PILKINGTON

First in Glass

Glass Strength in Solar Applications

International Materials Institute

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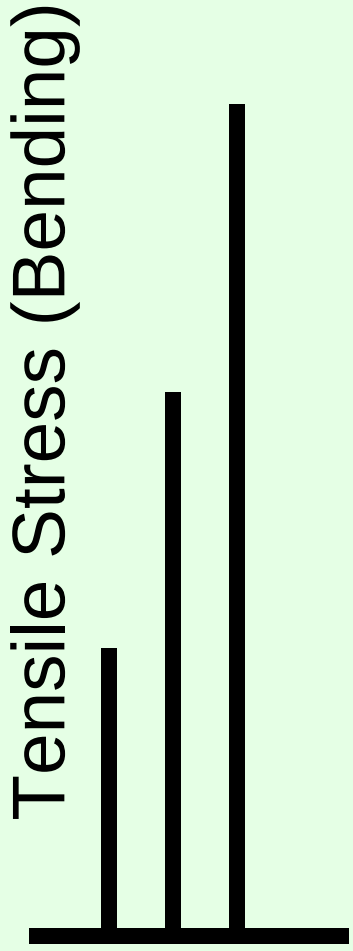
Breakage Causes

Glass breaks when an applied load exceeds the strength of the glass

The big question is:

Was the load too great, or was the glass too weak?

How Strong is Annealed Glass?



9,000 psi 992 Broken (8 not broken)

6,000 psi Half (~500) Broken

3,000 psi 8 of 1,000 Samples Broken

0 psi 1,000 Identical Test Samples

Conclusion: Don’t use glass for Rupture Disks

Glass Strength

1. **Tempered Glass is ~ 4 x Stronger than Annealed Glass**
2. **Heat-Strengthened Glass is ~ 2 x Stronger than Annealed Glass**
3. **Chemically Strengthened Glass can be > 4 times Stronger than Annealed Glass**

Surfaces and Strength

1. **Rolled texture? Prisms?**
2. **Non-glare, Acid Etch?**
3. **Sand Blast – 50%?**
4. **Coated (aging protection) + X%?**

Glass Edge Strength (ASTM E 1300)

Annealed Edges: **As Cut 2400 psi**

Seamed 2650 psi

Polished 2900 psi

Glass Strength Testing

1. **Non-destructive: ASTM E 998**
2. **Destructive: ASTM E 997**

Does Proof Testing create new damage?

EN Test methods exist for artificial weathering

Breakage Causes

1. **Tensile Stress**: 1.a. Bending
   1.b. Thermal
   1.c. NiS inclusion expansion in FT or HS
2. **Impact**: 2a. Hard Body – Hail Stones
   2b. Soft Body – Snow Slide
3. **Crushing**
4. **Acts of God**? *God doesn't break glass – we do*
5. **Mother Nature**? *Hurricanes happen – don't blame your mother*

Breakage Causes

FRACTOGRAPHICS can find the cause.

It only takes enough: time; money;

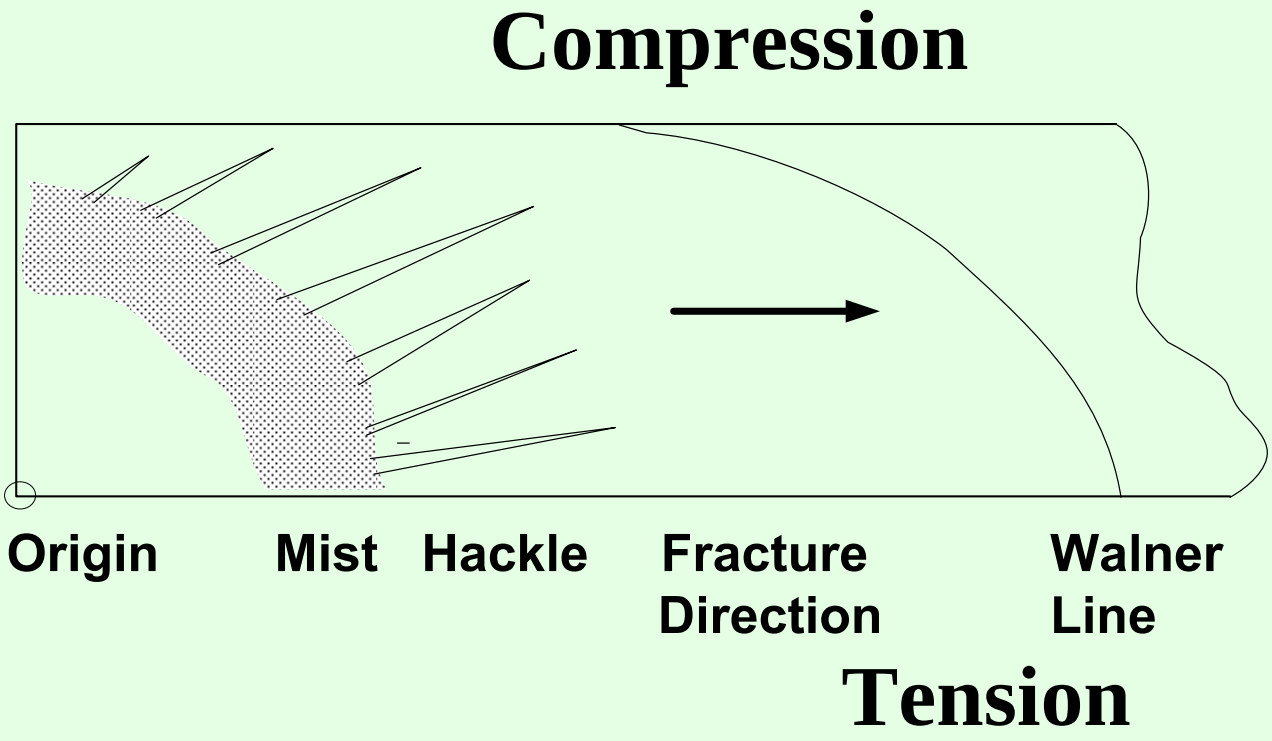
and having all the broken pieces

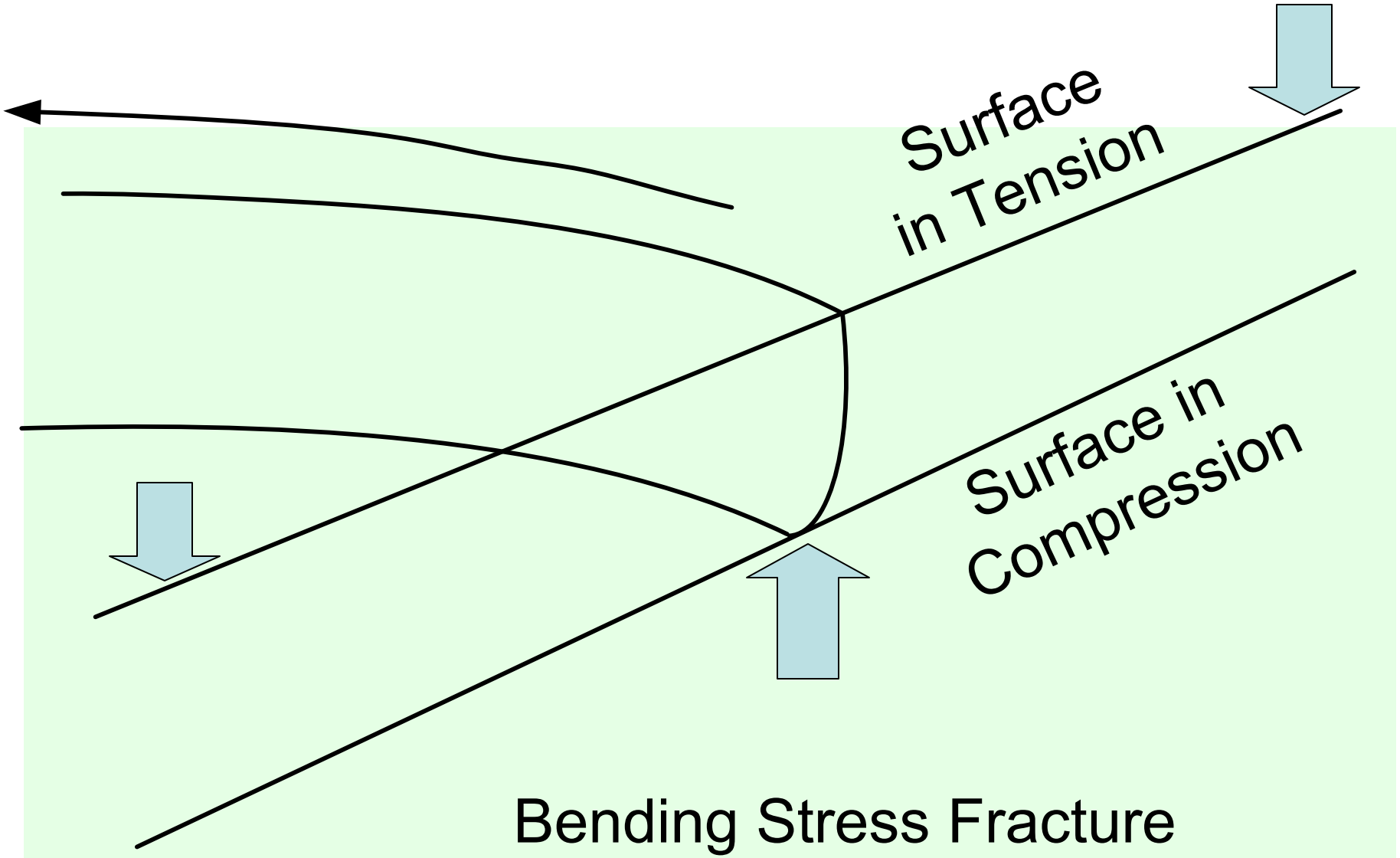
See: ASTM C 1256-93 "Interpreting Glass Fracture Surface Features"

