



FPD.DEV

THE FUTURE OF DISPLAY AND SYSTEMS DEVELOPMENT

DO-160 Display Qualification

Temperature and Pressure

CHAPTER 2

In this chapter

Hot Contrast and cold moving information

Thermal lag, material response and test sequence

Pressure loads, decompression and venting



Diggy Breiling

Founder of FPD.DEV · Instructor

ASQ · American Society for Quality

Current: CMDA

Previously held: CSSBB, CMQ/OE

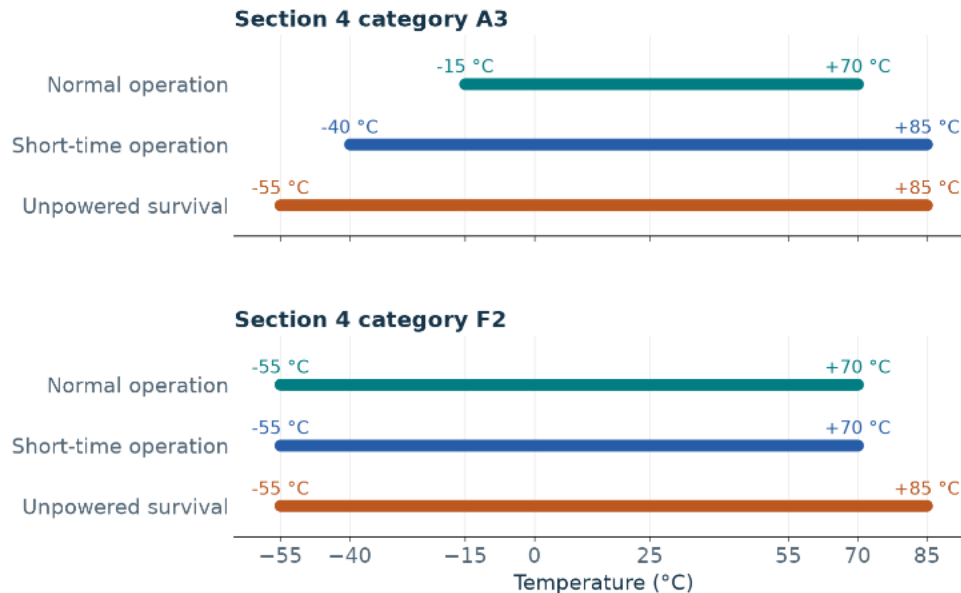
ASCM / APICS: CPIM, CSCP

Association for Supply Chain Management



Operating state gives a limit meaning

Temperature range depends on the operating state



Selected examples from DO-160G Table 4-1. Category definitions and altitude assumptions must also be satisfied.

Normal operation

Short-time operation

Unpowered ground survival



Reading Table 4-1

Environmental Tests			
	A		
	1	2	3
Operating Low Temp.	-15	-15	-15
Degrees C Paragraph 4.5.2			
Operating High Temp.	+55	+70	+70
Degrees C Paragraph 4.5.4			
Short-Time Operating Low Temp.	-40	-40	-40
Degrees C Paragraph 4.5.1			
Short-Time Operating High Temp.	+70	+70	+85
Degrees C Paragraph 4.5.3			

A3 operating low: –15 °C

A3 short-time operating low:
–40 °C

The category definition still
governs



Cold response and moving information

- 01** Cold increases LC viscosity and slows optical switching
- 02** Moving dials, indicators and maps can smear
- 03** Check dynamic readability during cold start and operation



CTE: what changes, and by how much?

$$\Delta L \approx \alpha L_0 \Delta T$$

α · Material CTE

Fractional length change
per degree

L_0 · Initial length

The length being
evaluated

ΔT · Temperature change

Final temperature minus
initial temperature

CTE: ppm/K or ppm/°C · 1 ppm = 10⁻⁶

Use approximately constant CTE only over an appropriate temperature interval.



