

Presented by

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Materials and processes

Fluid ingress in rudder sandwich structure

Effect of aggressive fluids on durability

A300-600/A310 and A330/A340 Pre-MOD 8827 / 40904

- Ingression and disbond as observed on one in-service rudder
- Material performance
- Specific test related to event
- Conclusion

Rudder disbond

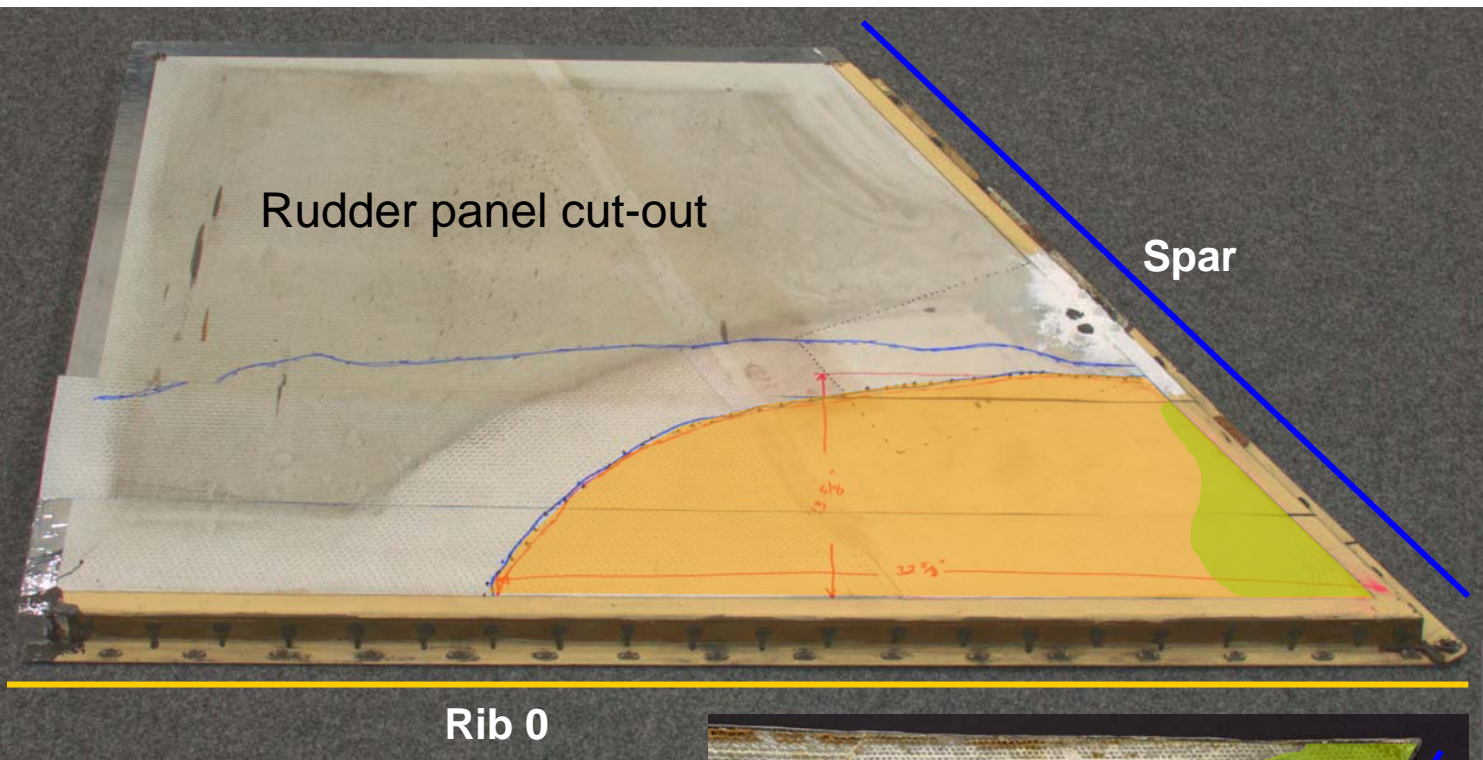
Occurrence

- December 2005
- Lower rib was removed for maintenance
- Inner skin to core disbond was detected

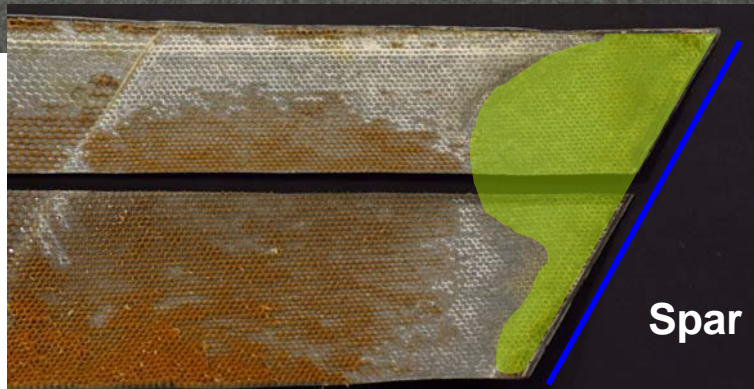


Rudder disbond

Hydraulic fluid contamination at inner face



Inner skin flipped after removal



Content

- Ingression and disbond as observed on one in-service rudder
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Materials applied

- Sandwich rudder skins typically made of
 - ▶ One glass layer as self adhesive prepreg (120 style, 55%)
 - ▶ One or more carbon fibre fabric prepregs (5HS, 370gr/m²)
 - ▶ Inner skin additionally covered with PVA foil
 - ▶ Outer skin surfacing film 150 gr/m²

- ▶ Two different prepreg combinations (A and B) used, each consisting of one glass layer and one or more carbon layers

