Composite Balloon Material Response

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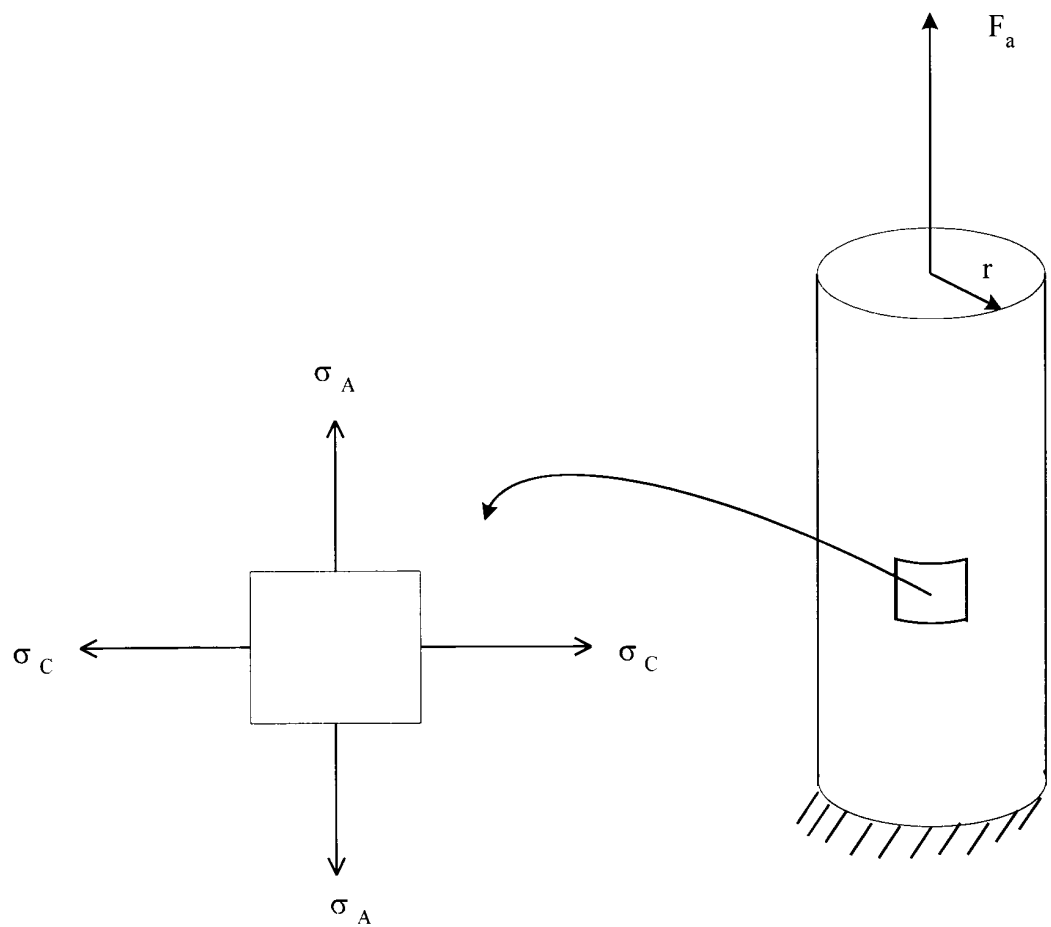
Creep Testing

- Uniaxial Testing
  - » 1 inch wide
  - » 24 inch Gage Length
  - » Displacement Measured Optically
- Biaxial Testing
  - » Cylindrical Specimen
  - » Displacement Measured Optically

Cylindrical Pressure Vessel



Determination of Stresses

Due to Differential Pressure, **ΔP** :

$$\sigma_{A,\Delta P} = \frac{\Delta P r}{2t} \qquad and \qquad \sigma_{C,\Delta P} = \frac{\Delta P r}{t}$$

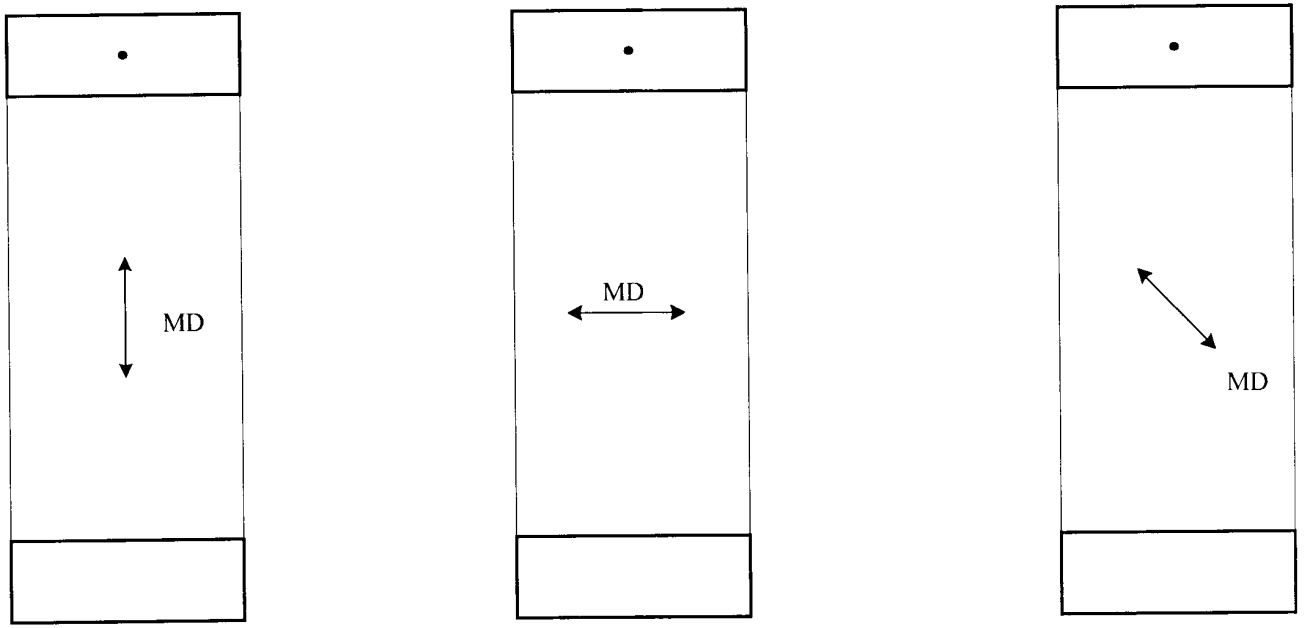
Due to External Axial Force, F_a :

$$\sigma_{A,F_a} = \frac{F_a}{2\pi r t}$$

Experimental Setup

- Cylindrical Specimen
  - » 0.8 mil thick LLDPE
- Test Temperatures
  - » -50° C to 30° C
- Loading
  - » Internal Pressure
  - » External Axial Load

