

# PACRIM Conference Vancouver: June 4, 2009

## Commercial Application Using Multiple Processes for Strengthening Glass

Presentation by Mark Doyle

World Kitchen, LLC



- In commercial production since 1970
- Over 3 billion pieces sold

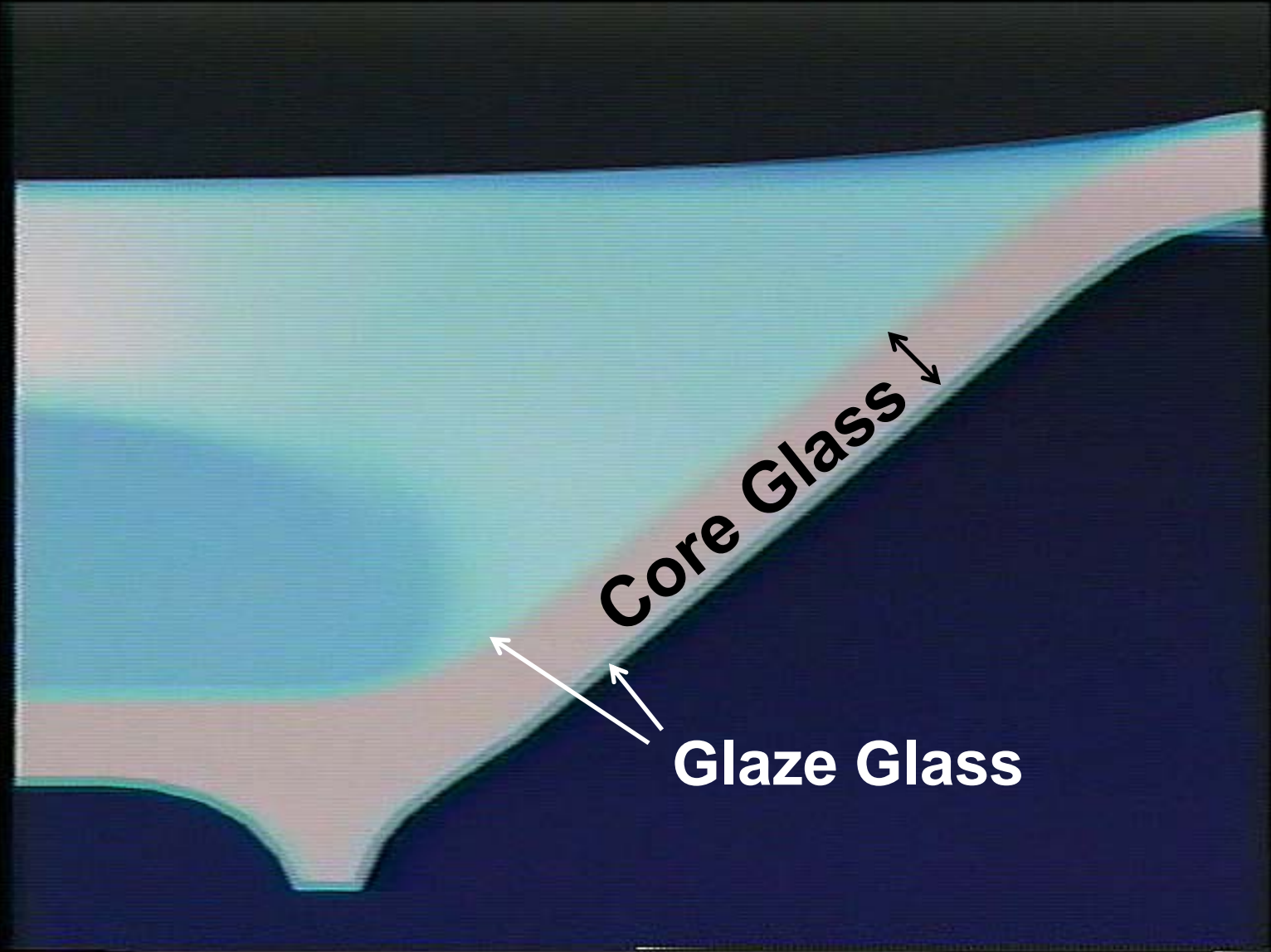
# What is Corelle®?