Qualification requirements

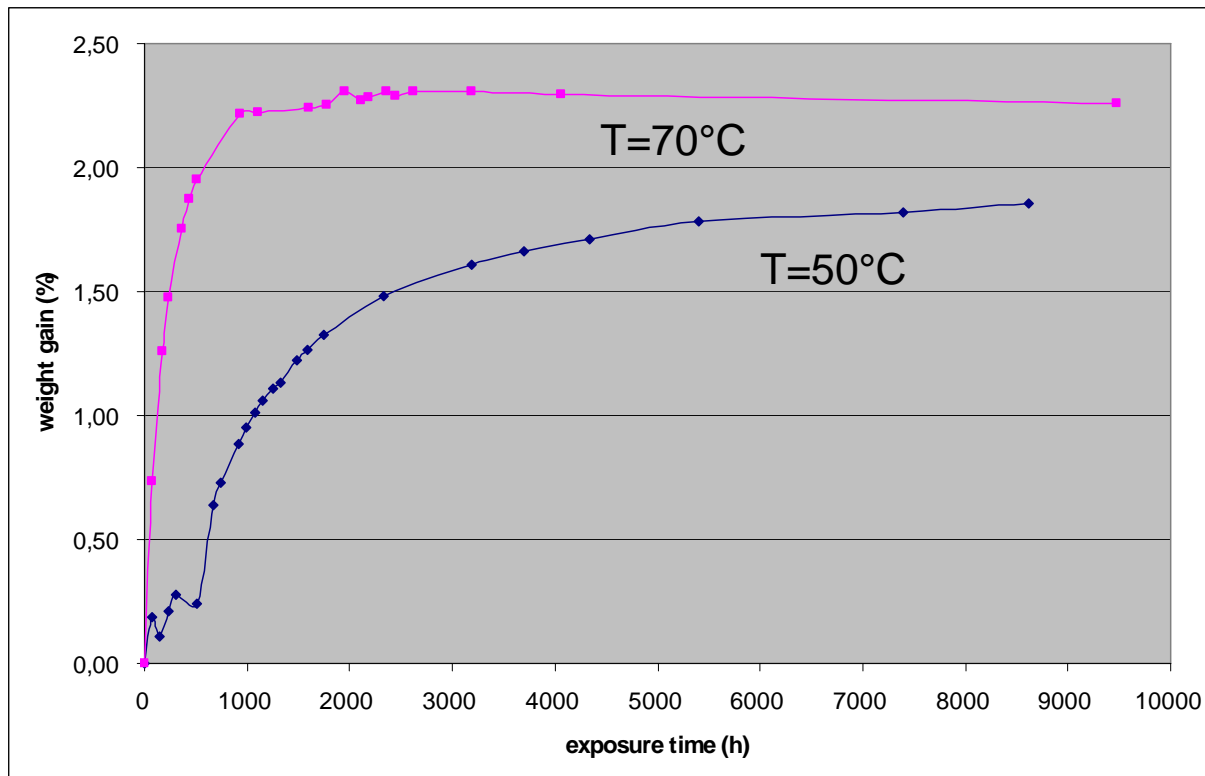
- Immersion tests for structural materials
 - ▶ 70°C, 1000h in Skydrol
 - ▶ 50°C, 1000h in Skydrol / Water
 - ▶ Compare to specimen saturated in 70°C / 85 % rel. hum
 - ▶ Tests performed in gaps on mix Skydrol / Water
- Primary structure materials (eg. carbon used in skin) do pass tests
- Secondary structure materials not tested at above conditions
- In all cases: avoid local Skydrol accumulation => drain + dry

Skydrol in sandwich not covered by existing results

Investigation Target

- Since Skydrol in sandwich not covered by existing results:
 - ▶ Investigation of long term behaviour of entrapped fluids in sandwich structure
 - ▶ For acceleration this was done under extreme conditions
 - Maximum temperature
 - Permanent ingress / exposure

Self Adhesive prepreg A: moisture absorption

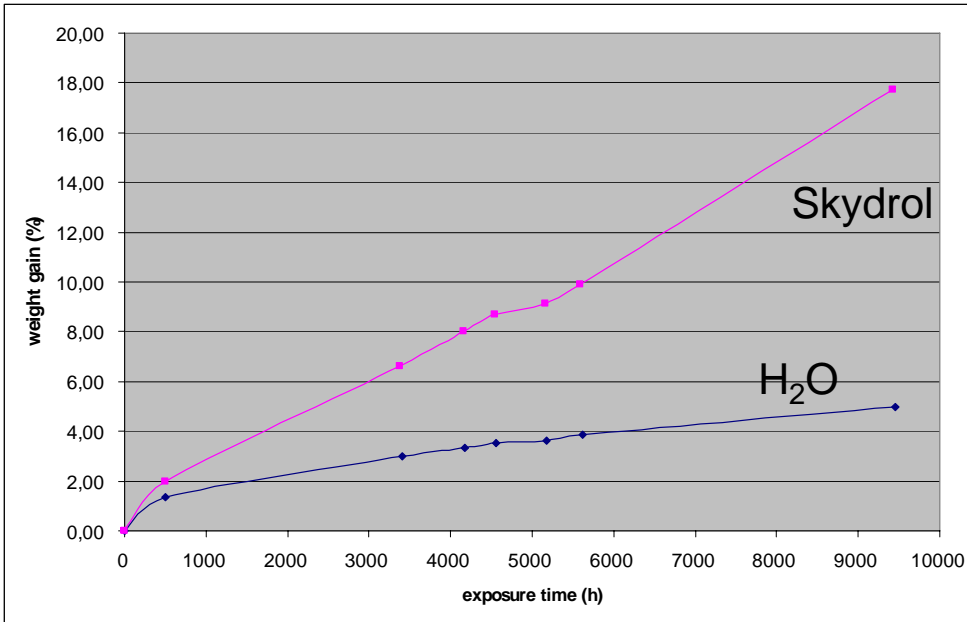


Exposed at
85% rel.H.

- as expected: diffusion rate increases with T
- untypical: different level of moisture gain