Orientation of Cylinders

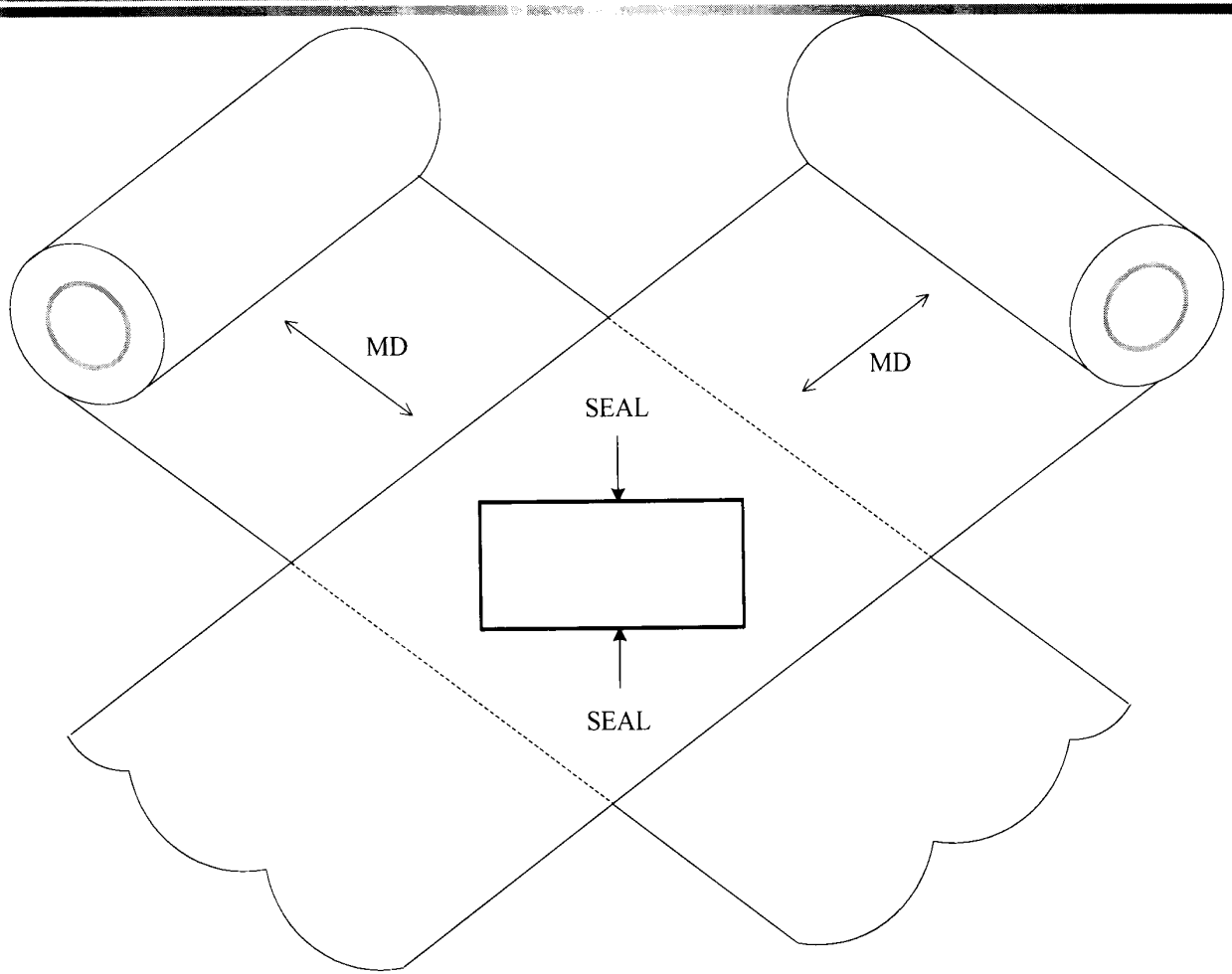


MACHINE DIRECTION

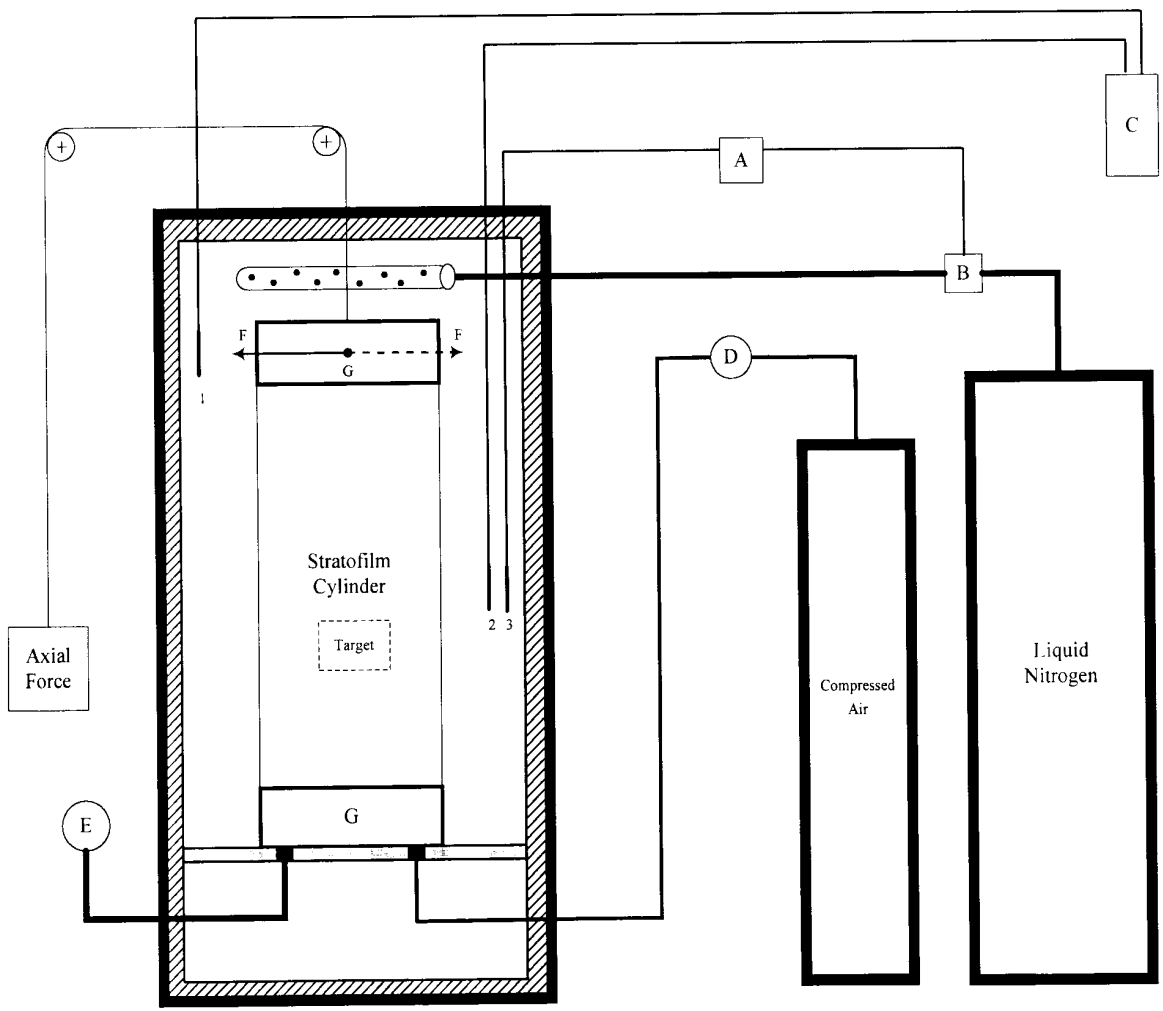
TRANSVERSE DIRECTION

45° DIRECTION

Construction of a 45° Cylinder

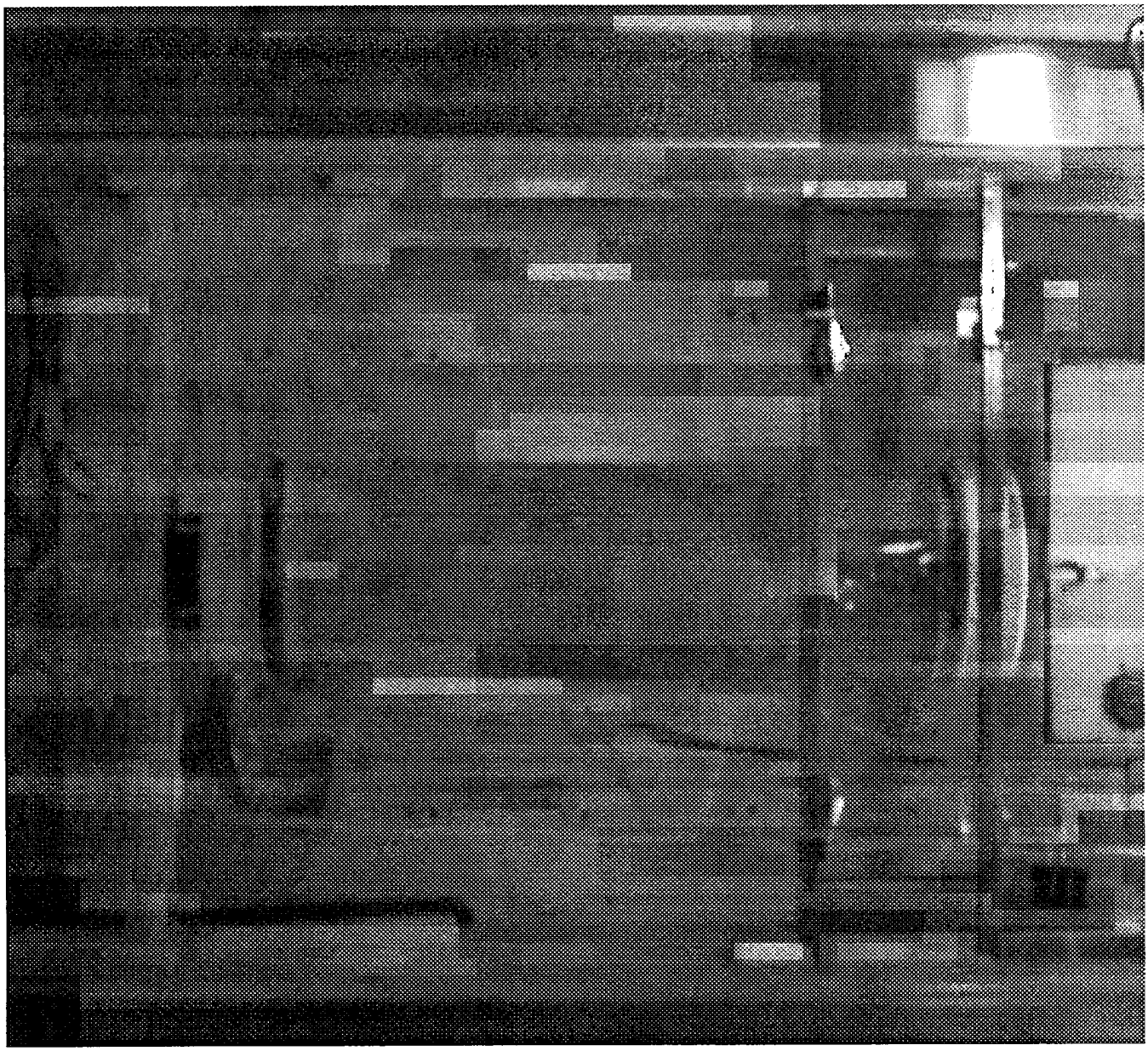


Environmental Chamber Configuration



Insulated Environmental Chamber

A = Temperature Controller
B = Cryogenic Solenoid Valve
C = Temperature Monitor
D = Pressure Regulator
E = Pressure Gauge
F = Shear Force
G = PVC Pipe Caps
1, 2, 3, = Temperature Probes
⊕ = Sheave



