Thermal Considerations of Composite Repairs

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Milliken™ | pipe wrap® Smart Pipe Repair Solutions

Outline

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- Application Temperature
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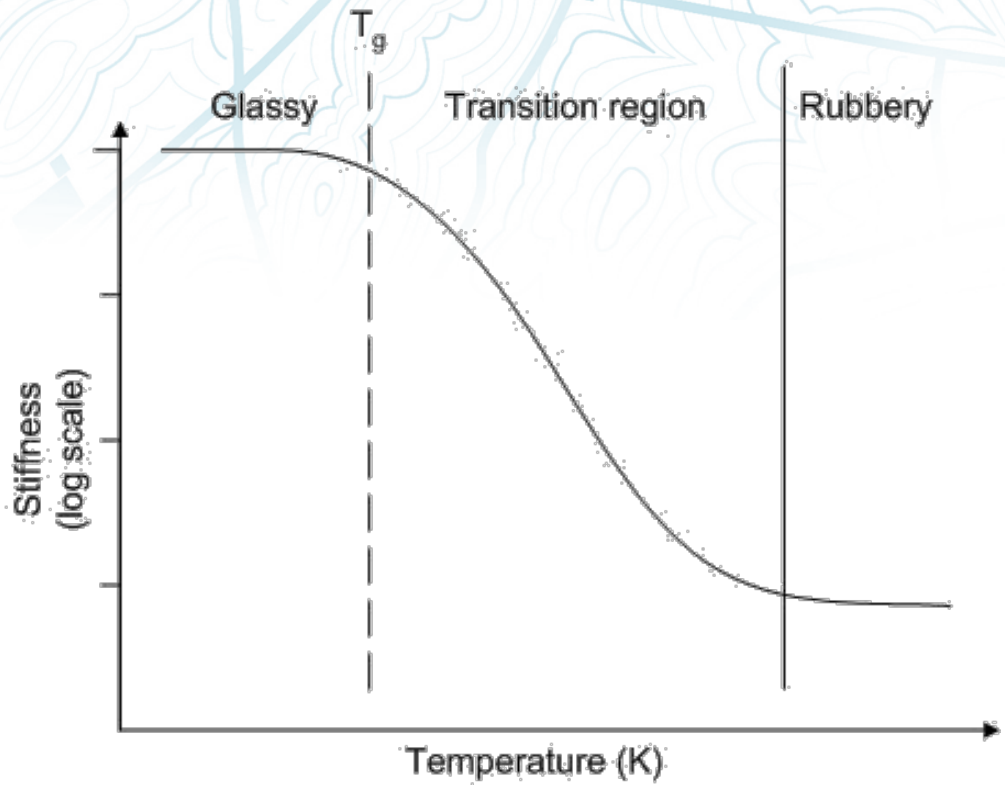
  - Cold Conditions
- Thermal Expansion
- Effects on Shear Strength
- Conclusion

Introduction

- As an industry, composites repairs are constantly breaking new ground
- Repairs on non-ambient piping systems are becoming very common
- However, there are many considerations that initially may not be taken into account and may not be obvious