Fluid contamination program

Absorption behaviour Self Adhesive prepreg A

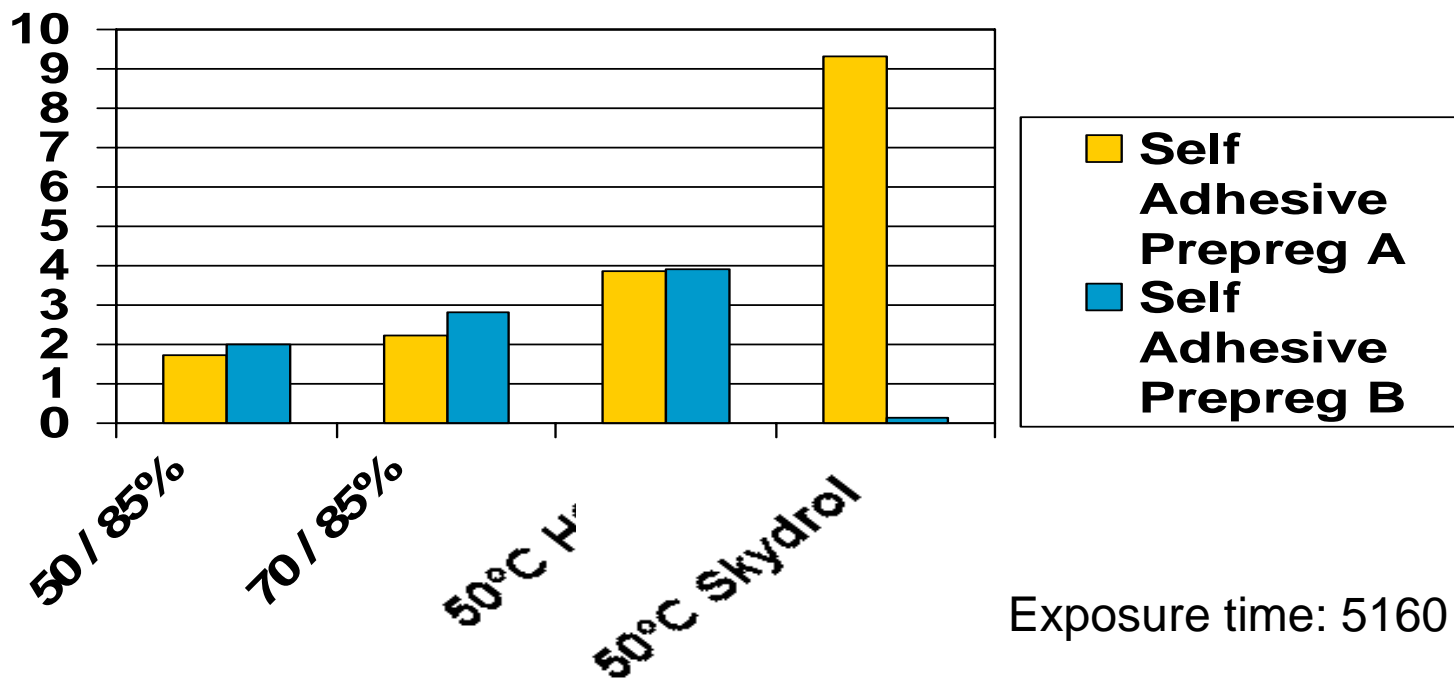


Exposure at T = 50°C

- untypical: no saturation in water
- untypical: resin picks-up Skydrol

Fluid contamination program

Humidity / fluid absorption of self adhesive prepregs



