Fluid Ingression Into Composite Sandwich Structure: History And Future Research

Allison Crockett, Wichita State
Hal Loken, Consultant
John Tomblin, Wichita State

NIAR
RESEARCH / DESIGN / TESTING / CERTIFICATION

Commercial Aircraft Composite Repair Committee (CACRC)
Meeting & Workshop for
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Fluid ingression into honeycomb core can have multiple causes

- Inadequate materials/design.
- Damage or structural overload.
- Facesheet system develops connecting microcracks in operating environment, allowing "global" ingression of fluids into the core .
- The first two can lead to localized fluid ingression and the issues become containment and repair.
- When they interconnect through the laminate facesheet, microcracks can lead to global water ingression.

Inadequate materials/design as a contributor to fluid ingression.

- A well-known example was the elevator trailing edge wedge on a 1970's wide-body transport
- The construction was woven fabric composite facesheets, solid laminate spar/attachment and aramid honeycomb core.
- The prepreg resin level had been minimized to reduce weight and the facesheet laminate had channels that directed water and Skydrol into the honeycomb core at the ply drop-offs.
- An increase in prepreg resin content solved this problem.
- As new materials and methods come into use, we must research application limits and define good practices.

Damage or structural overload as a cause of fluid ingression

- One of the biggest headaches for an airline operator is when large hailstones strike at a major airport.
- Composite sandwich fixed trailing edge panels are typically damaged by the hailstones
- If not sealed or repaired, these panels will later develop water ingression into the honeycomb core at the spot where each large hailstone struck.
- Research will establish a cost effective standard for hailstone resistance.

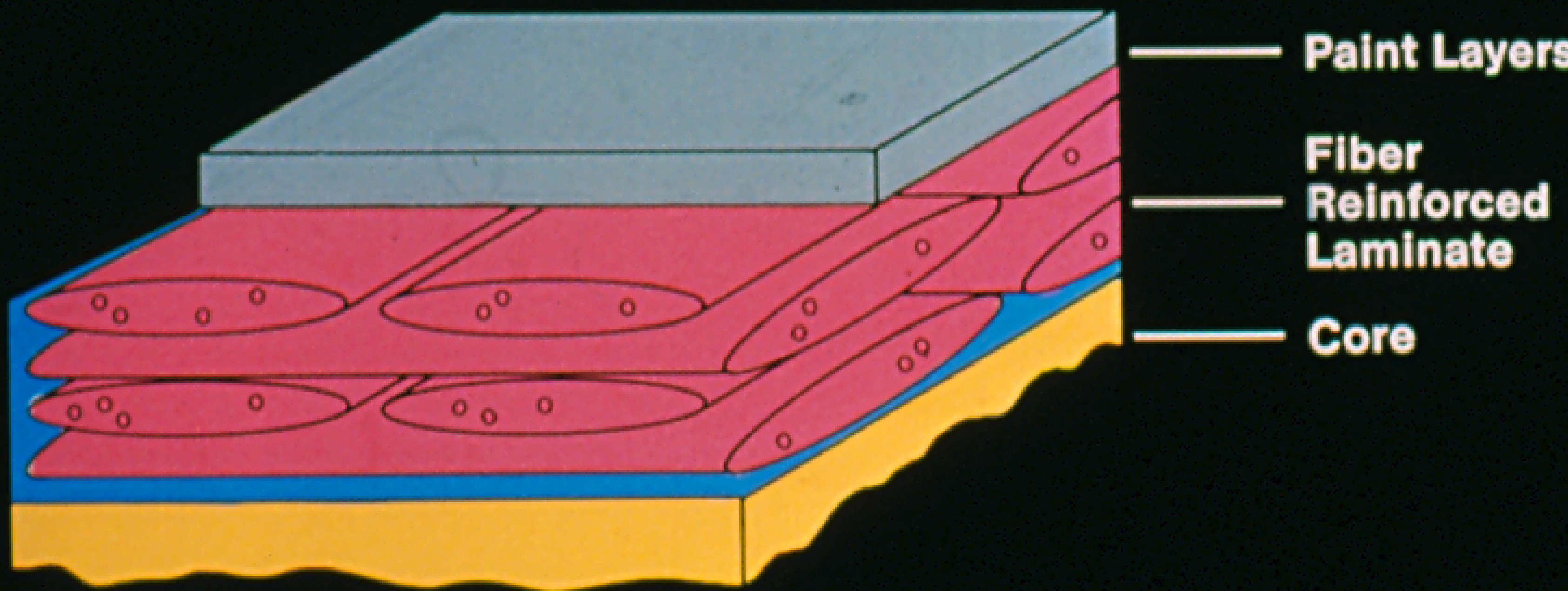
"Global" fluid ingression caused by facesheet system failure in operating environment

- When they connect through the laminate, facesheet microcracks can lead to global water ingression.
- These microcracks are the result of micromechanical residual stresses in the facesheet laminate
- Solutions were developed for materials systems in the 1980's and as a result this industry has become less concerned.
- However, as materials and process change, we must remember the past and establish the robustness of these new approaches.

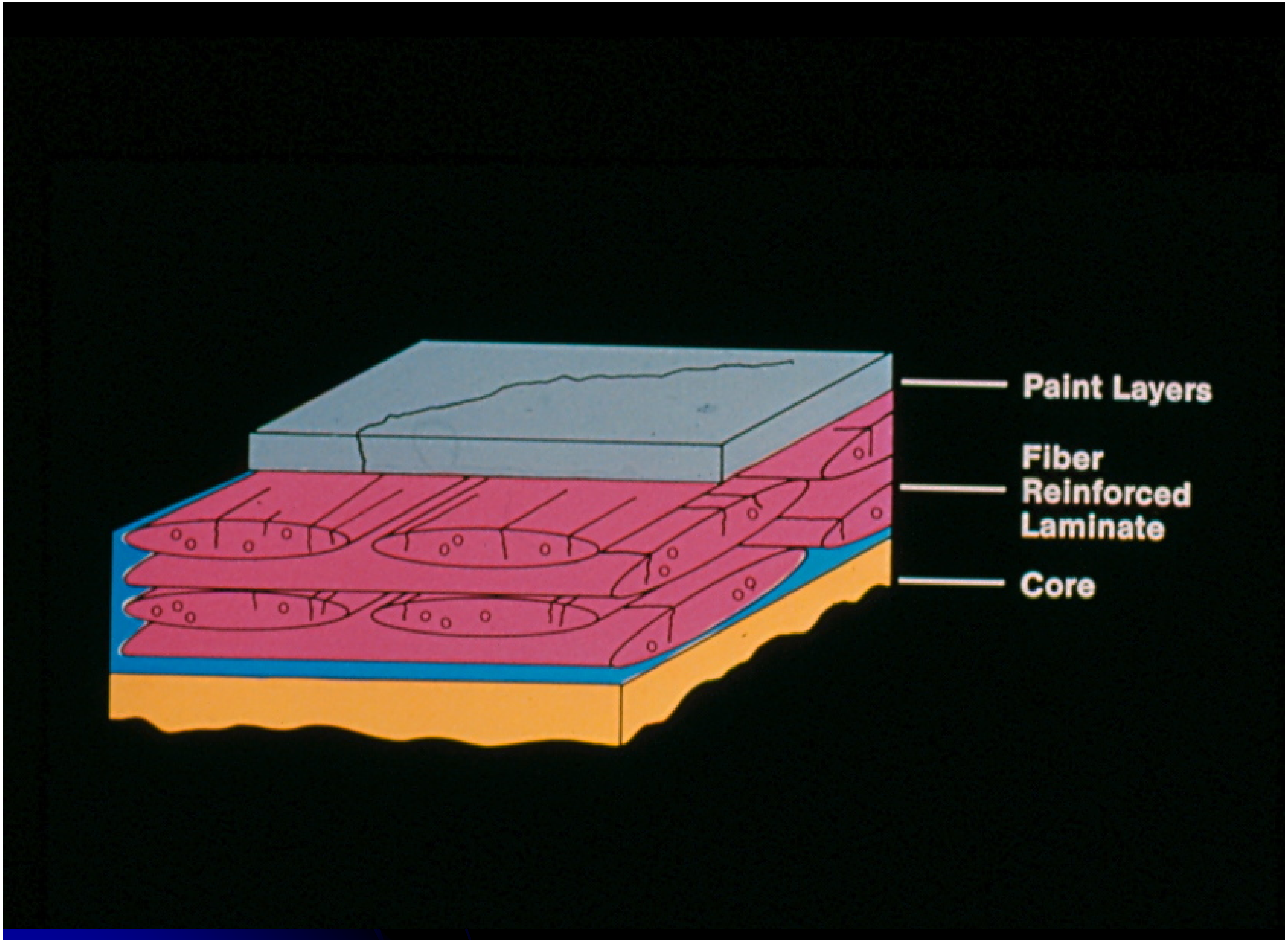
Microcracks Develop to Relieve Local Micromechanical Stresses