“White Boat Rock”

Bending or Thermal Cause

First, find the fracture origin



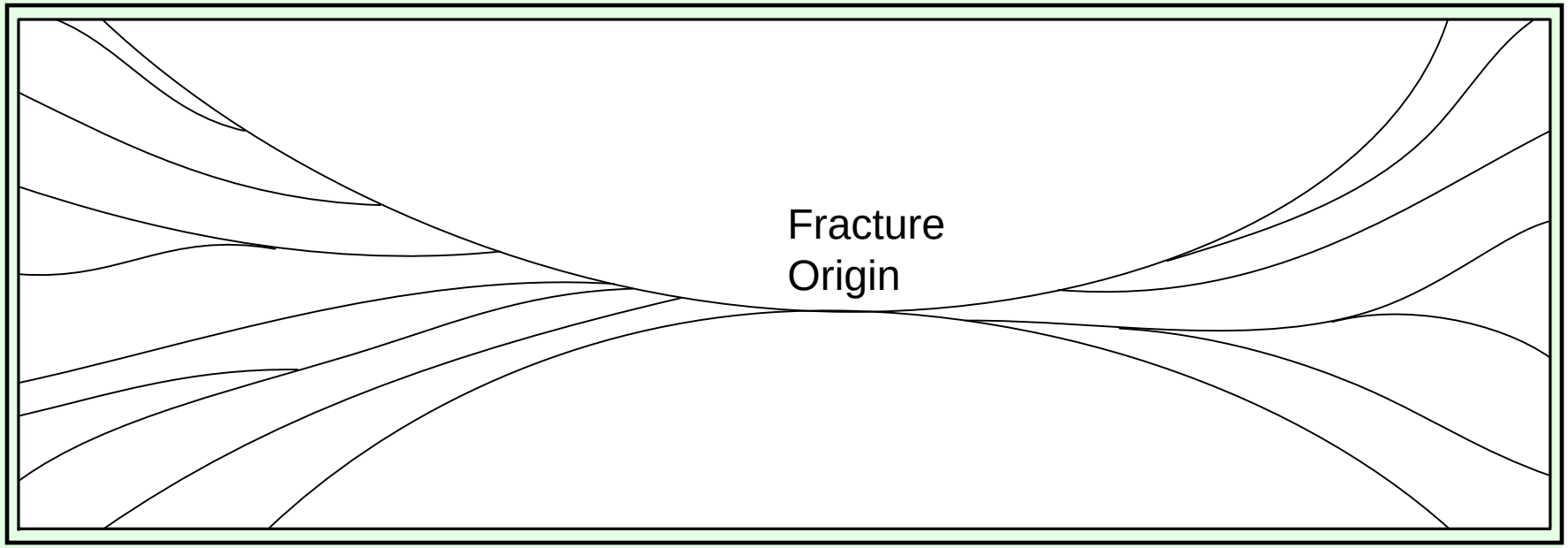


Bending Stress Fracture
Fracture starts in tension zone

Bending Stresses

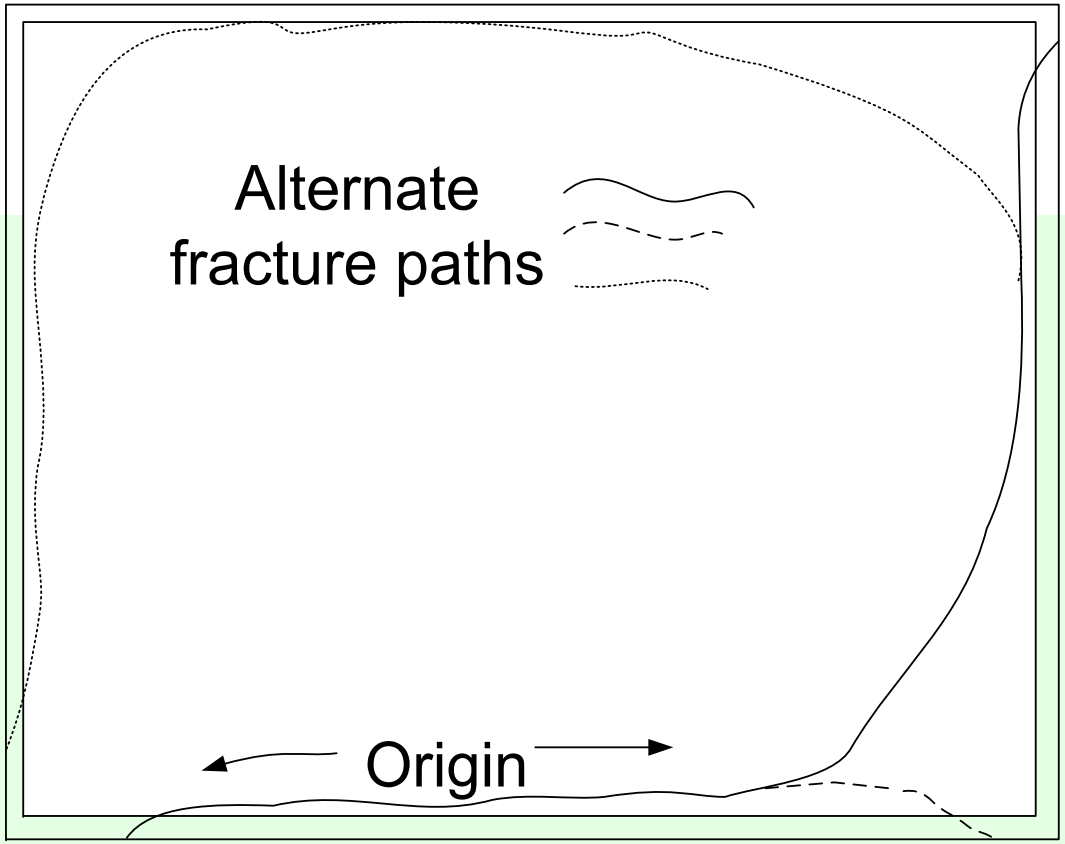
Cold Bending of Annealed or Heat Treated Glass?