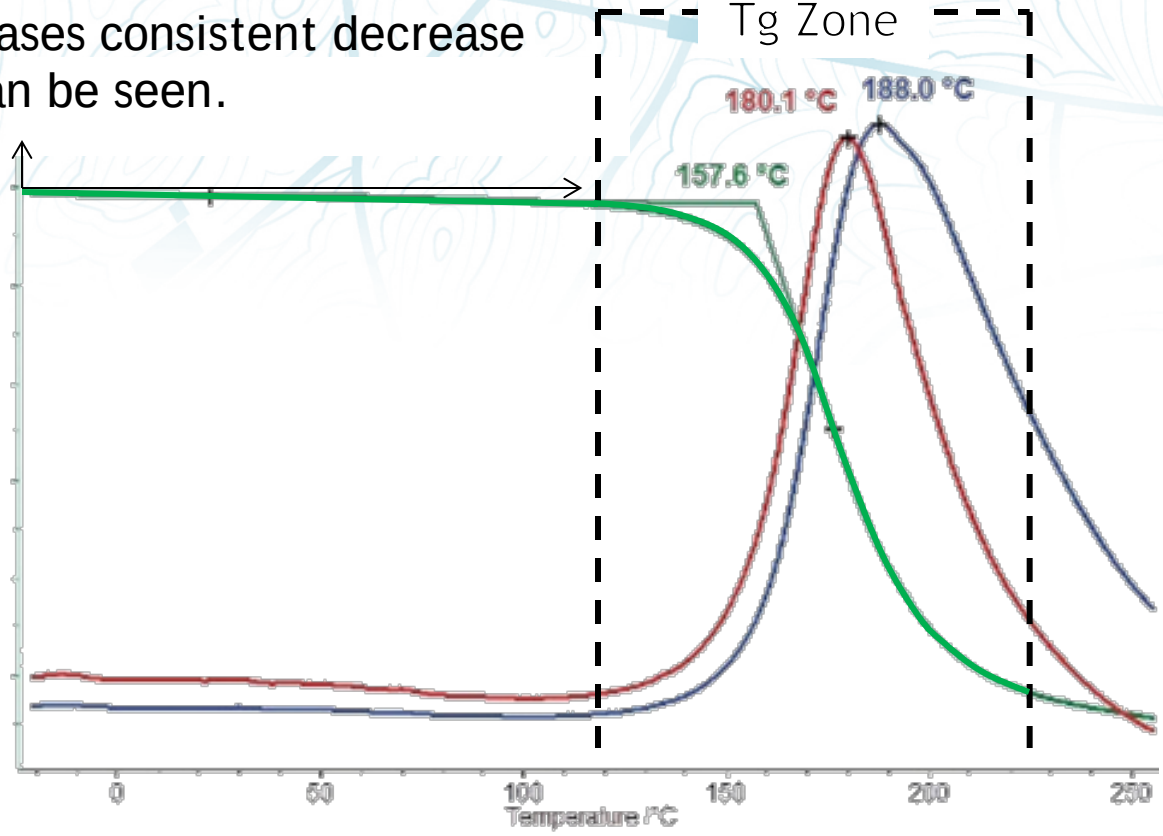
Glass Transition Temperature (Tg)

- Surpassing Tg reduces mechanical values
- ASME PCC-2 uses Tg as temperature limits
  - Leaking Repairs
    Tm = Tg – 54°F
  - Non-Leaking Repairs
    Tm = Tg - 36°F