Can be caused by a number of conditions

- Thermal cycling
- Moisture cycling
- Stress cycling

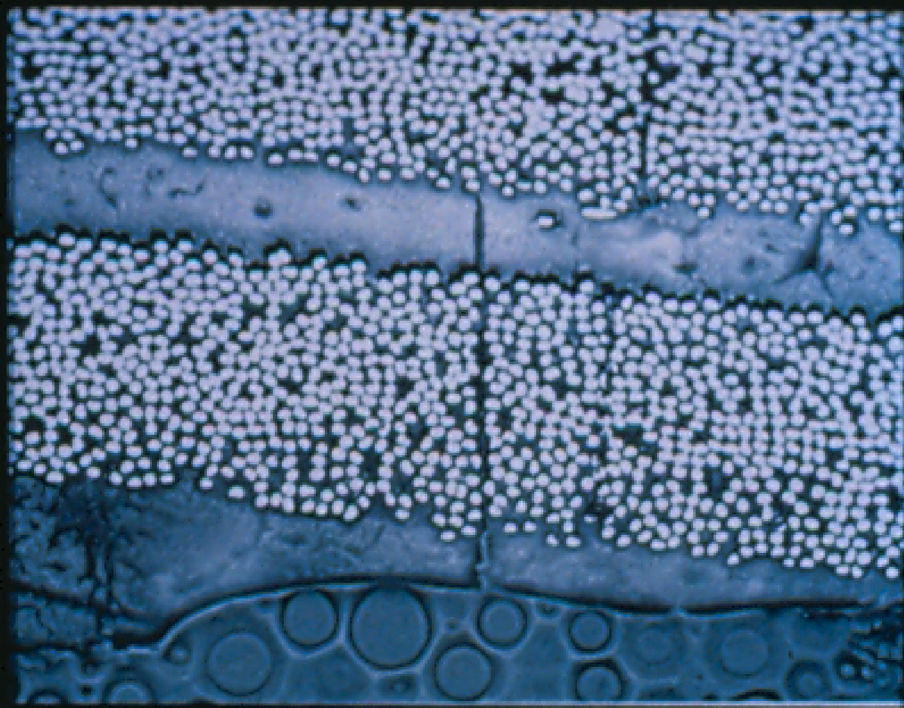


Paint Layers
Fiber
Reinforced
Laminate
Core


Paint Layers
Fiber
Reinforced
Laminate
Core

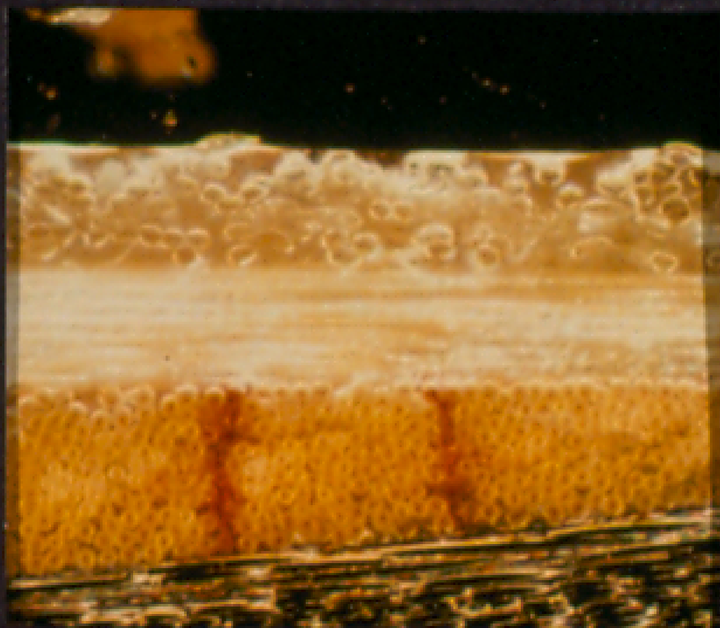
Hygrothermally Induced Transverse Matrix Microcracks in Carbon Fiber/Epoxy Composite

(1200 Lab Cycles)



200 X

Hygrothermally Induced Transverse Matrix Microcracks in KEVLAR® Fiber/Epoxy Composite (2400 Lab Cycles)



— Nonwoven KEVLAR

— 0° KEVLAR Layer

— 90° KEVLAR Layer

120 X

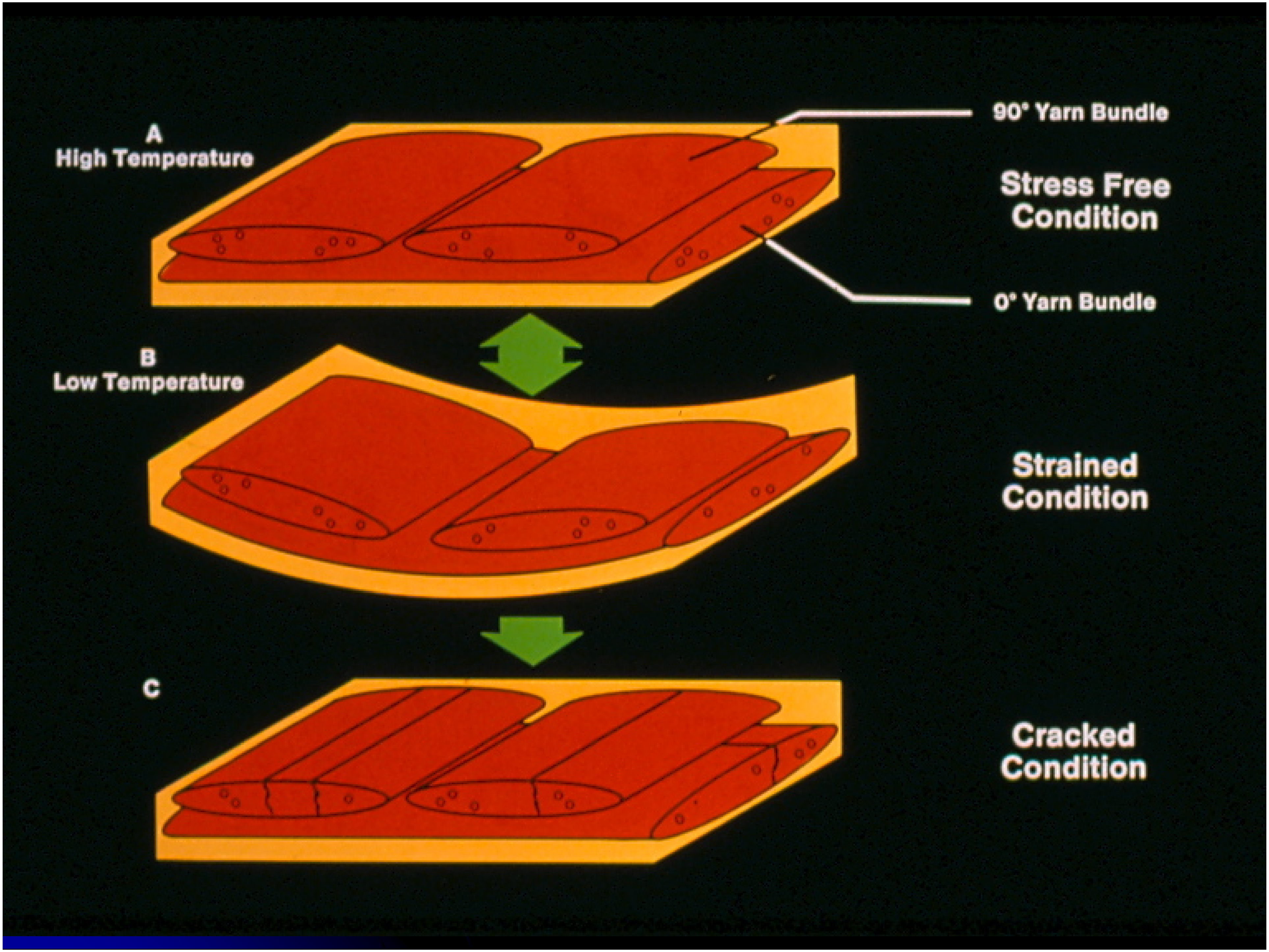
Thermal Expansion Coefficients of Fiber and Unidirectional Fiber Reinforced Composites (Fiber Volume = 0.5 in Epoxy Resin)

