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# FAA Bonded Structure Workshop
# June 2004

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# Bell Experience with Bonded Structures

**1950's – Bell Model 47**

**Bonded main & tail rotors - Originally wood core with metallic skins.**

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# Bell Experience with Bonded Structures


**Bell Model 412 with experimental composite tailboom**

**BMI solid laminate/co-cured honeycomb sandwich structure.**

**Production rotor blades – bonded composite construction.**

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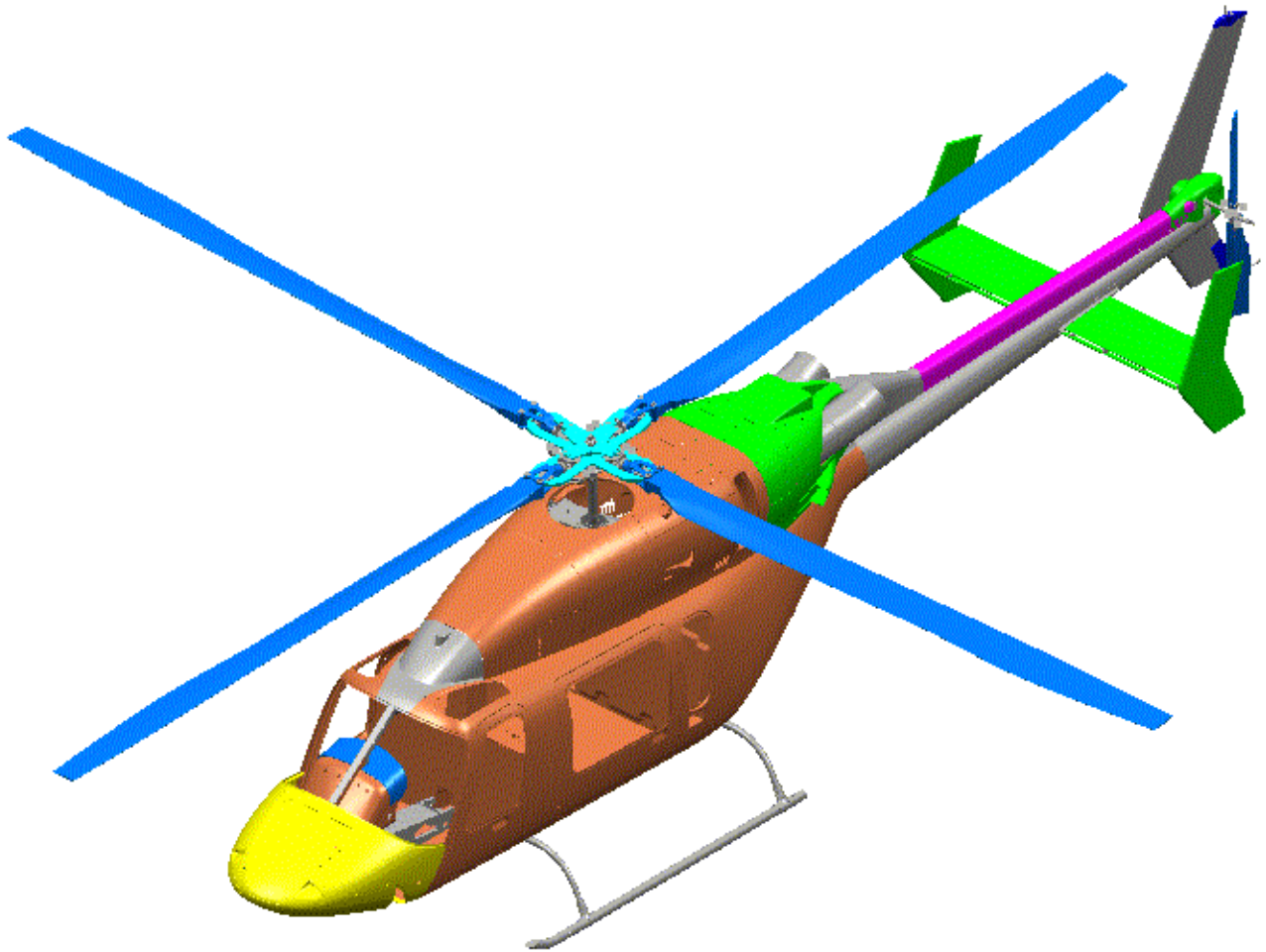
# Bell Experience with Bonded Structures