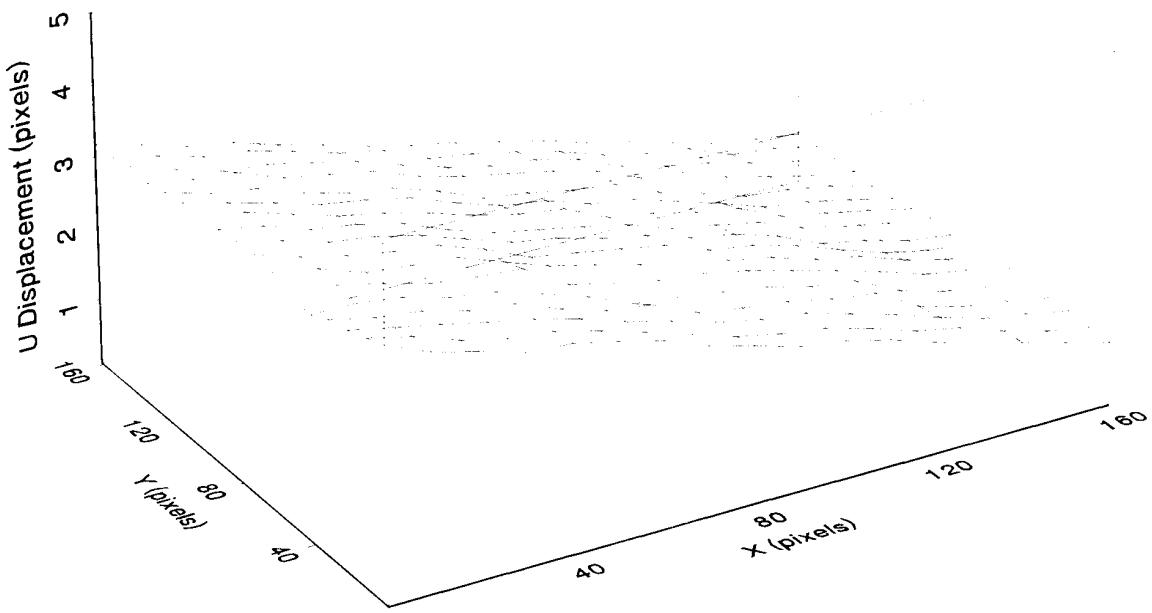
Experimental Considerations

- Camera Alignment
- Pressure Measurement
- Axial Force Measurement
- Ink Pattern
- Image Contrast
- Specimen Installation

Image Correlation

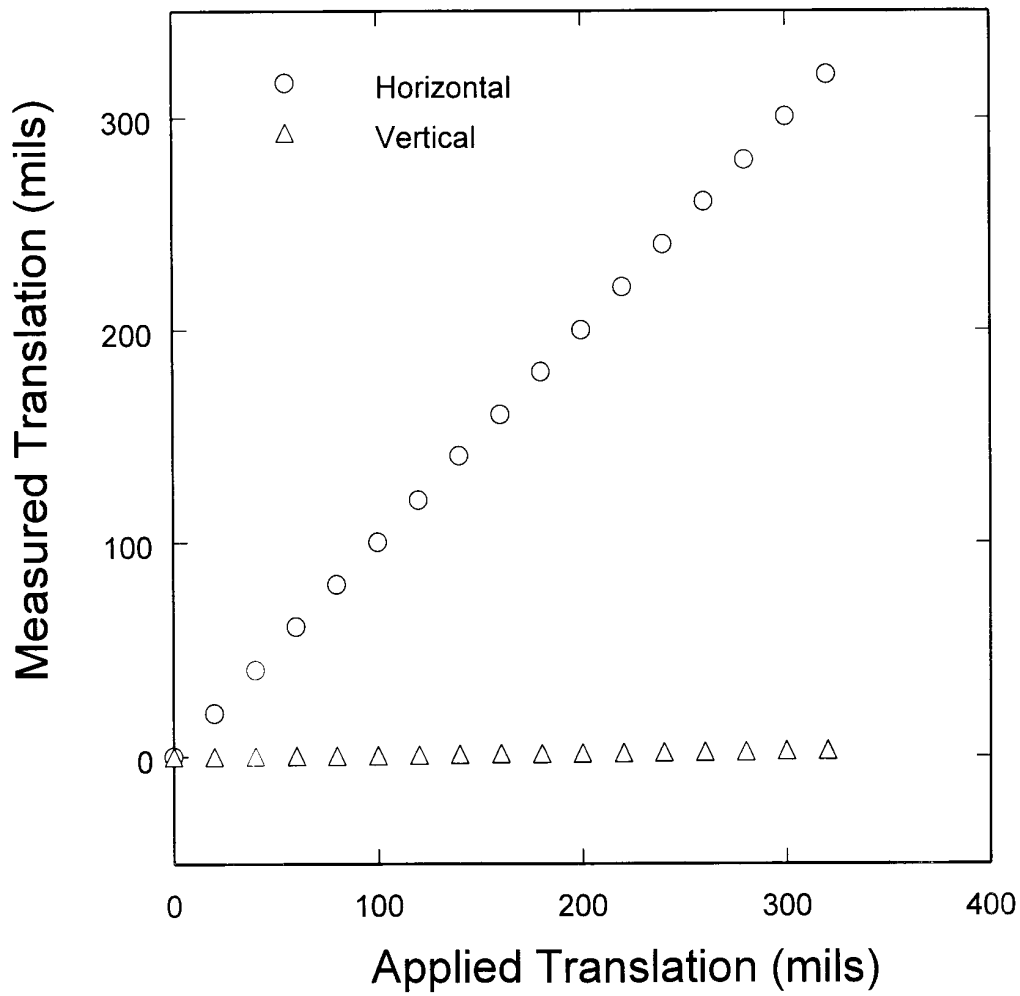
- Acquire Images Before and During Loading
- Determine “Coarse” Displacement using Subset from Center of Reference Image
- Correlate Images using Smaller Subsets
- End Result is Displacement Field

