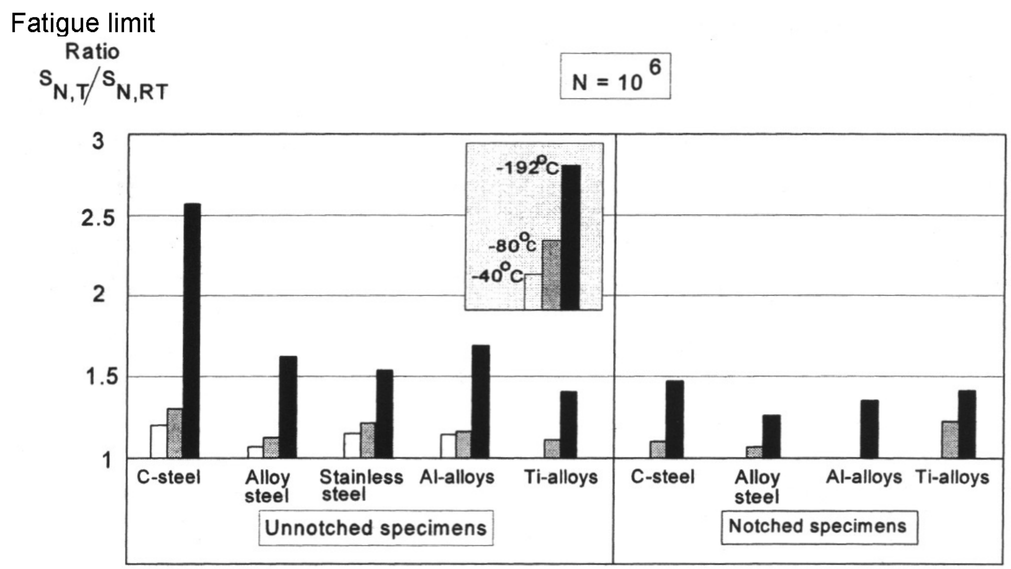




Material properties

Effect of low temperatures

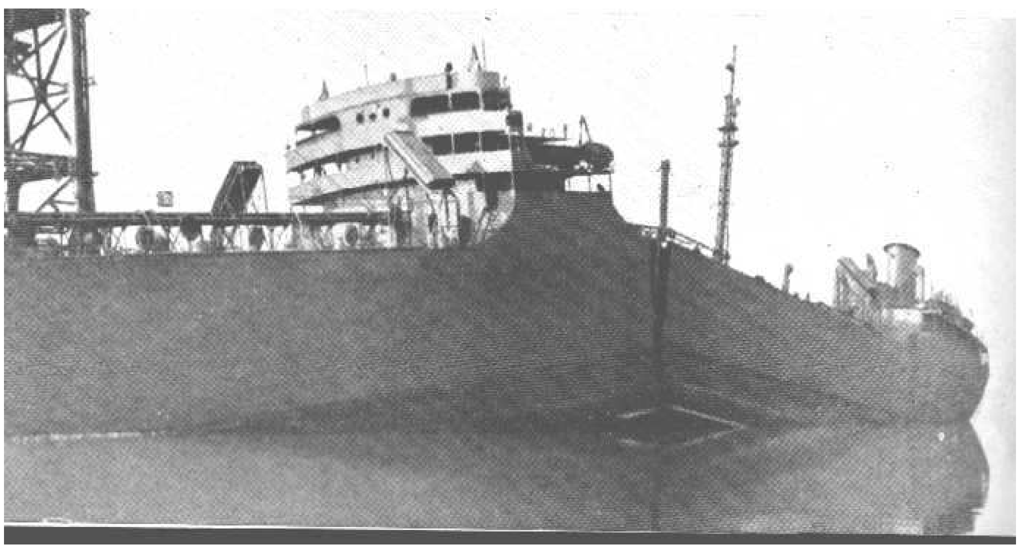
Mechanical properties ⇑
Resistance against plastic deformation ⇑
Chemical reaction & diffusion rates ⇓