**Bell Model 427: Grey = Metal , remainder is bonded composite structure**

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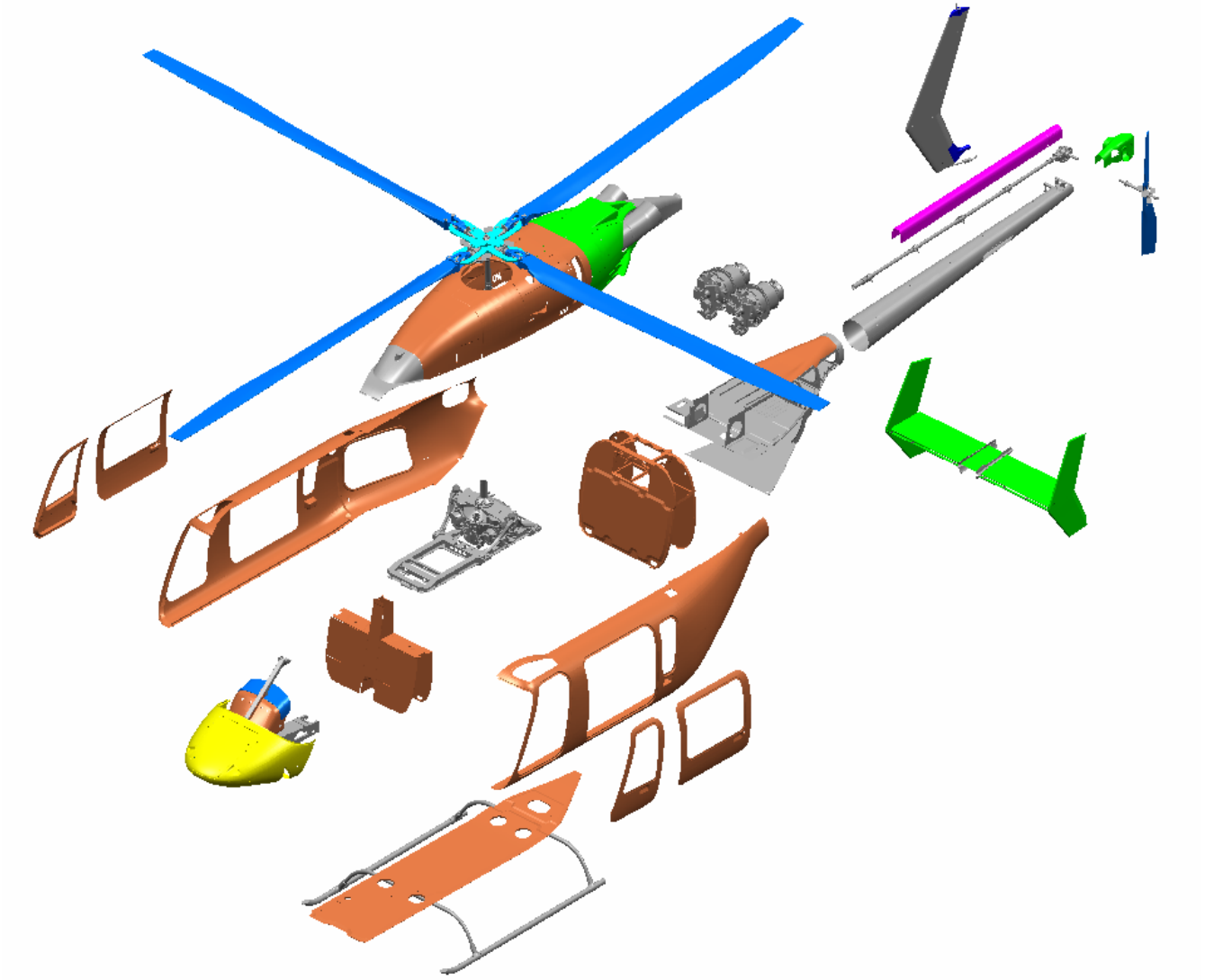
# Bell Experience with Bonded Structures



**Bell Model 427 – detail part assembly view**

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# Bell Experience with Bonded Structures

**Bell-Boeing V-22**

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# Bell Experience with Bonded Structures

**BA609 First Flight 2003**

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# Bell Experience with Bonded Structures


**BA609 First Flight 2003**

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# Bell Experience with Bonded Structure

Bonded Structures (Primary):

- Rotor Blades - Metallic and Composite (film adhesive/no fasteners)
- Bonded wing skin stiffeners - Co-bonded or Co-cured (Film adhesive)
- Bonded wing skin-to-rib structure - secondary bonded (Film adhesive).

