CACRC AE-27 Guidebook: Design of Durable Aircraft Composites: Problems with Sandwich Structure

Eric Chesmar, United Airlines

UNITED

17 May 2011

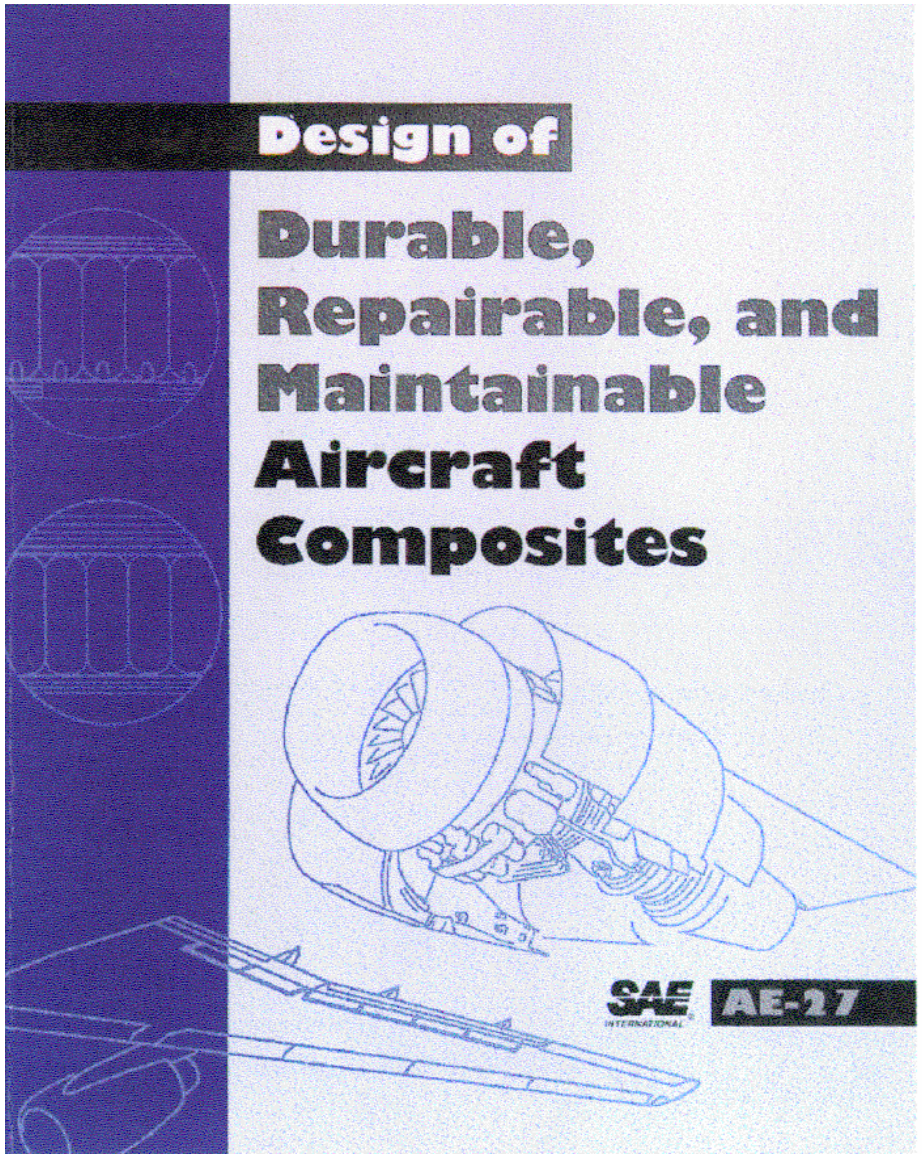
AE-27: Design of Durable, Repairable and Maintainable Aircraft Composites

Audience:

• OEM and subcontractor designers to in-service repair issues and problem design details.

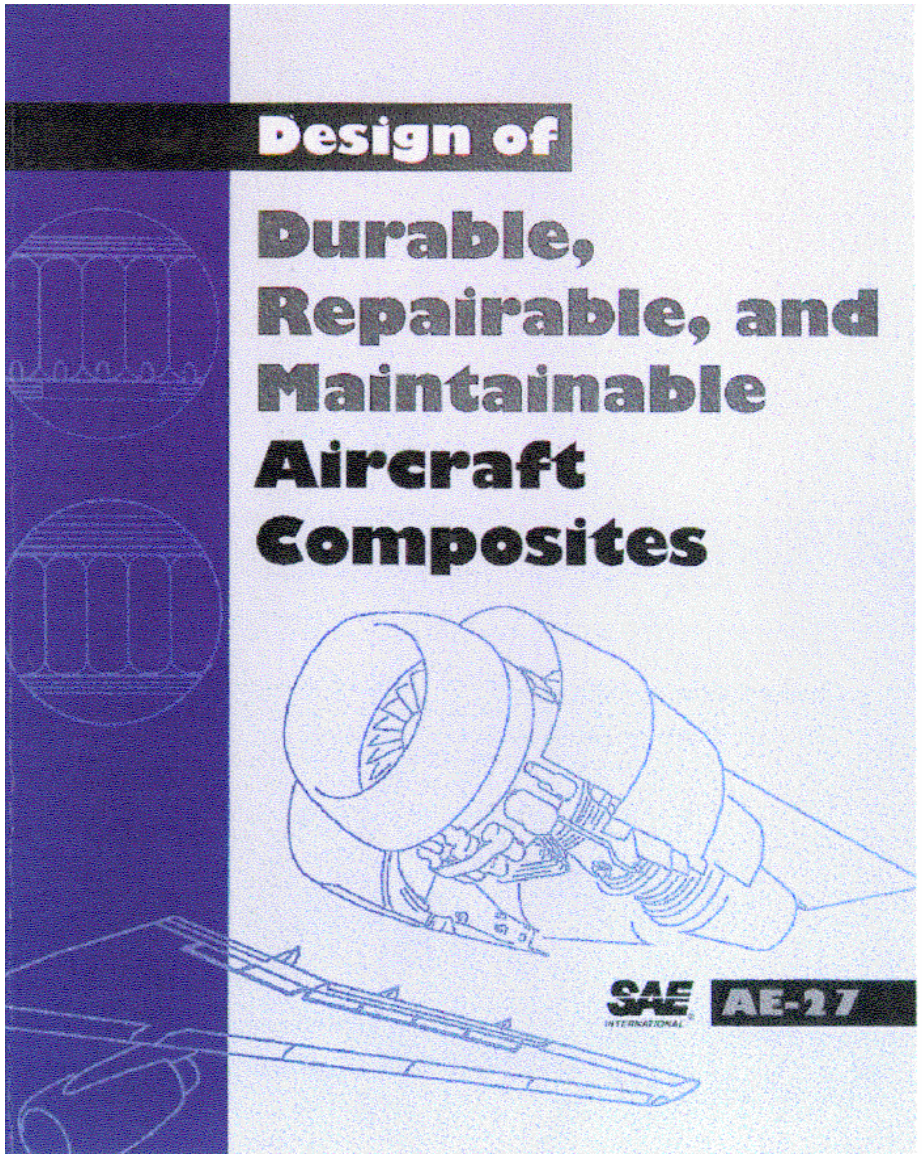
Contents:

- Current design deficiencies of composites as seen in-service.
- Overview of materials and processes
- Examples of poor design detail with examples of preferred alternatives
- Design case studies - presenting a discussion on selected problems, successful design case studies.
- Available from SAE.org for $80.