Horizontal Displacement Field



TD Cylinder Loaded for 88 minutes with 0.5 MPa Circumferential and 3.5 MPa Axial at 23° C

Horizontal Rigid Body Translation



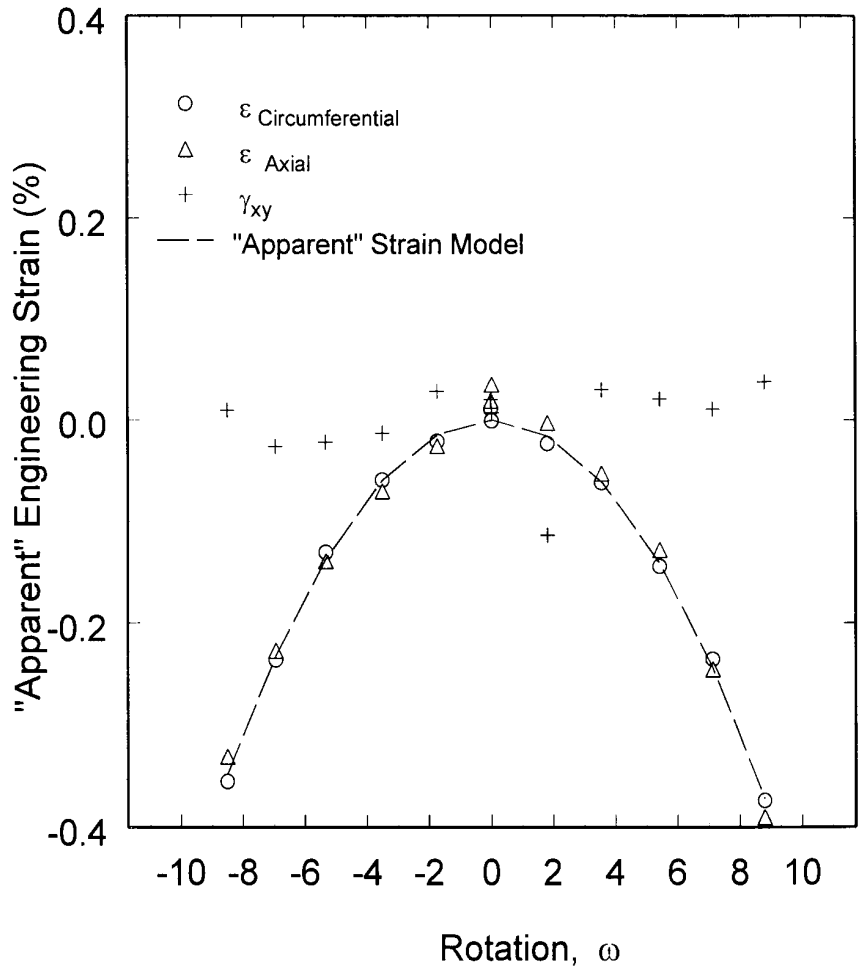
"Apparent" Strain Due to Rotation

Amount of Rotation :

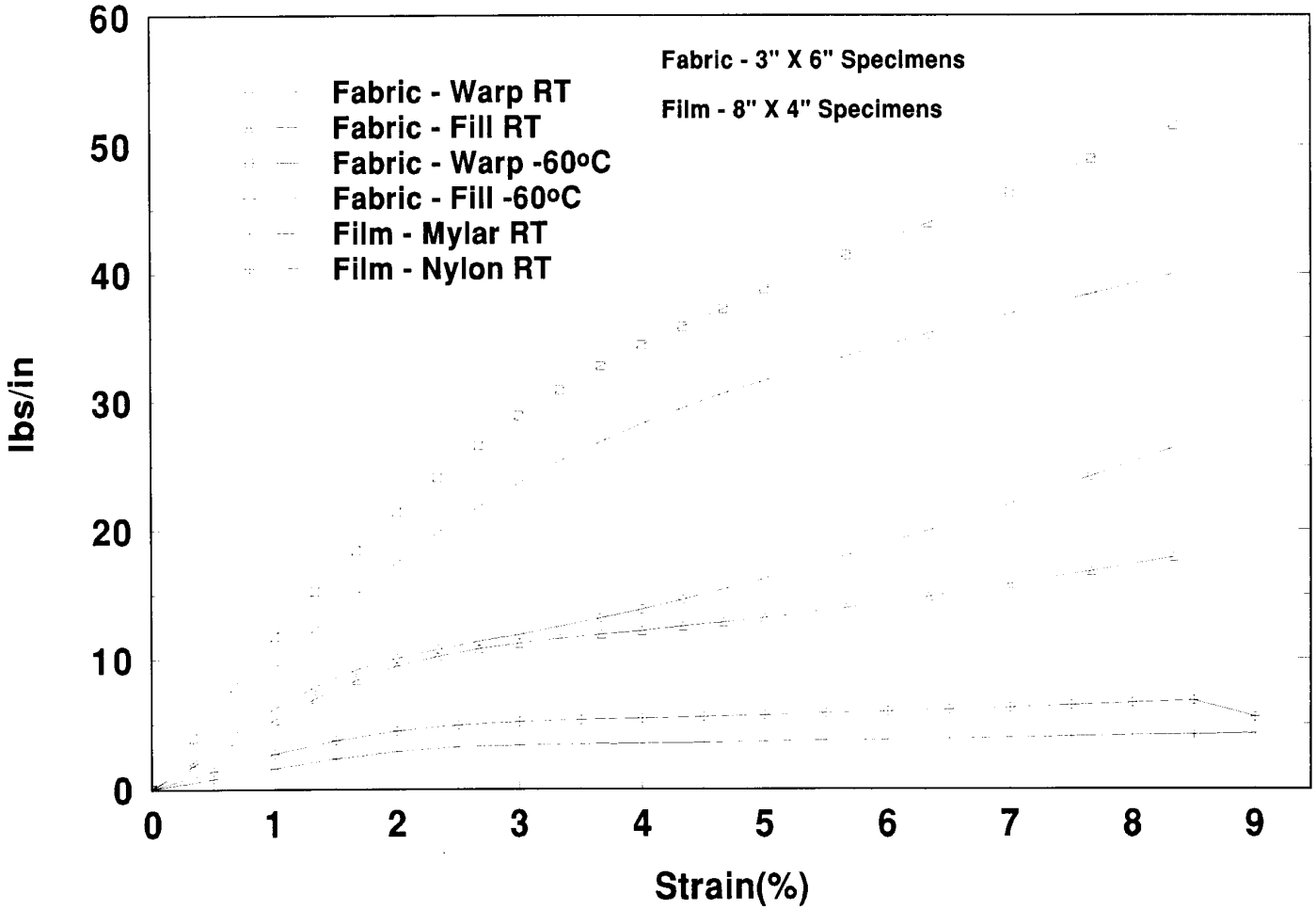
$$\omega = \frac{1}{2}\left(\frac{\partial u}{\partial y} - \frac{\partial v}{\partial x}\right)$$