Bonded Structures (Secondary):

- Co-cured sandwich structure – fairings, fuselage side of body panels (Film adhesive).
- Metal bond panels – sandwich and metal-to-metal (Film adhesive).
- Systems support – bonded brackets/standoffs ect. for electrical & hydraulic systems (paste adhesive or “composite bond”).

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# Bonded Structure Safety/Certification Issues

- ✓ Surface preparation (well defined/controlled by process specs)
  * Time limits for prepared surfaces.
  * Storage requirements for prepared surfaces.
- ✓ Mechanical property characterization (well defined by material specs)
  * New designs often require testing of adherend combinations beyond what was done for basic qual (RI vs Design Reqm’ts).
  * Co-cure requires prepreg/adhesive compatibility testing.
  * Type of carrier used in adhesive can make a significant difference for certain applications.
- ✓ Damage tolerance (usually element and/or full scale part with known defects – fatigue test with static residual strength).

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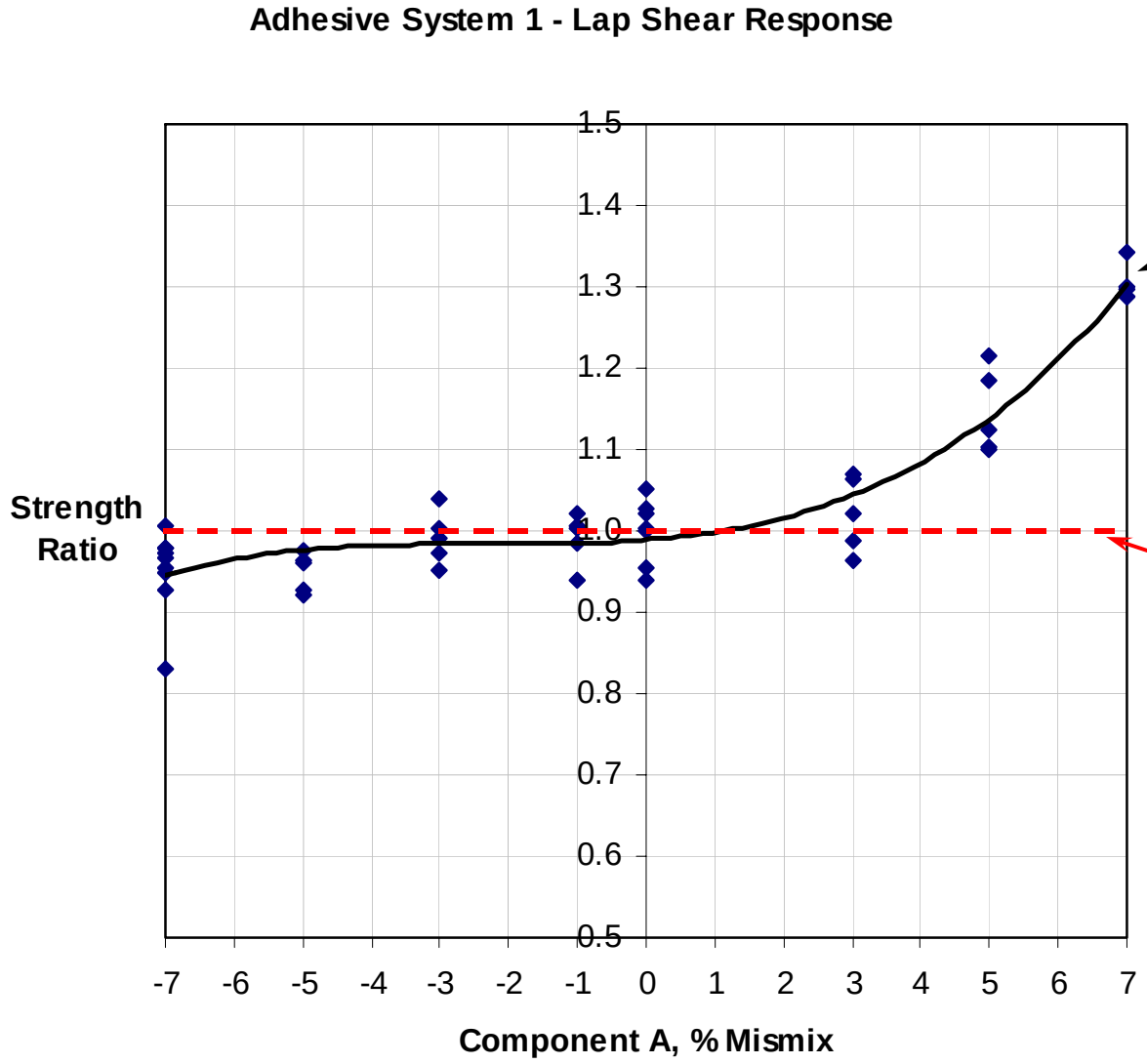
# Bonded Structure Safety/Certification Issues