Approx. CTE (10^6 CM/CM °C)

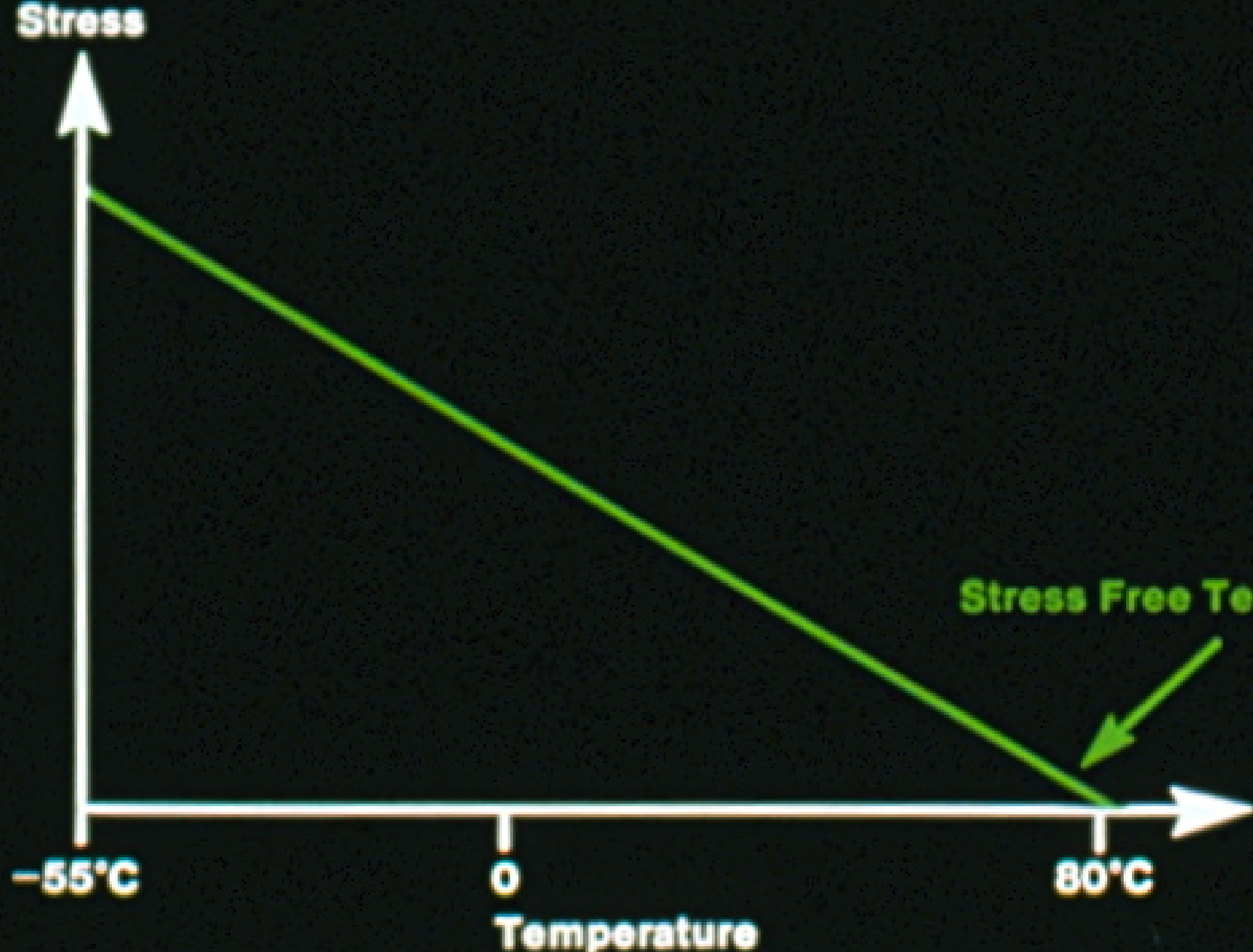
Material	Fiber		Uni-directional Composite	
	Axial	Radial	0° Direction	90° Direction
Glass	5	5	5	20
Carbon	1	18	1	30
KEVLAR®	−2	60	−1	70

Thermal Expansion Coefficients of Paint and Fabric Laminates

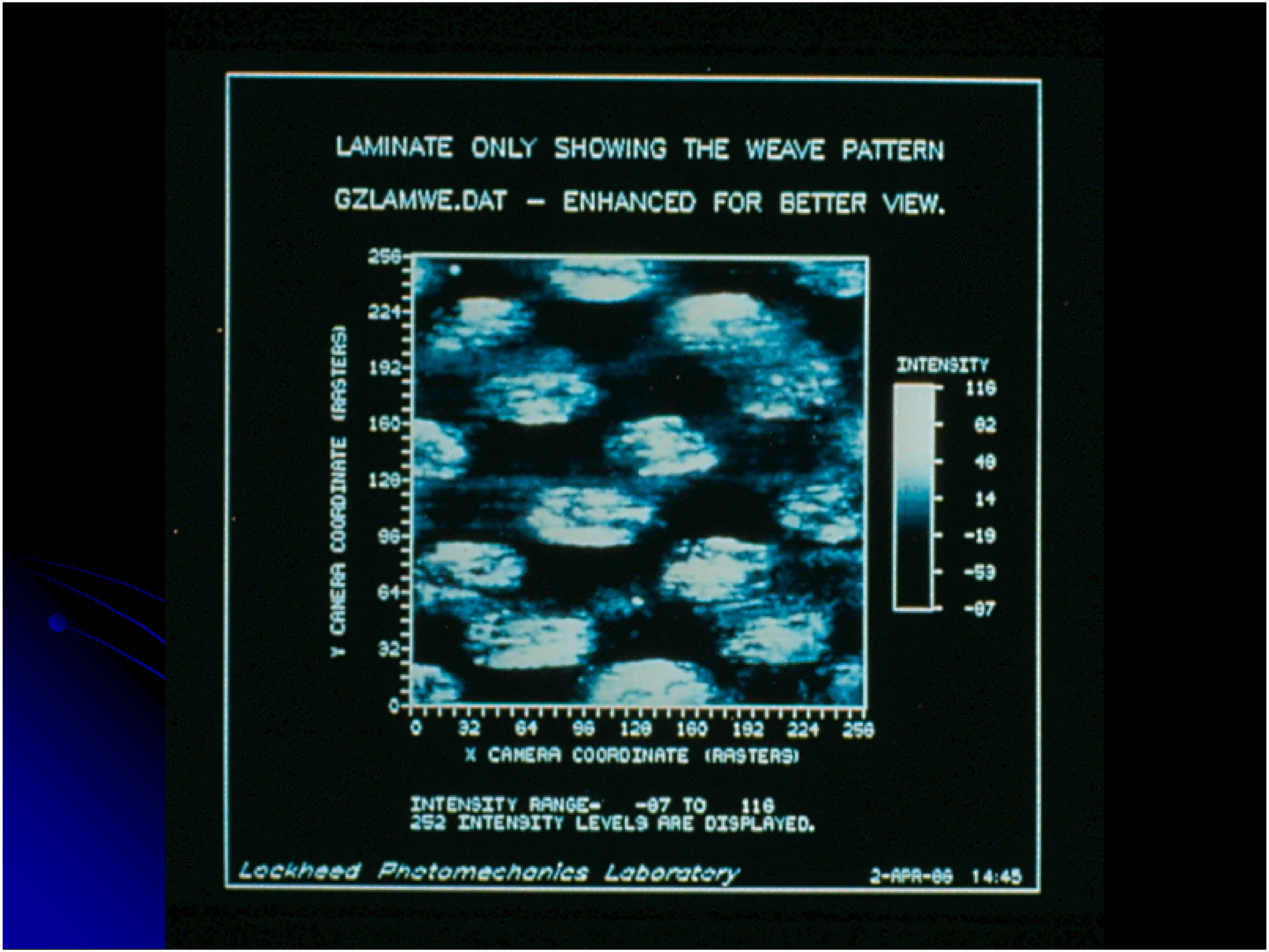
Material	CTE (10^6 CM/CM °C)
Typical resins and paint	50-100
Glass fabric laminate	15-25
Laminate of KEVLAR® fabric	5-10
Carbon fabric laminate	4-9