See Glass Performance Days 2007, Finland papers

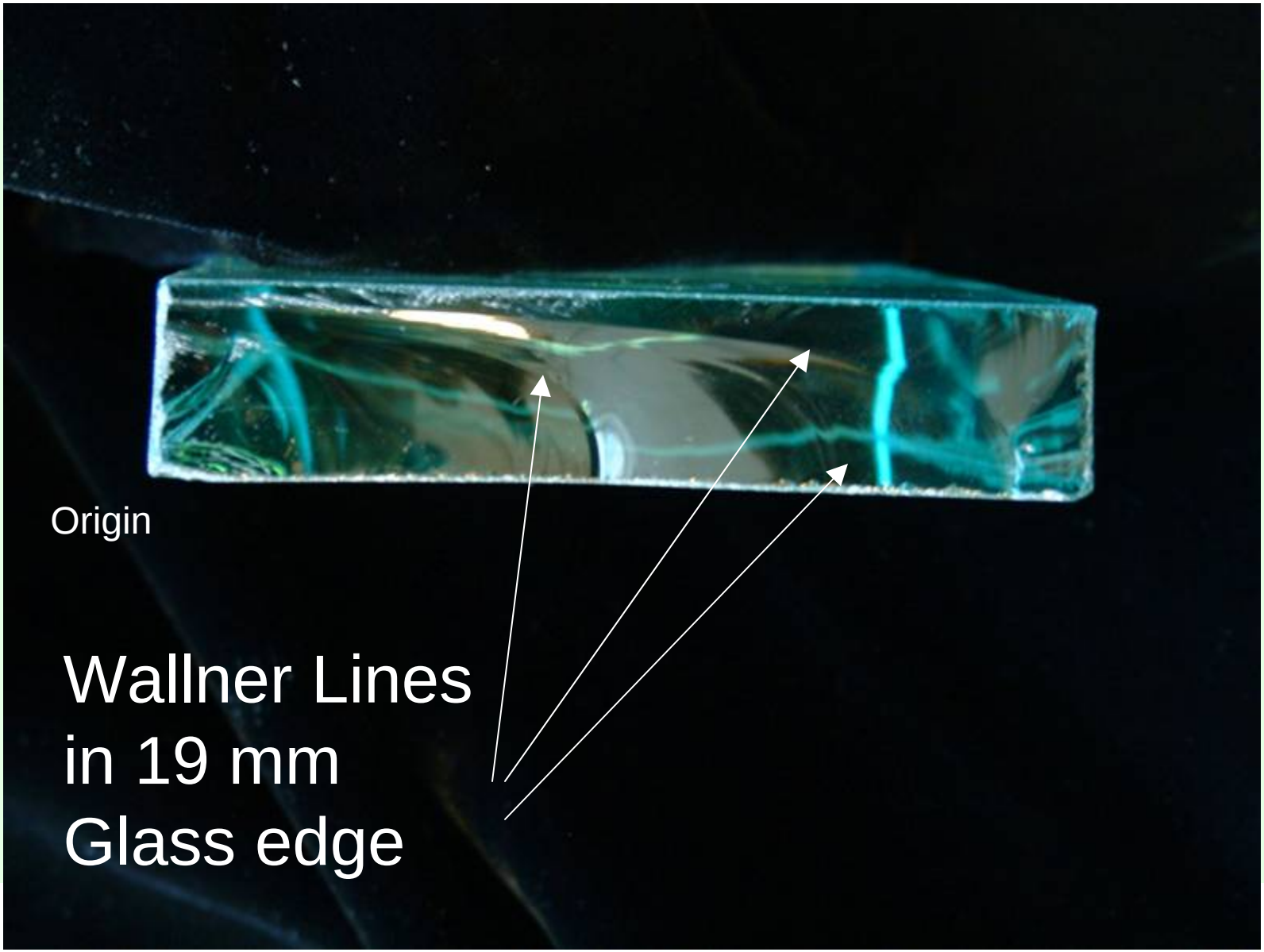


Properly glazed High Aspect Ratio Sealed Insulating Glass.

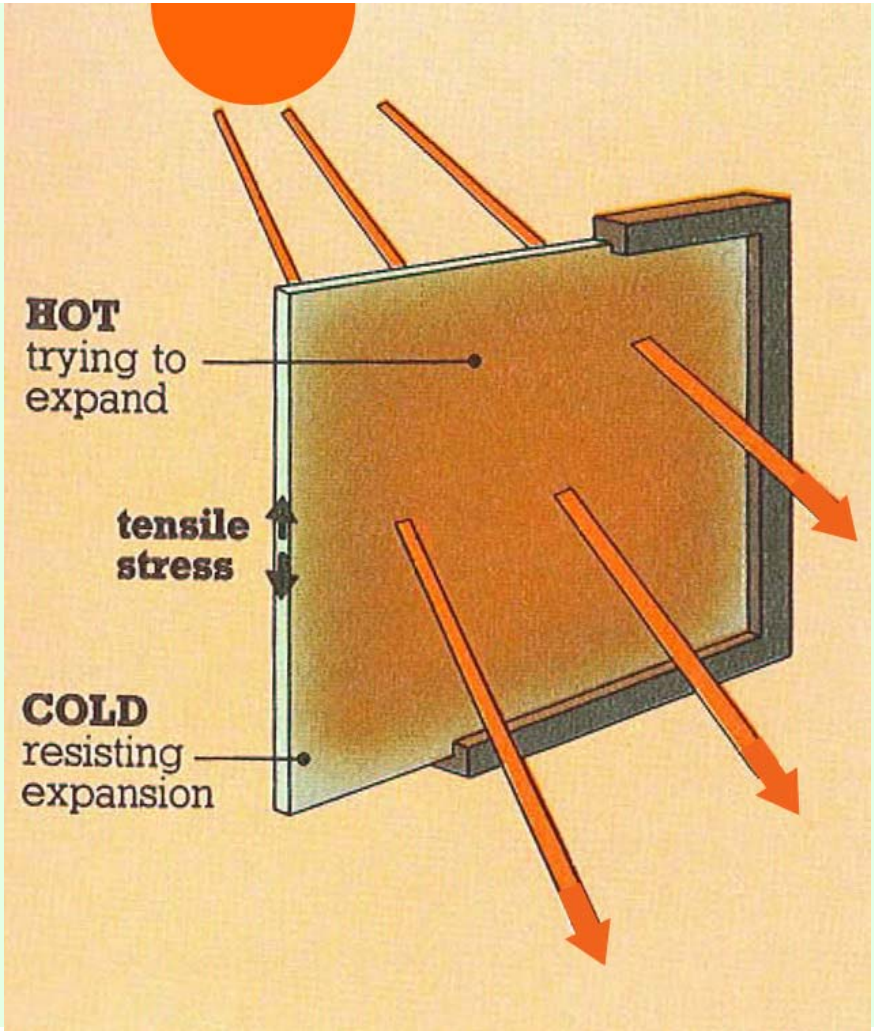
Breakage from too High or too Low air space pressure



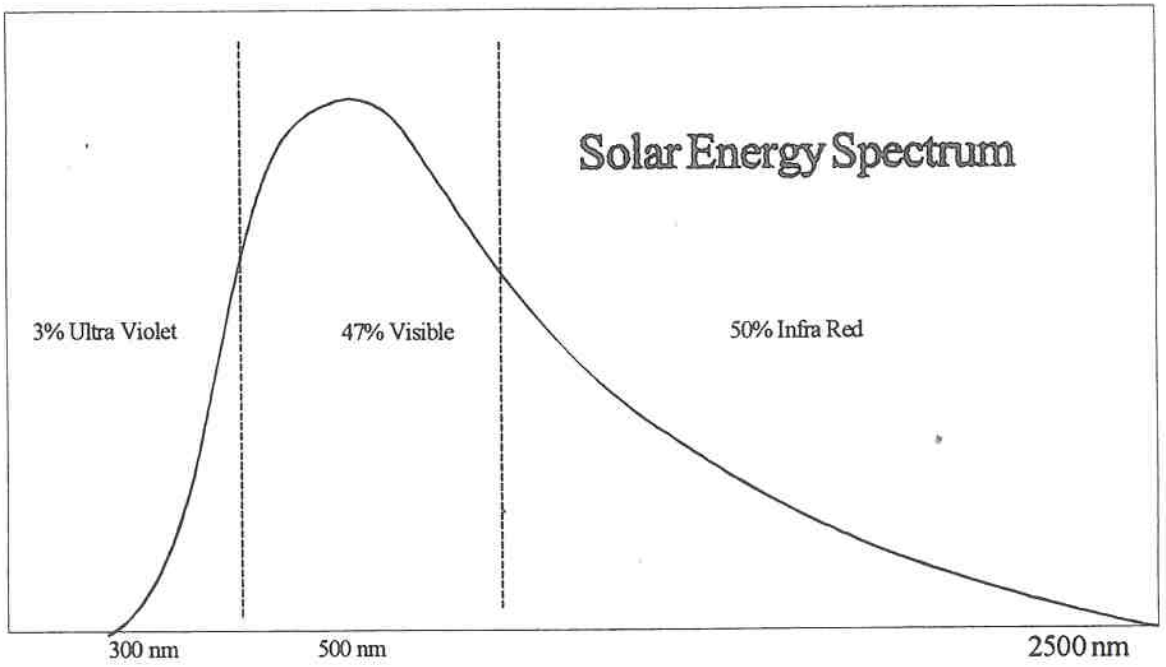
Incorrect ‘Clamped Edges’ create very high bending stresses at low temperatures in Insulating Glass. Fracture origin at a scratch.