- as expected: both pick-up moisture and water
- untypical: Skydrol pick-up for bonding prepreg A

Fluid contamination program

Tg onset explained

A conservative assessment of temperature capability

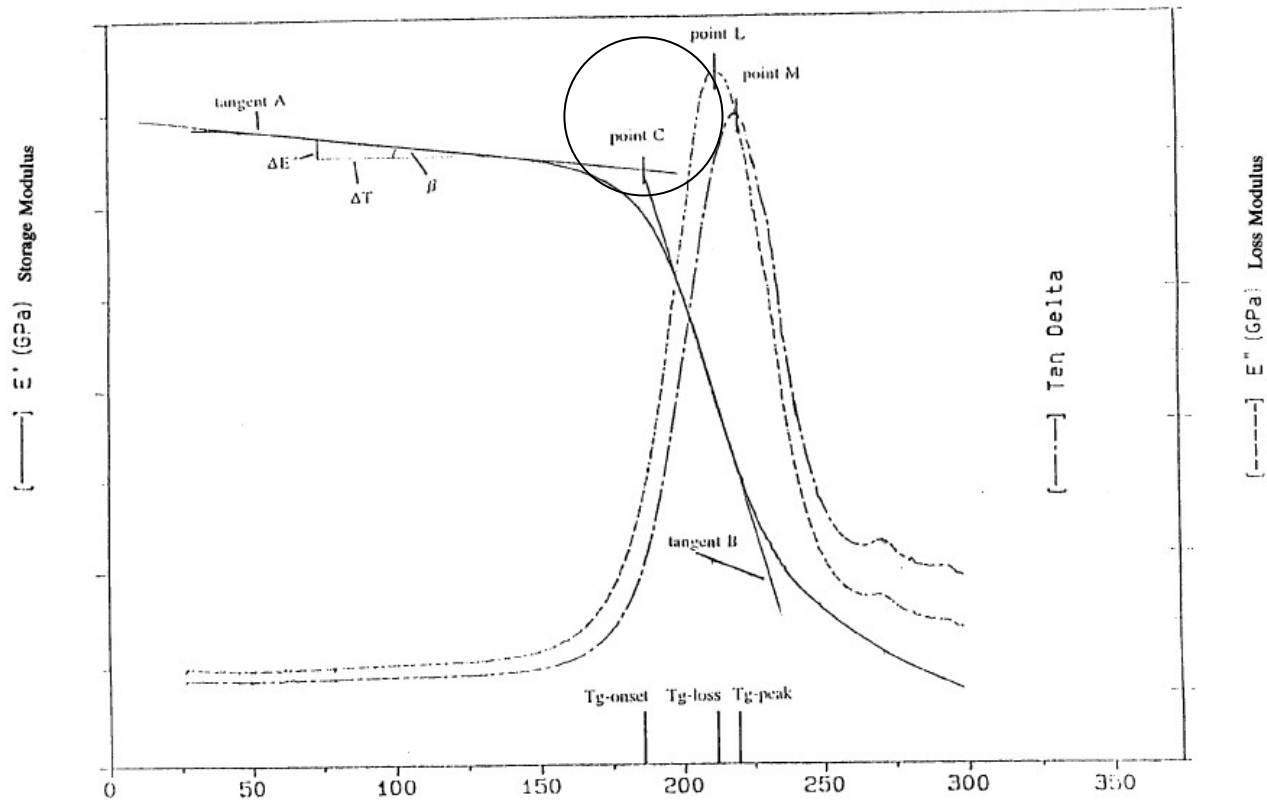
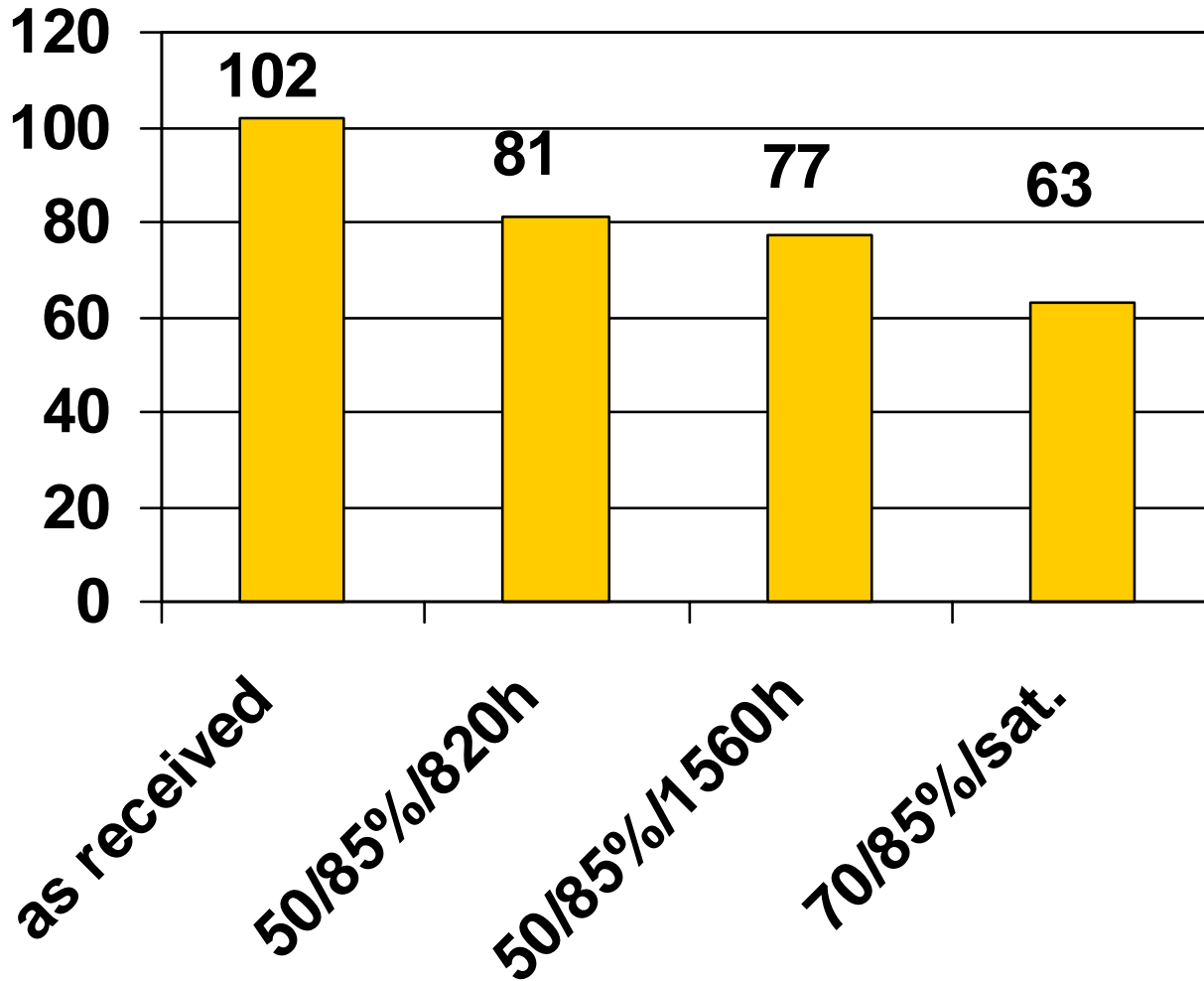