- Understand tolerances for mixing of paste adhesives.
  - Are scales with adequate capability clearly defined in the equipment section of the process specification for hand mixed adhesive? *(Example: mixing miss-match study)*
  - Is exotherm potential understood (maximum allowed mass/mix quantity defined in process spec)?
  - Have tests been performed to demonstrate that hand mixed vs. static mixed (kitted) adhesive produces the same result?…..does the QPL limit the kitted adhesive to approved kits/cartridges and specific approved mixing tips for each adhesive system?

- Material/Process Specs must provide the guidance necessary to ensure that design of the bonded structure assembly and associated tooling are consistent with adhesive processing limitations. *(Example: assembly time study)*

# Example 1a: Mixing Mis-match (Lap Shear)



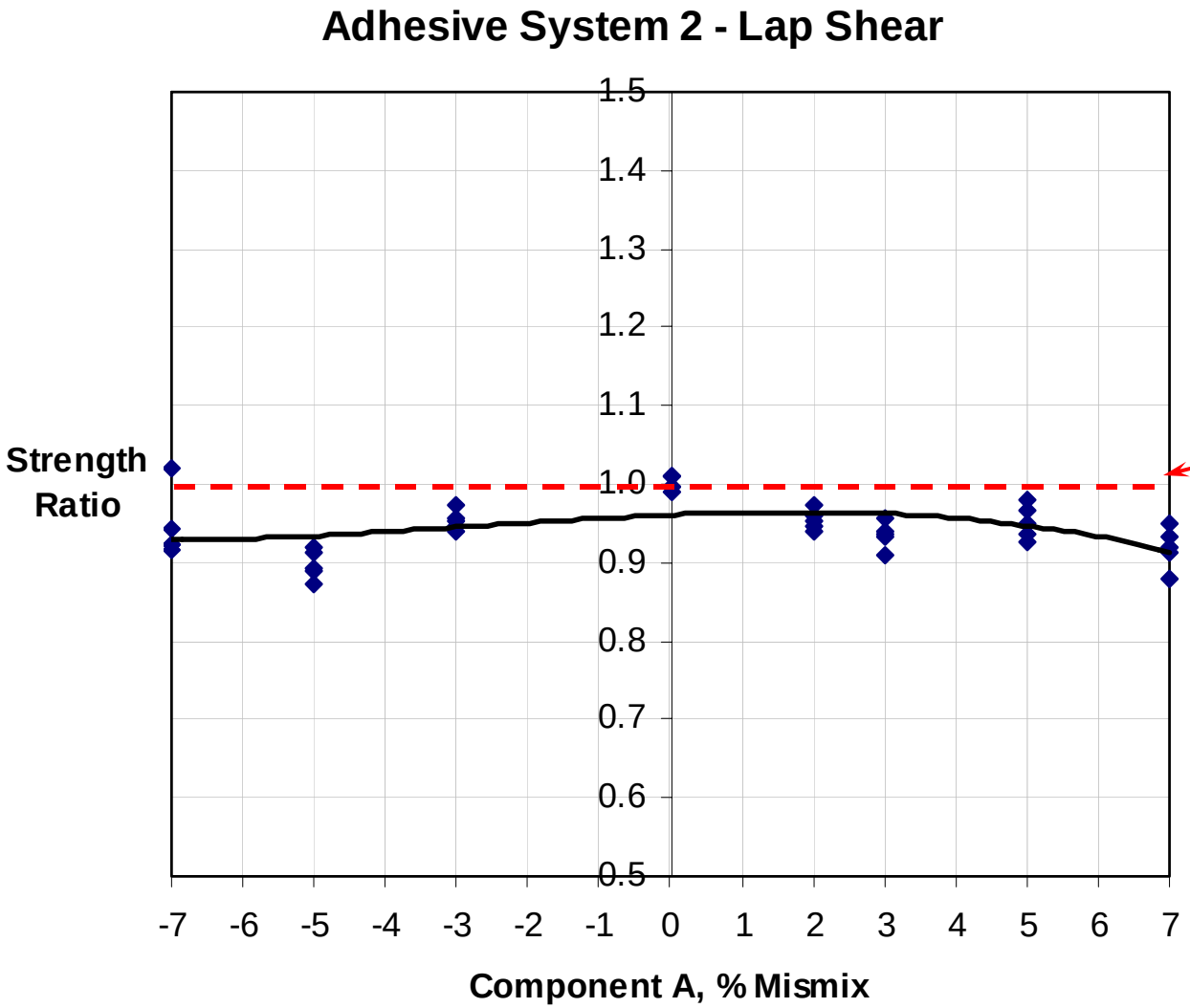

Higher than nominal mix performance is not necessarily "better".