AE-27: Design of Durable, Repairable and Maintainable Aircraft Composites

- Written by CACRC Design task group, consisting of 9 airlines members and 8 OEMs members
- Content based on survey of over 15 airlines
- Implementation by outreach to designers at OEMs. Presentations by Design Task Group available upon request.
- Goal to incorporate these lessons learned into company design guidelines
- Success will be measured by not repeating mistakes of the past



AE-27: Design of Durable, Repairable and Maintainable Aircraft Composites

Airline survey:

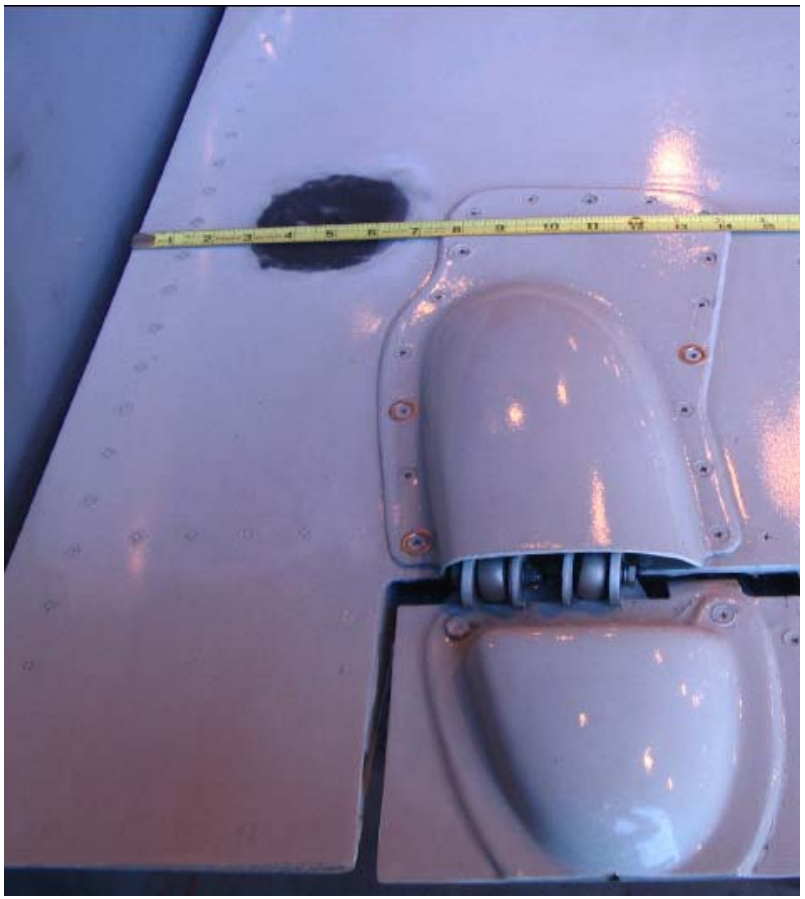
"What are top concerns with composites?"

- **Durability & Impact Resistance**
- **Fluid Ingression**
- **Erosion**
- **Overheating**
- **Protective Finish (Paint)**
- Complicated Repairs & Inspection Requirements
  - My interpretation of "complicated" =
    - Non-standardized, different repairs
    - Multiple people and skills required
    - Intermediate approvals or engineering needed

AE-27: Design of Durable, Repairable and Maintainable Aircraft Composites: Sandwich Designs

Impact Resistance:

- FOD
- Ground / Maintenance
  - Service vehicles
  - Service stands
  - Tools
    - Drop
    - Improper use
- Normal line maintenance
  - Opening
  - Latching
  - Over-opening
- Hail



Elevator skin puncture in critical area

AE-27: Design of Durable, Repairable and Maintainable Aircraft Composites: Sandwich Designs

Impact Resistance - Hail:

- Design considerations
  - Minimum skin gauge
  - Minimum honeycomb density
  - Skins less than minimum should not be in critical areas, and should have large allowable limits.
    - Repair must be considered during design
  - Avoid thin skins in zones that are critical, or have no allowable damage, or not deferrable.
- SRM needs to be updated to address:
  - Crushed core – “soft” but passes tap test
  - Remove paint to evaluate damage
  - Seal against skin matrix micro-cracking

Hail damage to paint

Hail damage to 3-ply graphite/honeycomb sandwich

AE-27: Design of Durable, Repairable and Maintainable Aircraft Composites: Sandwich Designs

Impact Resistance – Hail:

Evaluation, Allowable damage and repairability:

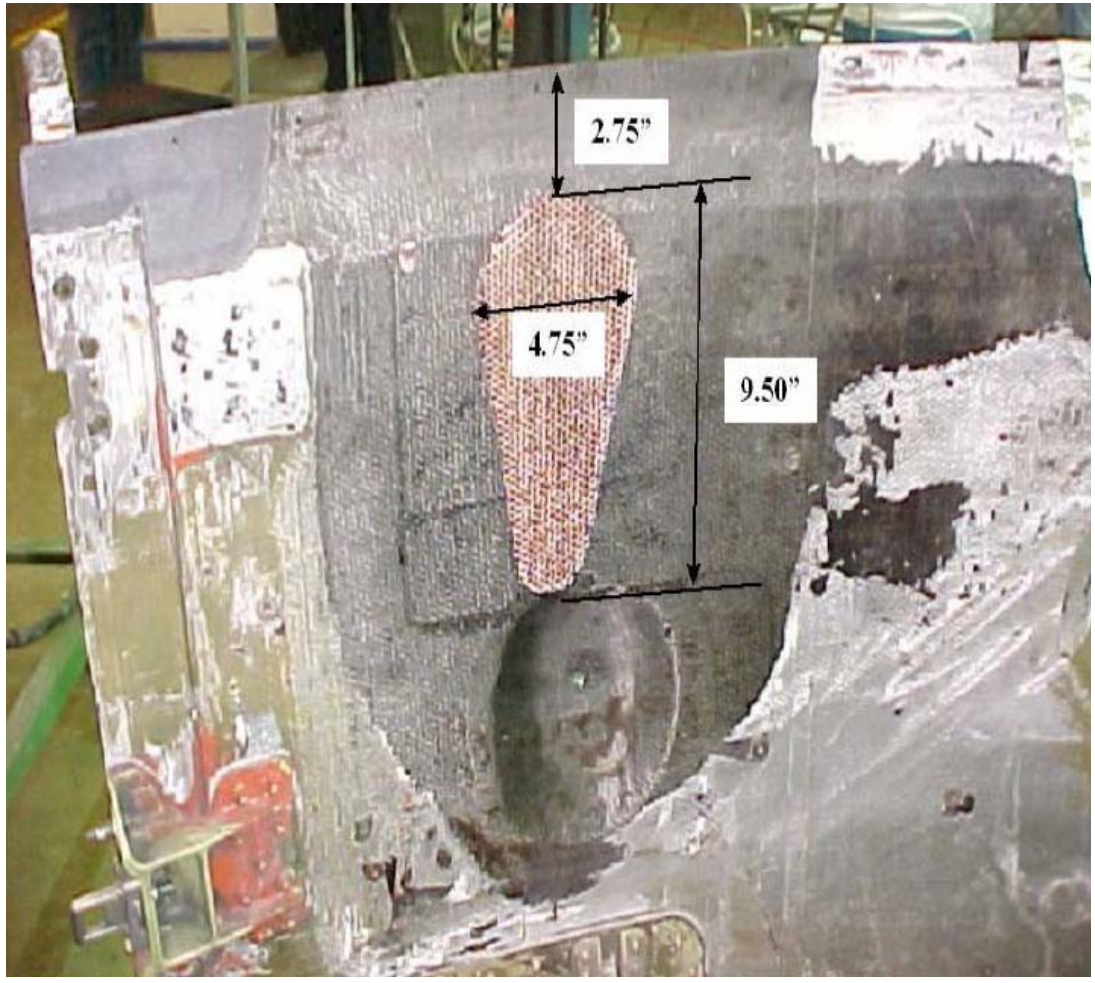
- Requires significant time just to evaluate. Consider there may only be cracked or delaminated paint.
- If beyond or not covered SRM, to get approval from OEM, the evaluations must be transferred to maps. Time increases ten-fold.