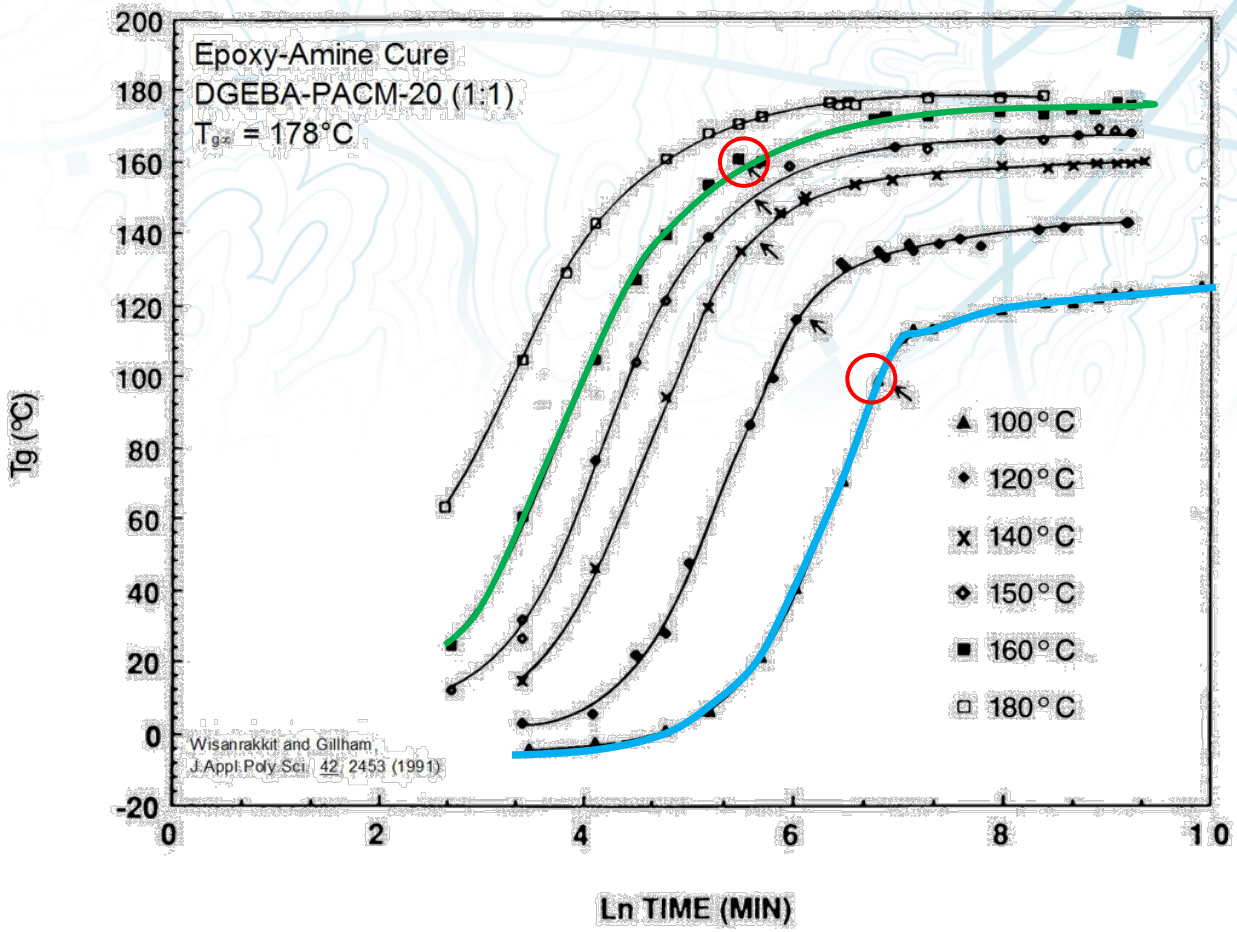
Effects on Mechanical Properties

- Tg Zone
  - Tg is not a specific value, it refers to range around the value stated
- Storage Modulus (green line)
  - As temperature increases consistent decrease in storage modulus can be seen.
  - At the Tg zone, modulus decreases