A
High Temperature
90° Yarn Bundle
Stress Free
Condition
0° Yarn Bundle
B
Low Temperature
Strained
Condition
C
Cracked
Condition

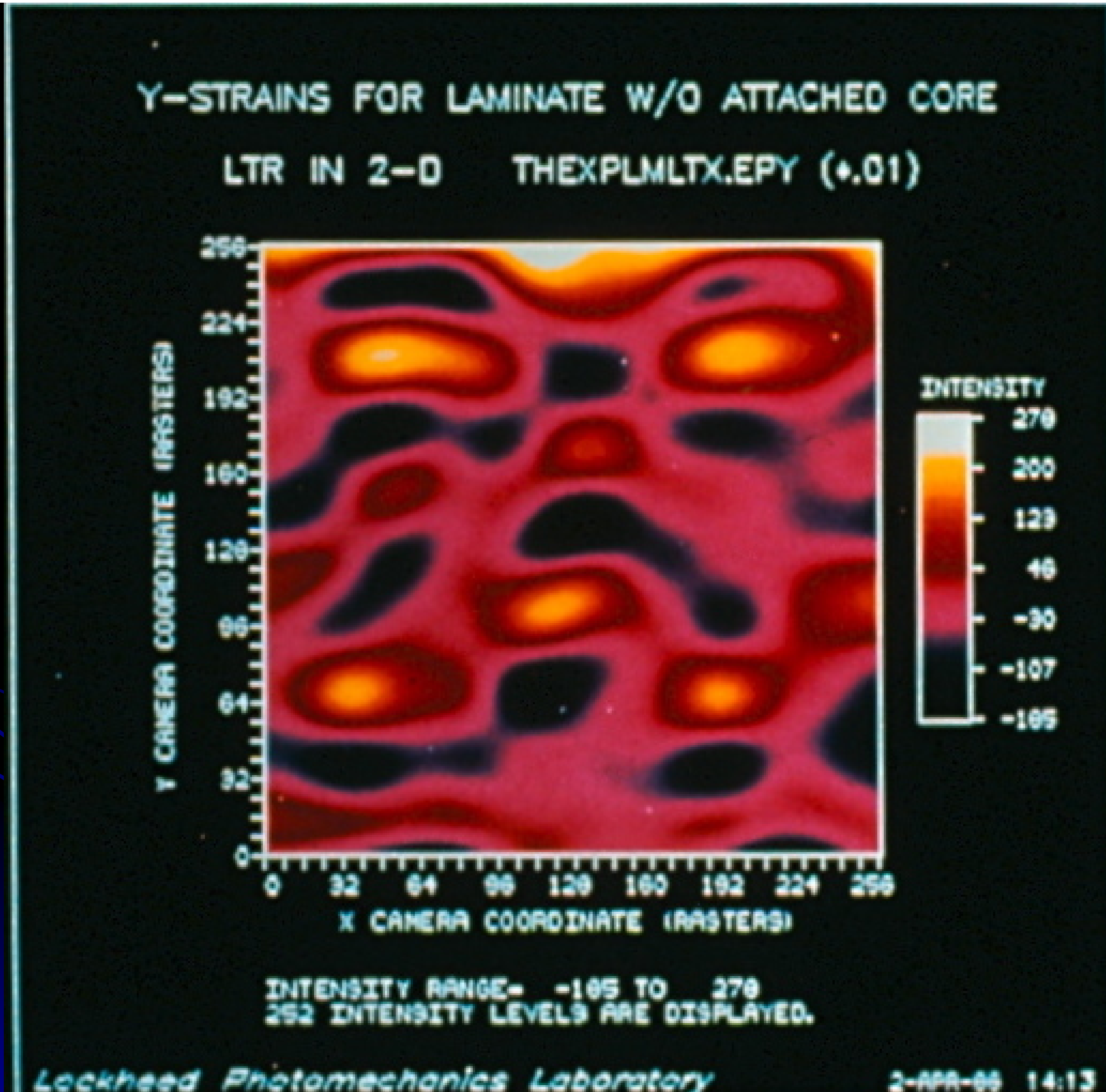
Transverse Residual Stress



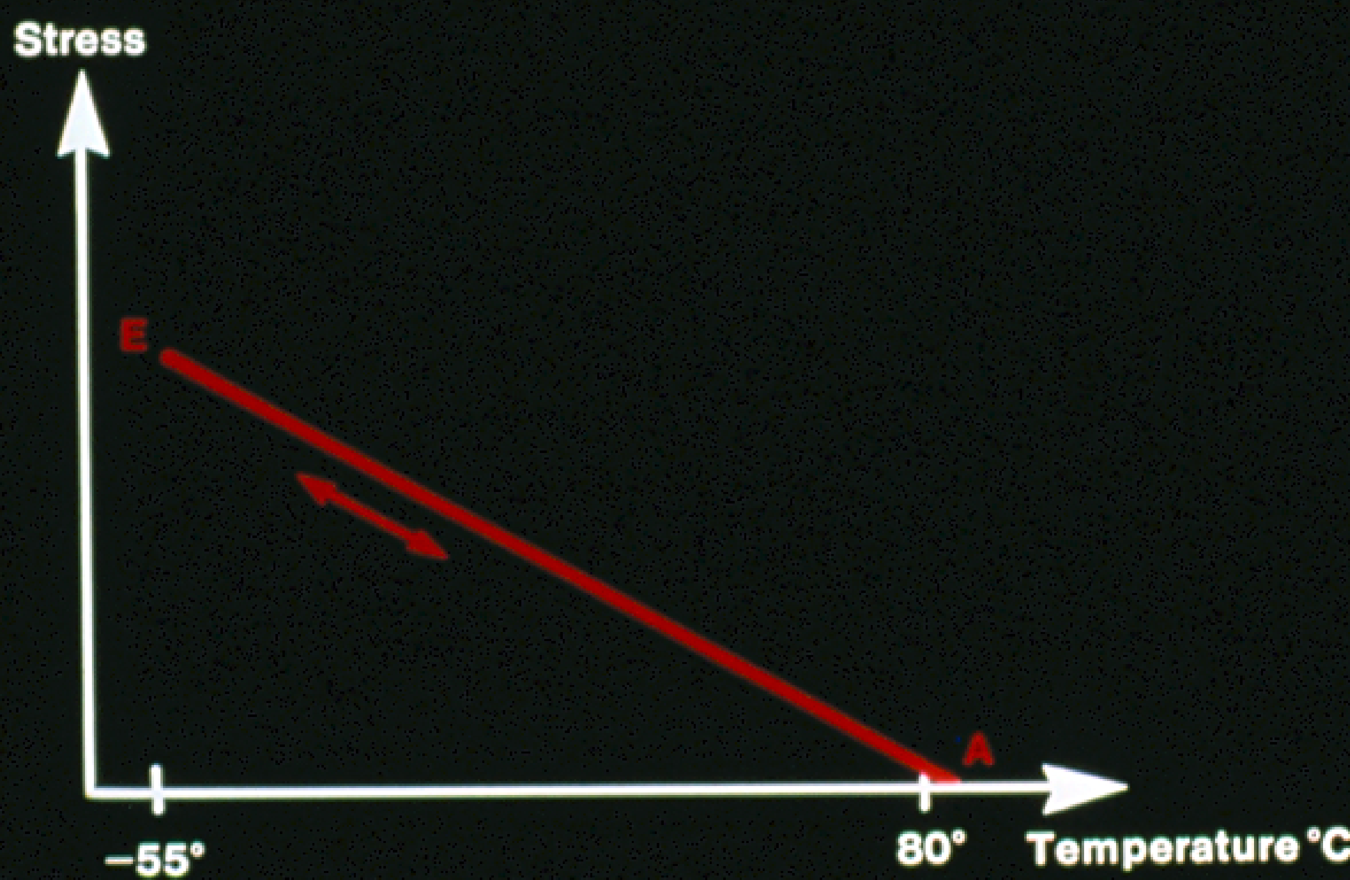
- Moisture has similar effect on transverse stress, with increasing moisture reducing the stress