**Nominal Mix**

Component A: Base Epoxy

Component B: Curing Agent

# Example 1b: Mixing Mis-match (Lap Shear)

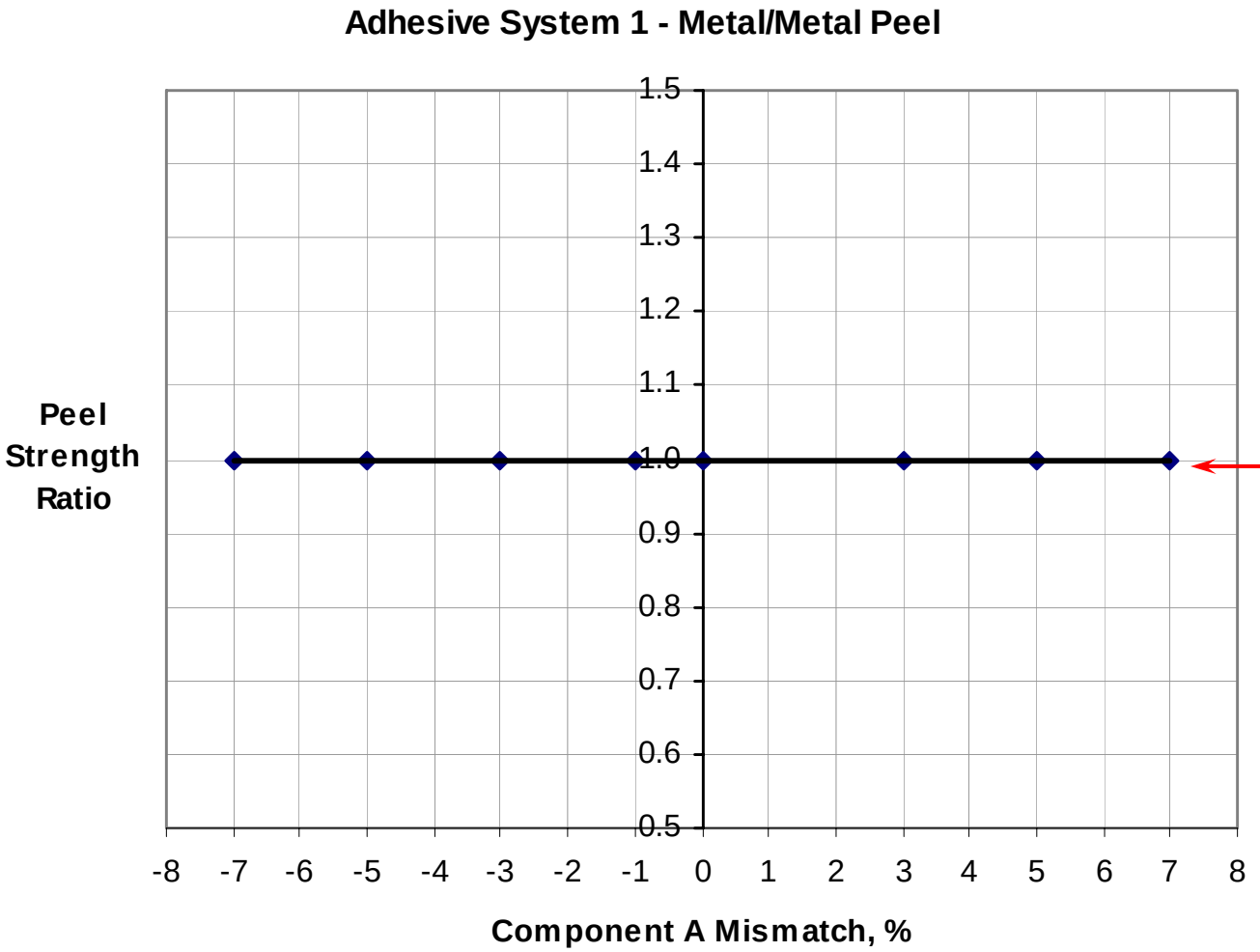



Component A: Base Epoxy

Component B: Curing Agent

**Nominal Mix**

# Example 1c: Mixing Mis-match (Peel)

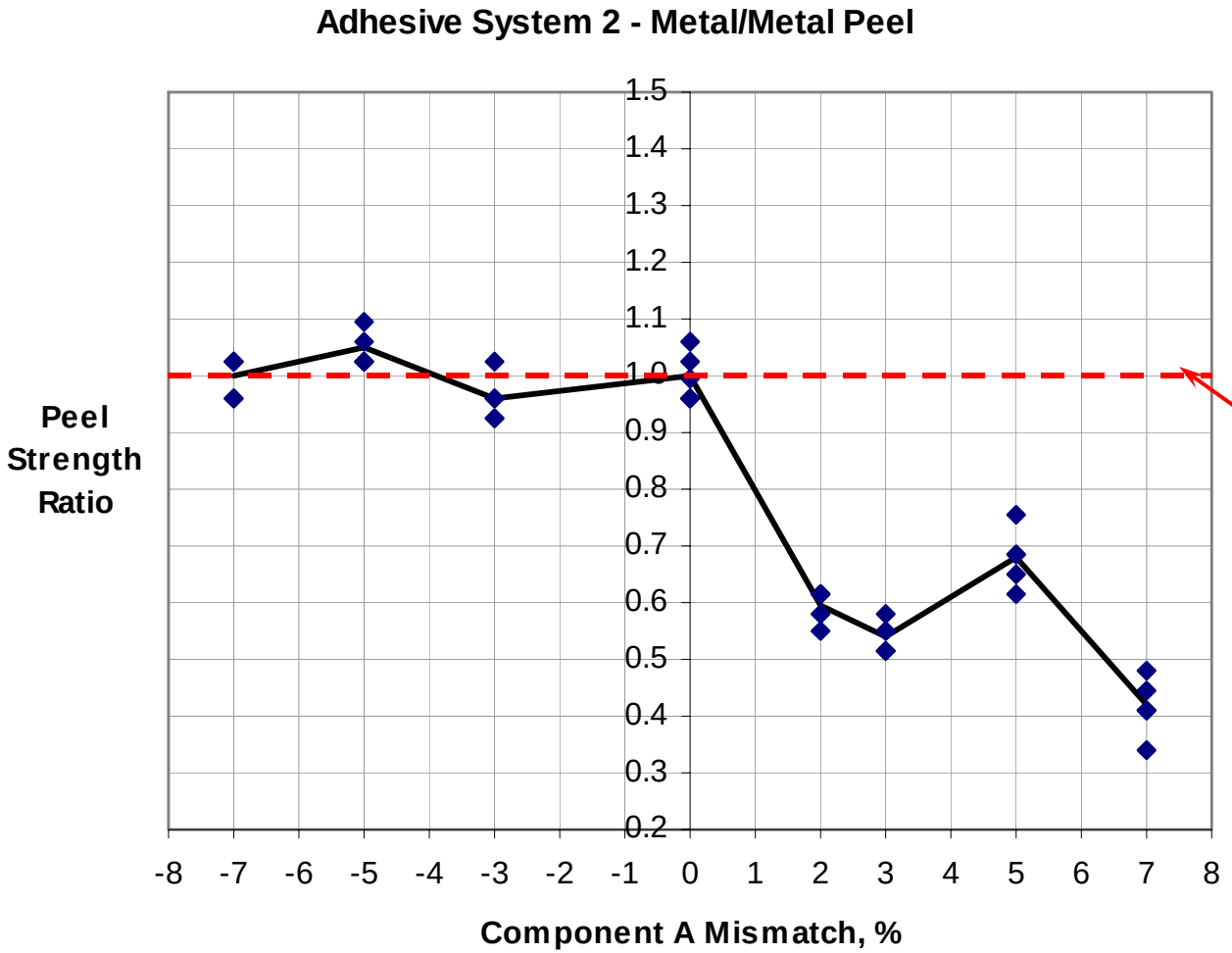



Component A: Base Epoxy

Component B: Curing Agent

**Nominal Mix**

# Example 1d: Mixing Mis-match (Peel)




Component A: Base Epoxy

Component B: Curing Agent

**Nominal Mix**

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# Mixing Mis-match Conclusions