Outboard Elevator after hail

AE-27: Design of Durable, Repairable and Maintainable Aircraft Composites: Sandwich Designs

Fluid Ingression:

- Hydraulic fluid
  - Fluid leaks are not unusual from many hydraulic system components
  - Difficult if not impossible to remove from damaged parts
  - Protect panels that are below hydraulic components that will leak, such as Belly Fairings and Fan Cowls.



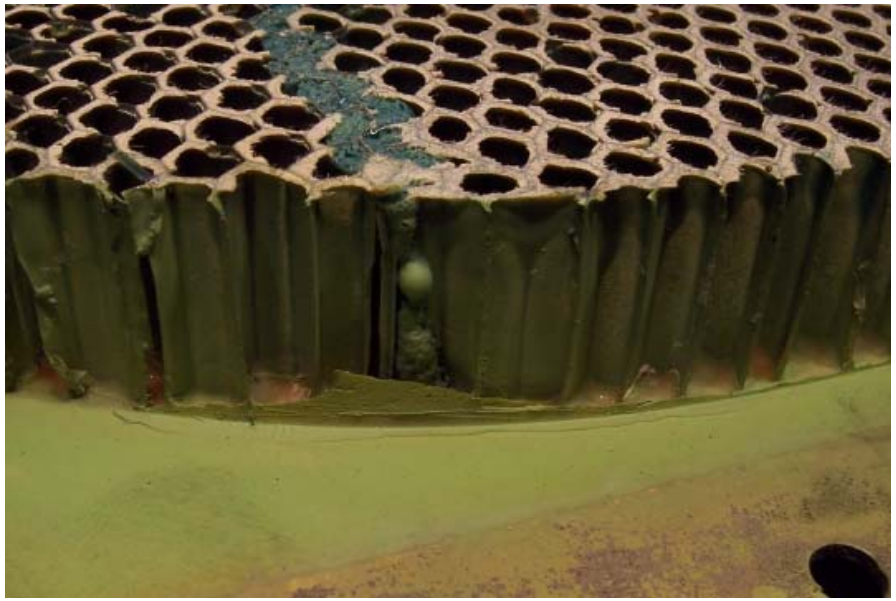
Fan Cowl

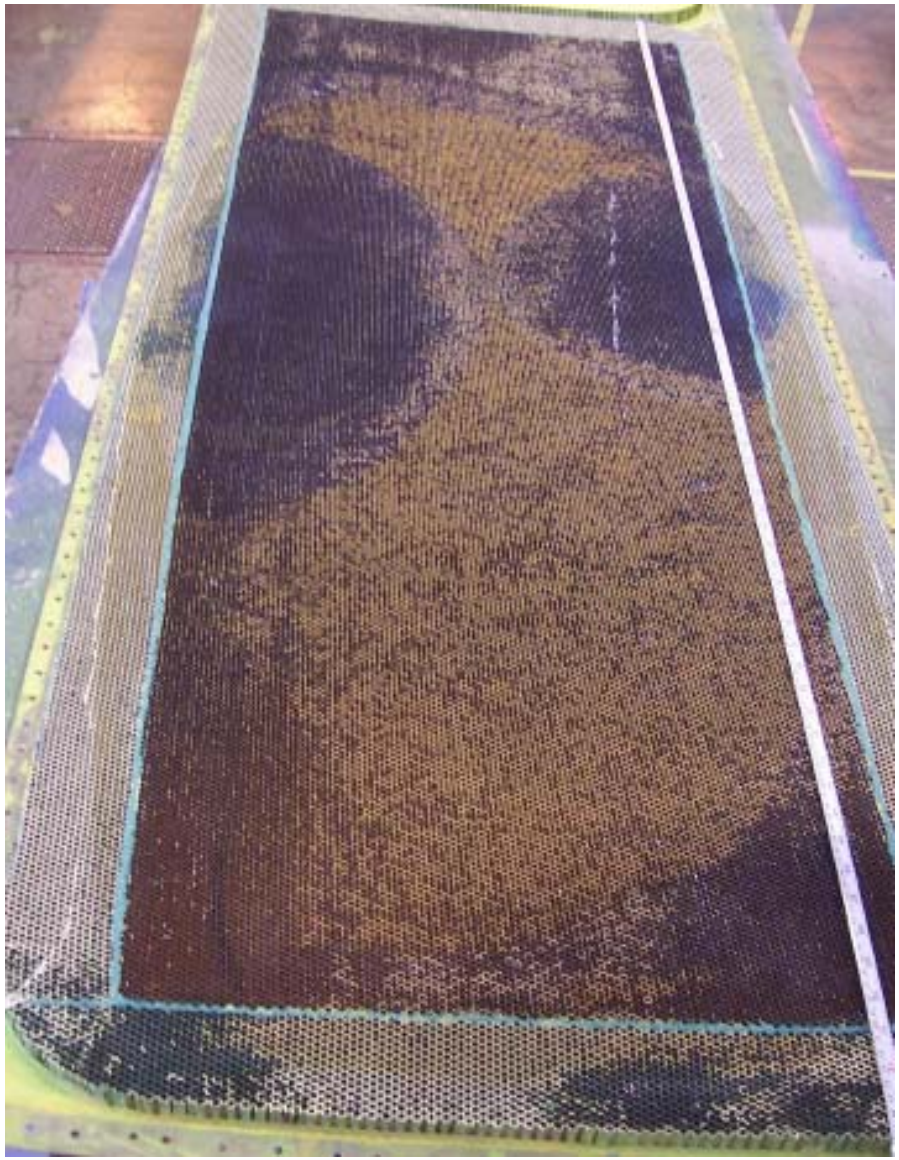
UNITED

AE-27: Design of Durable, Repairable and Maintainable Aircraft Composites: Sandwich Designs