Cure Profile Effects on Tg

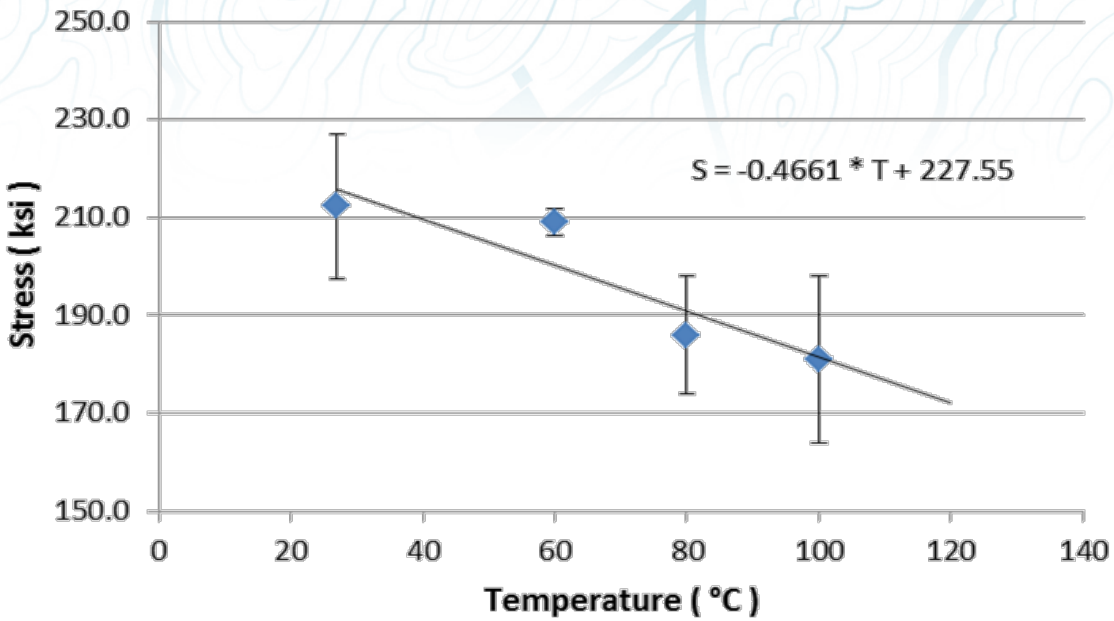
Maximum Tg will only be slightly above cure temperature



- Cure Temp: 160°C
  Tg ≈ 175°C
- Cure Temp: 100°C
  Tg ≈ 120°C

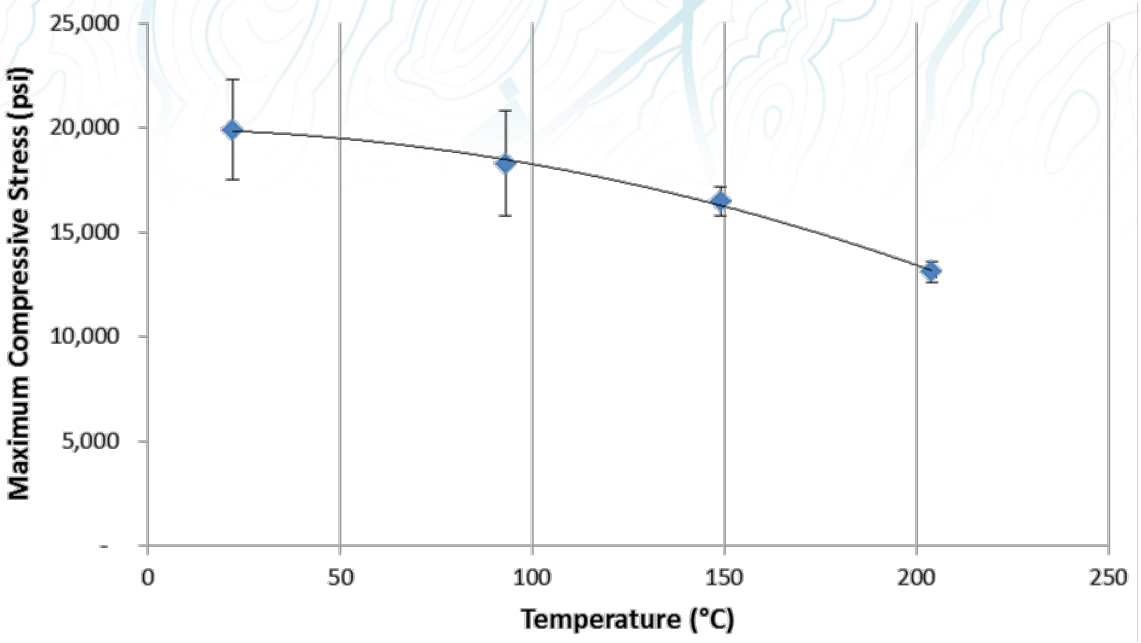
Effects on Mechanical Properties

- With any temperature increase, mechanical properties, such as tensile strength, decrease
- This decrease in strength should be considered for any high temperature repairs



