Instrumentation, Data Acquisition and Computer Control – A brief Introduction

1. Instrumentation requirements/specifications

2. Data acquisition systems

3. Computer control hardware and software

Laboratory Instrumentation

Primary instrumentation are transducers = convert mechanical action into electric response

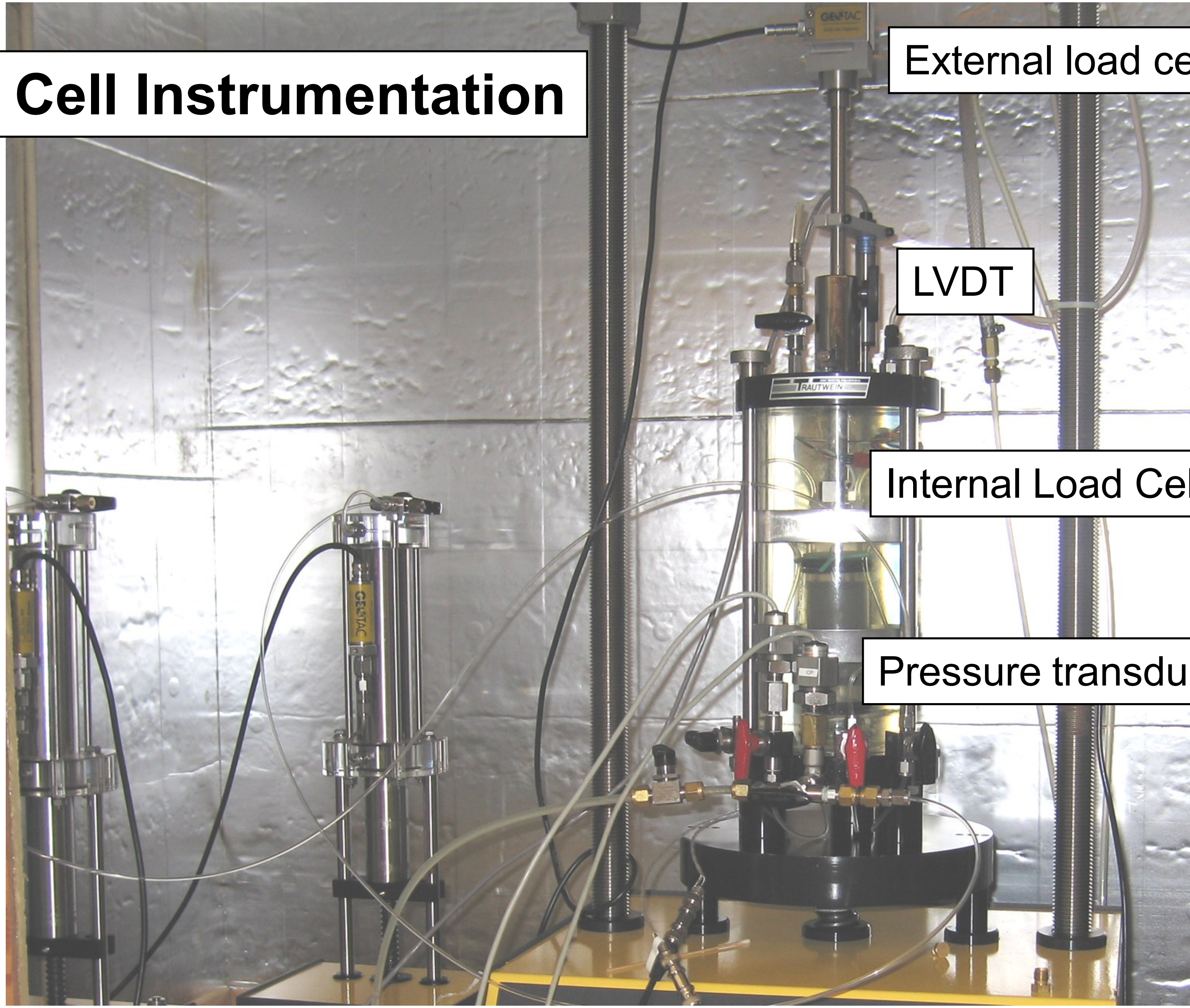
For geotechnical laboratory testing transducers include:

- force = load cell
- pressure = pressure transducer
- displacement = linear variable differential transformer (LVDT)

Other measurements:

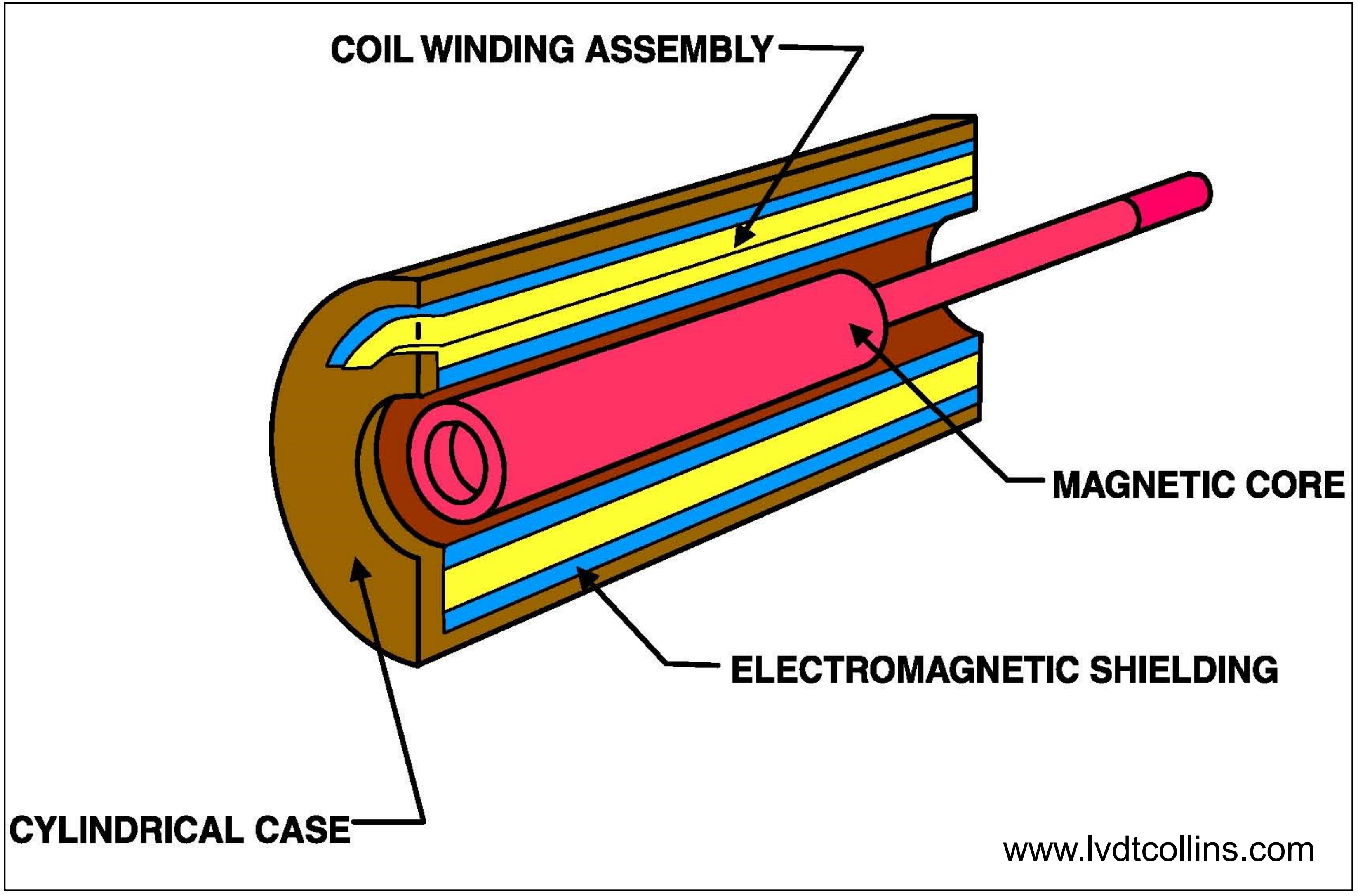
- volume change
- temperature
- acceleration
- shear wave velocity