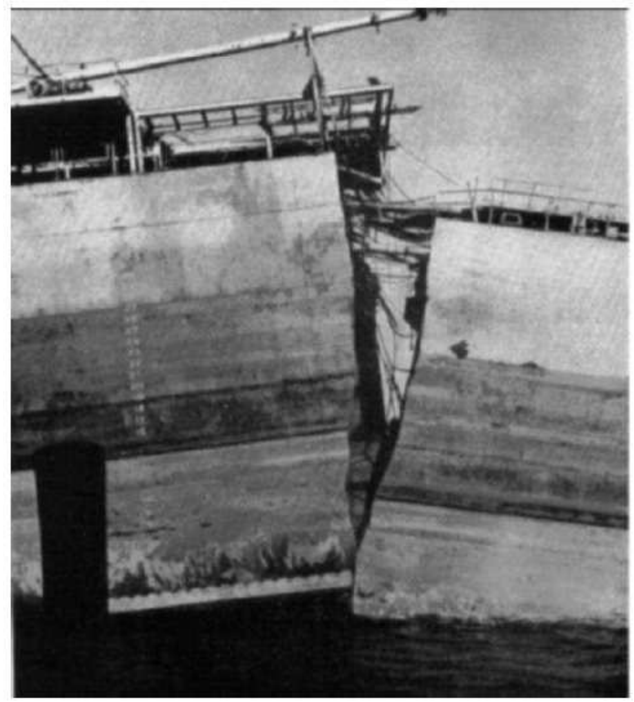


Material properties

Effect of low temperatures

- Fracture toughness
  - Example: T2 and Liberty ships



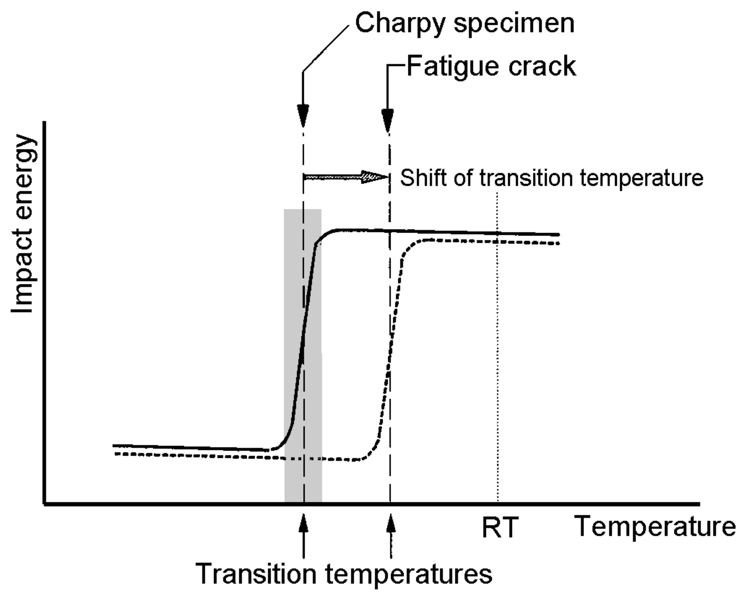


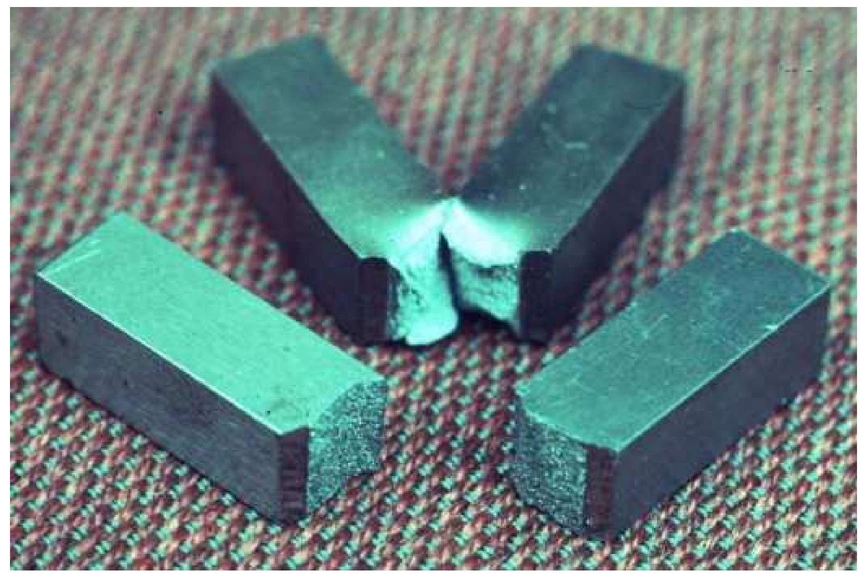
16 January 1943, S.S. Schenectady, a T2 tanker, 24 hrs old