Origin
Wallner Lines
in 19 mm
Glass edge

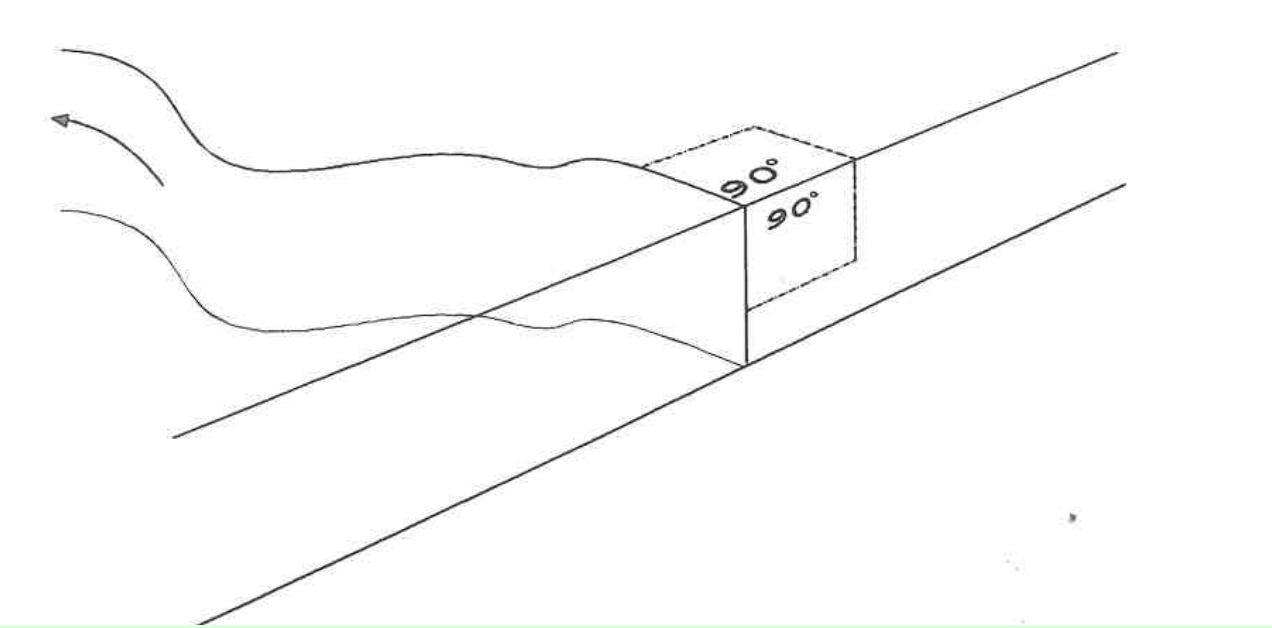
Thermal Stress Generation



Thermal Loads



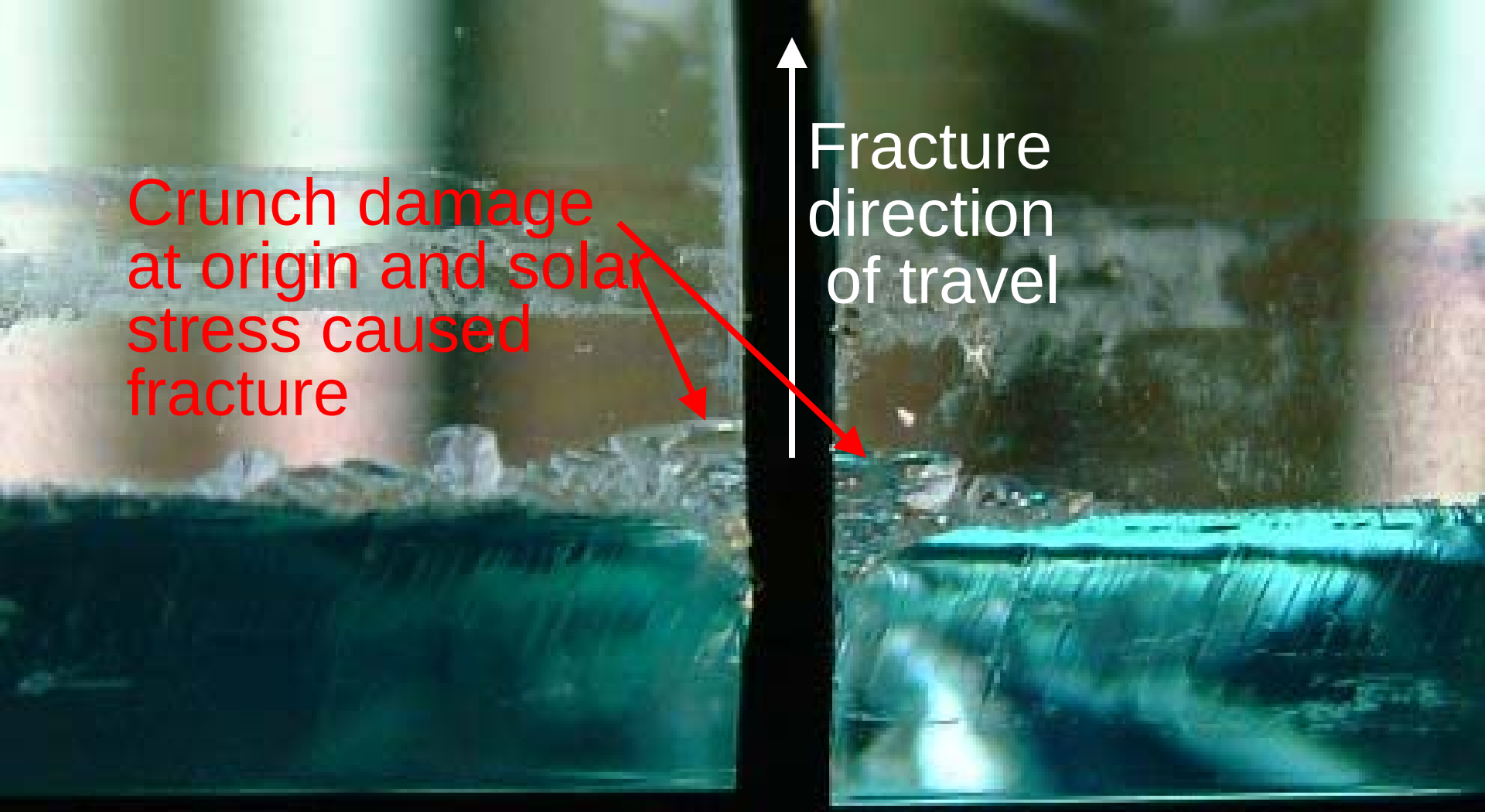
A glass or coating can appear clear yet absorb
a large amount of invisible Solar IR energy
and so incur significant stress



Classic Thermal Stress fracture origin.

Break typically starts in the central ¾ of the edge length and not at a corner.