- Successful commercial application of strengthened glass
- Uses complex process to make a commonplace product – the humble dish
- Uses multiple strengthening processes (lamination and tempering)

- 3 Layer glass laminate
  - Core glass
    - ❖ Fluoride opal
    - ❖ 95% or greater of the total thickness
    - ❖ Higher thermal expansion
  - Glaze glass
    - ❖ Alumino-silicate
    - ❖ Very thin (thousandths of an inch)
    - ❖ Lower thermal expansion
- Need to select glasses such that differential thermal expansion is correct and that have compatible viscosities to allow proper forming

# Laminate Structure



# Melting Process Overview



- Core Glass

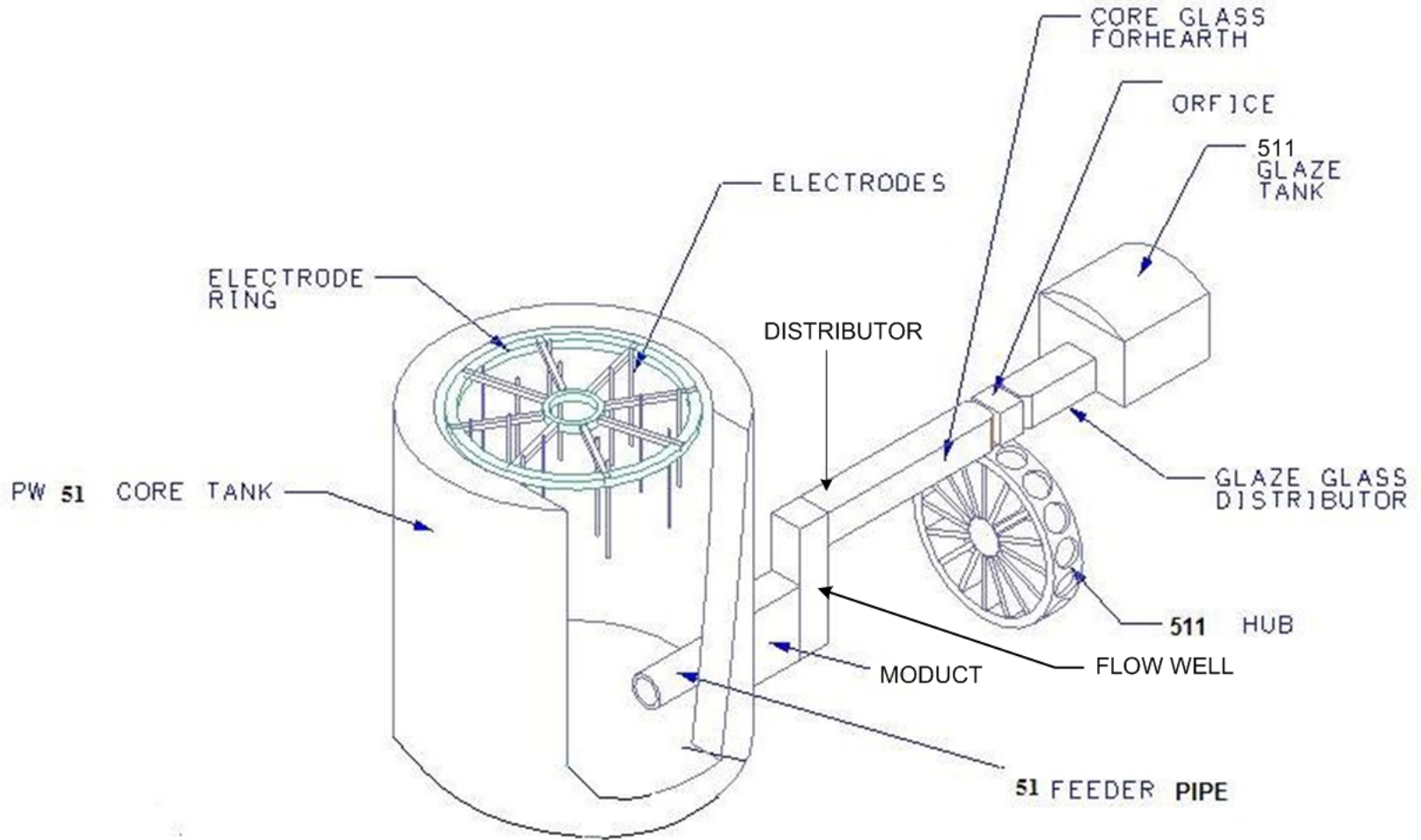
- 2X 100 ton/day all-electric, vertical, cold-crown melters
- 3 forming positions per melter
- Electric fired, submerged delivery system
- Gas-air fired bowls and distributor