Triaxial Cell Instrumentation



LVDT Operation

Displacement is proportionally converted to electrical signal



Strain gage based load cell and pressure transducer

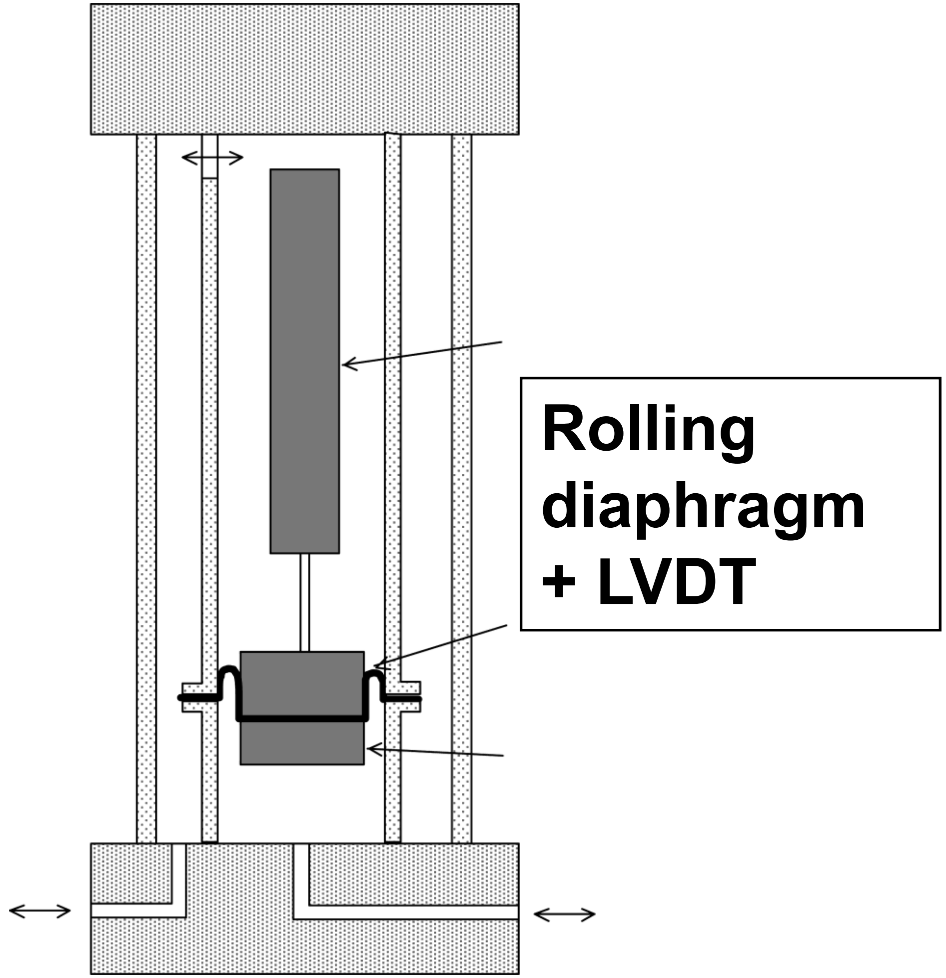
S-Type Load Cell

www.interface.com

Flush Diaphragm Pressure Transducer

www.omega.com

Volume change



From Clayton and Hight (2006)