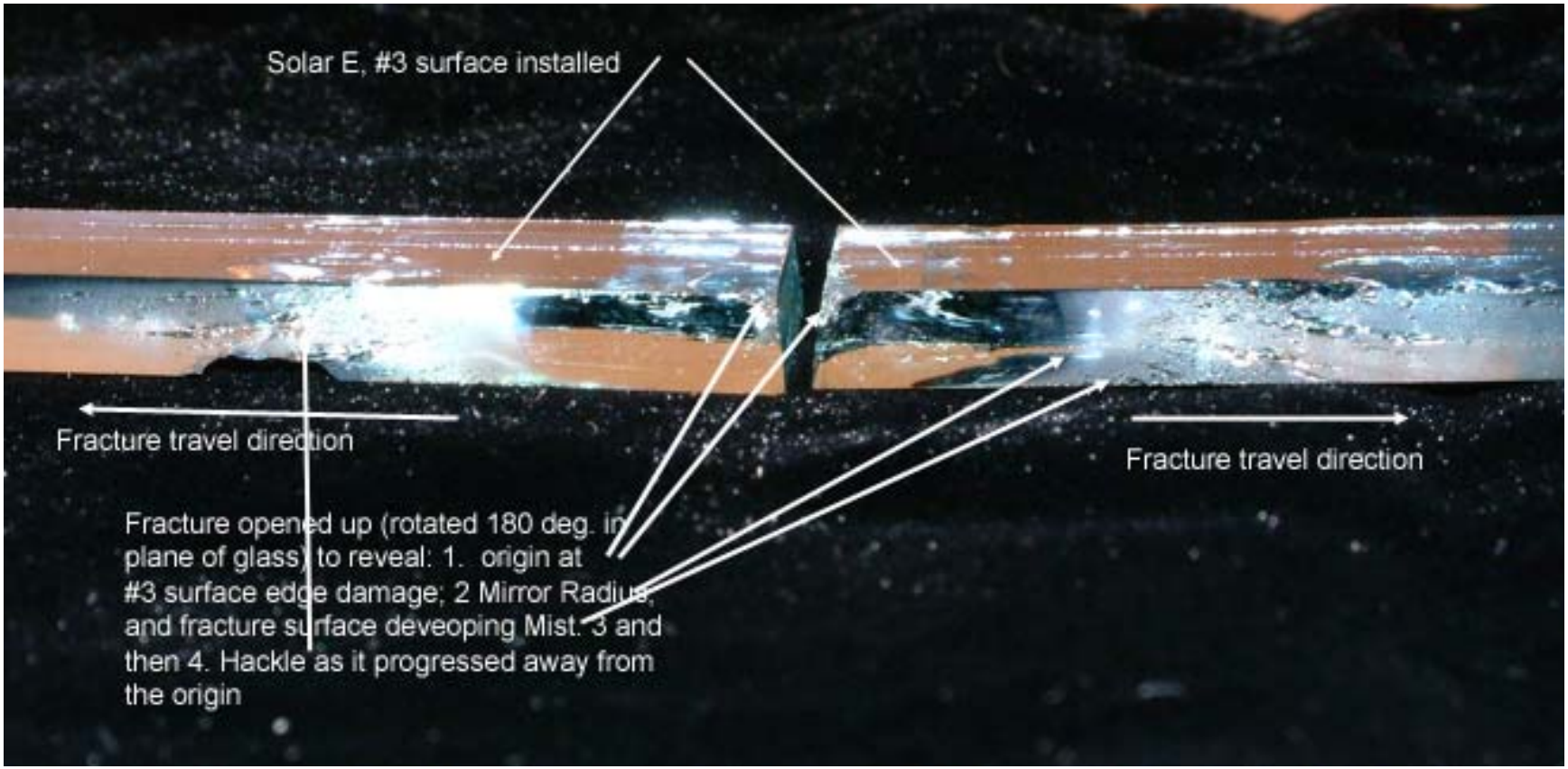

2004 3 12

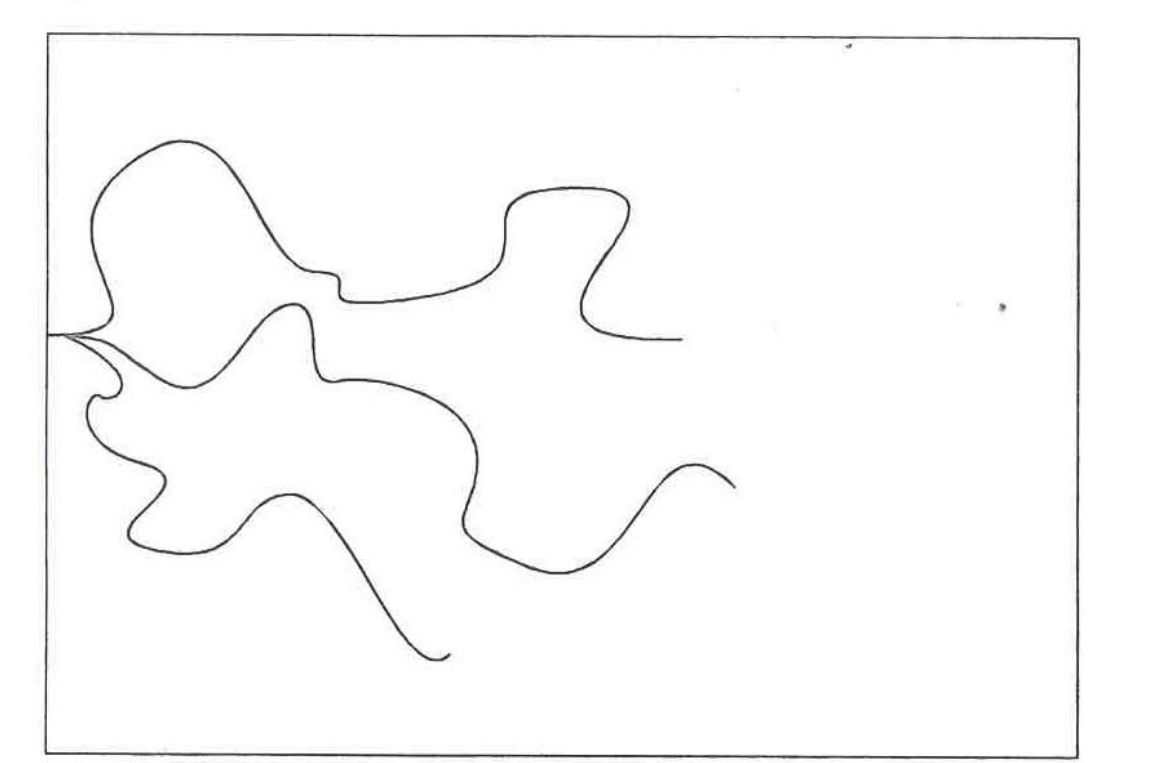


Cut edge – poor quality

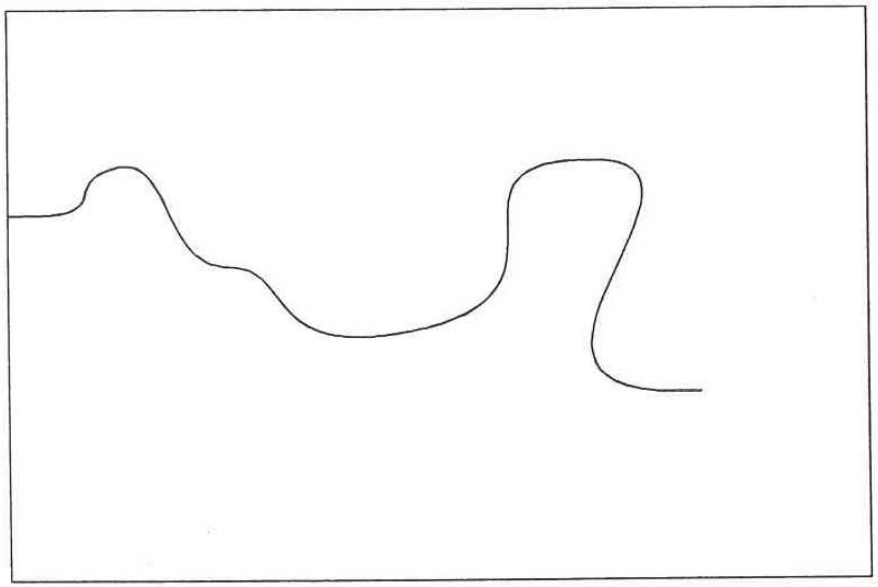
Solar E (solar absorbing Low E coating) incorrectly used on #3 Surface (should be #2).

Energy Advantage Low E can be correctly used on either #2 or #3 Surface

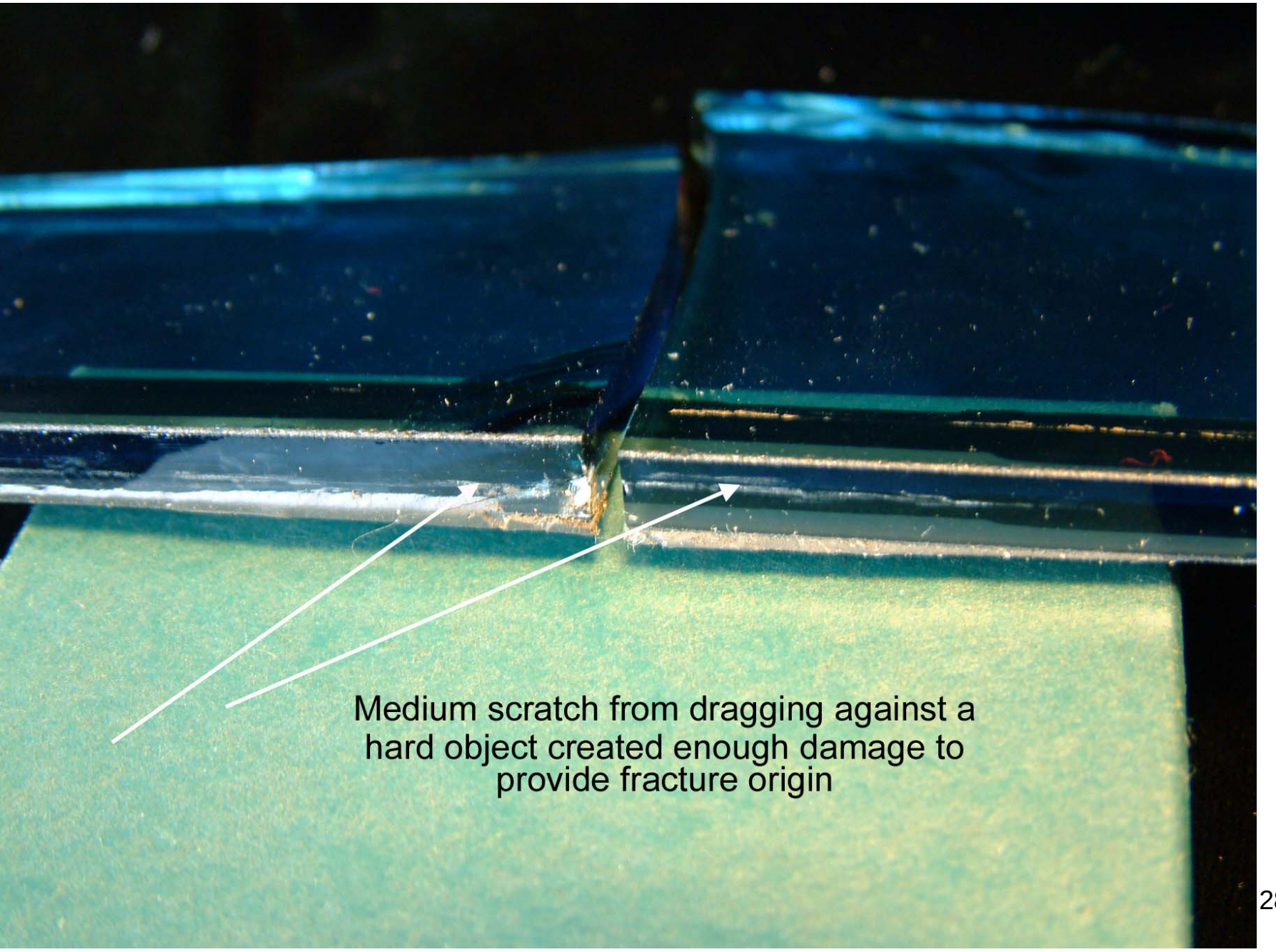

Solar E, #3 surface installed
Fracture travel direction
Fracture travel direction
Fracture opened up (rotated 180 deg. in plane of glass) to reveal: 1. origin at #3 surface edge damage; 2 Mirror Radius, and fracture surface deveoping Mist. 3 and then 4. Hackle as it progressed away from the origin



High Stress: Multiple crack surfaces were needed to absorb excessive energy.