Importance of Testing

- Every system reacts differently to temperature
- It is important to test every component of a system at temperature to determine any potential limitations



Application Temperature

- The environmental or pipe temperature can affect several application conditions:
  - Proper resin mixing
  - Working time
  - Set time
  - Viscosity
- Ensure application temperatures have been considered for pipe temperatures:
  - Below ≈ 60°F
  - Above ≈ 100°F,

Ambient Conditions

- Cold ambient conditions can:
  - Increase viscosity
  - Difficult to mix resins and wet-out fabric
- Hot ambient conditions can:
  - Decrease working time

Hot Pipes - Reduced Viscosity

- All wet resin material undergo changes in viscosity due to temperature
  - composite, adhesive, filler etc…

- Reduction in viscosity can liquefy resin:
  - Filler material not able to reshape pipe
  - Adhesive is too thin and runs off pipe
  - Wet resin runs from fabric

Hot Pipes - Reduced Set Time

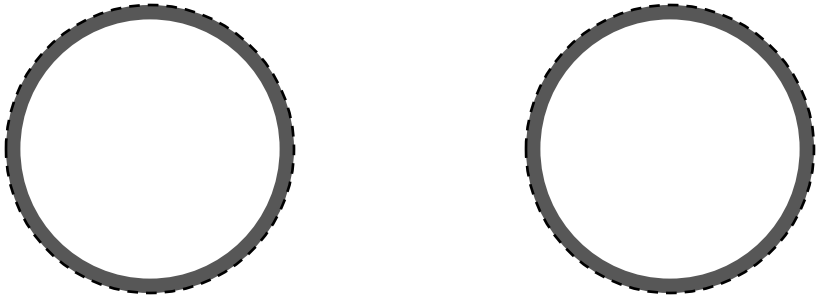
- Increasing temperature accelerates reactions
- Materials may set too quickly (within minutes)
  - Filler material
    - May set before reshaping is complete
  - Adhesive
    - Sets before wrapping can begin
  - Composite Wrap
    - Inner layers set before de-bulking

Cold Pipes

- Temperature effects set time of polymers
  - Ex:
    At 80°F : Resin A sets in 2 hours
    At 30°F : Resin A sets in 3 days
    At -10°F : Resin A sets in 6 weeks
- Cure time is typically 10x longer!

Thermal Expansion

- Coefficient of Thermal Expansion (CTE):
  Used to determine amount of expansion due to difference in temperature
- Most materials expand when heated and shrink when cooled
- Materials have different CTEs
  - Needs to be considered when large temperature differences are expected

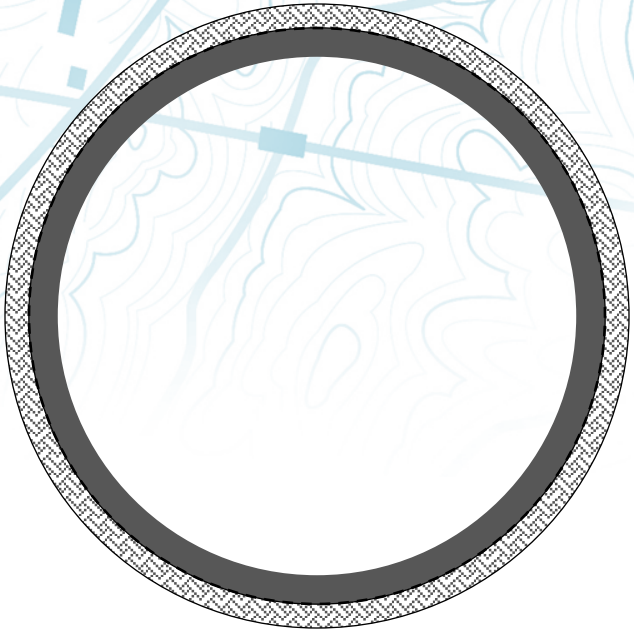


Thermal Expansion

- Thermal Expansion in the hoop direction can be a concern with:
  - Hot pipes
    Ambient installation temperature
    High operational temperature
  - Pipes with temperature spikes
    Installed at warm temperatures
    Experiences high temperature conditions
- Need to consider "Design Temperatures" over lifetime of repair – not current operating conditions