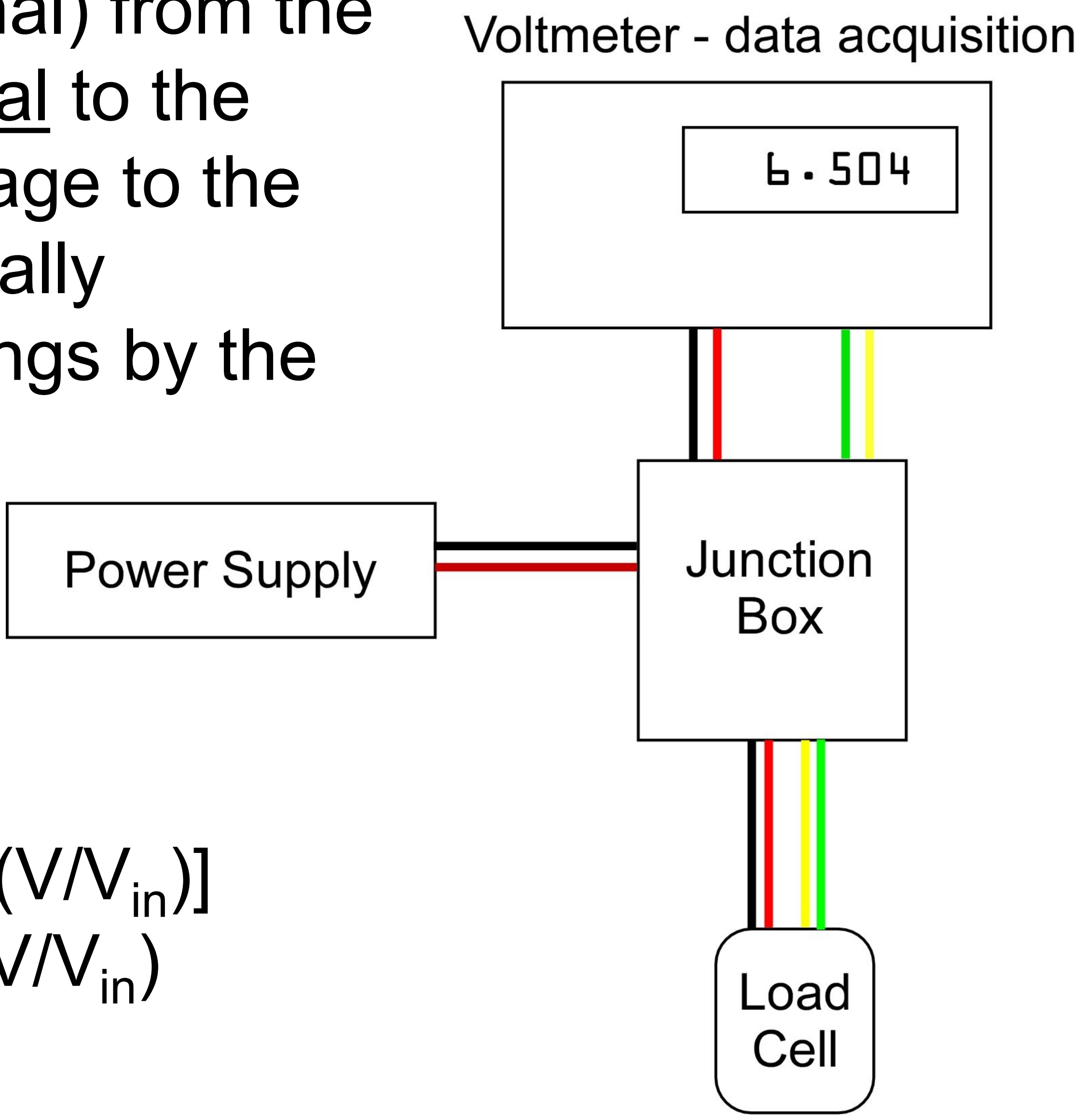
Transducers:

Conversion of voltage to mechanical response (measurement)

R = CF(V – Z)

R = reading in mechanical units (kPa, KN, cm, etc.)
CF = calibration factor
V = voltage reading
Z = zero or reference reading

The voltage output (signal) from the transducer is proportional to the input (or excitation) voltage to the transducer, hence, typically normalize CF and readings by the input voltage (V_{in})



$$\mathbf{R = CF(V/V_{in} - Z/V_{in})}$$

where
CF = [mechanical units/(V/V_{in})]
e.g., kPa/(V/V_{in}) or cm/(V/V_{in})

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Transducer Properties:

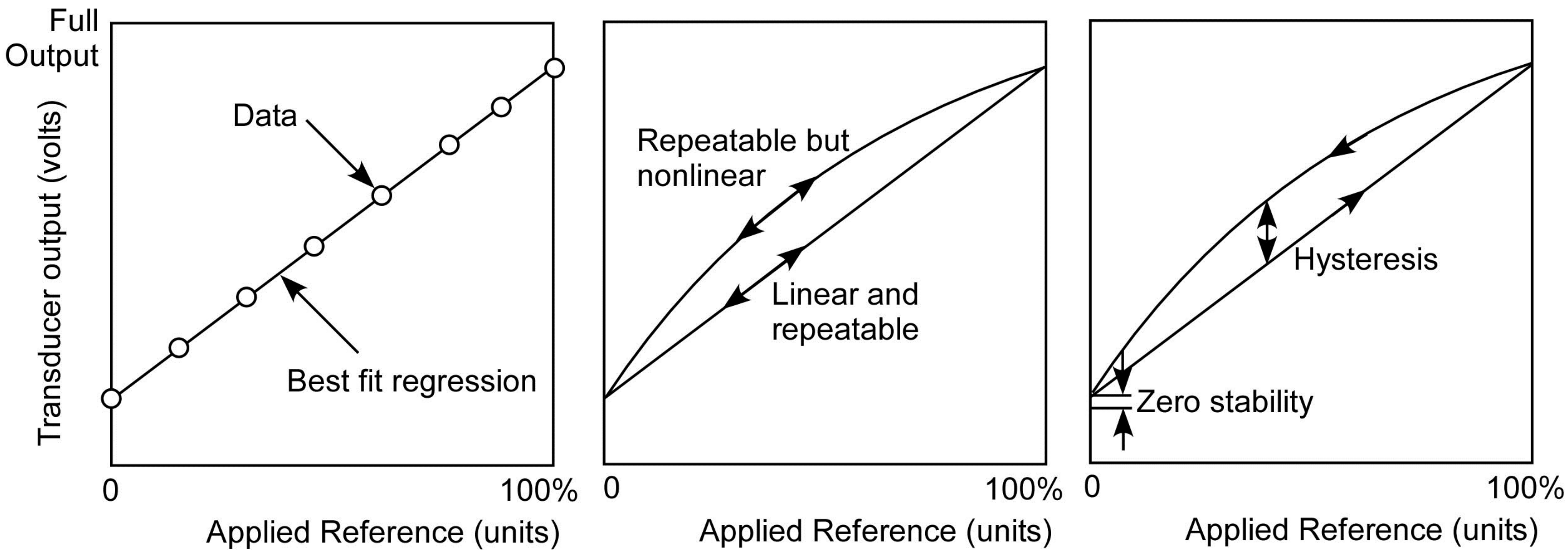
- Full scale range
- Required input voltage
- Output (signal) voltage range (e.g., mV or V)

Accuracy = f(several characteristics):