✓ **Sensitivity to mixing ratio is adhesive system dependent.**

✓ **Sensitivity to mixing ratio should be considered when specifying minimum acceptable amount to mix and capability of weight measuring equipment.**

✓ **Mixing ratio effects should be addressed in training.**

✓**Best solution is to qualify a metered/static mixed kit form when practical.**

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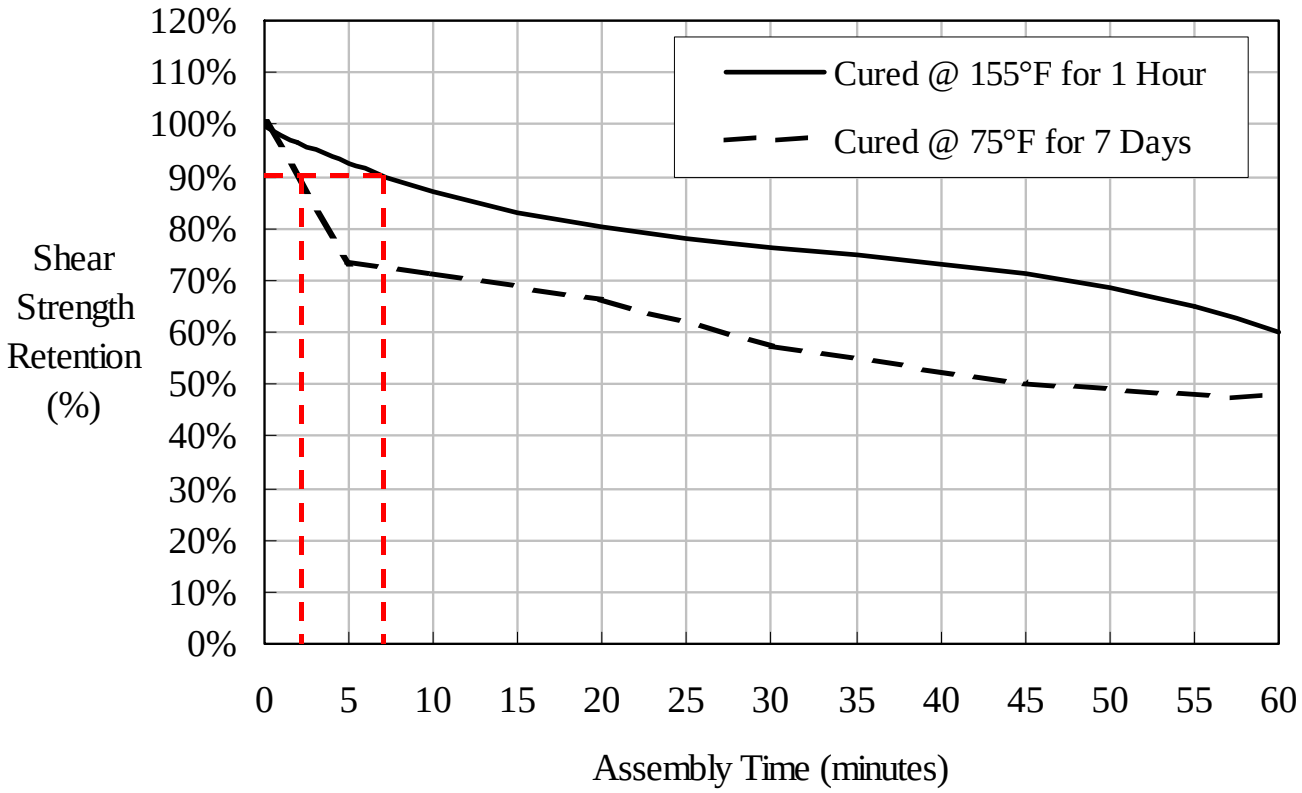
# Example 2a: Bonded Joint Assembly Time