Thermal Expansion Fiberglass

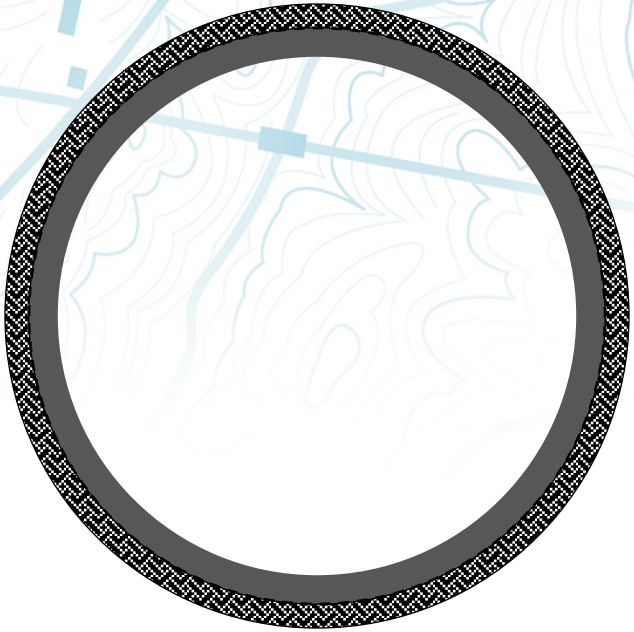
- When heated:
  - Pipe expands
  - Fiberglass expands MORE



- Effects:
  - Repair separates from pipe
  - Strains adhesive

Thermal Expansion Carbon Fiber

- When heated:
  - Pipe expands
  - Carbon Fiber expands LESS



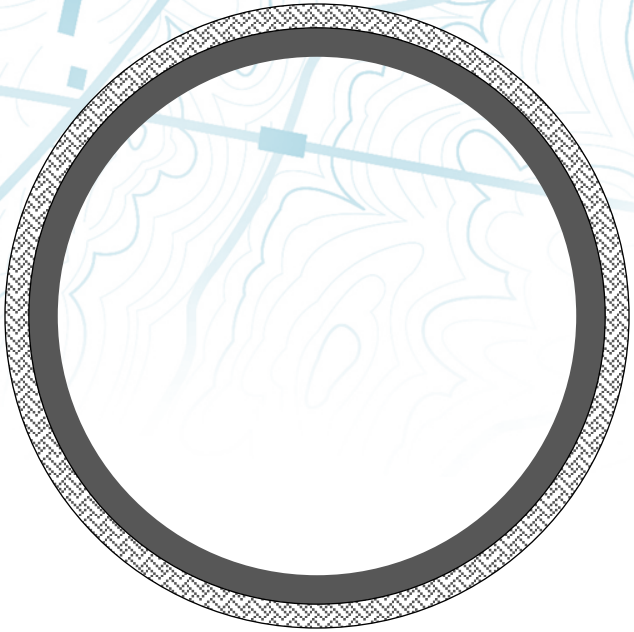
- Effects:
  - Repair compresses pipe
  - Engaged repair

Thermal Contraction

- Thermal Contraction in the hoop direction can be a concern when:
  - Cold pipes:
    Ambient installation temperature
    Sub-zero operational temperature
    ex: Liquid Nitrogen line
  - Installation performed at high temperature and then pipe is temporarily out of service