Fluid Ingression:

- Square-edged panel close-out
  - Porous Foaming adhesive
  - Film adhesive bondline
  - Alum honeycomb edges painted with primer
  - Alum honeycomb corrodes





AE-27: Design of Durable, Repairable and Maintainable Aircraft Composites: Sandwich Designs

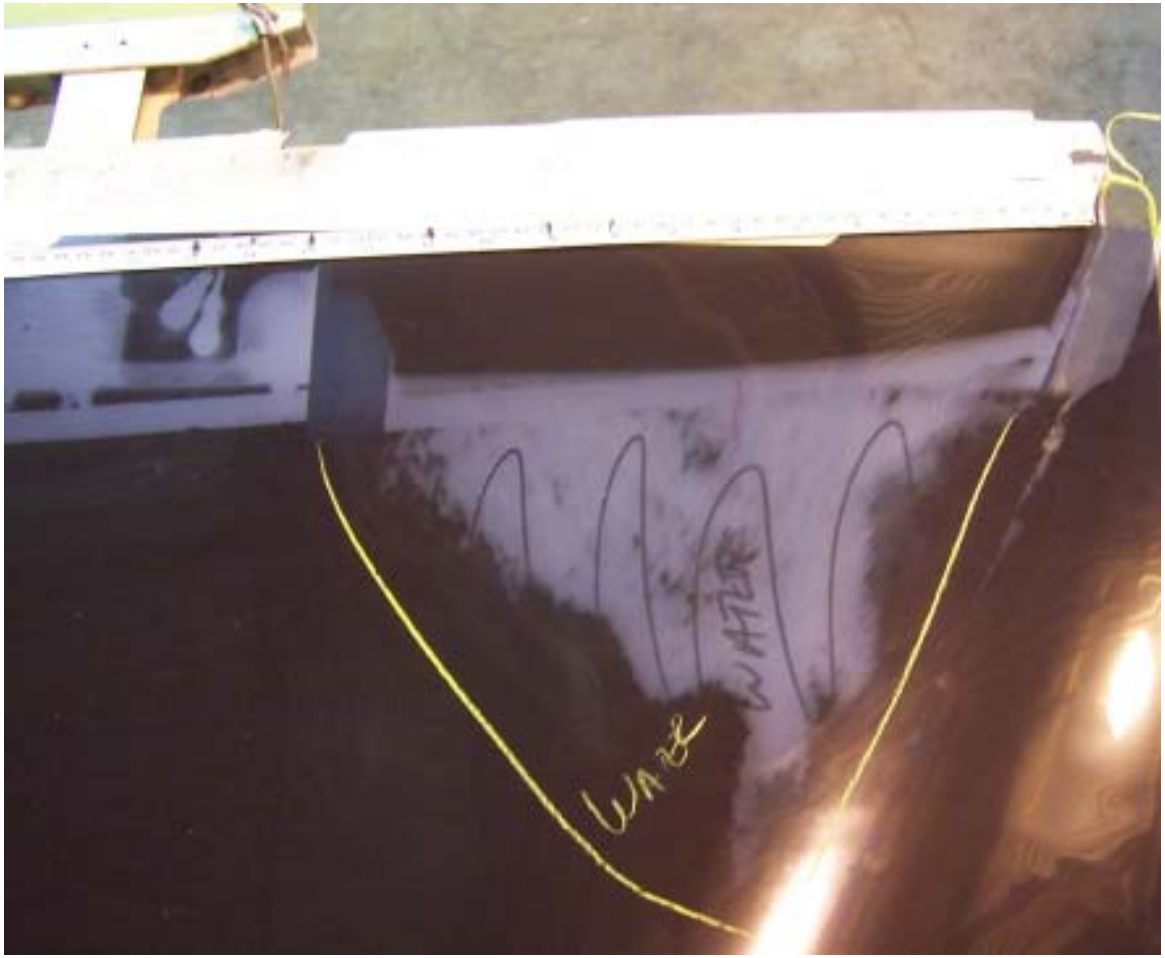
Fluid Ingression:

- Close-out of trailing edge wedges – aluminum metalbond
  - Ingress through square edge close out and bondline
  - Propagation via foaming adhesive
  - Failure mode is corrosion of aluminum honeycomb

AE-27: Design of Durable, Repairable and Maintainable Aircraft Composites: Sandwich Designs

Fluid Ingression:

- Close-out of trailing edge wedges
  - Square-edged panel close-out without skin covering.
  - Phenolic sheet bonded to honeycomb.
  - Sealant breaks down over time or sheet is deformed.
  - Foaming adhesive allows propagation



X-ray of outboard end of Aileron showing extent of water ingression into honeycomb

UNITED

AE-27: Design of Durable, Repairable and Maintainable Aircraft Composites: Sandwich Designs

Fluid Ingression - Close-out of trailing edge wedges:.

- Original design is a thin sheet bonded with sealant to honeycomb.
- Potting alone on end will crack with age and flexing.
- Alternative – Pot honeycomb and wrap skins.

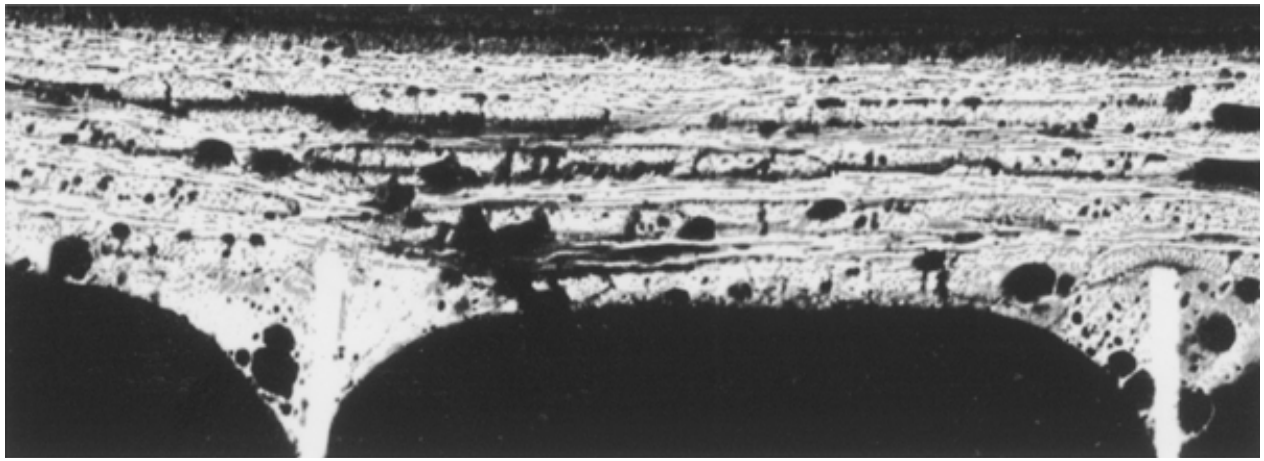
Removed sheet that was covering outboard end.