Worked example: 0.120 mm of mismatch

CTE difference

$$23 - 8 = 15 \text{ ppm/K}$$

Distance from constraint

$$L = 100 \text{ mm}$$

Temperature change

$$\Delta T = 80 \text{ K}$$

$$\Delta u \approx 15 \times 10^{-6} / \text{K} \times 100 \text{ mm} \times 80 \text{ K}$$

0.120 mm

Relative free movement
from the center constraint to the edge

Teaching inputs, not material specifications. Bonded layers cannot freely move this amount.

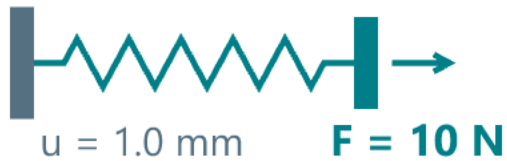


Stiffness, force and movement

Same imposed movement

Both joints stretch equally. Reaction force differs.

$k = 10 \text{ N/mm}$



$k = 40 \text{ N/mm}$



Same applied force

The more compliant joint moves farther.

$k = 10 \text{ N/mm}$



$k = 40 \text{ N/mm}$



$F = k u$ Assembly stiffness k depends on material AND geometry.

Axial bar: $k = E A / L$. Material modulus E differs from joint stiffness k .

Illustrative linear springs; equal geometry in this comparison. Softer is not automatically better.



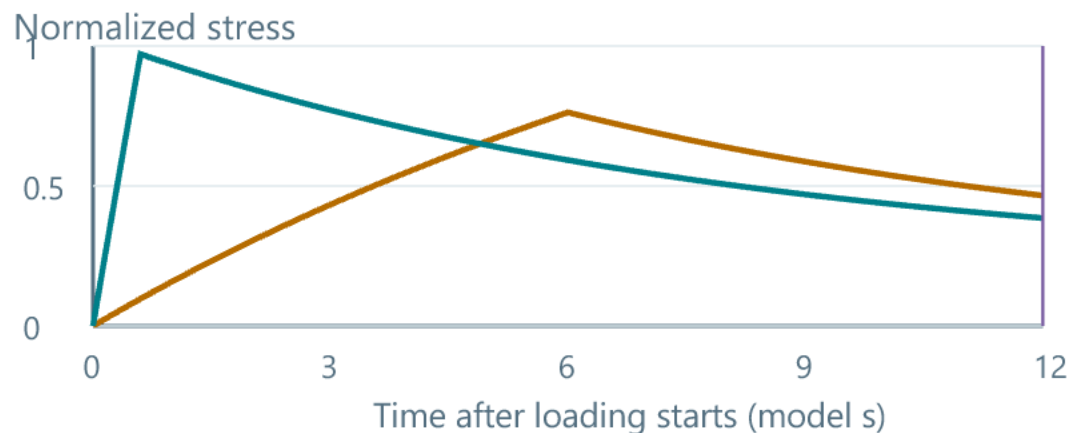
Temperature and loading rate

Same final strain. Different ramp times and relaxation times.

Model time: 12.0 s Fast ramp: 0.6 s Slow ramp: 6 s Then hold the strain.