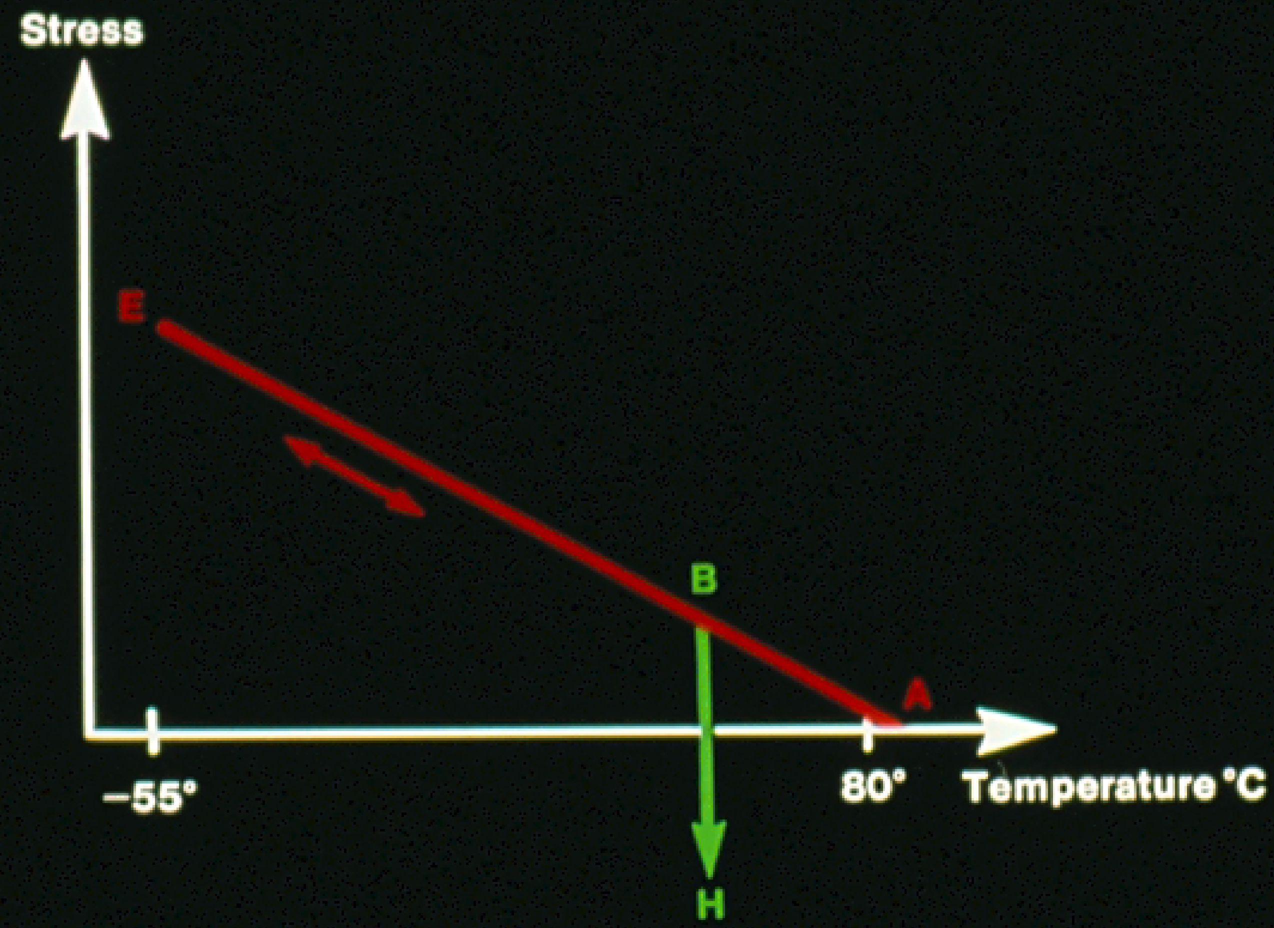
LAMINATE ONLY SHOWING THE WEAVE PATTERN
GZLAMWE.DAT – ENHANCED FOR BETTER VIEW.
Y CAMERA COORDINATE (RASTERS)
0
32
64
96
128
160
192
224
256
X CAMERA COORDINATE (RASTERS)
0 32 64 96 128 160 192 224 256
INTENSITY
116
82
48
14
-19
-53
-87
INTENSITY RANGE= -87 TO 116
252 INTENSITY LEVELS ARE DISPLAYED.
Lockheed Photomechanics Laboratory
2-APR-86 14:45


Y-STRAINS FOR LAMINATE W/O ATTACHED CORE
LTR IN 2-D THEXPLMLTX.EPY (*.01)
Y CAMERA COORDINATE (RASTERS)
0
32
64
96
128
160
192
224
256
X CAMERA COORDINATE (RASTERS)
INTENSITY
270
200
123
46
-30
-107
INTENSITY RANGE= -105 TO 270
252 INTENSITY LEVELS ARE DISPLAYED.
Lockheed Photomechanics Laboratory
14:13