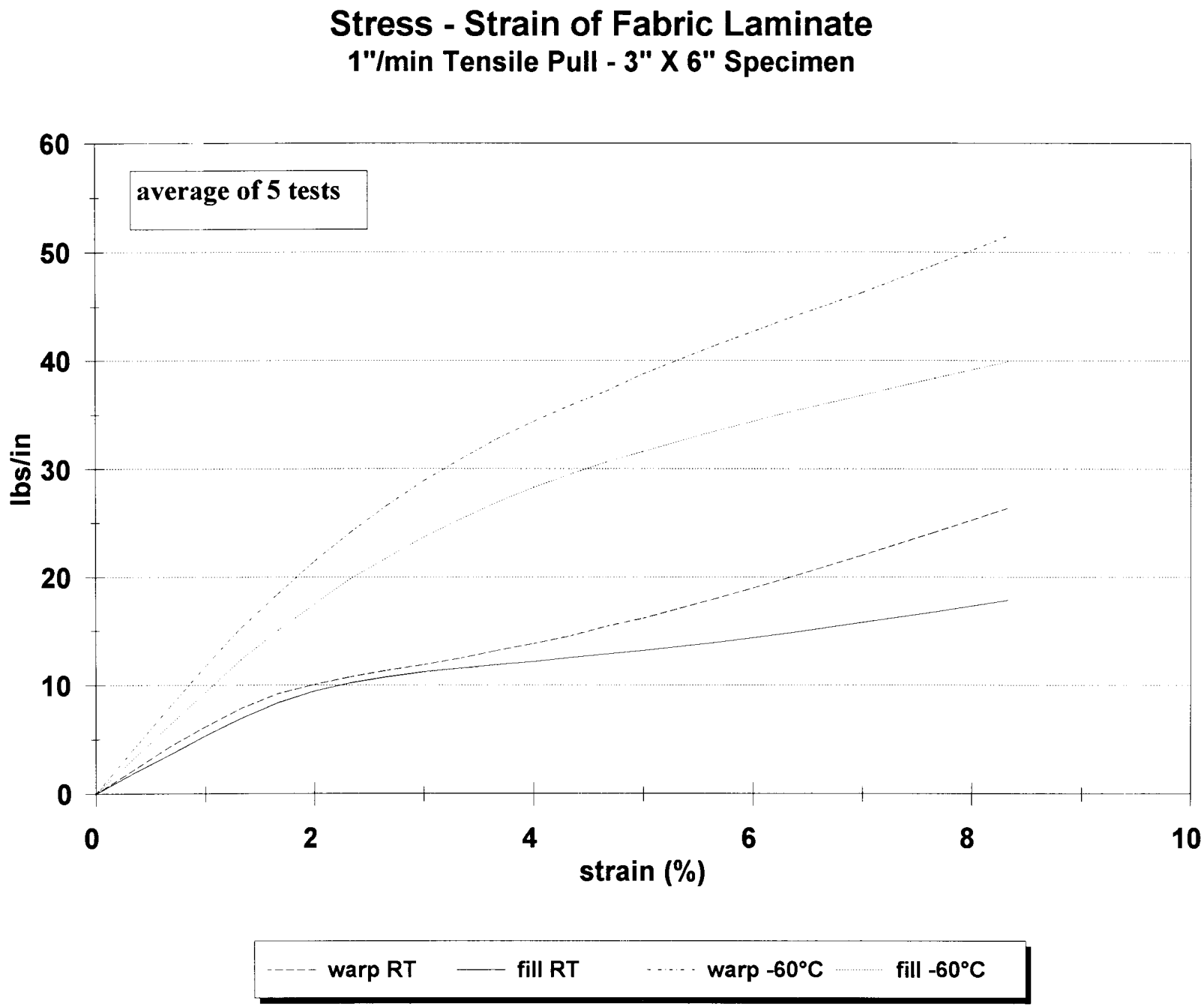
Apparent Strain :