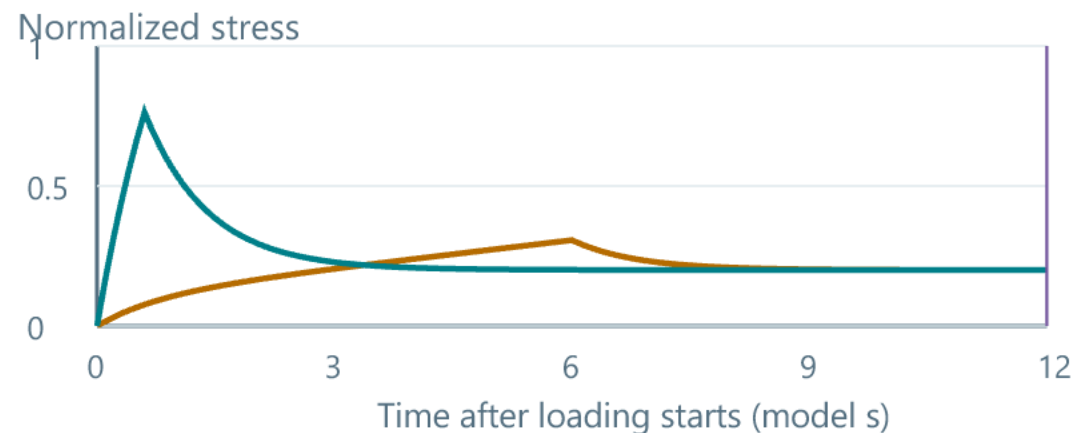
COOLER example: slower relaxation

Fast  Strain: 100% of target
Slow  Strain: 100% of target



WARMER example: faster relaxation

Fast  Strain: 100% of target
Slow  Strain: 100% of target



Illustrative viscoelastic model, not material data. Mechanical strain rate differs from chamber °C/min.

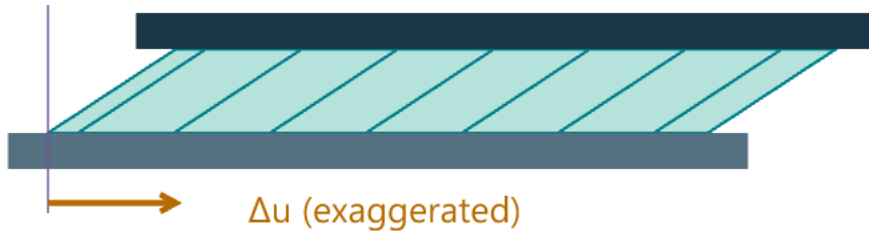


Bond thickness and shear strain

Same relative movement across two bond thicknesses

Relative displacement $\Delta u = 0.050$ mm Assumed shear modulus $G = 0.20$ MPa

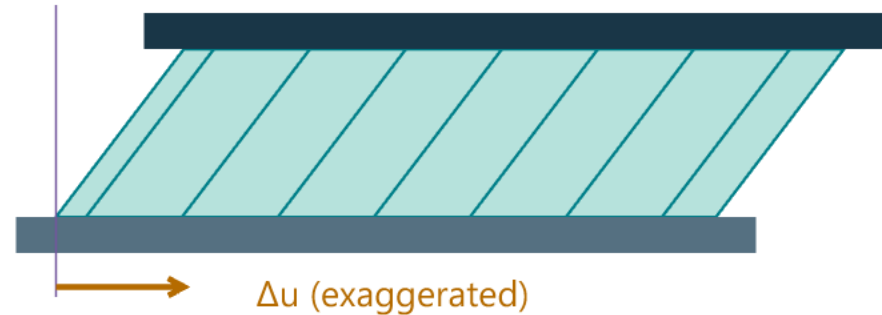
Bond thickness $t = 0.5$ mm



Shear strain $\gamma = \Delta u / t = 10.0\%$

Elastic stress $\tau = G \gamma = 20.0$ kPa

Bond thickness $t = 1.0$ mm



Shear strain $\gamma = \Delta u / t = 5.0\%$

Elastic stress $\tau = G \gamma = 10.0$ kPa

Half the thickness doubles strain for the same imposed displacement.

Temperature and loading rate change the effective modulus and stress history.

Uniform simple-shear example only. Edge peel, creep, strength and optical performance need separate checks.



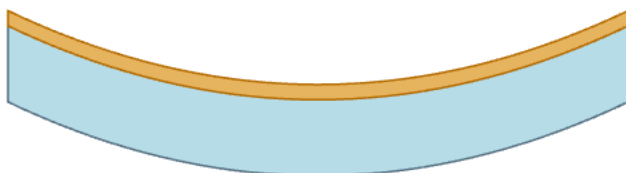
Laminate mismatch and restraint

Film shrinks relative to glass

Bonded mismatch creates stress. Amber: film. Blue: glass. Positive stress: tension.