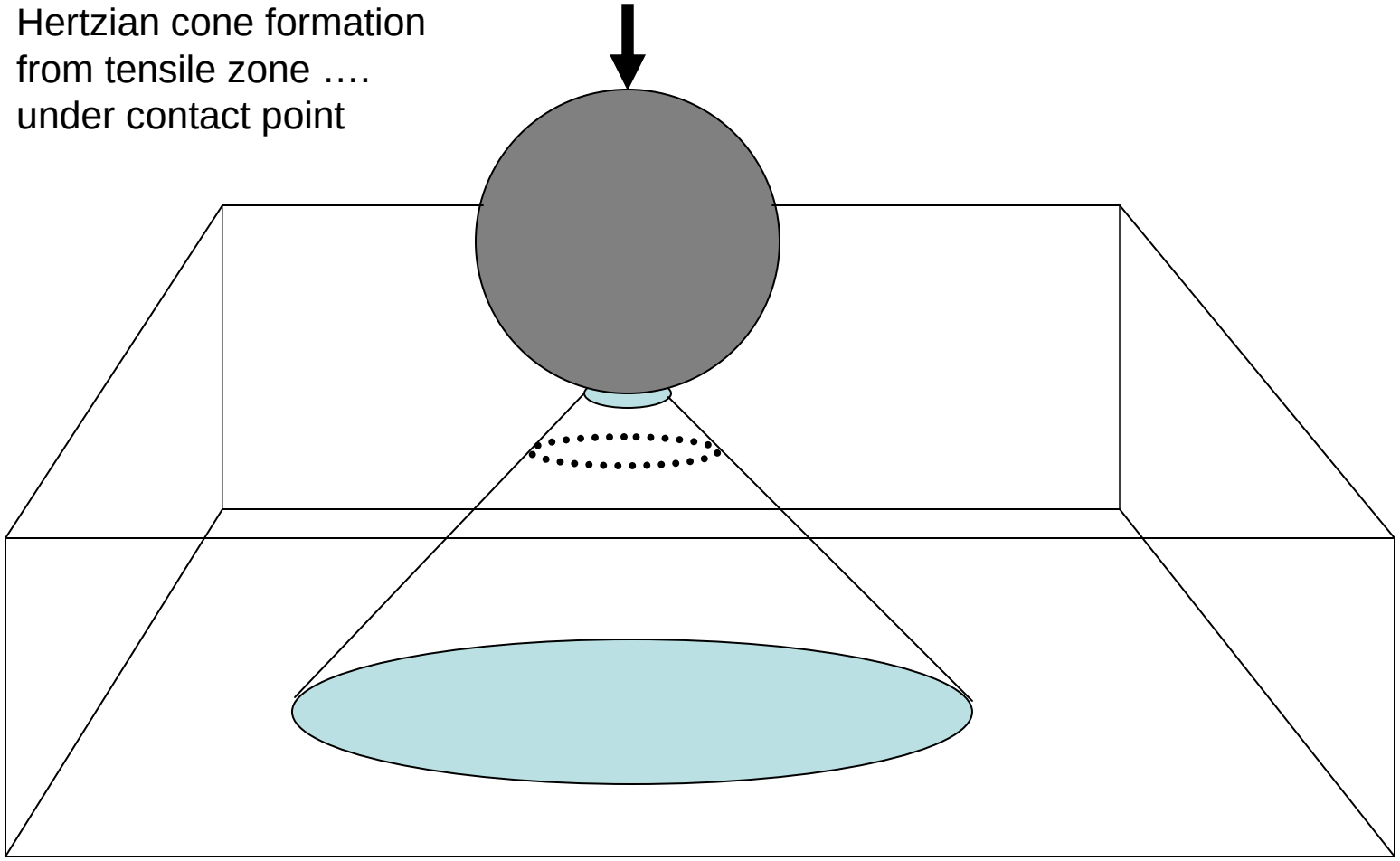


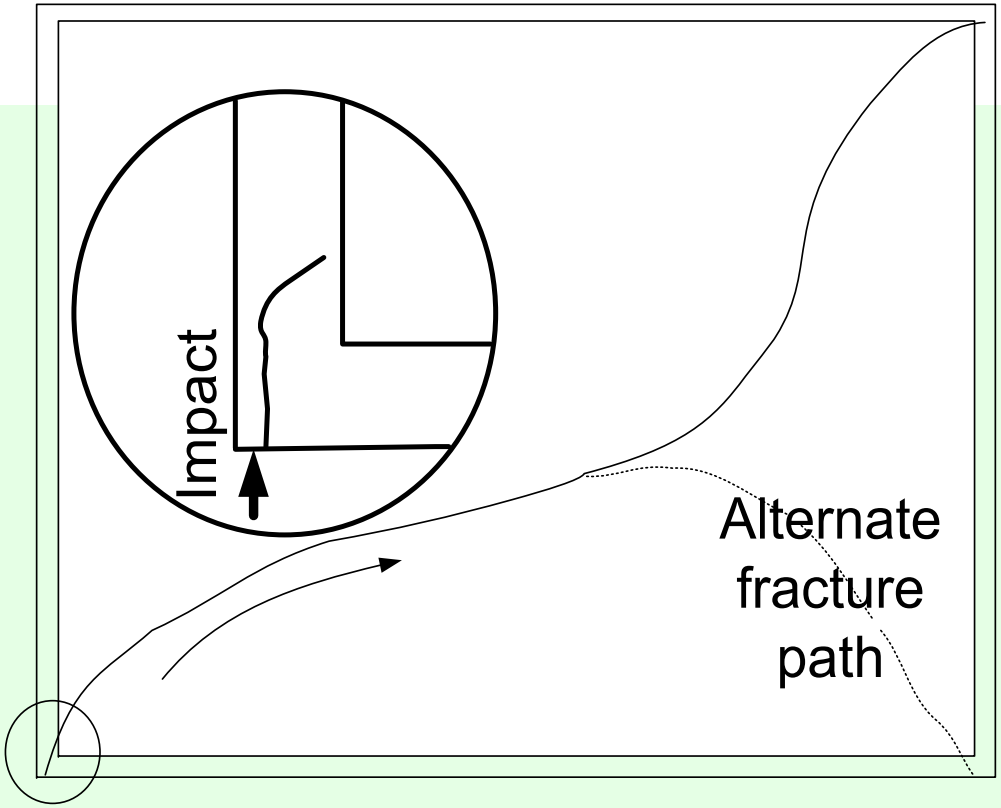
Low Stress: Single crack suggests a weaker glass edge. Less energy was needed to propagate the crack


Medium scratch from dragging against a hard object created enough damage to provide fracture origin

Impact Cause

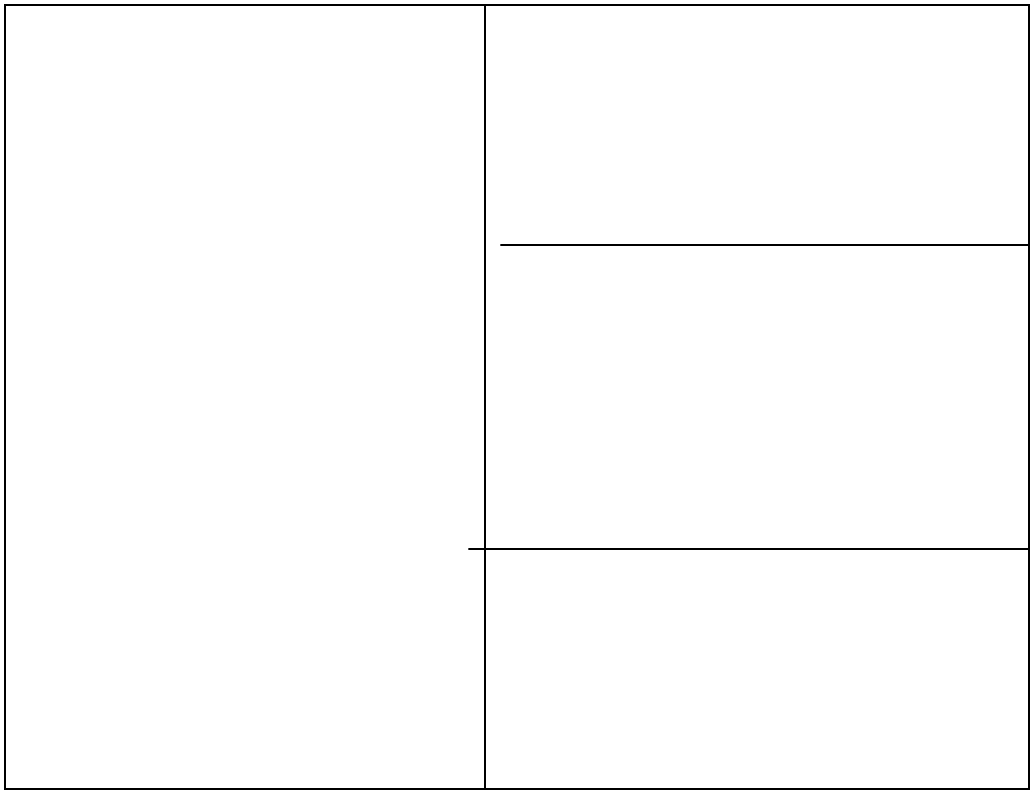
Hertzian cone formation
from tensile zone ….
under contact point