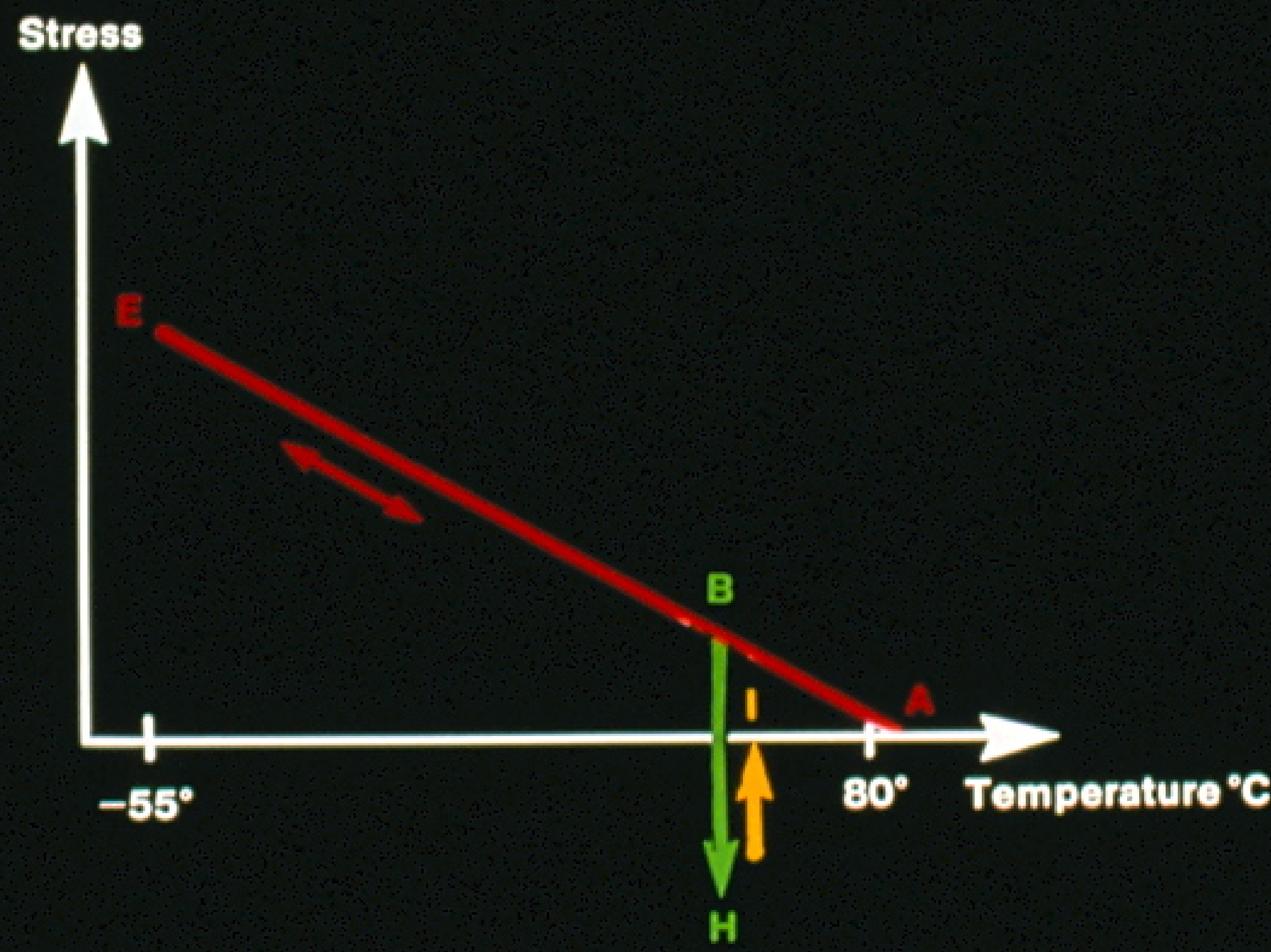
Moisture-Temperature Cycling



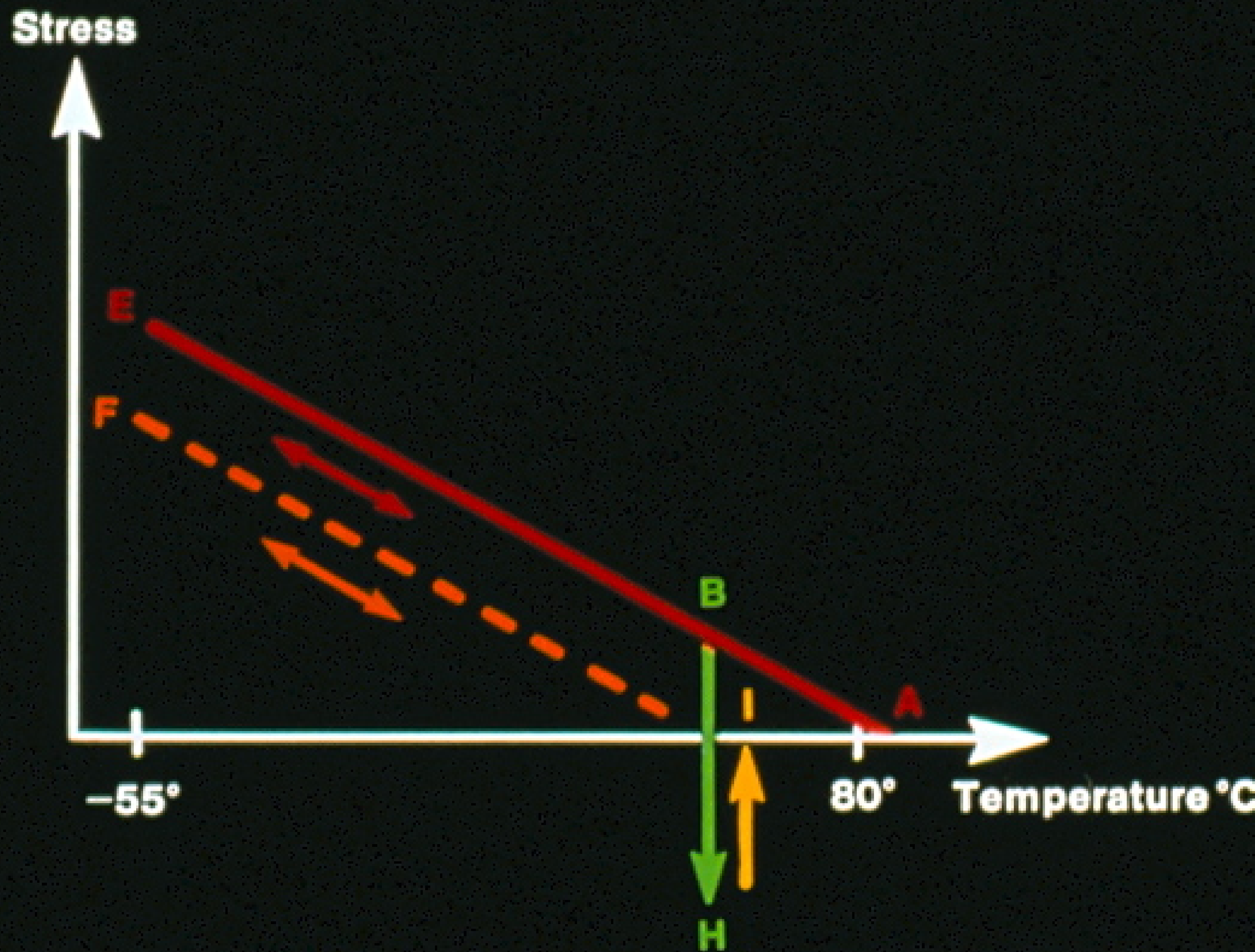
Moisture-Temperature Cycling



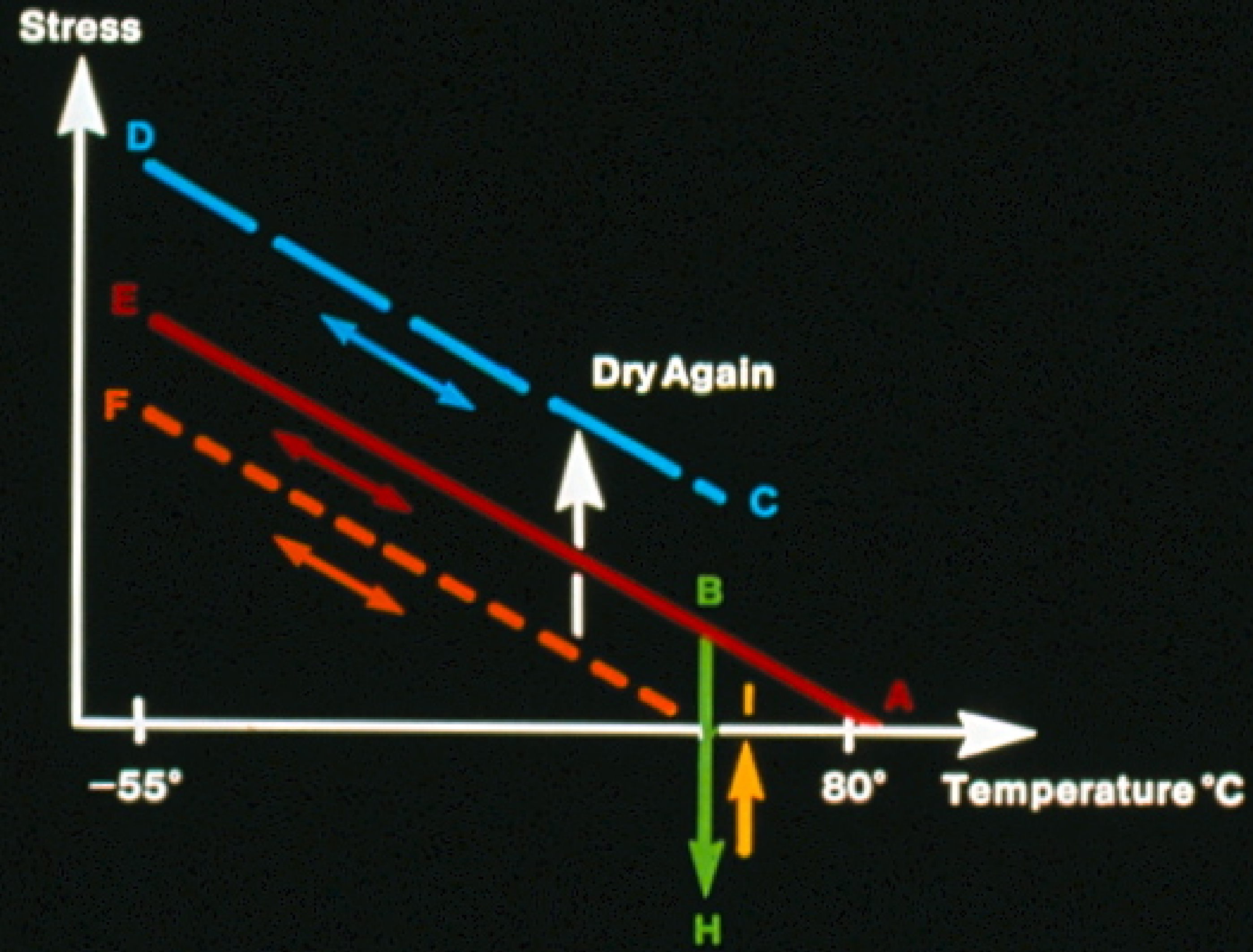
Moisture-Temperature Cycling

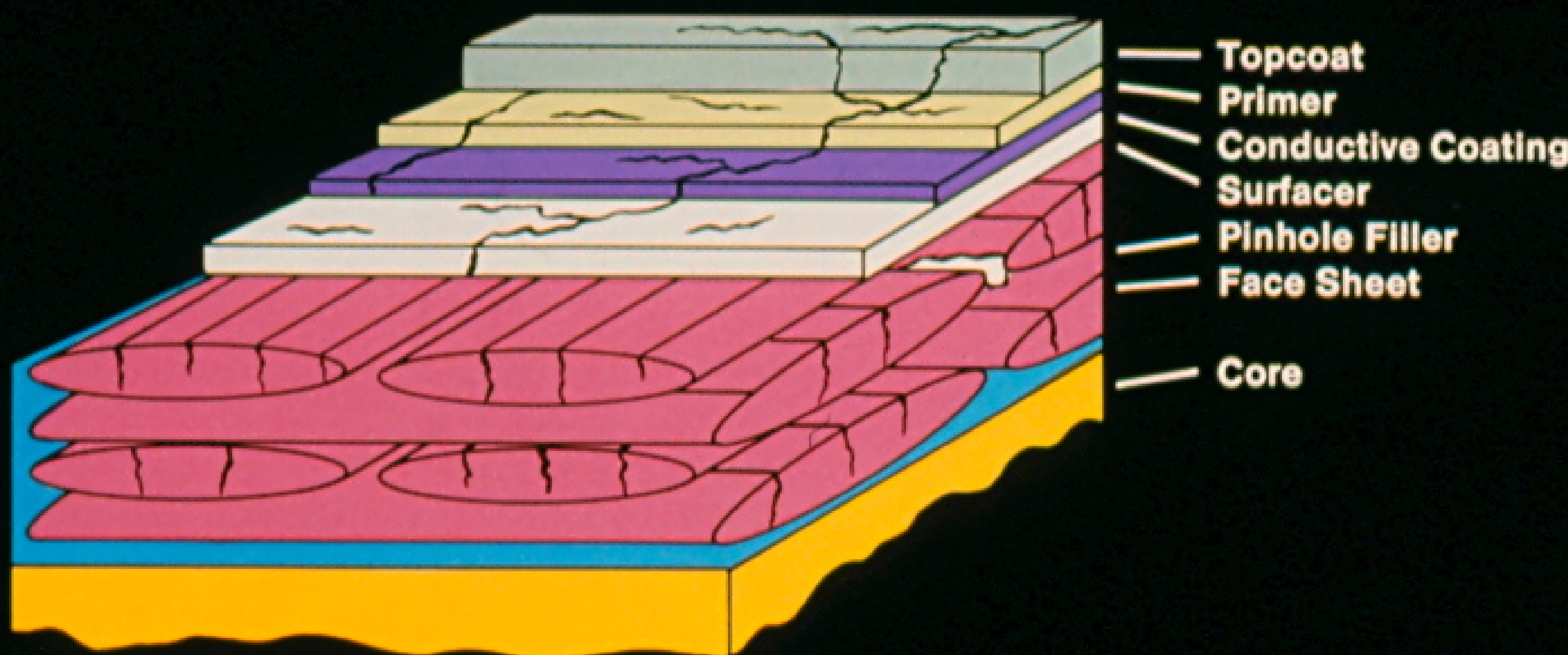


Moisture-Temperature Cycling



Moisture-Temperature Cycling




Topcoat
Primer
Conductive Coating
Surfacer
Pinhole Filler
Face Sheet
Core

Phenomenon is Water Ingression into Core

Condition necessary for water ingression

- Passageways for water through thin laminate facesheet into honeycomb core
  - Environmental cycling of adequate severity and frequency to cause through cracking
  - Laminate system prone to through cracking

Residual Long Beam Flex Test of KEVLAR®/Epoxy Honeycomb Sandwich After Thermal Cycling (−55°C to 70°C)

Specimen	Cycled	Flexural Ultimate Load in Newton	(St. Dev.) in %	Flexural Modulus Newton/mm²	(St. Dev.) in %