Outboard end showing crushed honeycomb.

AE-27: Design of Durable, Repairable and Maintainable Aircraft Composites: Sandwich Designs

Fluid Ingression:

- Through skins –
  - Porosity from cure
  - Fracturing of skins and delamination after impact
  - Micro-cracking of matrix



Photomicrograph of impacted skin 3 plies 7781/epoxy prepreg, co-cured in autoclave to honeycomb

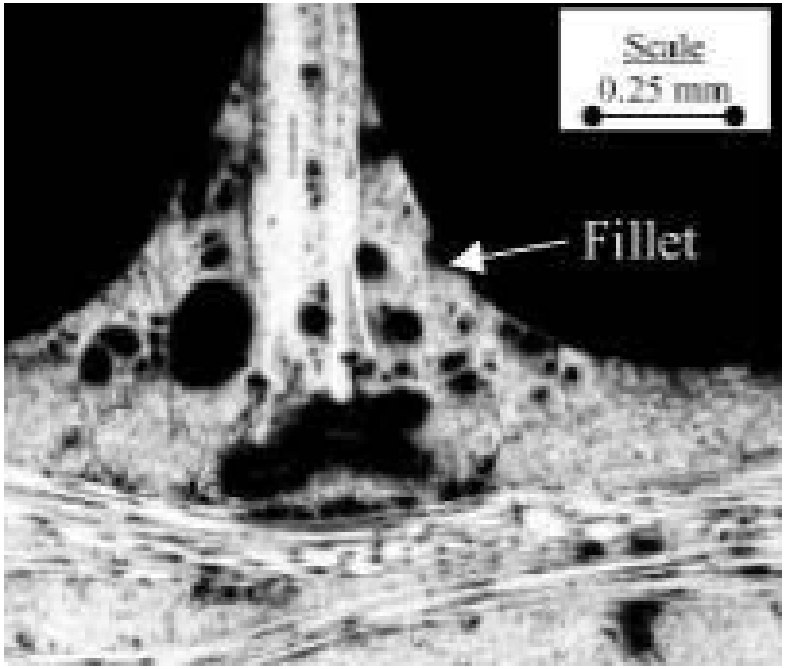
AE-27: Design of Durable, Repairable and Maintainable Aircraft Composites: Sandwich Designs

Fluid Ingression:

Water progression/propagation

- Through film adhesive
  - Over cell walls
  - Porosity

- Through cell walls
  - Porous to water vapor



Photomicrograph of film adhesive fillet after autoclave cure

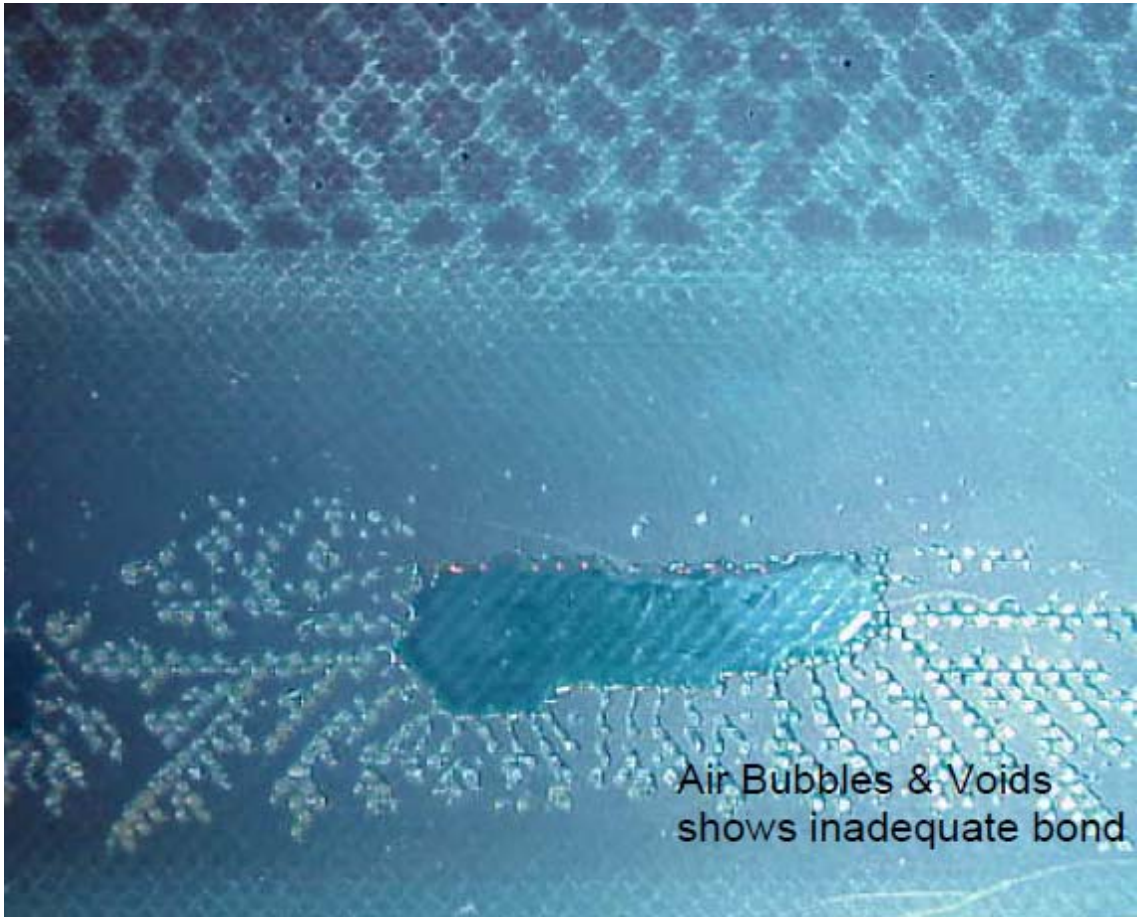
UNITED

AE-27: Design of Durable, Repairable and Maintainable Aircraft Composites: Sandwich Designs

Fluid Ingression:

Water progression/propagation (continued)