Figure 1

Typical diagram storage modulus, tan delta and loss modulus versus temperature determination of tg-onset, tg-peak, tg-loss and β

Fluid contamination program

Tg onset

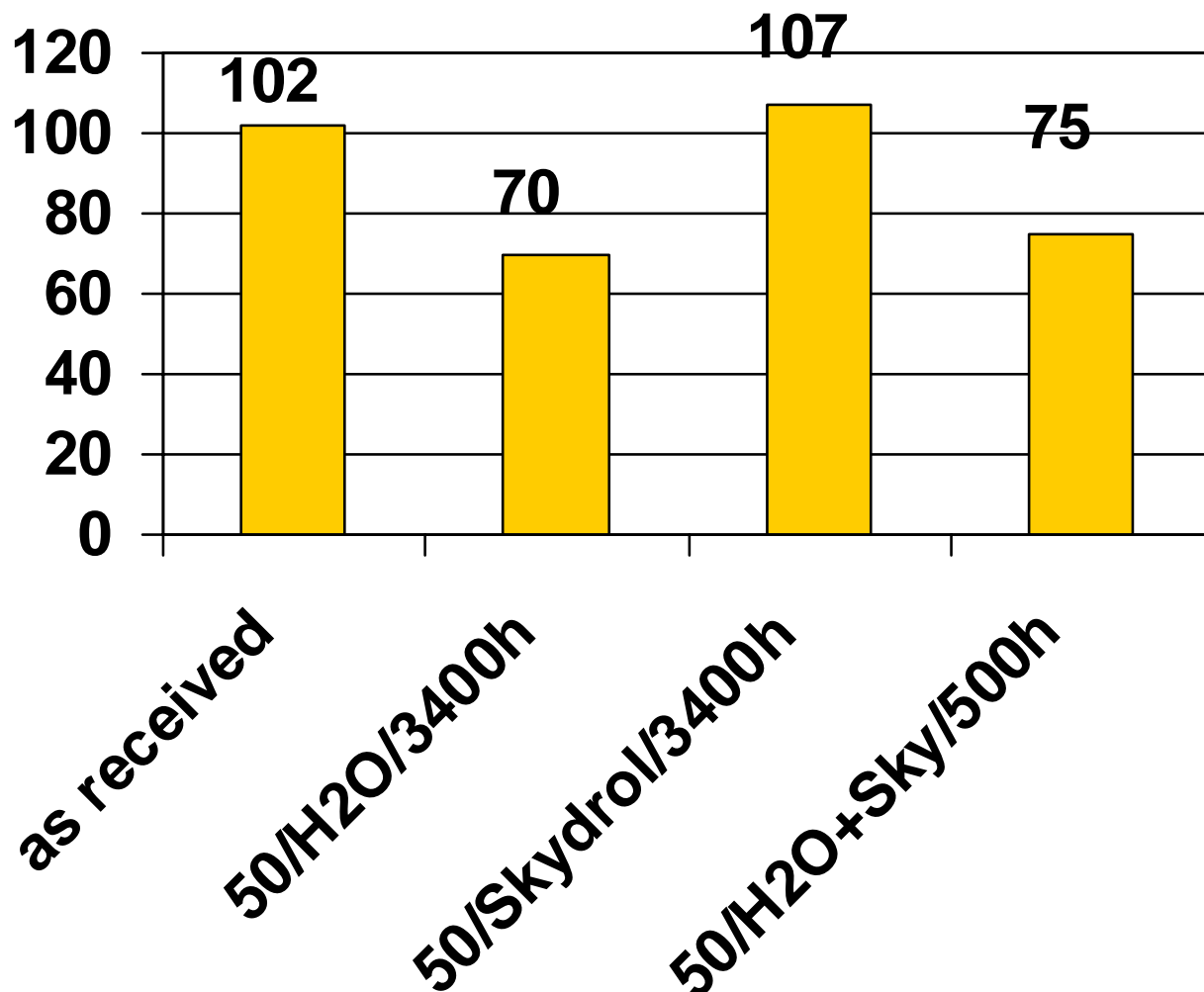


■ Self Adhesive Prepreg A

- Typical behaviour of self-adhesive resins

Fluid contamination program

Tg onset

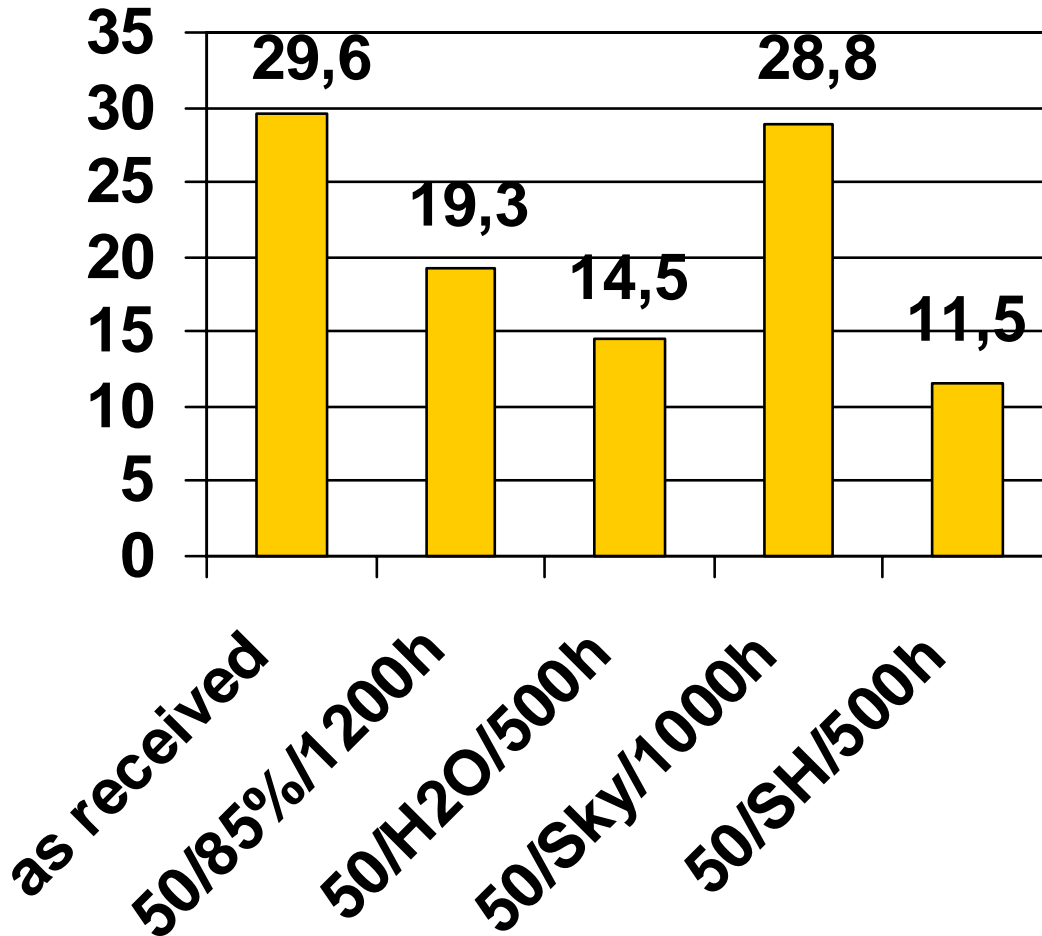


■ Self Adhesive Prepreg A

- Humidity effects
- no effect due to Skydrol (3400 h)
- Skydrol/water affects resin, after 500 disintegration of specimen