Material properties

Effect of low temperatures

- Fracture toughness
  - Transition from ductile to brittle fracture
  - Temperature ⇓ ⇒ ductility ⇓ and notch sensitivity ⇑





Environmental aspects

Example environments

- Air/moisture/salt
- Space & re-entry
- Fuel
- Hydraulics
- Cleaning agents

Environmental aspects

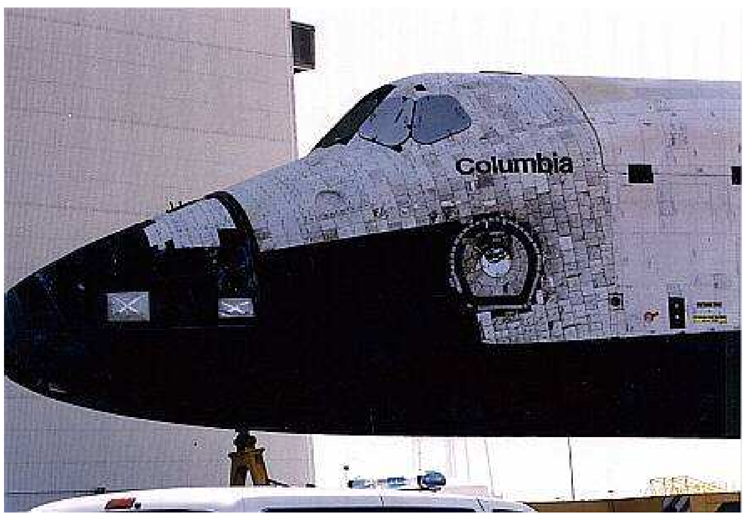
Example environments

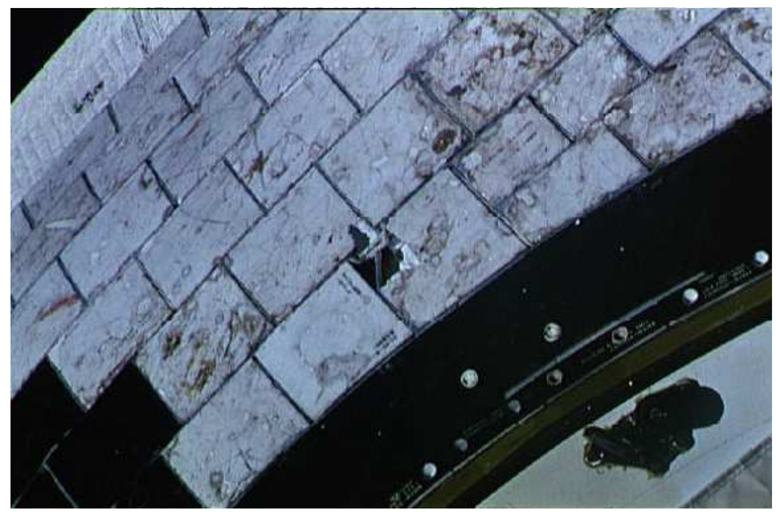
- Air/moisture/salt
  - Sea

Environmental aspects

Example environments

- Space & re-entry
  - Radiation/UV exposure
  - Atomic Oxygen (O^{+})
  - Vacuum (degassing)