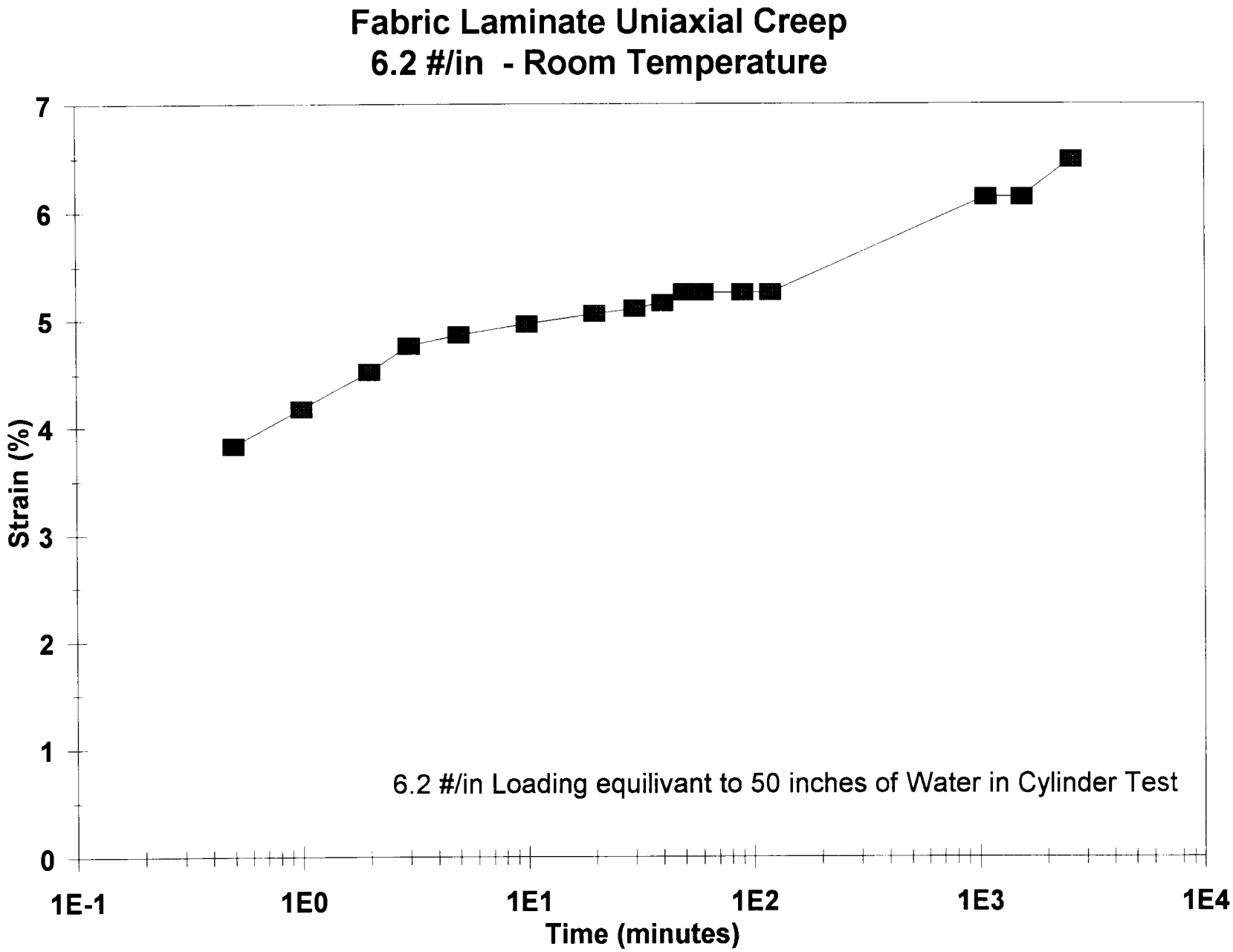
$$\epsilon_{apparent,rotation} = -0.004806\left[\frac{1}{2}\left(\frac{\partial u}{\partial y} - \frac{\partial v}{\partial x}\right)\right]^2$$