Thermal Contraction Fiberglass

- When cooled:
  - Pipe shrinks
  - Fiberglass shrinks MORE



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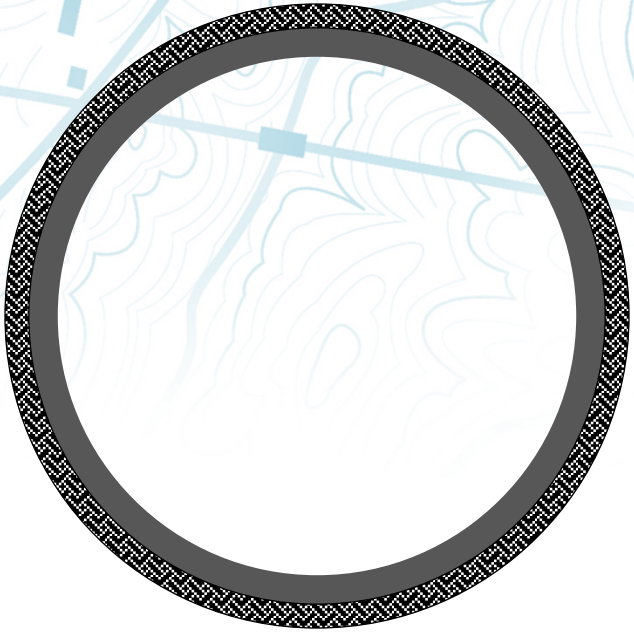

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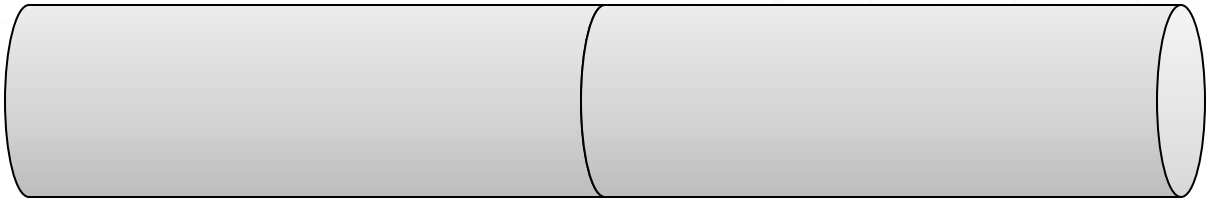
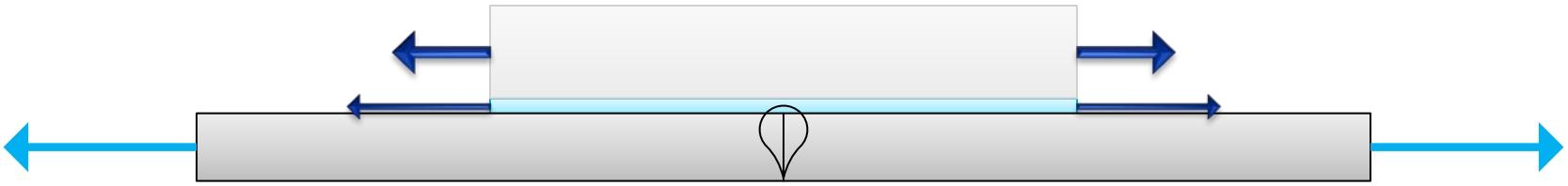
Axial Thermal Contraction

- Thermal contractions can be a significant source of failure in weakened girth welds
- As the pipe segments contract, they create stress in the weld