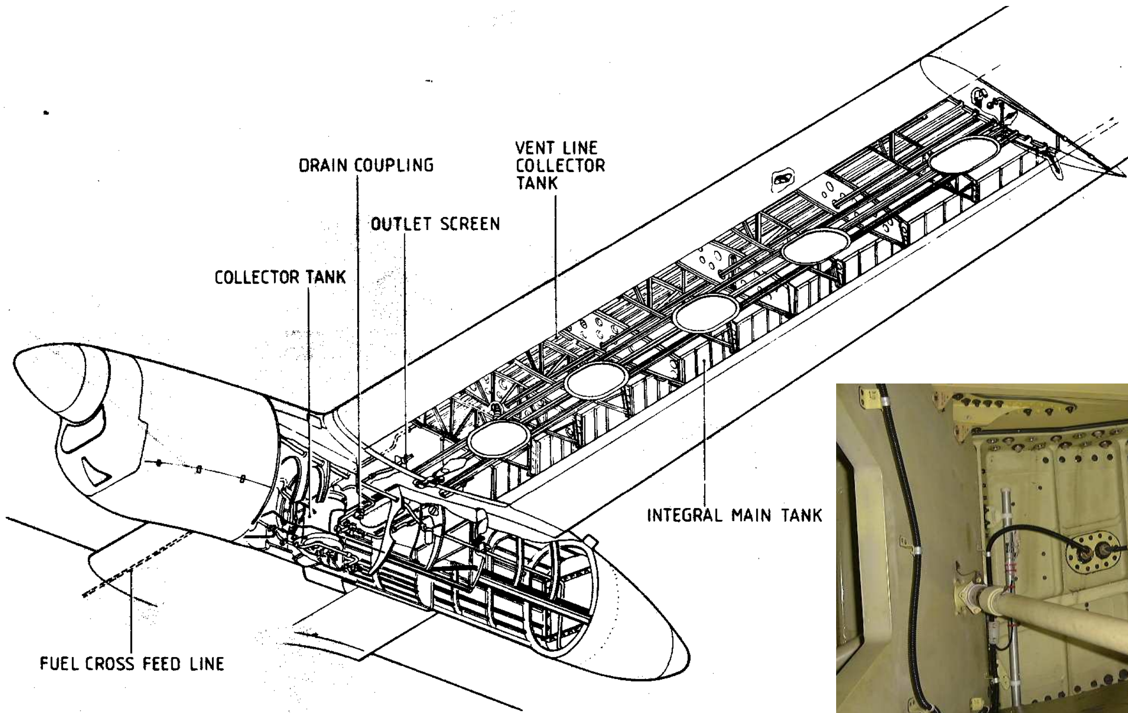


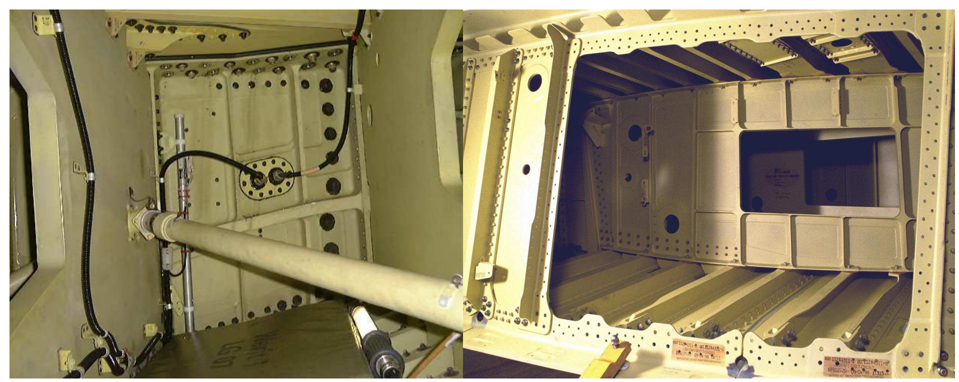


Environmental aspects

Example environments

- Fuel
  - Integral fuel tank: structure sealed during manufacturing

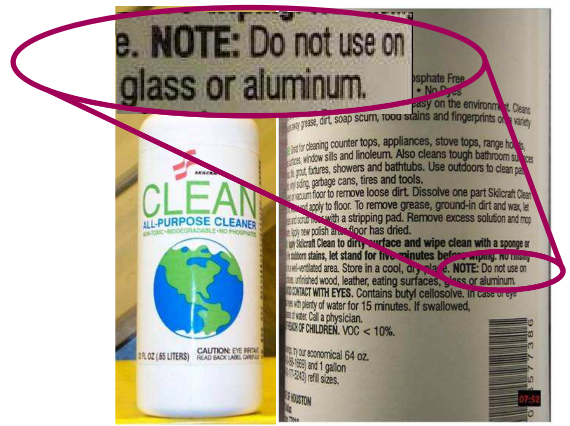




Environmental aspects

Example environments

- De-icing
  - Mechanical/thermal (scraping/heating)
  - Liquid chemicals (salts/alcohols/glycols)
- Cleaning compounds
  - Prescribed cleaning method



Environmental aspects

Example environmental effect: corrosion

- In time environment affects the material & structure…

Environmental aspects

Example environmental effect: corrosion

- Example: Galvanic corrosion
  - Bicycle in winter: road salt & mud
  - ⇒ galvanic corrosion between chromium plated brass spoke nipple and aluminium rim

Summary

Temperature & environment

- Material properties change with temperature
- Properties may change drastically
  - Glass transition temperature for polymers/composites
  - Ductile to brittle transition temperature for certain steel alloys
- Environment may affect properties in time
  - Air/moisture/salt
  - Space & re-entry
  - Fuel
  - Hydraulics
  - Cleaning agents