Fluid contamination program

Interlaminar shear strength ILSS at 70°C



■ Self Adhesive Prepreg A

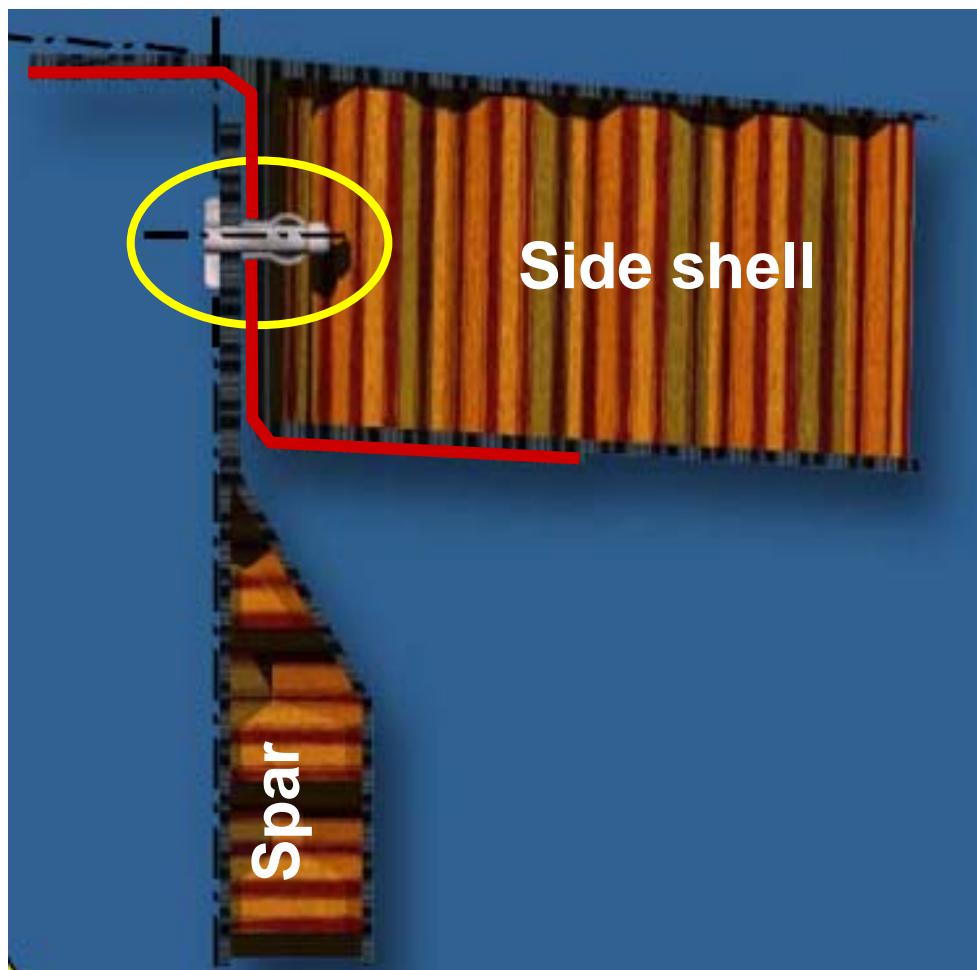
- Humidity effects
- no effect due to Skydrol (1000 h)
- Skydrol/water affects resin, after 500 disintegration of specimen

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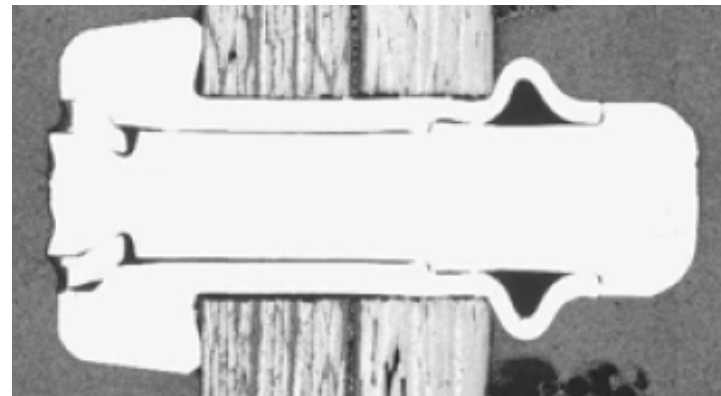
Rudder disbond

Fluid path specific to Z-profile design rudder series

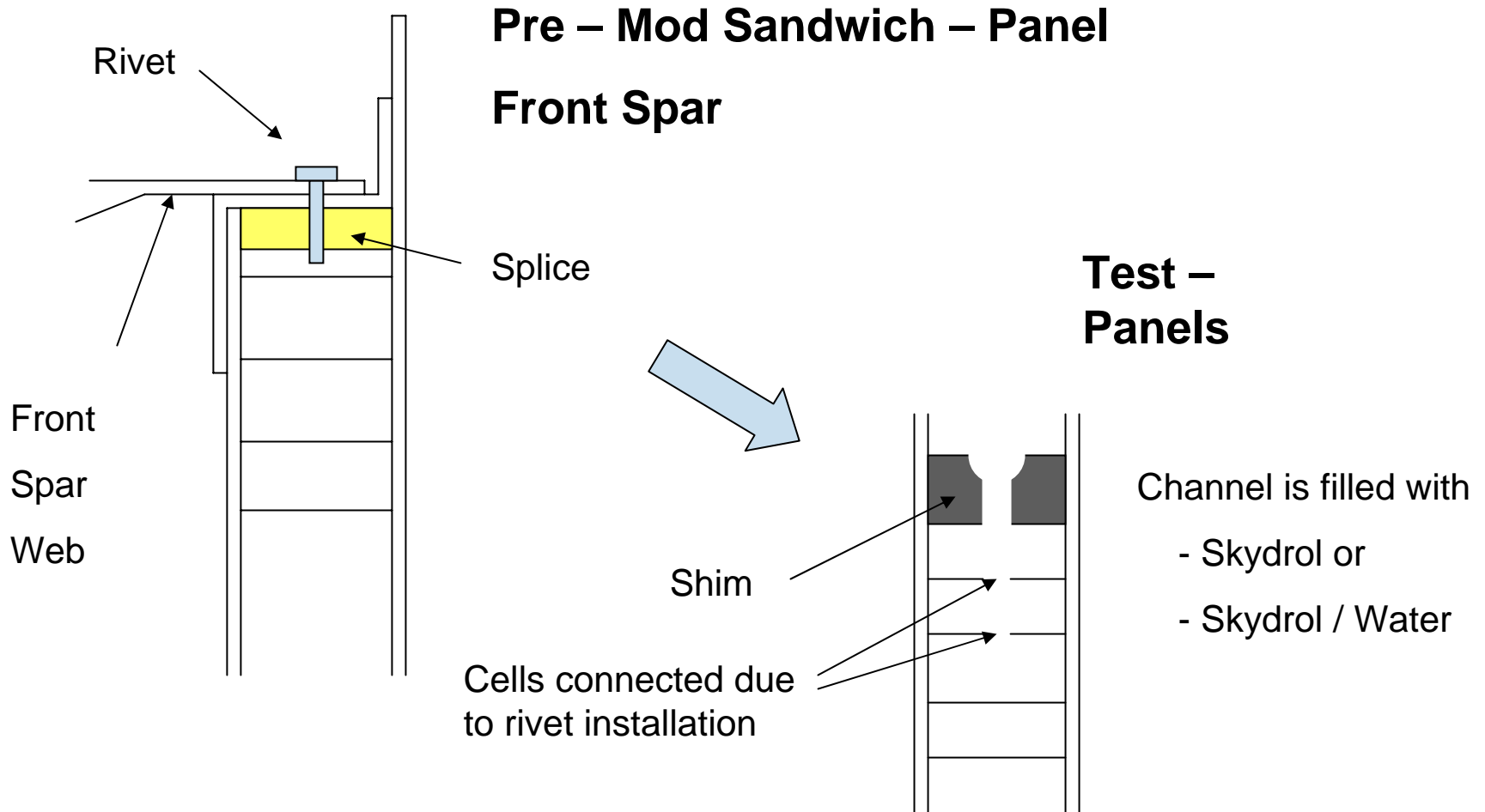


- Blind rivets used for spar to shell connection
- Hydraulic fluid had penetrated past some rivets