- repeatability
- linearity
- hysteresis
- temperature stability

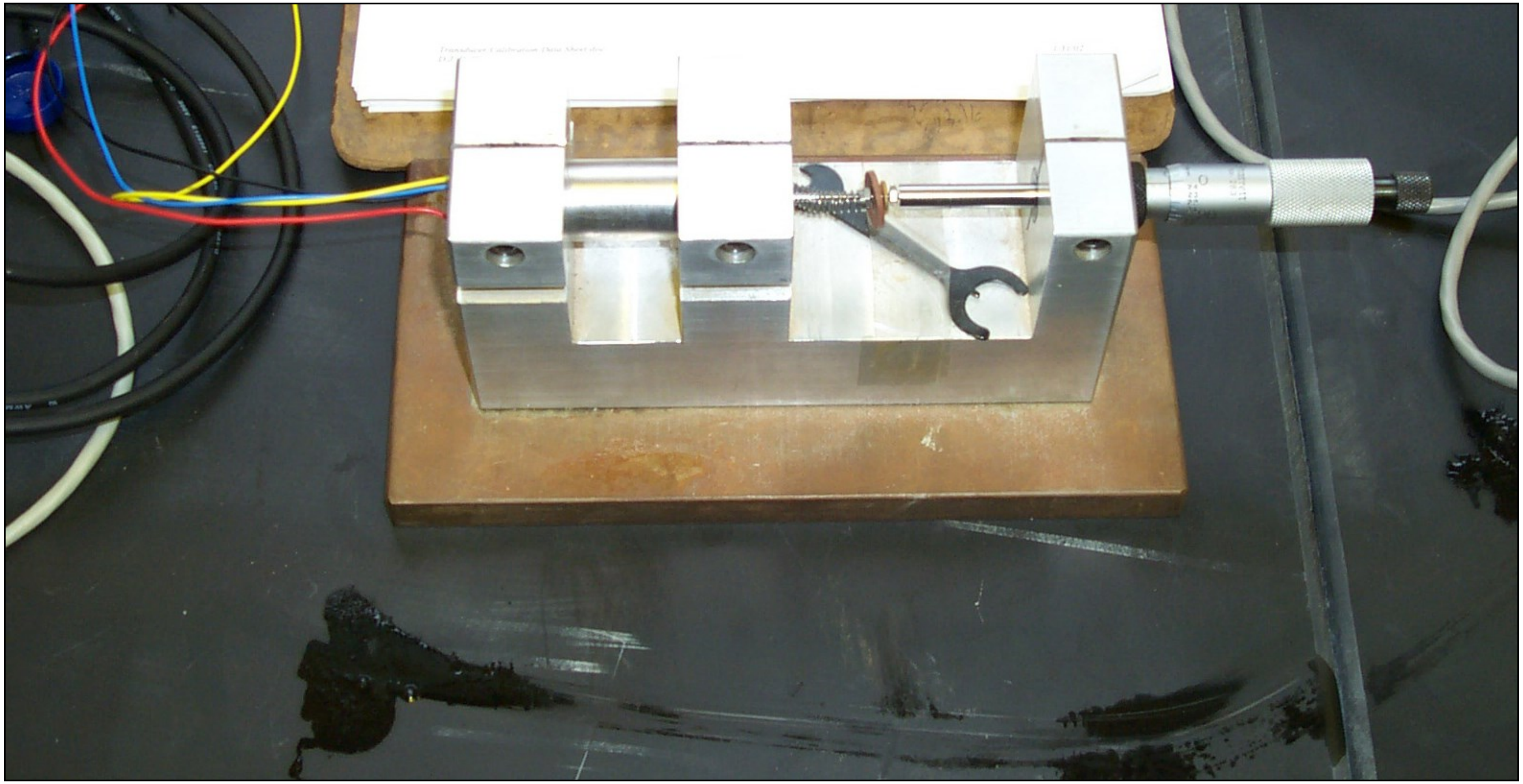
Calibrate transducers using known reference

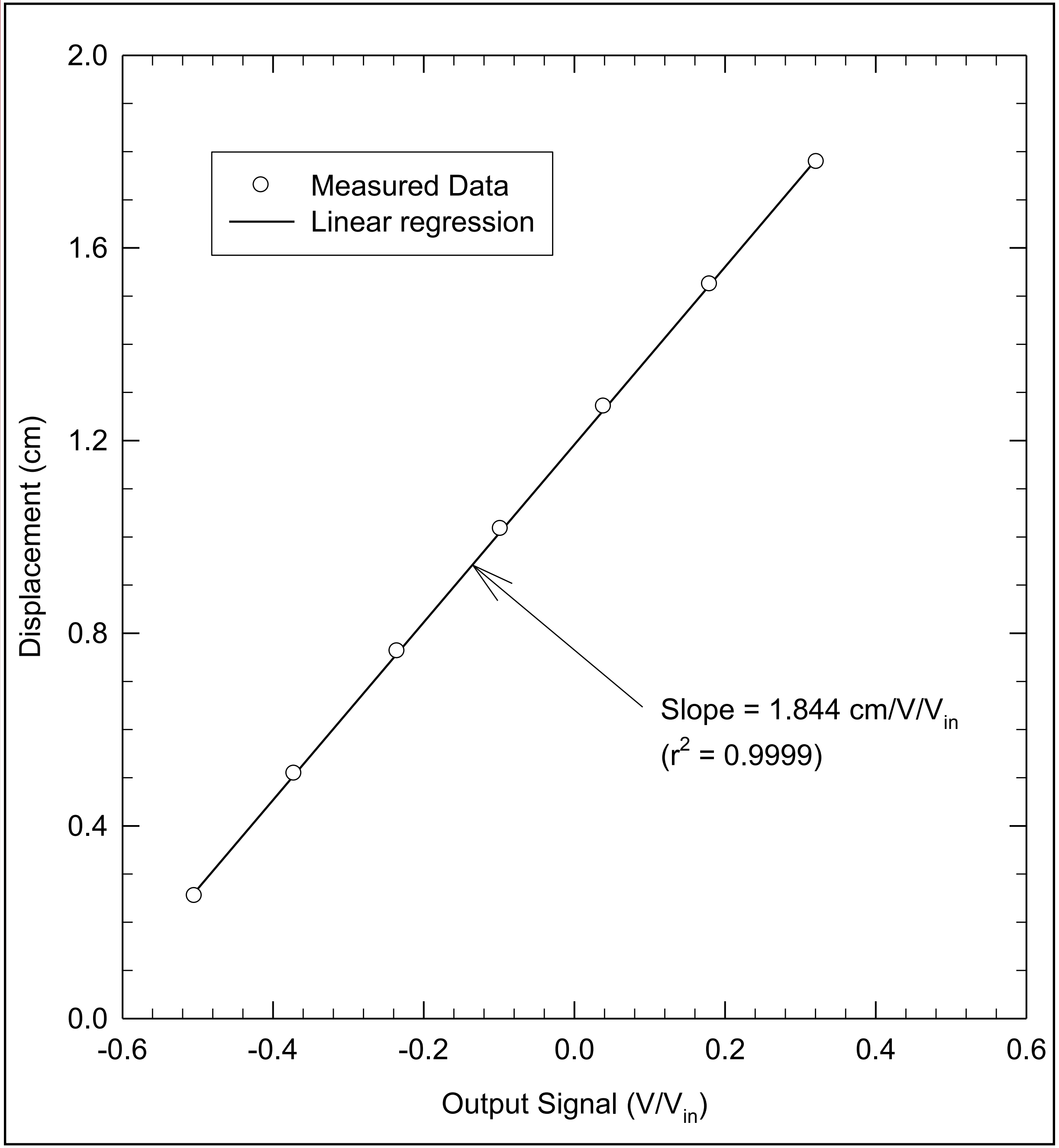
Transducer Properties



<u>Ideally want transducer response to be</u>: linear and repeatable without hysteresis and zero drift