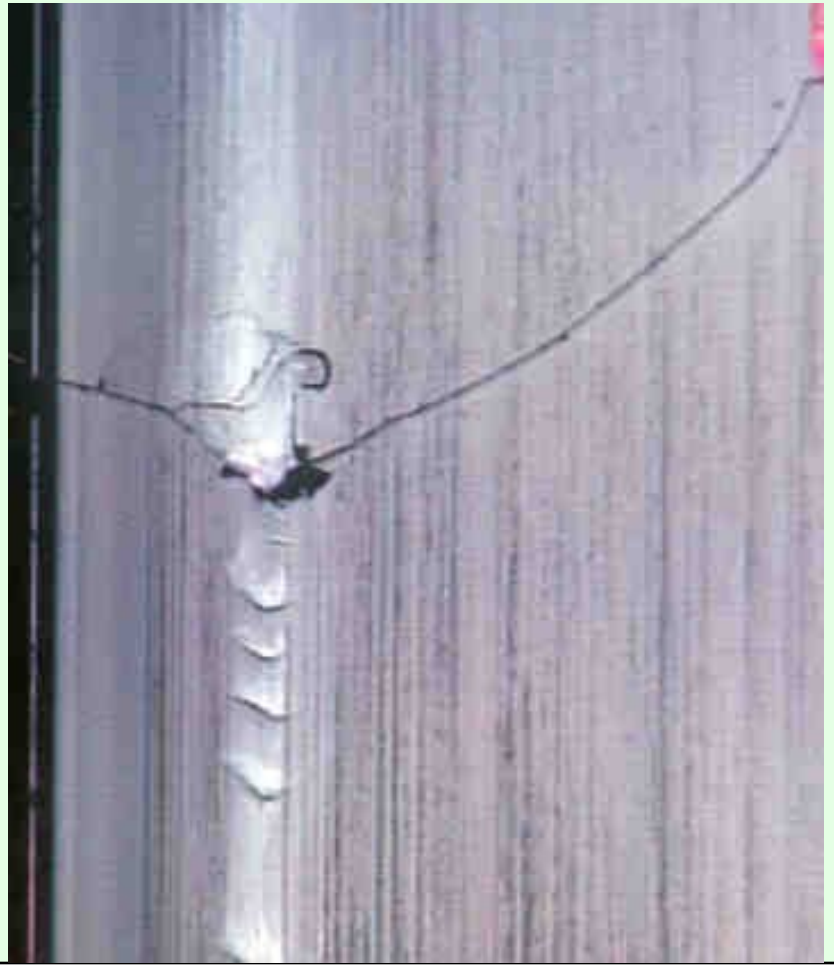
A corner impact easily creates a 10 or 20 mm long crack which waits for a high stress situation to make it run. Here low winter temperature contracts the sealed air space and creates a large bending stress.

Over-running
Interrupted Cut Score Line

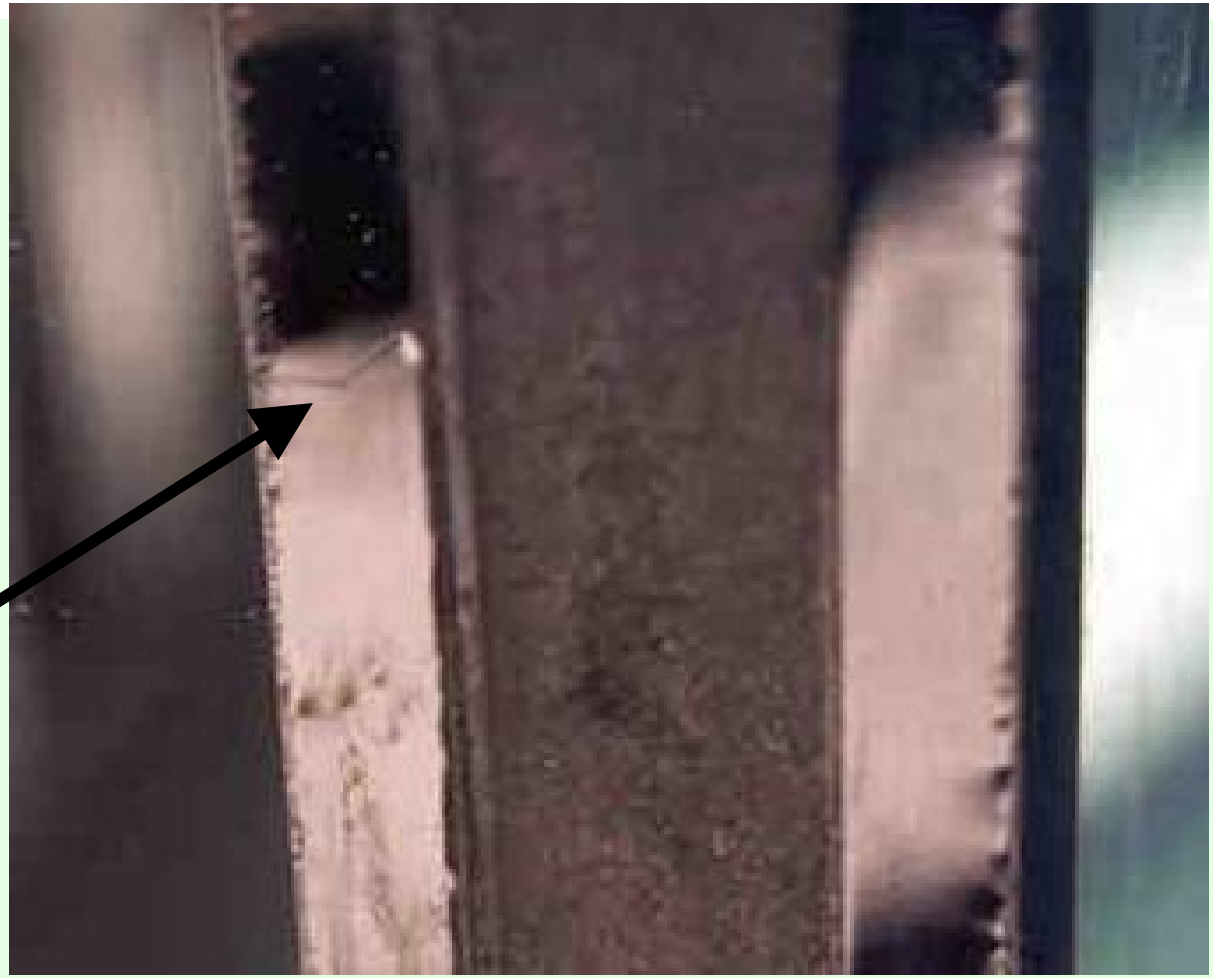



Weld Splatter Damage

Insufficient sealant in IG gun head made rub marks causing many vents of sub-millimeter size in glass cut edge



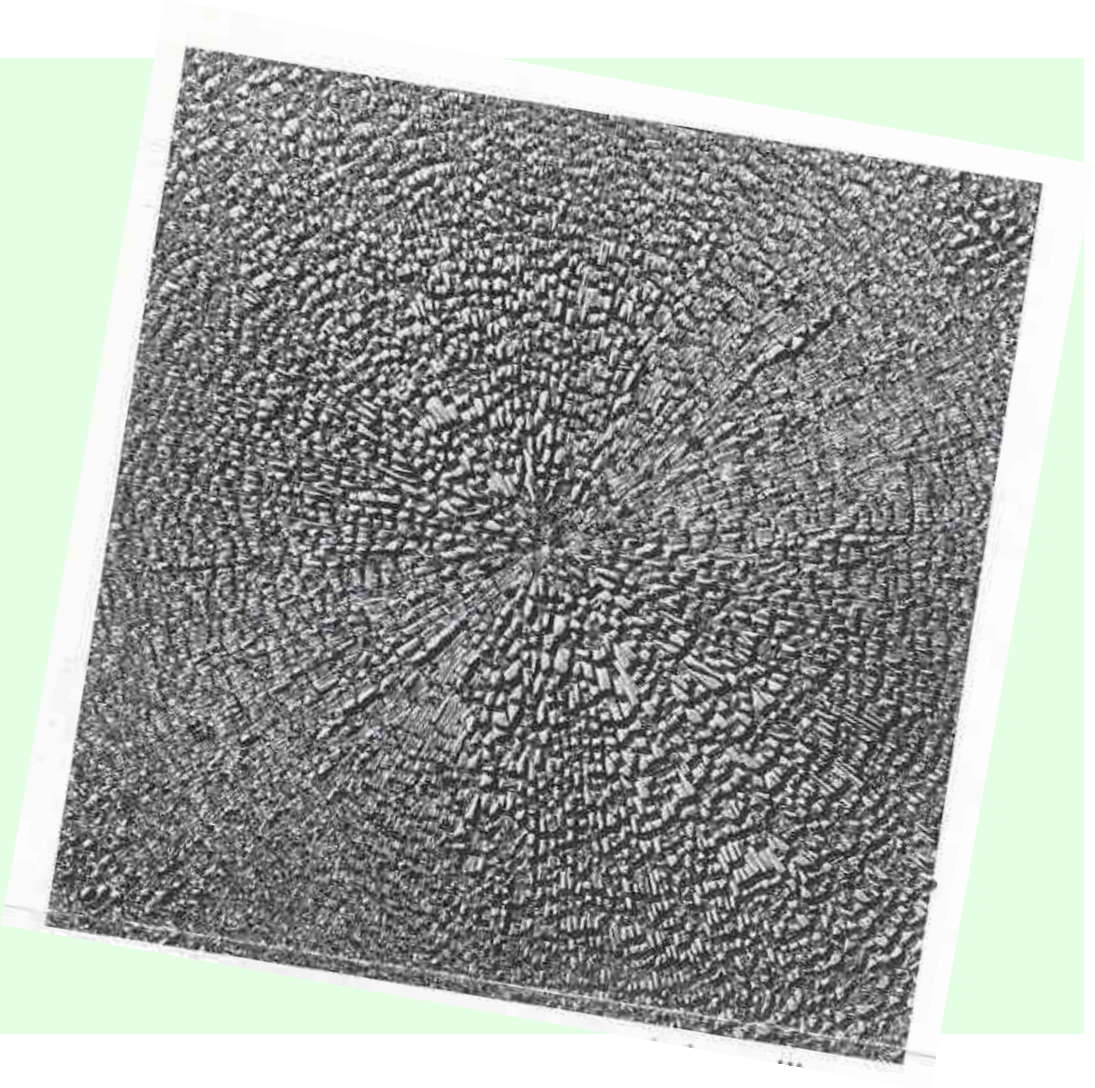
Fracture Origin at rub mark on IG cut edge. Thermal stress caused the small vent to run