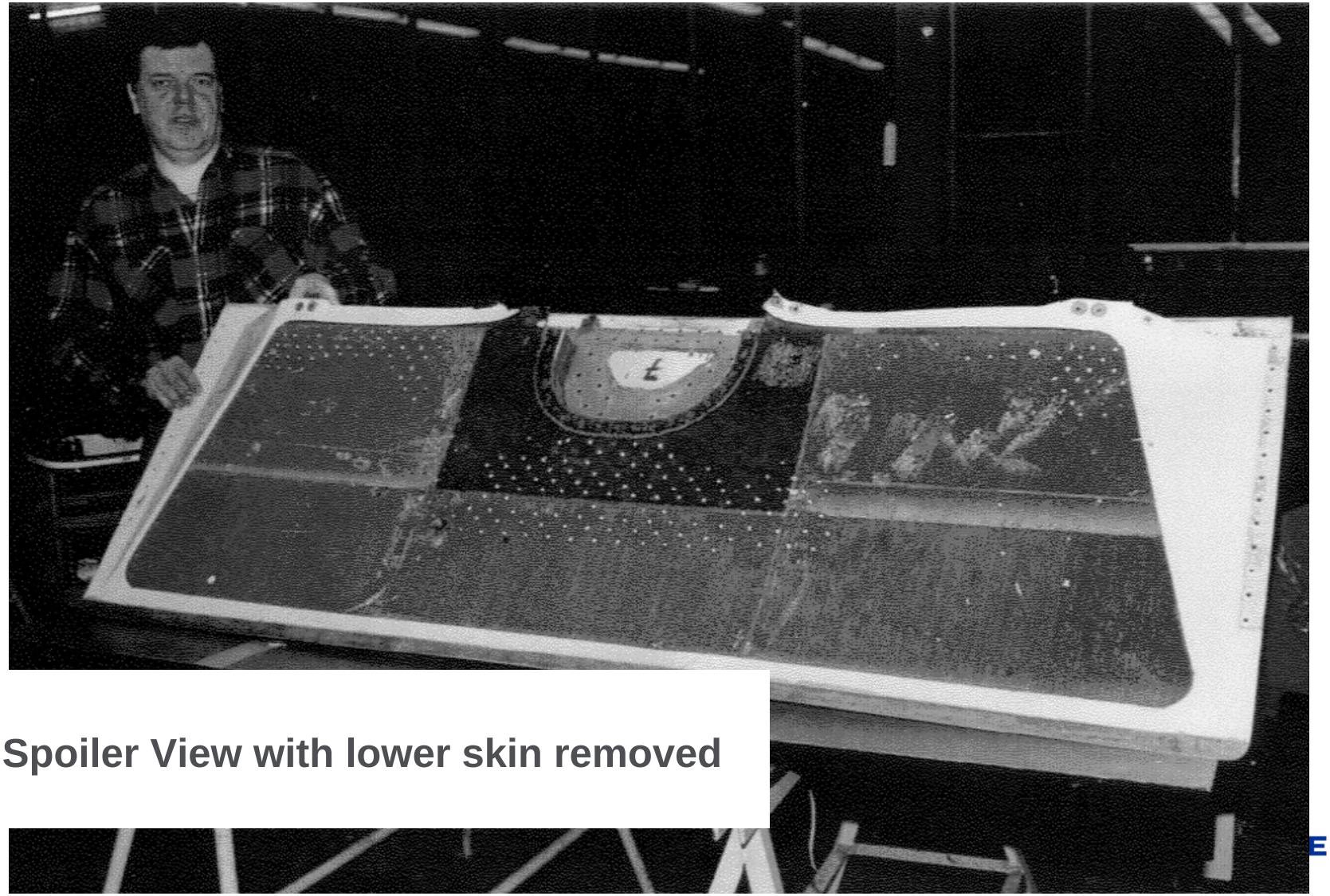
- Through film adhesive
  - Along scrim/carrier
  - Gaps due to poor fit-up core and skins



Vacuum-bag metalbond repair

UNITED

AE-27: Design of Durable, Repairable and Maintainable Aircraft Composites: Sandwich Designs

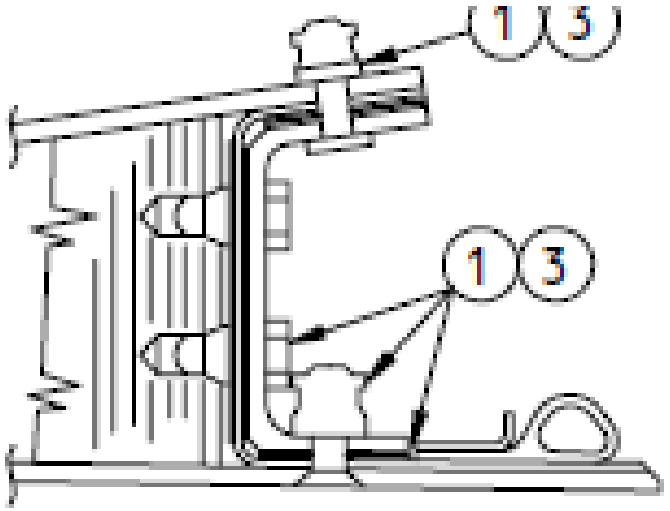


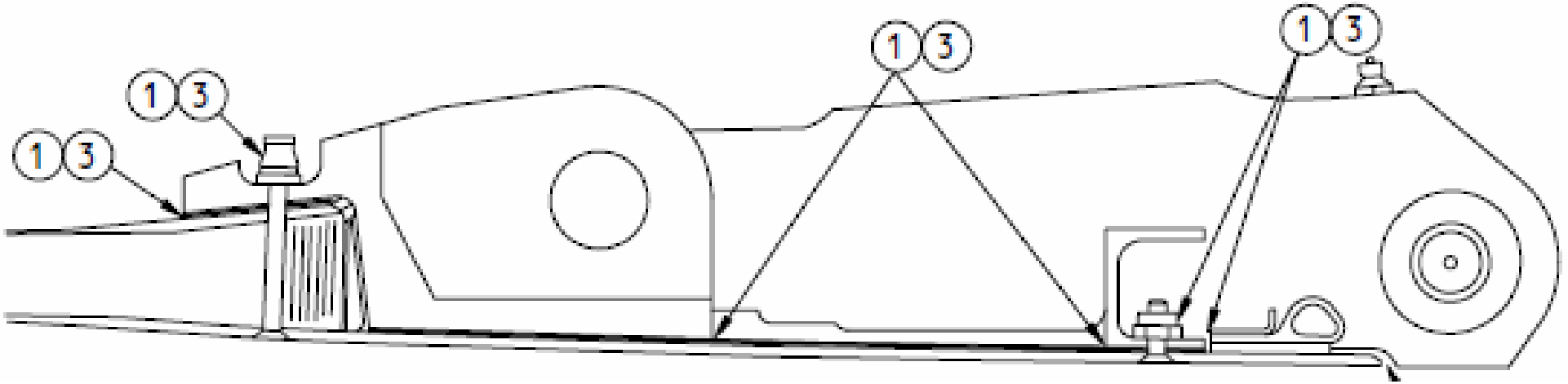
Spoiler View with lower skin removed

AE-27: Design of Durable, Repairable and Maintainable Aircraft Composites: Sandwich Designs