LVDT calibration - micrometer



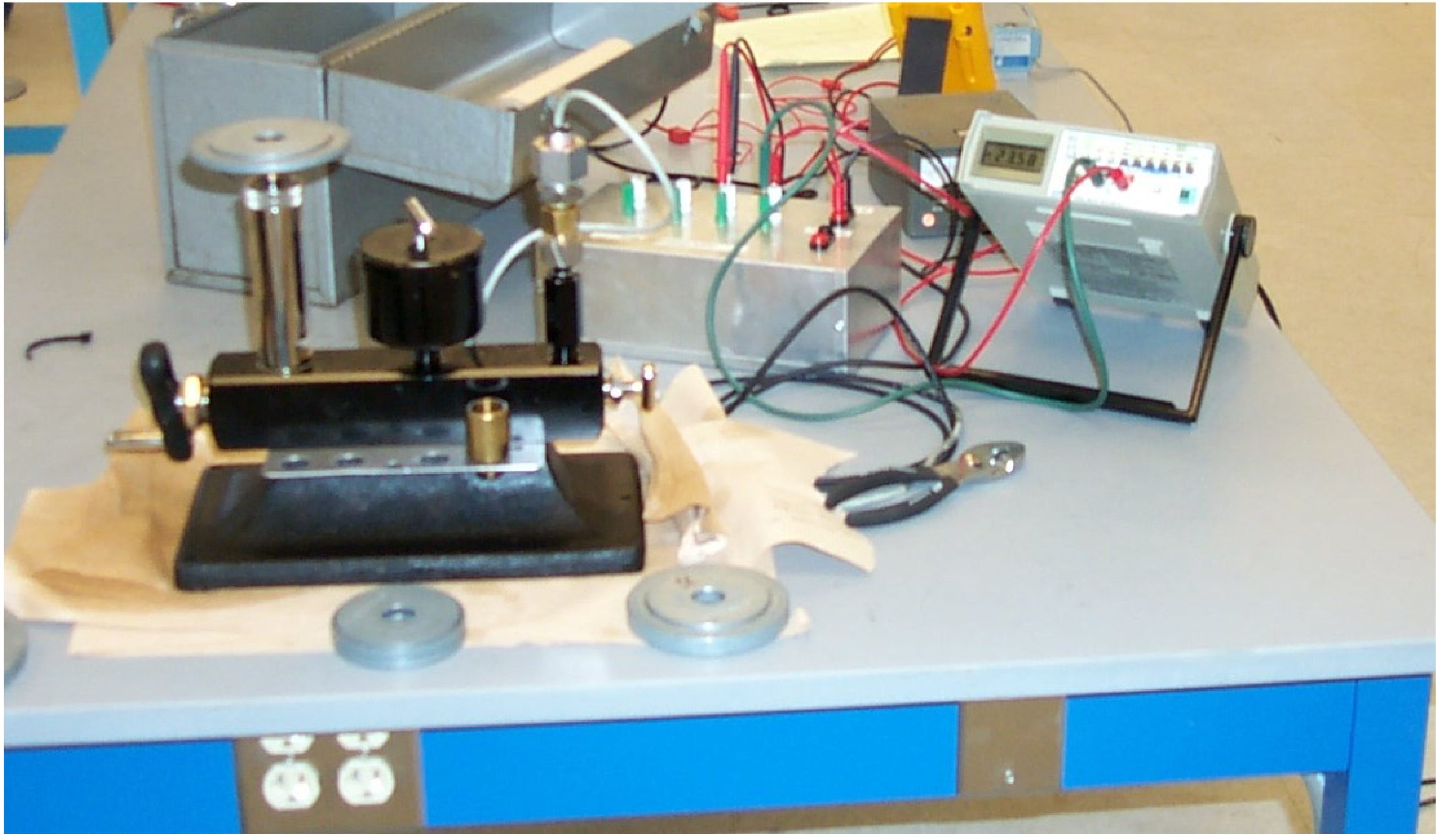


Example LVDT calibration

Displacement (from micrometer) vs normalized LVDT signal voltage

Slope best fit linear regression = calibration factor

Pressure transducer calibration – hydraulic dead weight tester



Data Acquisition

Computer based "automated" acquisition of electrical signals from transducers and other instrumentation

Components:

- analog to digital (A/D) converter
- multiplexer (number of channels)
- signal conditioning
- power supply
- timer/frequency readings
- cabling
- software

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Analog to Digital Conversion

Key issue is bit resolution – smallest significant digit

$R = V/(2^n - 1)$

where

R = resolution

V = full scale voltage range

n = numbers of bits

+ need adequate signal to noise ratio

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Example – A/D resolution

14 bit data acquisition card with +/- 10V signal range

$$R = (20)/(14^2 - 1) = 0.0122\ V = 1.22\ mV$$

If use 16 bit card

$$R = 0.31\ mV$$

If use 16 bit card with +/- 1V signal range

$$R = 0.015\ mV$$

Full scale load voltage output:
LVDTs: ≈ 1 to 10 volts
Pressure Transducers: ≈ 10 to 200mV
Load Cells: ≈ 10 to 200mV

Use "auto-ranging" in A/D conversion to match required resolution and transducers

Data Acquisition cards: Higher bit resolution, reading frequency and number channels = higher cost

Computer connections = PCI, PXI, USB, etc.