Tempered Glass

Fracture origin at plate center

Look for surface damage or very small inclusion in glass at origin



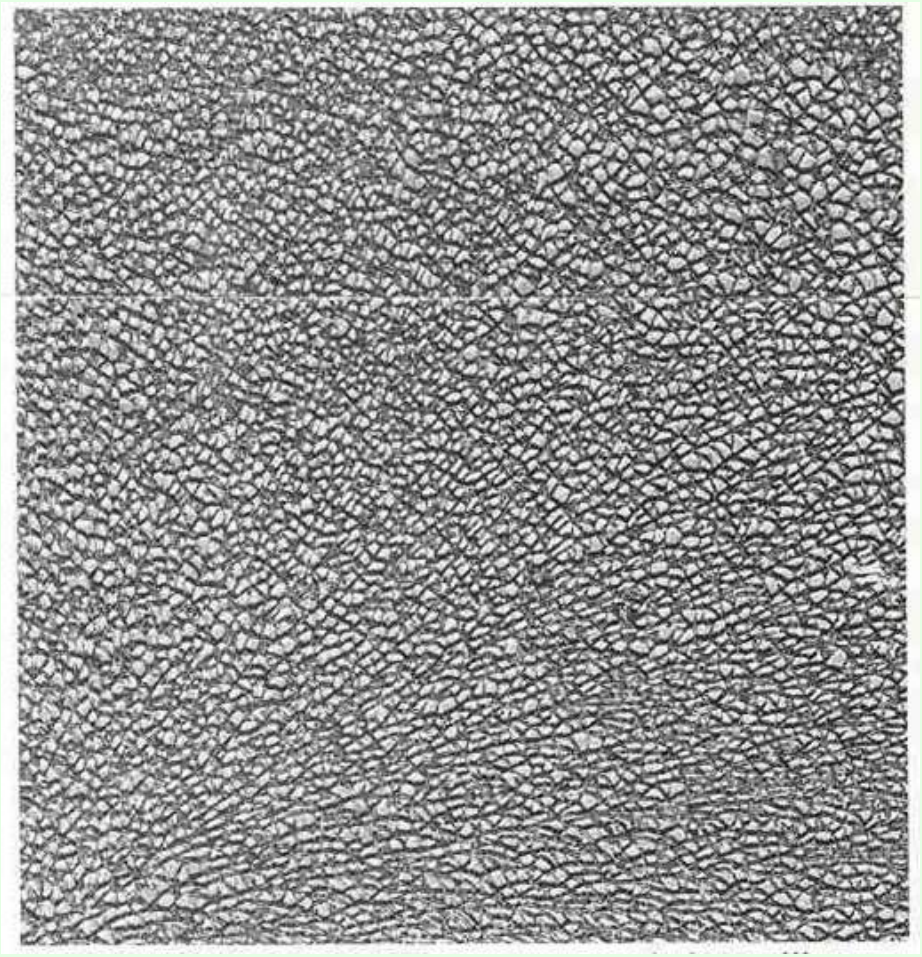
TEMPERED GLASS

– On rare occasions, heat-treated (tempered and sometimes even heat-strengthened) glass can break spontaneously, without any applied load, due to small inclusions that may be present in all float glasses.

Tempered Glass

Corner origin of fracture.

Look for corner-crunch damage



Wind Loads

Wind Loads used to be 60 second duration gusts.

Now the building codes use 3 second duration gusts.

3 second gusts are greater than those of 60 sec.

But Glass is stronger when the load duration is shorter so there was little change when the codes changed.

Summary

Will my glass break?

Nobody knows for sure. You can't tell how strong it is, until it was.

Design glass not to break (low probability), but if it does, the consequences must be acceptable.

What to Do

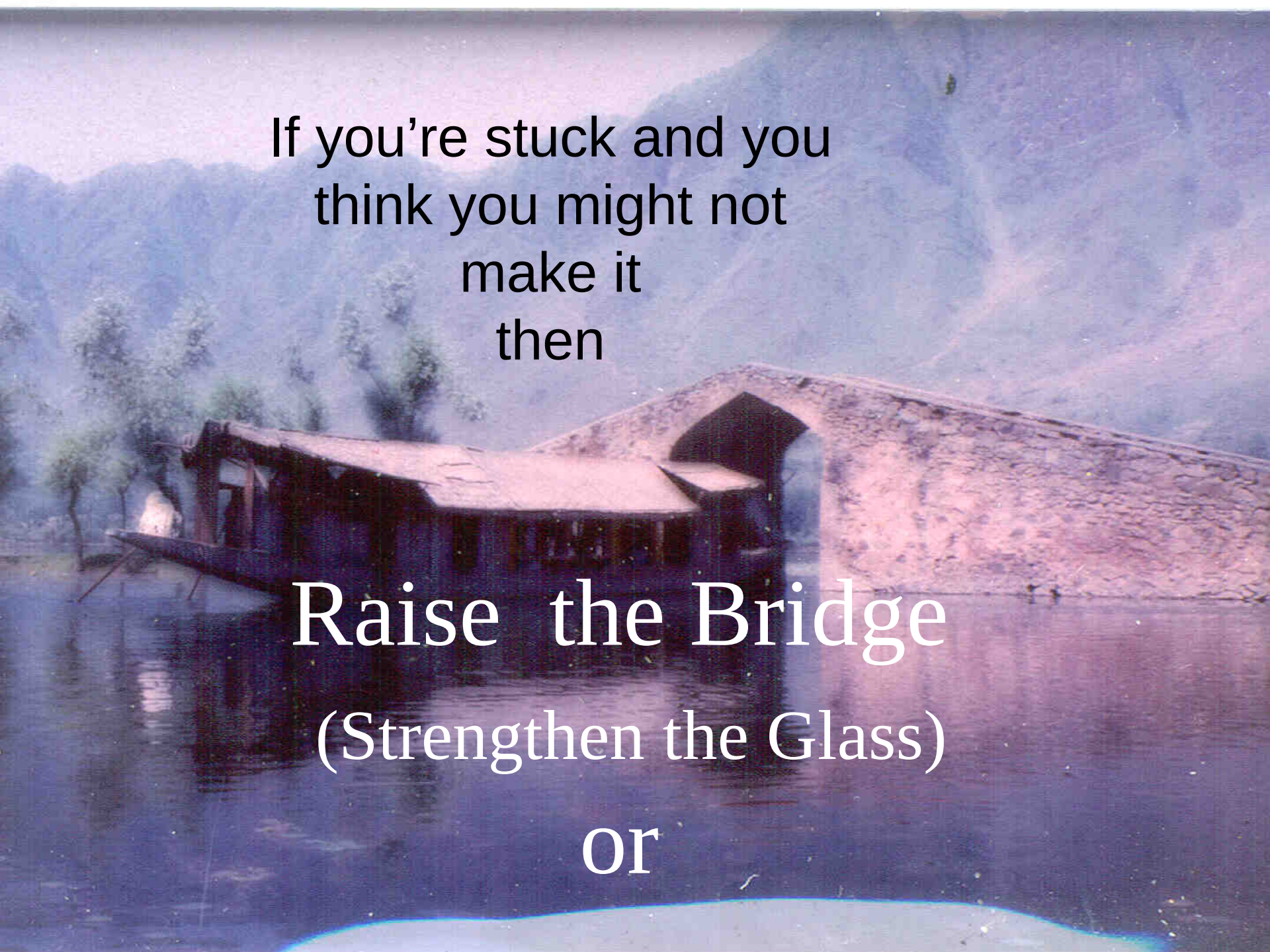
Was the load too great?

(Better Load Specification Needed)

or

Was the glass too weak?

(Better Glass Strength Testing Needed)


If you’re stuck and you
think you might not
make it
then
Raise the Bridge
(Strengthen the Glass)
or

Lower the River
(Reduce the Load)