Fluid Ingression:

- Fasteners through skin into core
- Porous Foaming Adhesive or potting – porous so acts as water path
- Honeycomb splices and cavities not completely filled
-

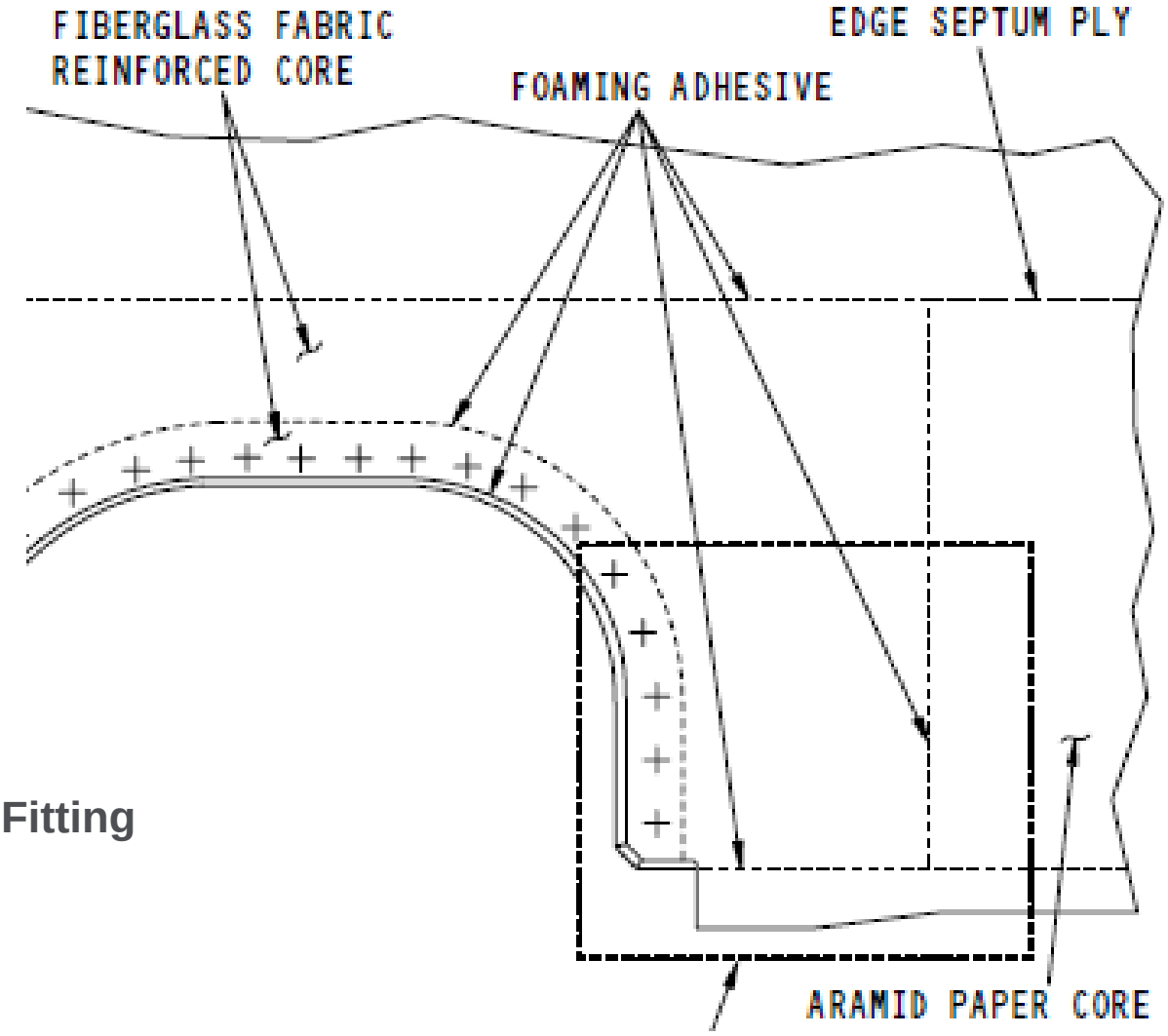




AE-27: Design of Durable, Repairable and Maintainable Aircraft Composites: Sandwich Designs

Fluid Ingression:

- Honeycomb septum has high porosity
- Tooling holes in spar



Spoiler Bottom View without Fitting

AE-27: Design of Durable, Repairable and Maintainable Aircraft Composites: Sandwich Designs

Fluid Ingression – Example of ongoing maintenance issues:

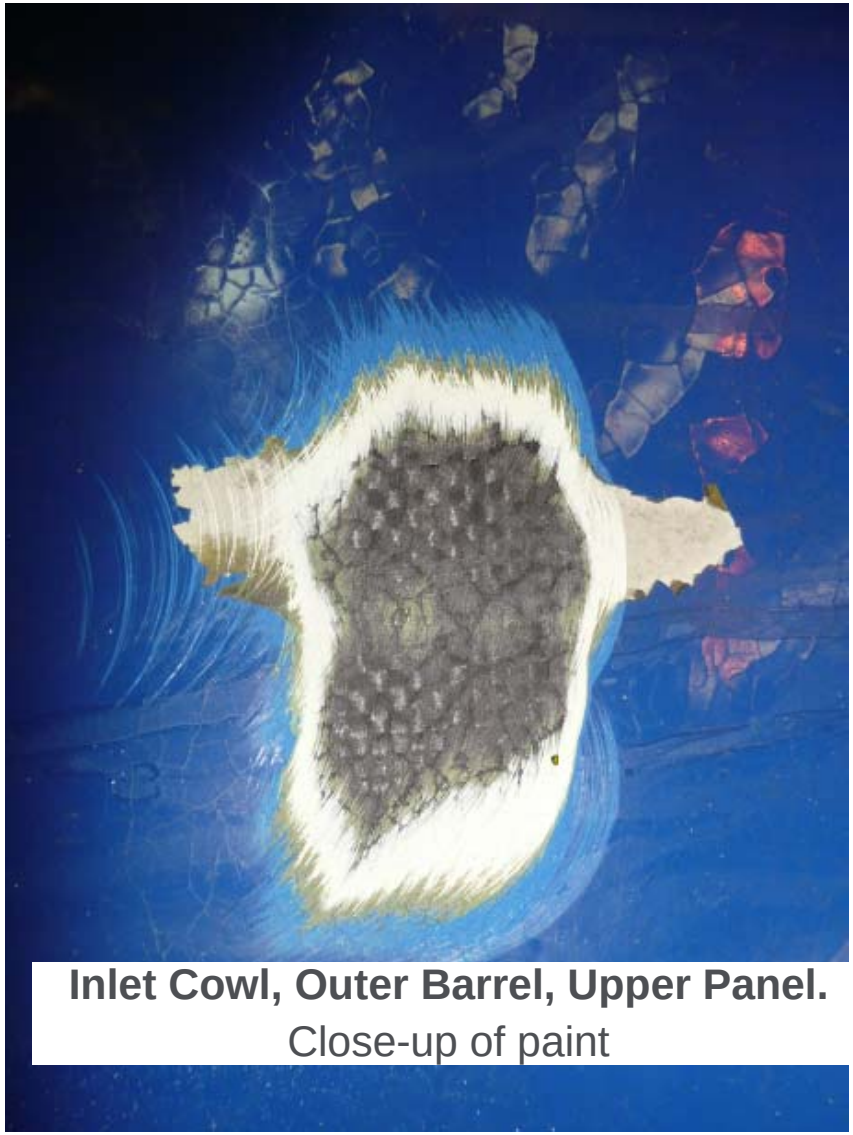
- Water found visually at overnight check. No delamination, no scratches. Tap test fine, but thermography performed showed water scattered across about 30% of surface, but no single area more than 2” on cells with water touching.