Section cut of blind rivet



Specific sandwich test



Specific sandwich test

Chanel with holes filled with Skydrol

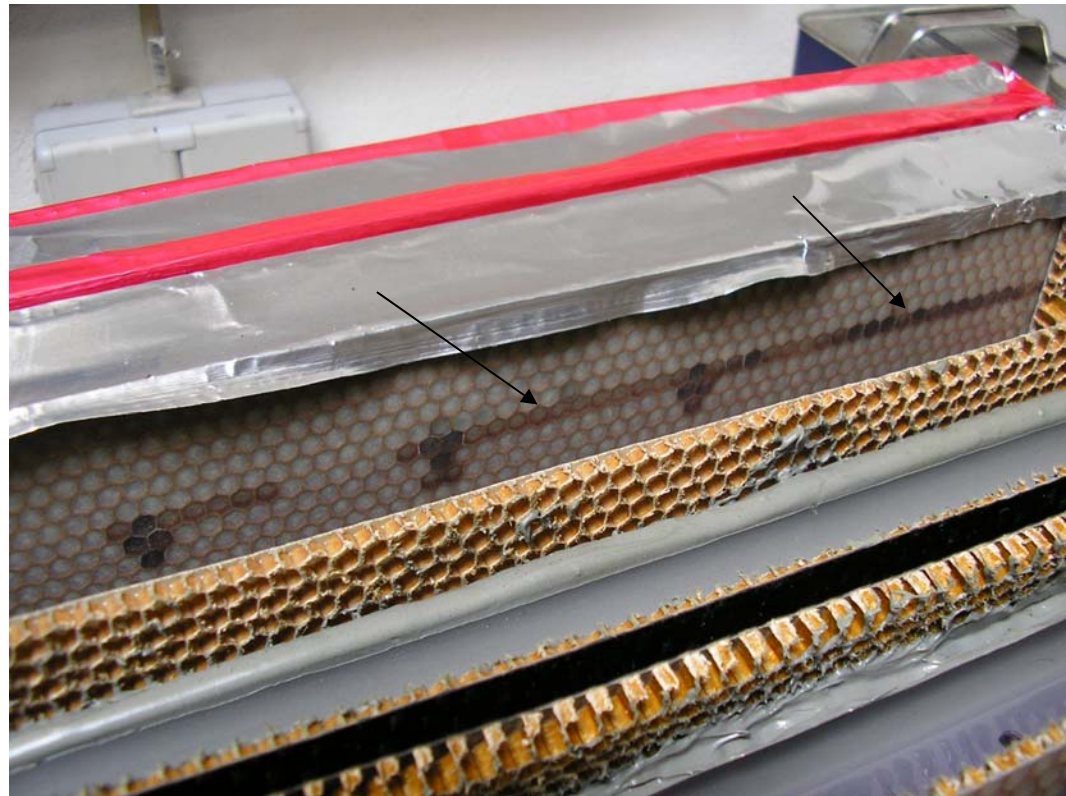


Specific sandwich test

Exposure: 790 h at 50 °C / Water Skydrol Mix

Skin Material: Self Adhesive Prepreg A

- **More liquid at infiltration channel**
- **No further cells filled below holes**



Specific sandwich test

Exposure: 3500 h at 50 °C / Skydrol + Water Mix

Skin Material: Self Adhesive Prepreg A

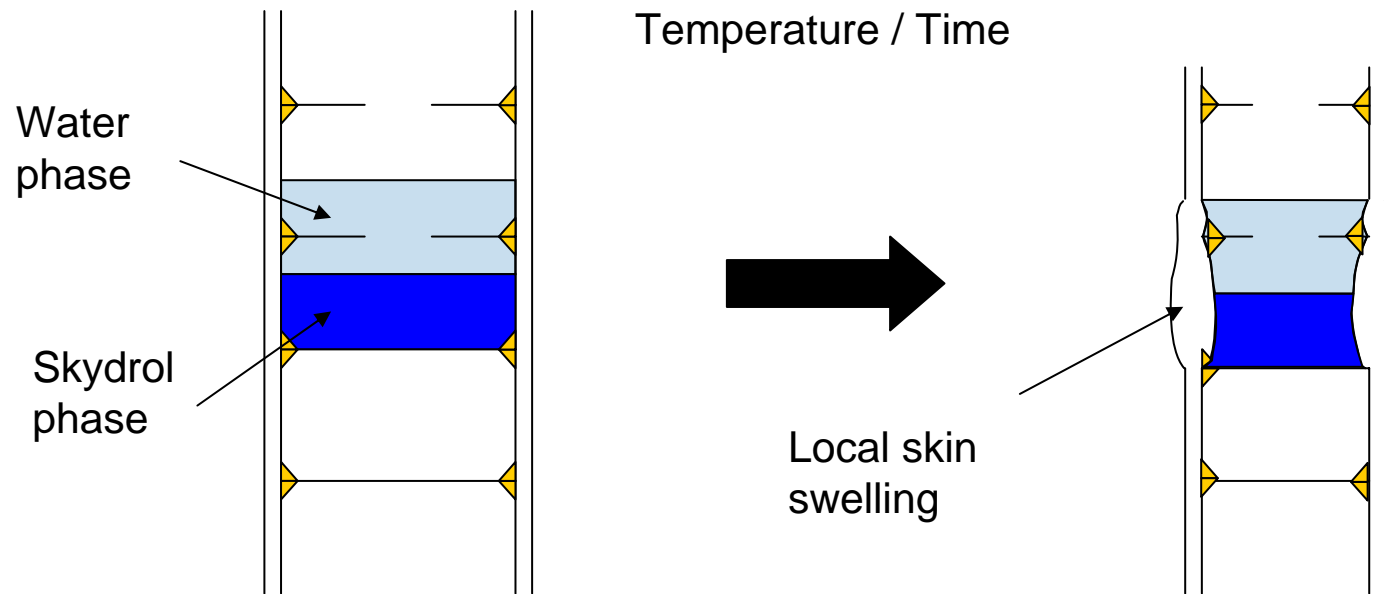
- **More liquid at and one row below infiltration channel, physical connection by gaps**
- **No further cells filled below holes**