1	NO	508	2.17	14	2.54
	YES	501	2.66	14.4	2.82
2	NO	378	2.61	16.7	3.03
	YES	382	2.72	18.6	3.58
Values are average of five measurements on each sample					

Conclusion: No statistically significant change in properties at equilubrium matrix crack density.

Conclusions:

- Transverse matrix microcracking mechanism involves local micromechanical stresses, not global stresses
- Effect of transverse matrix microcracks on the mechanical properties of carbon and KEVLAR® systems are minor to insignificant
- New approaches will control transverse matrix microcracking

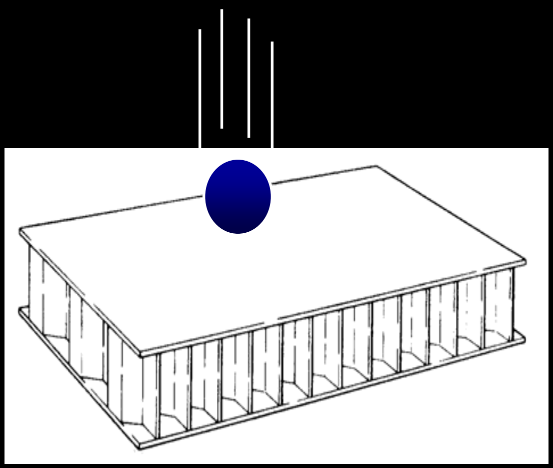
1980's Solutions

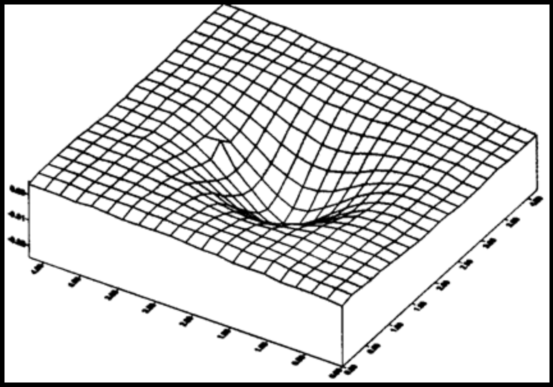
- Crack arresting layers or coatings
- Material/process – improved prepreg
- Are these improvements applicable to today's material systems?
- How do we show what is good enough today?