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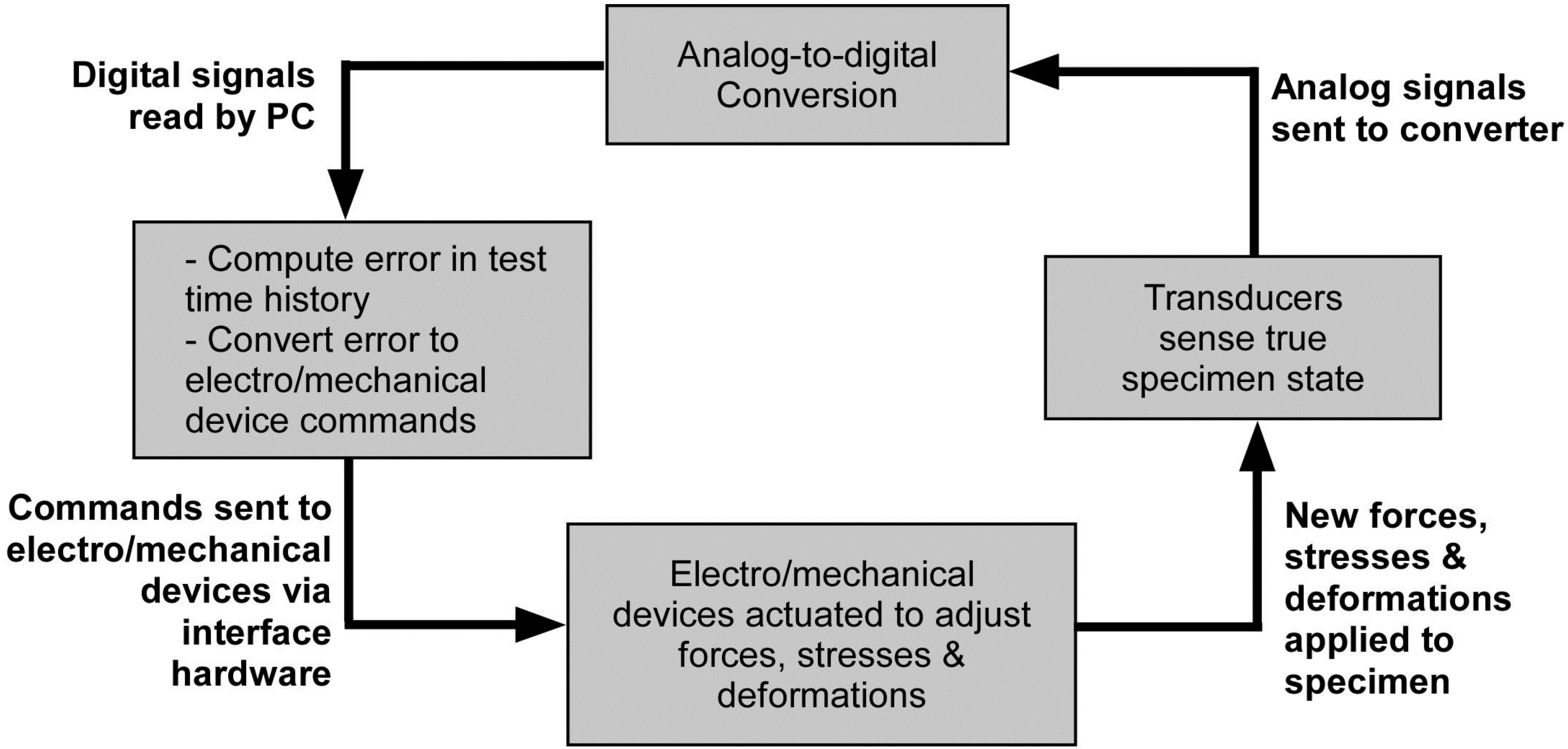
Computer Control

Use "closed" feedback loop to control specimen state



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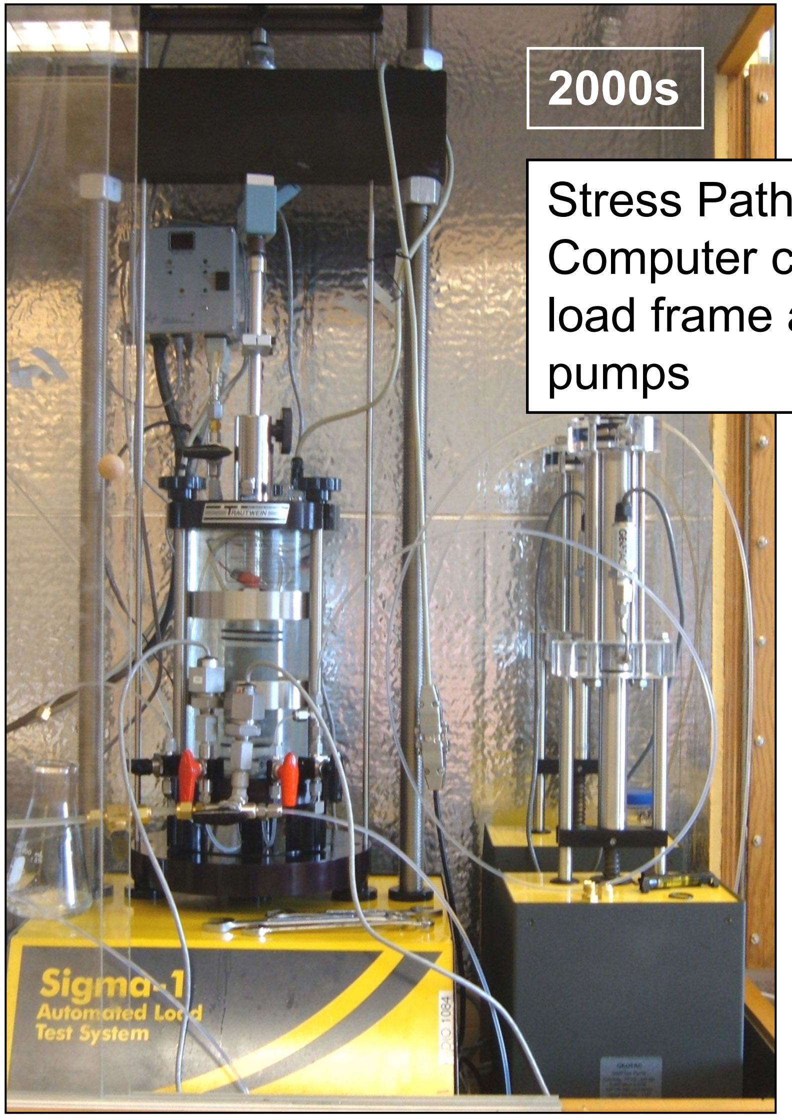
Automated Triaxial Testing

1960s

2000s

Stress Path Cell with Computer controlled load frame and flow pumps



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Automated Triaxial Testing

1. Prescribe specimen set-up conditions, i.e., seating stresses
2. Automated application of back pressure + user determined B value checks
3. Automated consolidation: stress or strain controlled + unload-reload if needed + creep phase
4. Automated shear: stress or strain controlled