Free asymmetric laminate

Film free mismatch: -0.50%



Bending + internal stress

Mean front-film stress: 14.3 MPa

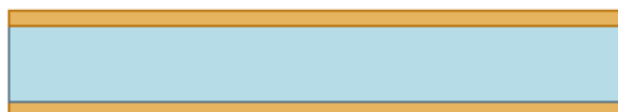
Longer layer lies outside the curve.

Bimetal analogy. LCD films can shrink, relax and respond differently along each direction.

Assumed elastic layers; bow exaggerated. Not a prediction of LCD curvature, mura or a safe temperature.

Balanced front and rear films

Film free mismatch: -0.50%



Little bow; internal stress remains

Mean front-film stress: 14.7 MPa

Symmetry cancels bending coupling.

Held flat by a support

Film free mismatch: -0.50%



Support resists bending

Mean front-film stress: 14.9 MPa

Reaction moment is nonzero.



A display has several temperatures

- 01** Chamber air and the LCD cell can differ
- 02** Measure the panel, backlight and electronics
- 03** Heater and sunlight create local hot spots
- 04** Define the location behind each temperature limit



Hot Contrast: a worked comparison

Illustrative state	White / black (cd/m ²)	Ambient contrast
Before enhancement	800 / 200	4:1
After enhancement	720 / 120	6:1

Illustrative: 70 °C panel, 50,000 lux at the display



Cold motion and heater control

- 01** Test scrolling maps and moving indicators
- 02** Measure response at the actual LCD temperature
- 03** Separate warm-up time from continuous operation
- 04** Check heater faults and local temperature gradients



A temperature procedure has stages



Conditioning and power state

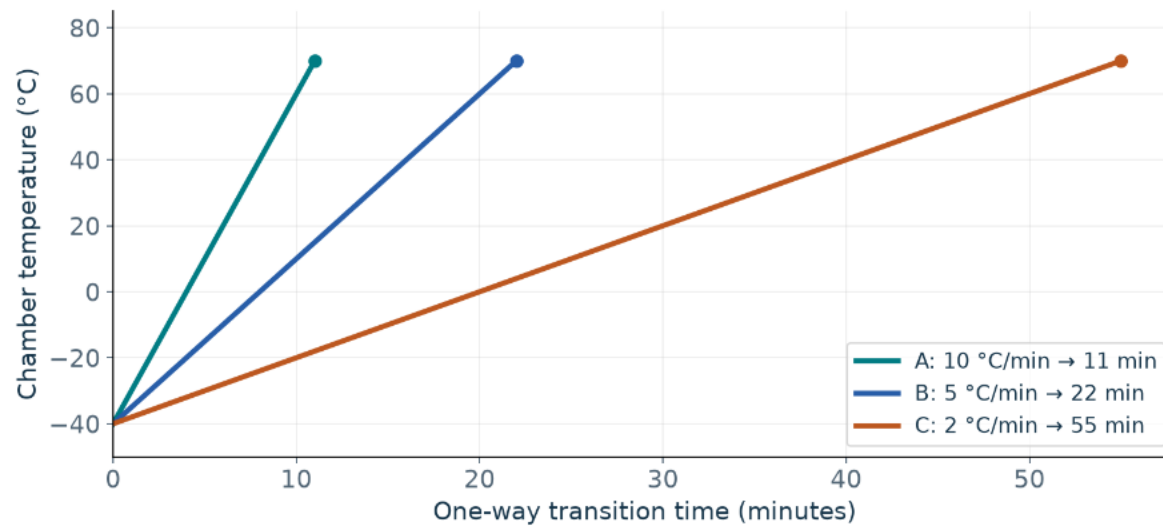
Equipment stabilization and timer trigger

Functional checks with recorded temperatures



Temperature variation and thermal lag

Ramp rate changes transition time



-40 to +70 °C teaching endpoints; linear ramps at the Section 5 A/B/C minimum rates. Stabilization and dwells excluded.