FAA Research Investigations

Research Objective

Characterize the fluid ingression phenomenon in composite sandwich structures as well as to document the damage mechanisms which allow the fluid ingression to propagate and potentially degrade the structural performance





Terminology

Fluid Ingression Damage Tolerance

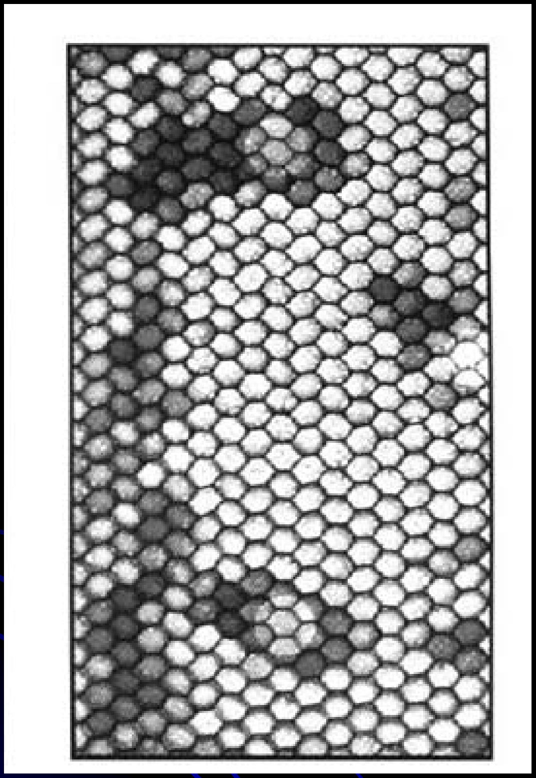
Resistance to the propagation of damage due to fluid ingression and degradation of structural performance

Fluid Ingression Damage Resistance

Material performance, design details and maintenance practices which resist fluid ingression into the core

Proposed research program will focus on
Fluid Ingression Damage Tolerance

Proposed Program Outline



BASIC ASSUMPTIONS

- Fluid ingression path is established

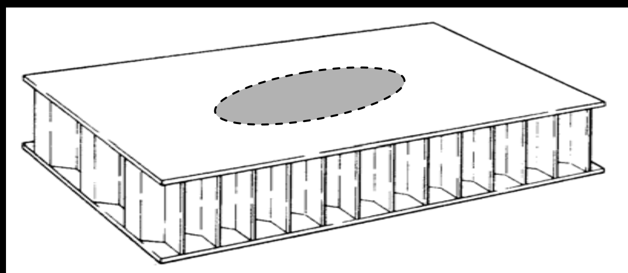
  and

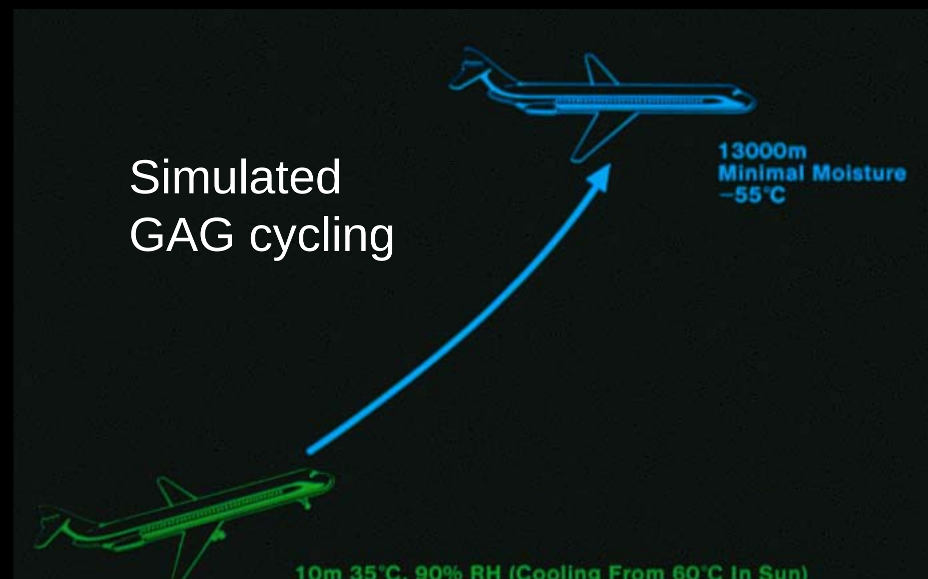
- Ingression **HAS** occurred

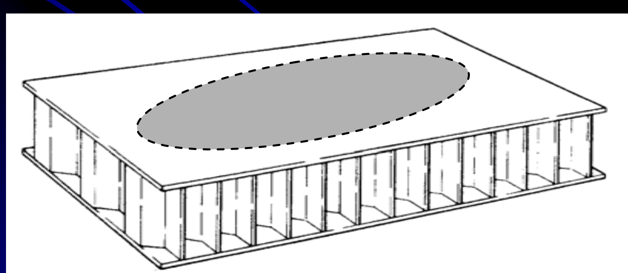
GOAL

Characterize the fluid ingression growth mechanisms and rates due to hygrothermal exposure based upon a number of variables

Proposed Program Highlights

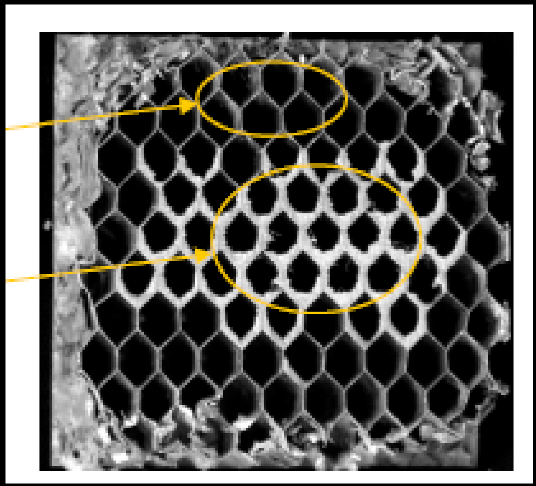


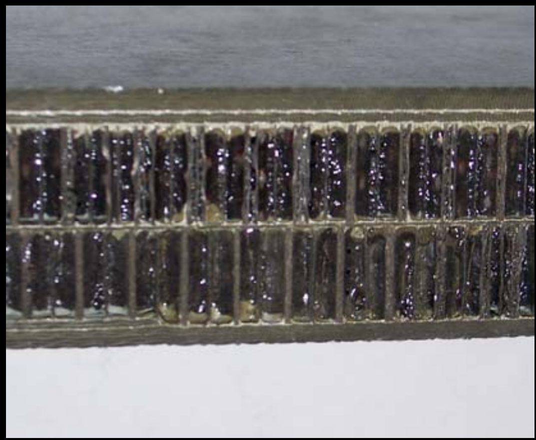




Proposed Program Outline

- Proposed Experimental Laboratory Variables
  - Different Core Types
  - Different Core Densities
  - Different Fluid Types
  - Characterize common core design details related to fluid propagation such as septum





Proposed Program Outline

Characterize existing structural parts and configurations (with potential aging effects)

Direction

- Program is still in planning stages and we would appreciate your input

- Contact Info

Allison Crockett

(316) 978-5461

allison.crockett@wichita.edu