Inlet Cowl, Outer Barrel, Upper Panel.
Thermography indications

AE-27: Design of Durable, Repairable and Maintainable Aircraft Composites: Sandwich Designs

Fluid Ingression – Example of new maintenance issues:

- Checked with OEM for other operator experience.
- Refinished paint
- At engineering direction, deferred repair until next C-check with re-check at A-check.
- Before next check, we bought spare panels with 120 day lead time, built an autoclave tool, and performed 350F prepreg autoclave repair



Inlet Cowl, Outer Barrel, Upper Panel.
Close-up of paint

AE-27: Design of Durable, Repairable and Maintainable Aircraft Composites: Sandwich Designs

Erosion:

- Surface mismatch or positive step or facing into wind
- Primarily fairings, leading edge panels, radome
- Can lead to delamination and moisture ingression

Thrust Reverser Sleeve

AE-27: Design of Durable, Repairable and Maintainable Aircraft Composites: Sandwich Designs

Overheating:

- Engine cowls
  - Heat due to normal engine exhaust on pylon panels above and aft of tail cone
  - Actual in-service temperatures and heat higher than design. Example: Accessory compartment hotter due to engine core temperature
  - Heat due to failed valves in open-position
  - Heat from bleed air exhaust

AE-27: Design of Durable, Repairable and Maintainable Aircraft Composites: Sandwich Designs

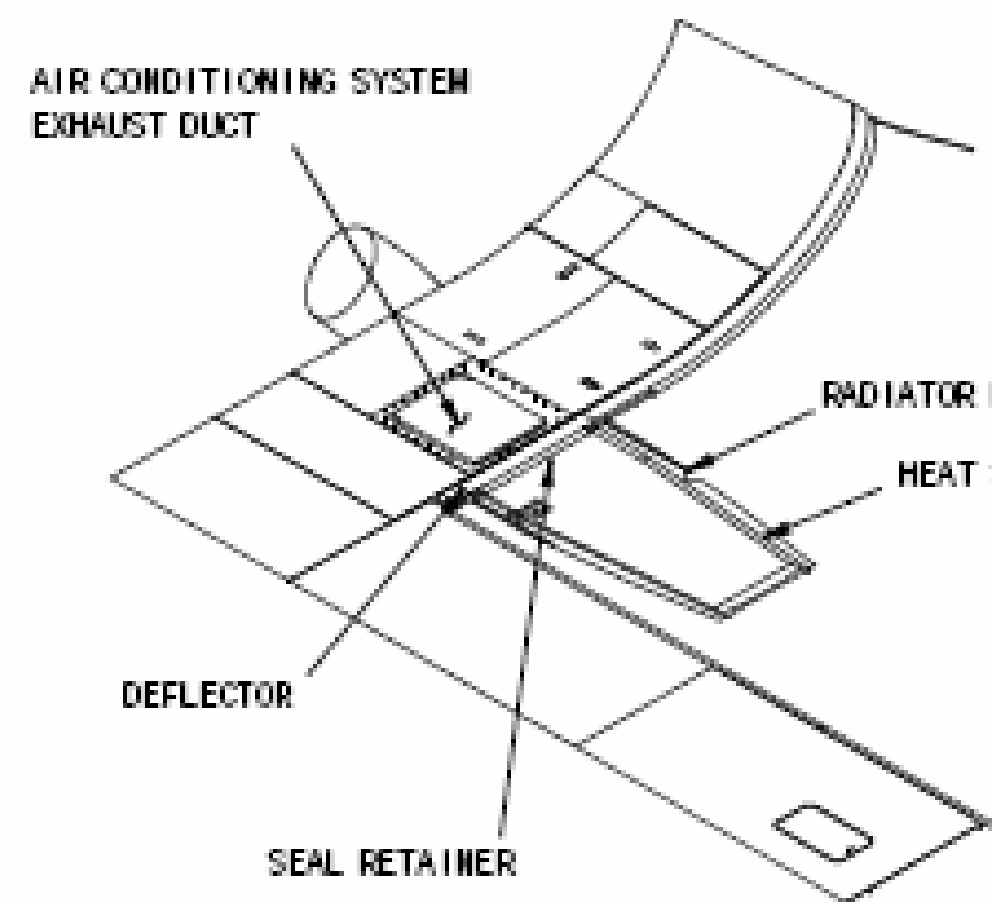
Overheating:

- Engine cowls
  - Abnormal heat due to failed valves in open-position, or boroscope plug left out
  - Heat from to bleed air exhaust
  - Heat from due to failed valves in open position

AE-27: Design of Durable, Repairable and Maintainable Aircraft Composites: Sandwich Designs

Overheating:

- Air Conditioning exhaust vents on fuselage
  - Heat from bleed air exhaust after heat exchanger
  - Heat from due to failed valves in open position
  - Heat shields used which aren't big enough
  - Heat shield materials not



Heat shield aft of AC exhaust

UNITED

AE-27: Design of Durable, Repairable and Maintainable Aircraft Composites: Sandwich Designs

Protective Finish (Paint):

- Needed for protection of structure against UV, moisture, and erosion, etc.
- Observations:
  - Paint is process sensitive – many premature failures
  - Fillers and excess thickness still wide-spread practice
- Recommendations
  - Touch up of in-service wear and tear should part be standard maintenance program - monitoring and corrective action program
  - Need to stress cosmetic versus protection functions
  - Need to publish limits to on size and time allowed to defer re-painting of bare composite structure for line operations

AE-27: Design of Durable, Repairable and Maintainable Aircraft Composites: Sandwich Designs

Final thoughts on Fluid Ingression:

- Freeze-thaw cycle commonly identified as failure, but not verified.
- Water lowers adhesive strength
- Honeycomb & Foam Cores both susceptible

"Nature abhors a vacuum". Assume water will get in.

- Water can enter as liquid and vapor
- Water continues to accumulate and spread over time until leak path is eliminated or sealed
- Water in honeycomb is inevitable and acceptable
  - Assuming weight not an issue, water does exist inside honeycomb
  - What level is acceptable?
  - For how long will it be acceptable? Propagation rates?

Questions?

.

UNITED