Section 5 A / B / C: 10 / 5 / 2 °C/min minimum

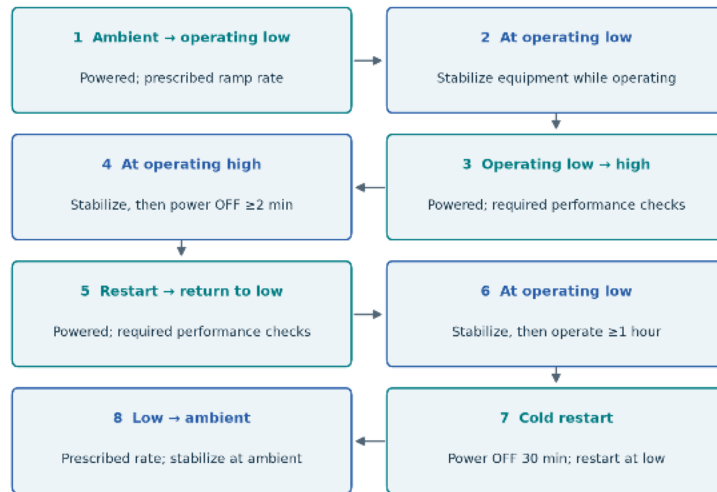
110 °C at 5 °C/min takes 22 minutes

Transition time excludes stabilization and dwell



The complete variation sequence

Temperature variation: one non-combined cycle



Repeat at least TWO cycles; add cycles if needed for complete performance checks.

DO-160G §5.3.1 overview. Boxes are sequence stages, not time-scaled intervals. Combined Section 4/5 tests add requirements.

Powered transitions and restart checks

At least two cycles for A / B / C

Additional checks and full method remain applicable



Thermal lag changes the exposure

- 01 Air reaches the setpoint before heavy parts
- 02 Record the gradient across the optical assembly
- 03 Use the adopted stabilization requirements
- 04 Preserve the required operating sequence



Temperature evidence before and after

- 01** Baseline the optical and functional measurements
- 02** Monitor critical functions during exposure
- 03** Repeat measurements after the specified recovery
- 04** Retain transient faults even if recovery is complete



Absolute pressure and altitude

Pressure Altitude	Absolute Pressure			
	kPa	(mbars)	(in Hg)	mm Hg
-15,000 ft (-4,572 m)	169.73	1697.3	50.12	1273.0
-1,500 ft (-457 m)	106.94	1069.4	31.58	802.1
0 ft (0m)	101.32	1013.2	29.92	760.0
+8,000 ft (+2,438 m)	75.26	752.6	22.22	564.4