Fabric Laminate Tensile Results
1"/min

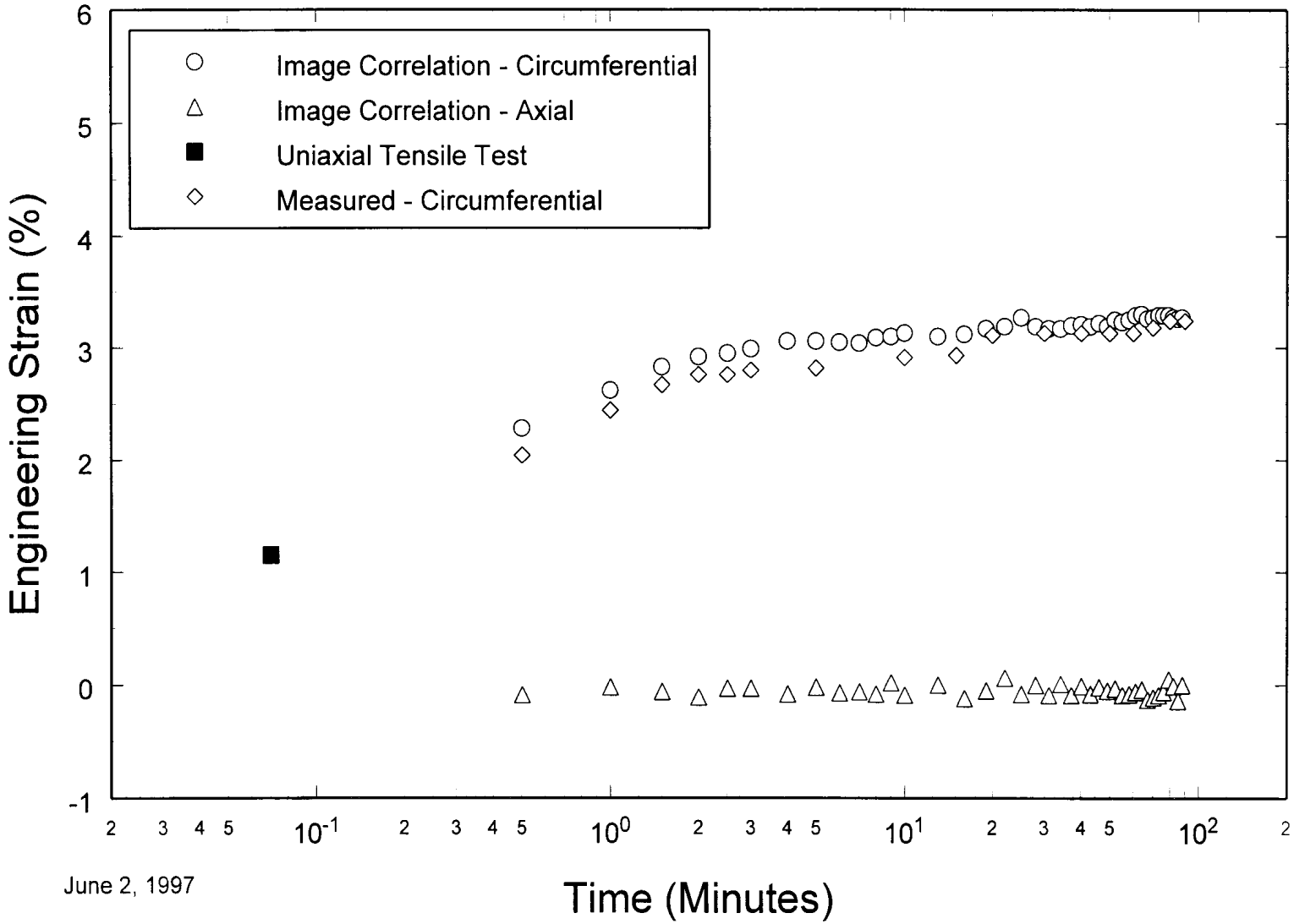



Stress - Strain of Fabric Laminate
1"/min Tensile Pull - 3" X 6" Specimen
average of 5 tests
lbs/in
60
50
40
30
20
10
0
0
2
4
6
8
10
strain (%)
warp RT
fill RT
warp -60°C
fill -60°C


Fabric Laminate Uniaxial Creep
6.2 #/in - Room Temperature
Strain (%)
0
1
2
3
4
5
6
7
1E-1
1E0
1E1
1E2
1E3
1E4
Time (minutes)
6.2 #/in Loading equilivant to 50 inches of Water in Cylinder Test

Biaxial Strain of Fabric Laminate Cylinder

50 inches of Water - Room Temperature



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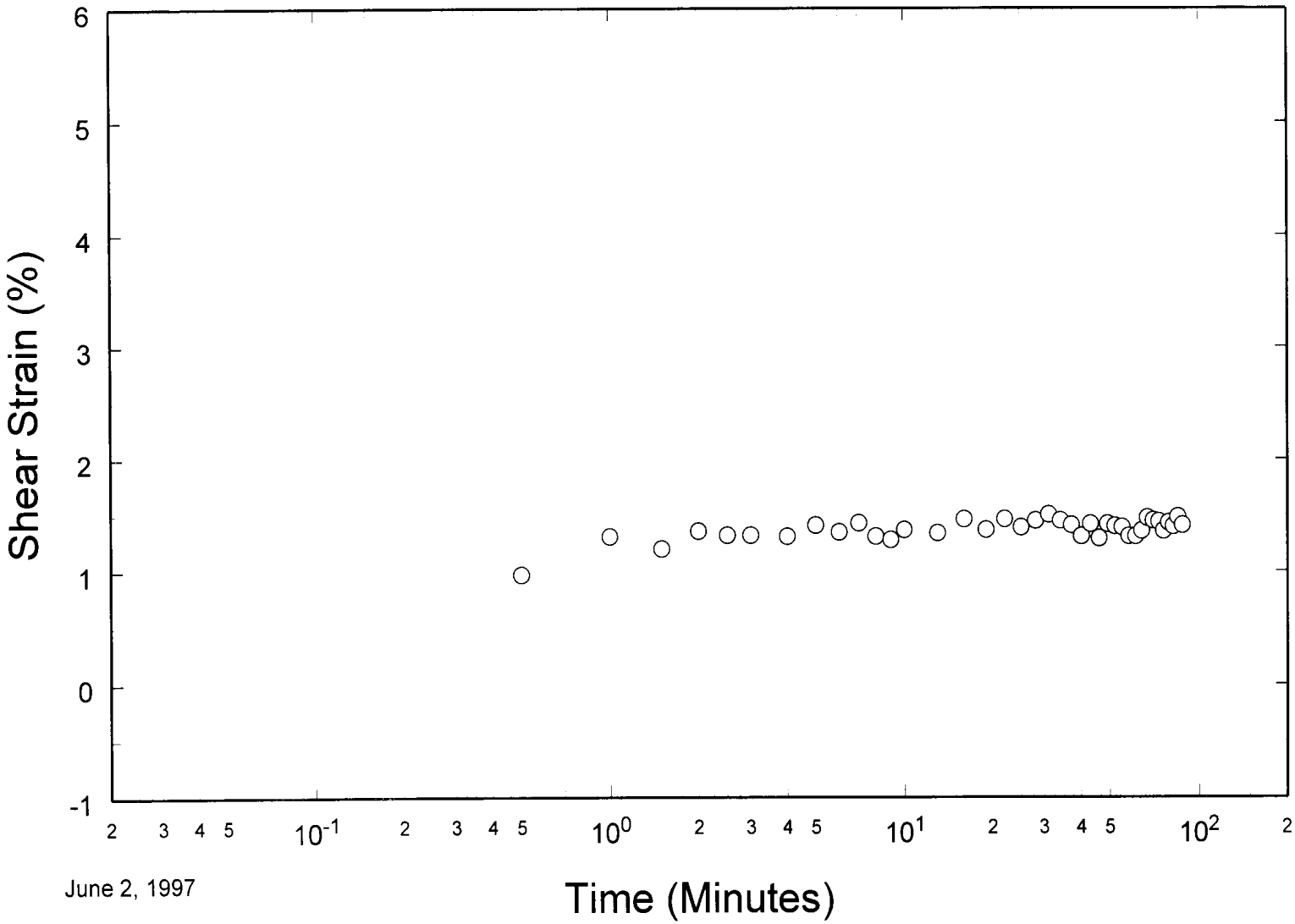
Biaxial Strain of Fabric Laminate Cylinder

50 inches of Water - Room Temperature



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Conclusions

- Composite ULDB Materials are Viscoelastic
- Techniques Developed for Polyethylene Film Apply
  - » Analytical
  - » Experimental
- Candidate ULDB Materials should be screened by Uniaxial Testing
  - » Constant Rate
  - » Creep
- Biaxial Technique should be refined
- Most Promising ULDB Materials should be modeled
  - » Biaxial Data
  - » Linear / Nonlinear Model