- Glaze (skin) Glass

- 2 ton/day, gas-oxy fired, electric boosted melter
- Gas-air fired delivery system
- One glaze system per forming position

- Lamination occurs in Corelle<sup>®</sup> orifice

# Melting Process Schematic



# Forming Process Overview



- Laminated sheet from orifice passes through rollers to set thickness and strike-in opal
- Sheet is vacuum formed in molds on Hub machine
- Ware cut out of sheet by trimmer
- Immediately fire polished to seal edges of formed dish to prevent oxidation

Process

# Why Was Corelle® Developed?



- Developed as competition for plastic tableware (1960's)
- Desired Properties:
  - Lightweight
  - Stackable
  - Strong and tough
  - Impact resistant
  - Thermal shock resistant
  - Inexpensive
  - Stain resistant
  - Scratch resistant

# Strength



- Corelle® uses a combination of lamination and tempering processes to achieve:
  - High strength
  - Toughness
  - Impact resistance
  - Thermal shock resistance
  - Scratch resistance

Testing

# Limits on Strength



- 2X possible with current process
- Seven layer process even stronger
- Since Corelle<sup>®</sup> is consumer tableware, maximum allowable strength is limited by:
  - Resulting number of pieces when broken
  - Stored energy in ware

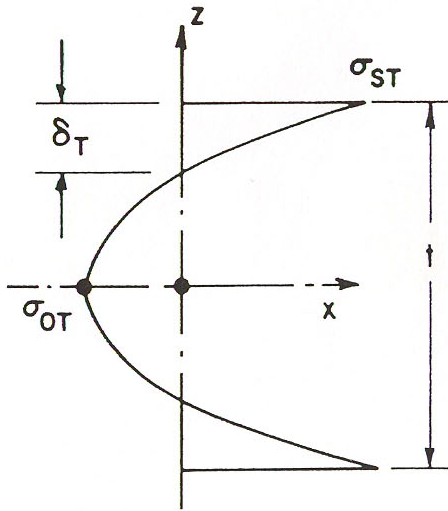
# Strengthening of Glass

- Induce compressive stresses on surface and a deep compressive layer to enhance damage resistance of glass articles during day-to-day usage
- Three commercial techniques
  - i) tempering
  - ii) lamination
  - iii) ion-exchange

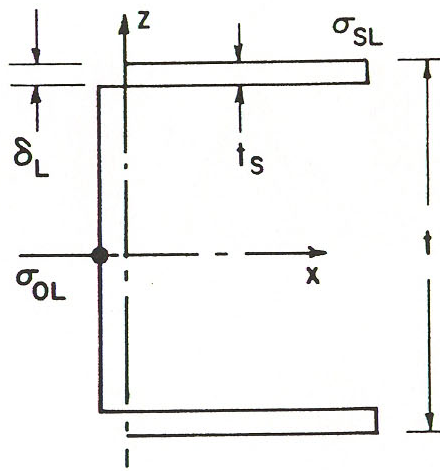
# Characteristics of Strengthening Techniques