Specific sandwich test

Swelling effect

- Absorption of Water and / or Skydrol



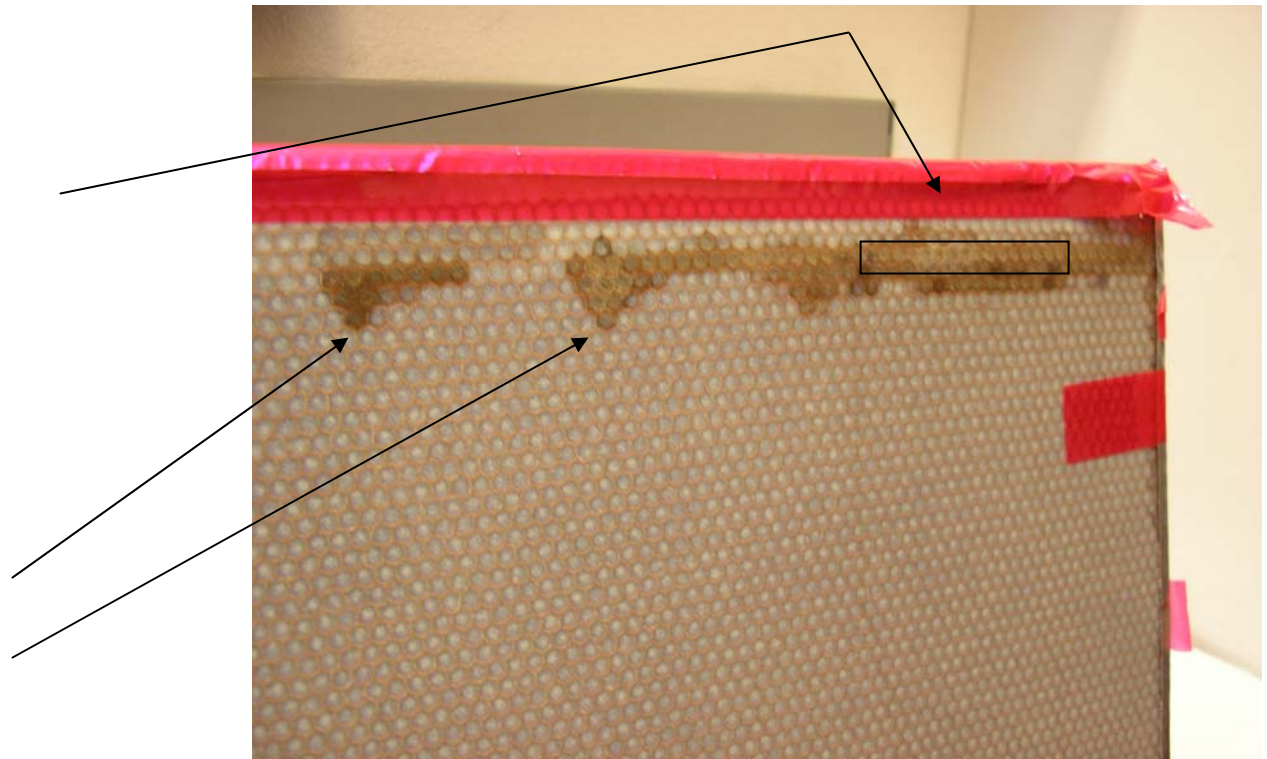
Specific sandwich test

Exposure: 3750 h at 50 °C / Skydrol + Water Mix

Skin Material: Self Adhesive Prepreg A

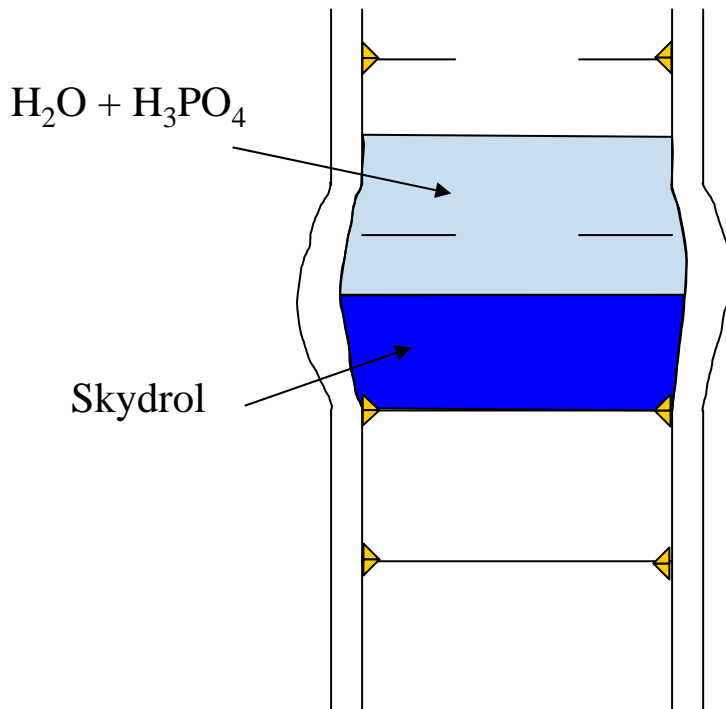
- **Local Skin Debonding**

- **No Vertical Propagation**



Specific sandwich test

- **Local Skin Debonding**



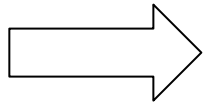
- In a cell filled with emulsified water and Skydrol the two phases will separate immediately.
- Phosphoric acid develops start under specific climatic conditions only:
 - $T = 40^{\circ}C$ for more than
 - $t = 14$ days
- The phosphoric acid will be dissolved in the water phase
- Fillets are be damaged in water / phosphoric acid

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Conclusion

- Self Adhesive Prepreg A exhibits “untypical” behaviour
 - ▶ Skydrol gain
 - ▶ No saturation at water exposure
- Use of Self Adhesive Prepreg A was never intended for such an extreme environment
- But: Very limited “self propagation” of disbond even at extreme conditions and long time exposure



Investigation supported the conclusion that disbond occurred first at observed damage

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