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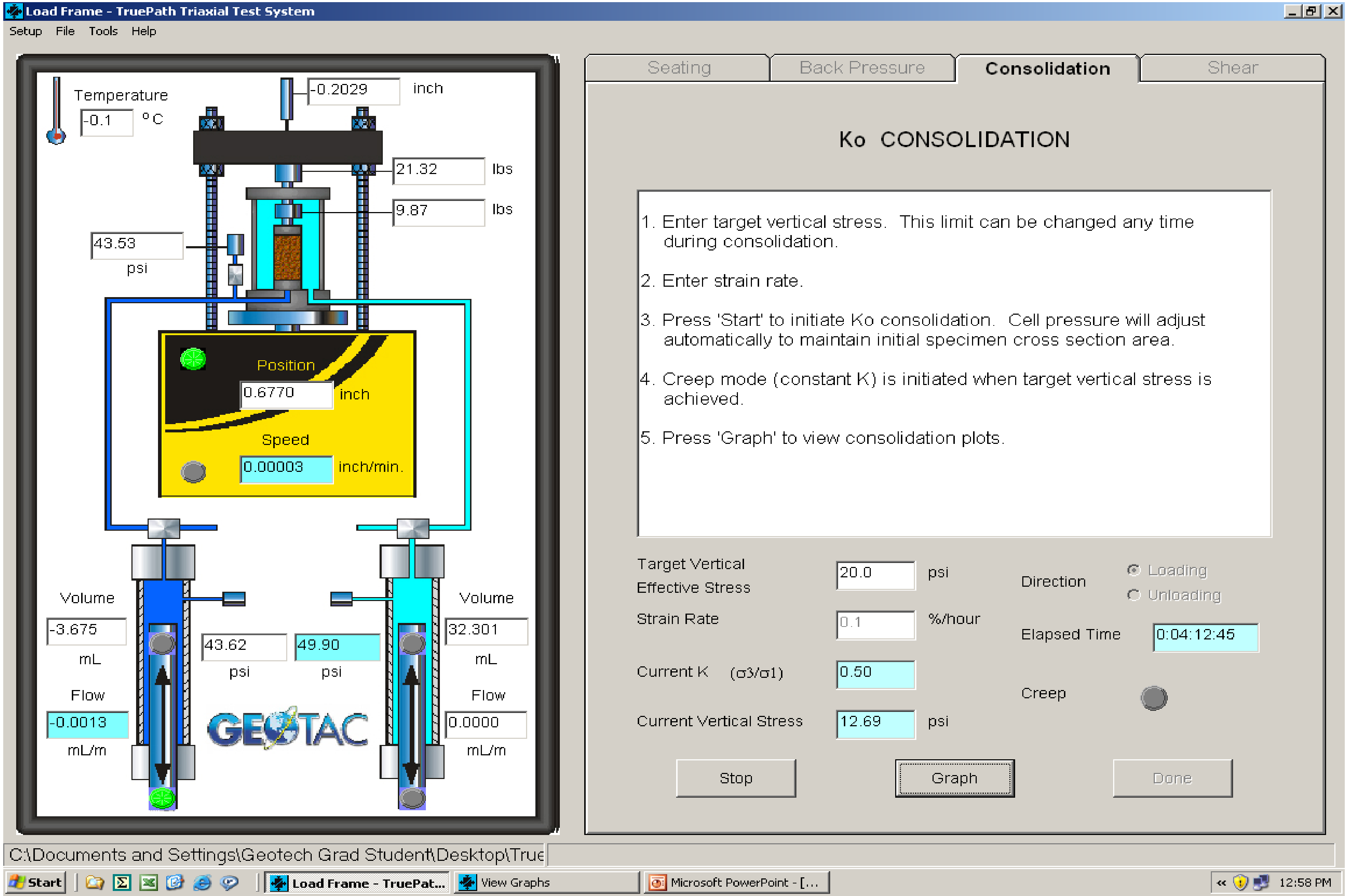