Technique	Surface Compression	Depth of Compression
<b>Tempering</b>	<b>Moderate (X)</b>	<b>Very Deep (0.21 t)</b>
<b>Lamination</b>	<b>2X to 3X</b>	<b>Skin deep</b>

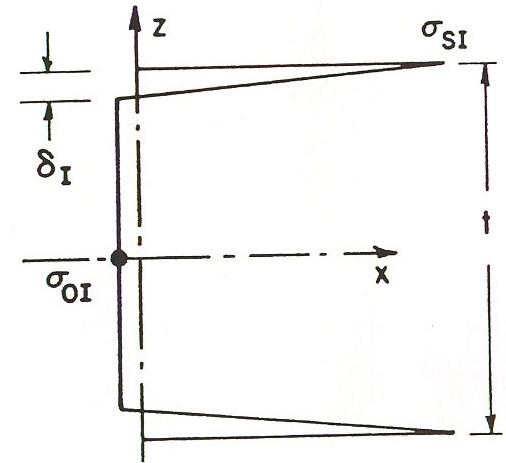
# Stress Profiles for Different Strengthening Techniques



tempering

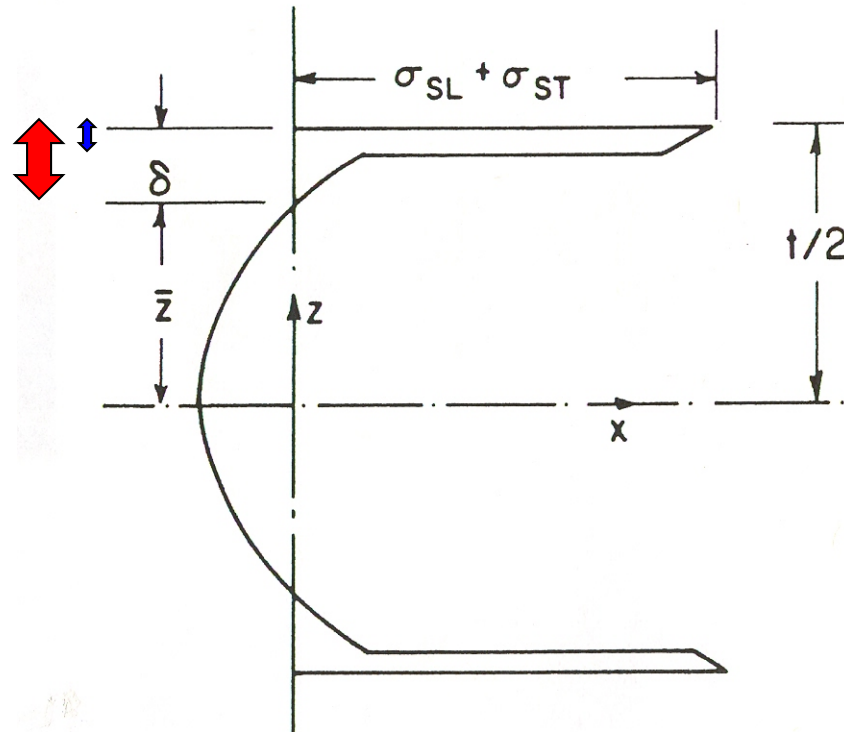


lamination



ion-exchange

# Lamination + Tempering



Depth of compression is quadrupled compared to lamination alone!

# Rim Impact Data for 10.25" Dinner Plates

(N = 20, IE = 0.7 ft lb, t = 2.7 mm)

	Laminated	Laminated + Tempered
Surf. Compression	205 MPa	430 MPa
<b>Depth of Comp'n</b>	<b>60 microns</b>	<b>250 microns</b>
# Chipped Rims	8 / 20	4 / 20
# Broken Plates	4 / 20	0 / 20
Chip Depth	45 microns	150 microns

# Summary



It is possible to produce commercially viable products using multiple strengthening processes for glass

# Questions