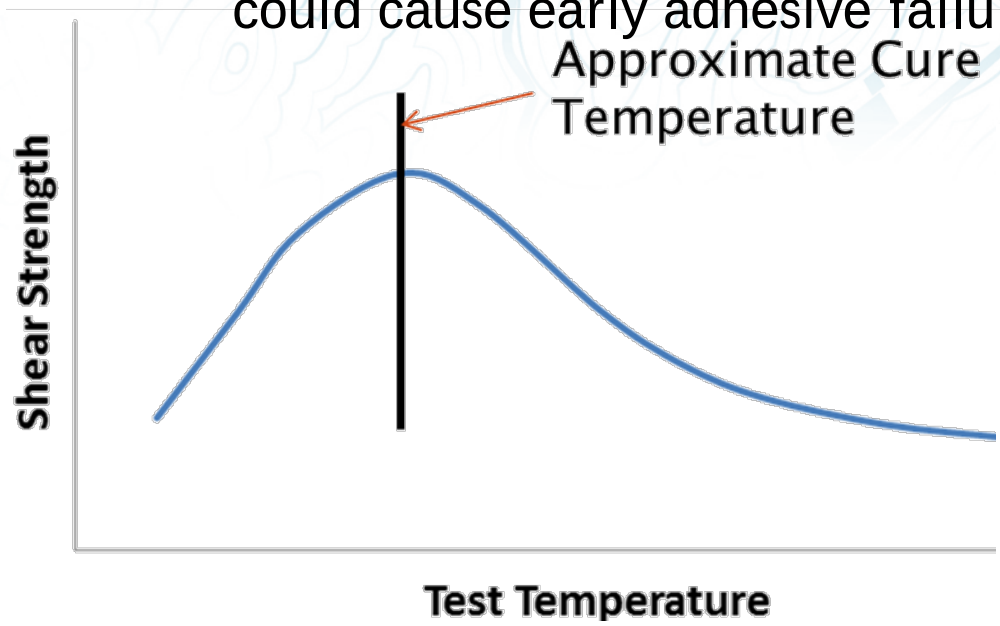
Axial Stress Transference

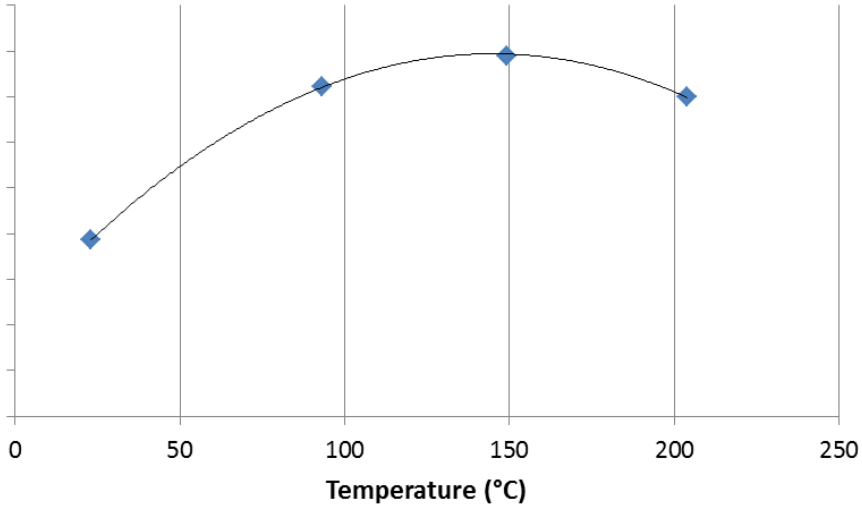
- To repair welds suffering from cyclic axial loading, composites can be used
- Adhesive shear properties are very important
  - If adhesive is too brittle, may crack and fail
  - If adhesive is too rubbery, load may not transfer



Shear Strength

- Max adhesive strength occurs at cure temperature
- Any change in temperature creates a thermal stress due to differences in CTE
  - If applied at ambient and brought up to temperature, could cause early adhesive failure





Conclusion

- There are many thermal considerations in any low or high temperature system
  - Changes in mechanical strength
  - Maximum temperature limits
  - Restrictions on application
  - Thermal expansion / contraction
- If everything is considered and accounted for, composites can provide an excellent repair for a large temperature range

Any Questions?

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