8,000 ft corresponds to 75.26 kPa absolute

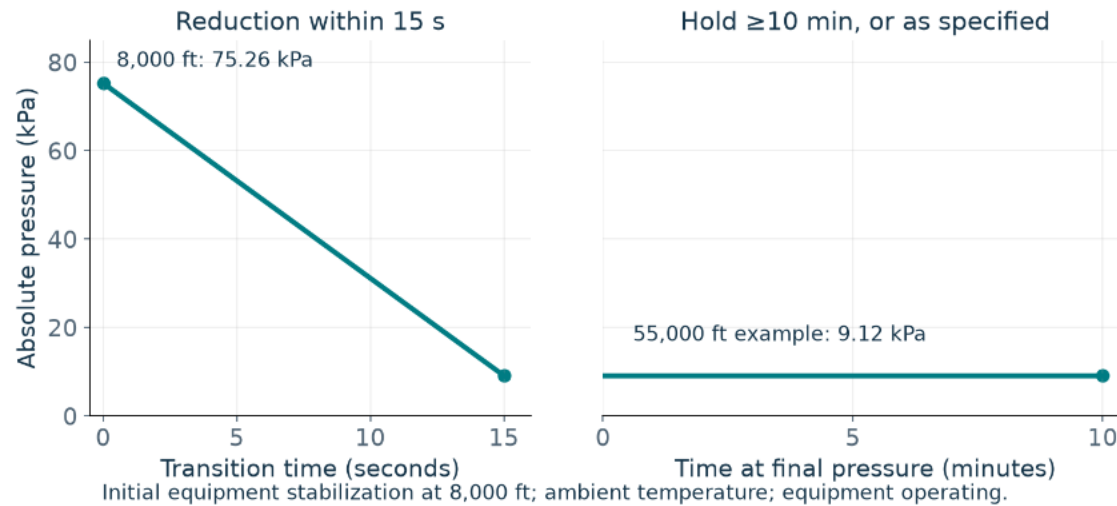
Gauge pressure needs a reference

Altitude alone does not define the profile



Decompression is a pressure transient

Decompression: transition and hold are different



DO-160G §4.6.2 / Table 4-2. Illustrative 15 s linear pressure fall; shape is not prescribed. Final altitude is aircraft-specific.

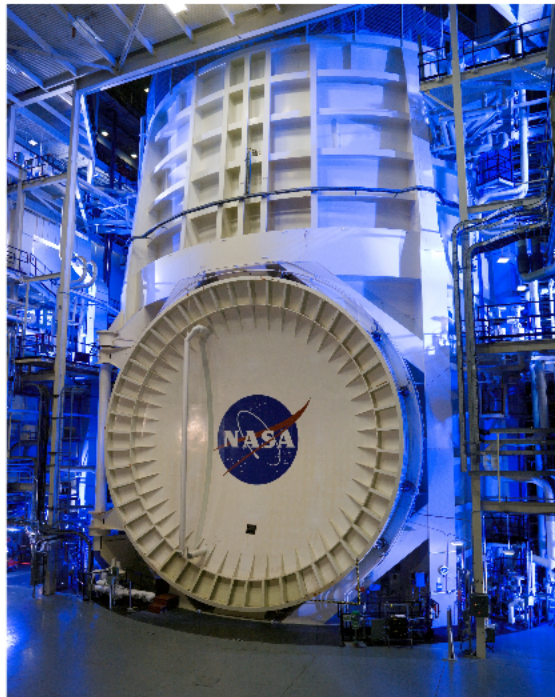
Initial condition: 8,000 ft equivalent

Endpoint: aircraft maximum operating altitude

Within 15 s; hold at least 10 min or as specified



Pressure-test equipment



Vessel, seals and pressure instrumentation

Pressure profile and powered feedthroughs

Aircraft conditions differ from space vacuum

NASA Johnson Space Center; Public domain in the United States



Altitude, decompression and trapped air

- 01 Restricted equalization creates a pressure difference
- 02 Trapped gas can expand or load a constrained cavity
- 03 Vents, leakage and decompression rate govern equalization



Adhesive and cohesive failure

Failure location	Meaning
At a bonded interface	Adhesive failure
Within adhesive or sealant	Cohesive failure
Within film, coating or glass	Identify the damaged layer

The fracture location identifies the failure mode



Pressure effects across the adhesive system

- 01** Optical silicones and adhesive films
- 02** EMI tapes, bonded gaskets and seals
- 03** Potting and encapsulation compounds



Pressure difference loads the window

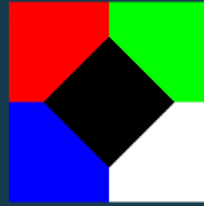
Quantity	Illustrative value	Meaning
Window area	$0.200 \text{ m} \times 0.150 \text{ m}$	0.030 m^2
Pressure difference	20,000 Pa	Internal minus external
Resultant force	$20,000 \times 0.030$	600 N

Illustrative load before structural analysis



Vents, seals and pressure monitoring

- 01** Track internal and external pressure separately
- 02** Assess vent flow through the installed path
- 03** Include filters, membranes and blocked-path risks
- 04** Inspect optical interfaces after recovery



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The Future of Display and Systems Development

Next chapter

Moisture and Contamination

I'm Diggy Breiling. Thank you for joining me.

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