Adhesive System 1

- 2 minute assembly time = 90% strength with 75F cure.
- 7 minute assembly time = 90% strength with 155F cure

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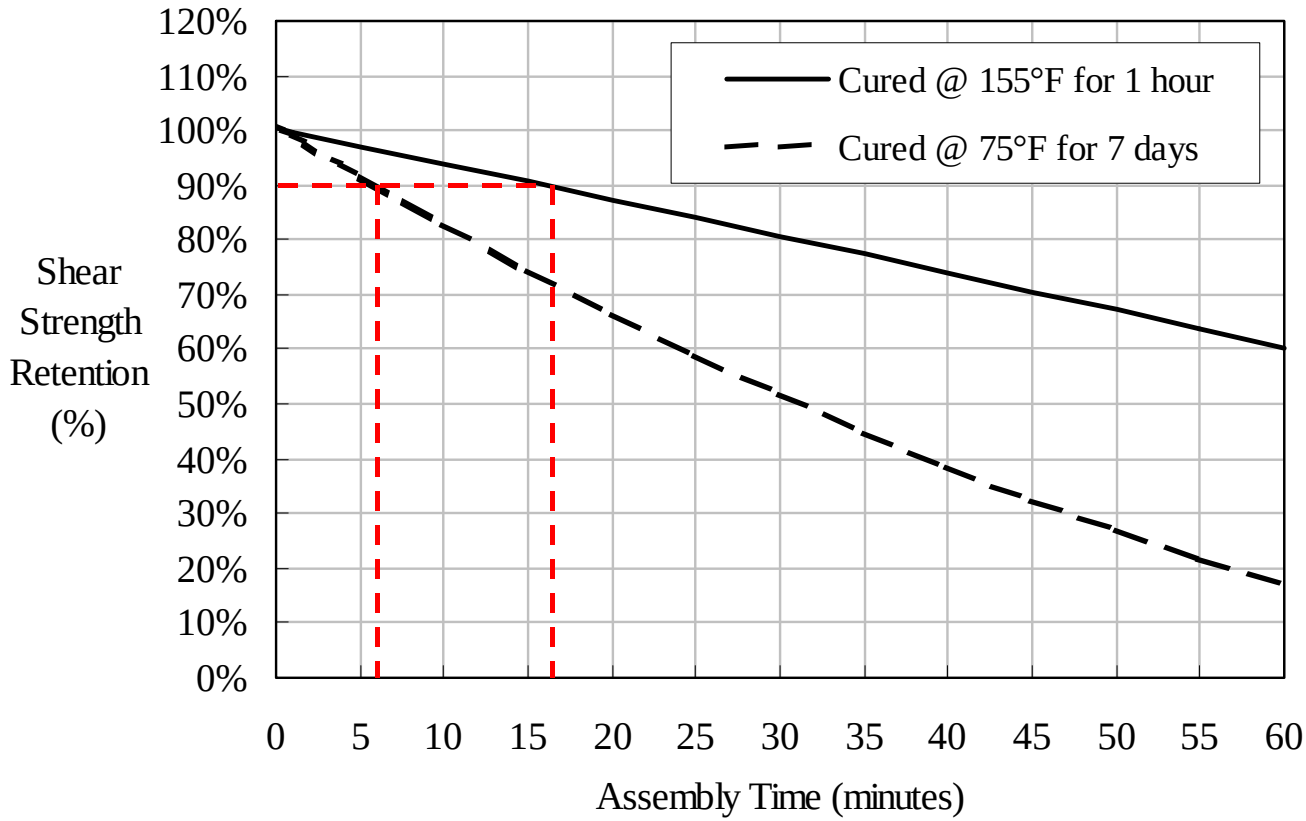
# Example 2b: Bonded Joint Assembly Time




Adhesive System 2

- 6 minute assembly time = 90% strength with 75F cure.
- 16 minute assembly time = 90% strength with 155F cure

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# Assembly Time Conclusions

✓ **Perform enough tests during development to understand assembly time effects.**

✓ **Significance of assembly time effect is adhesive system dependent.**

✓ **Specify elevated temperature cure in production planning when practical to provide maximum assembly time window.**

✓ **Adhesive training program should include focus on assembly time in addition to pot life (working life) of mixed 2-part paste adhesives.**

✓ **Process specification should include upper limit on assembly time when applicable.**

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# Structural Adhesive Bonding

**Biggest lessons learned – Clearly defined processes / Well trained personnel**

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