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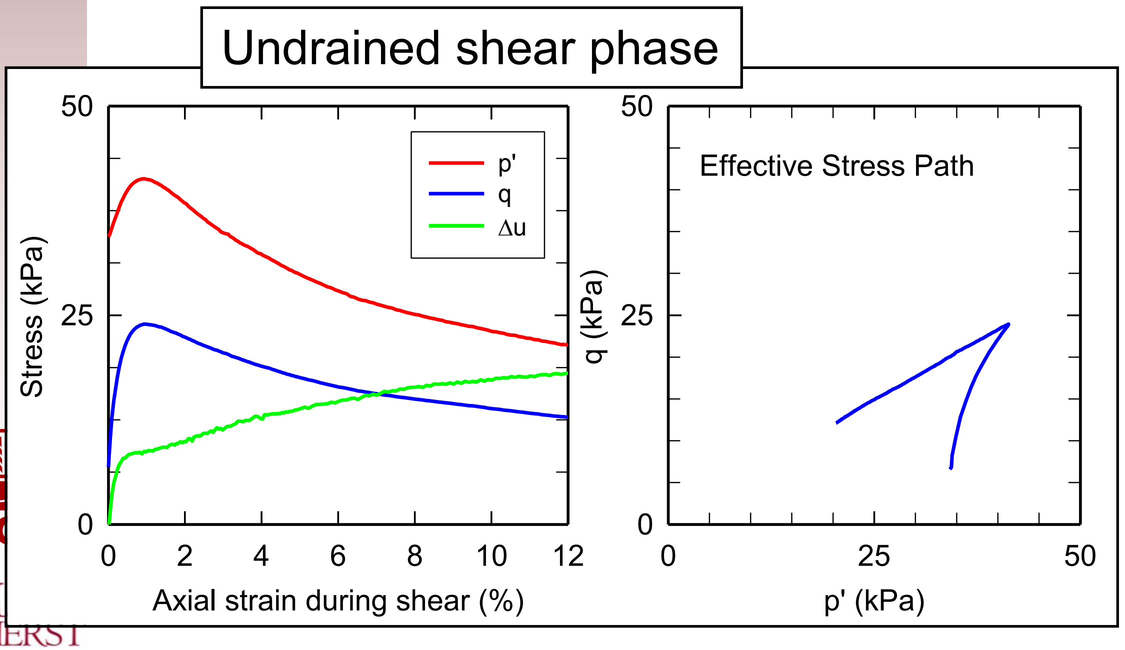
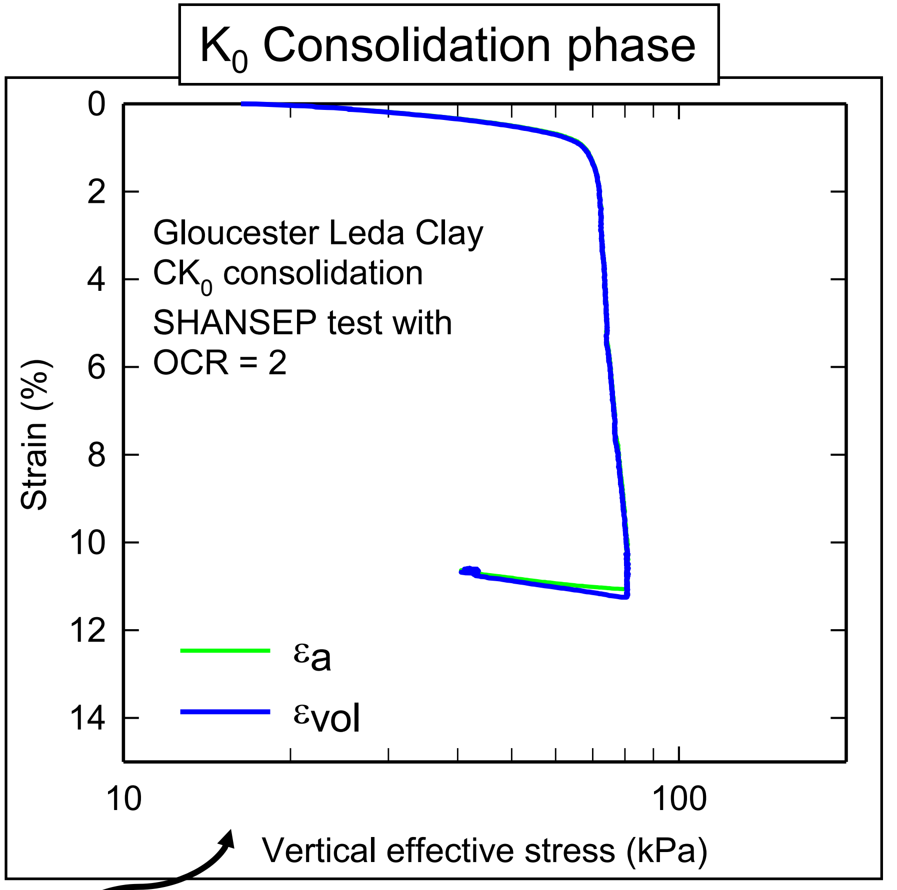
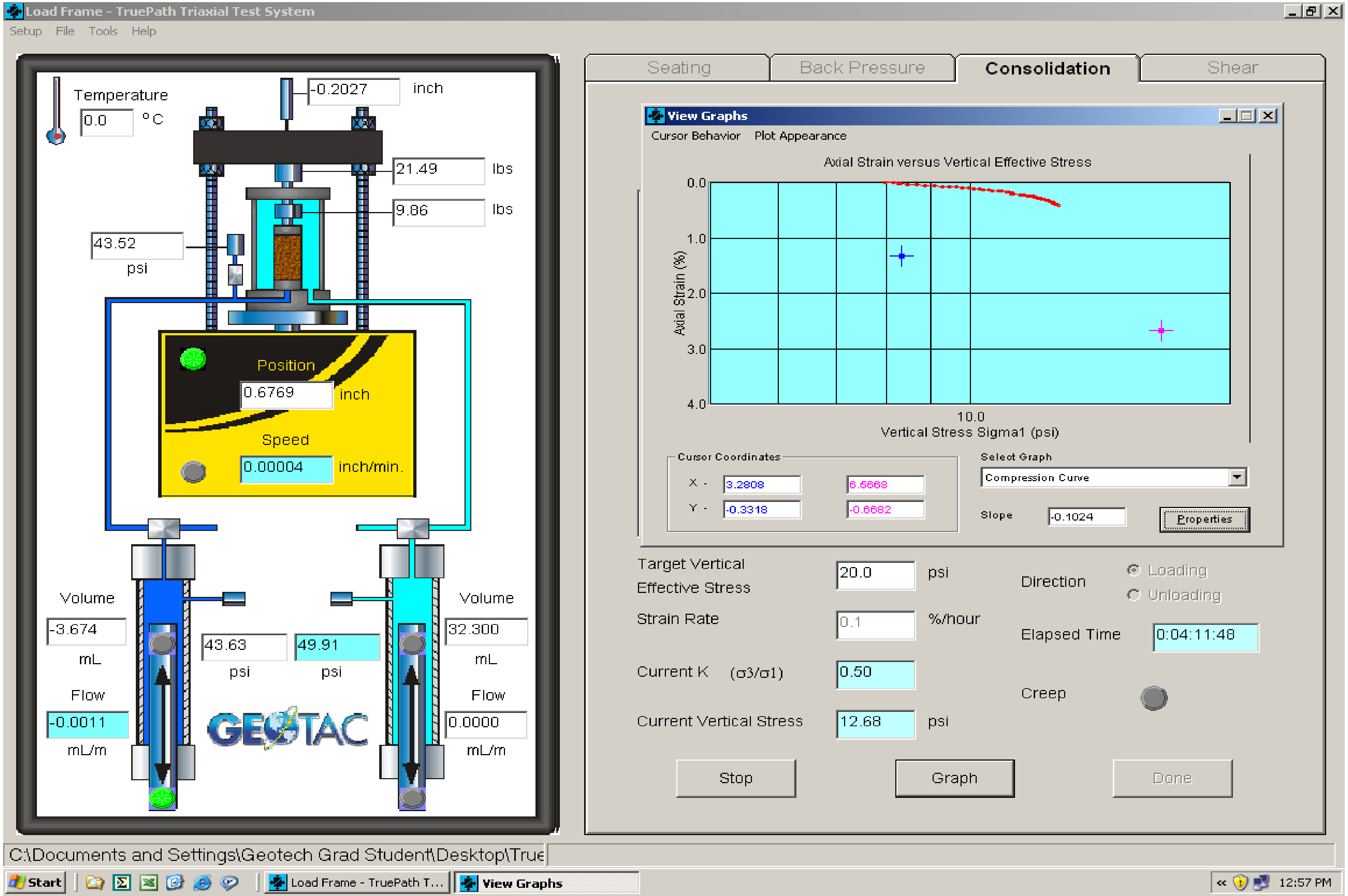
Example – Automated CK_0 Consolidation

Automated Back Pressure Saturation and K_0 Consolidation:
- Apply consolidation strain rate (e.g., = 0.1%/hr) via load frame and maintain $\varepsilon_{vol} = \varepsilon_a$ (i.e., 1-D strain) via flow pump control of cell pressure

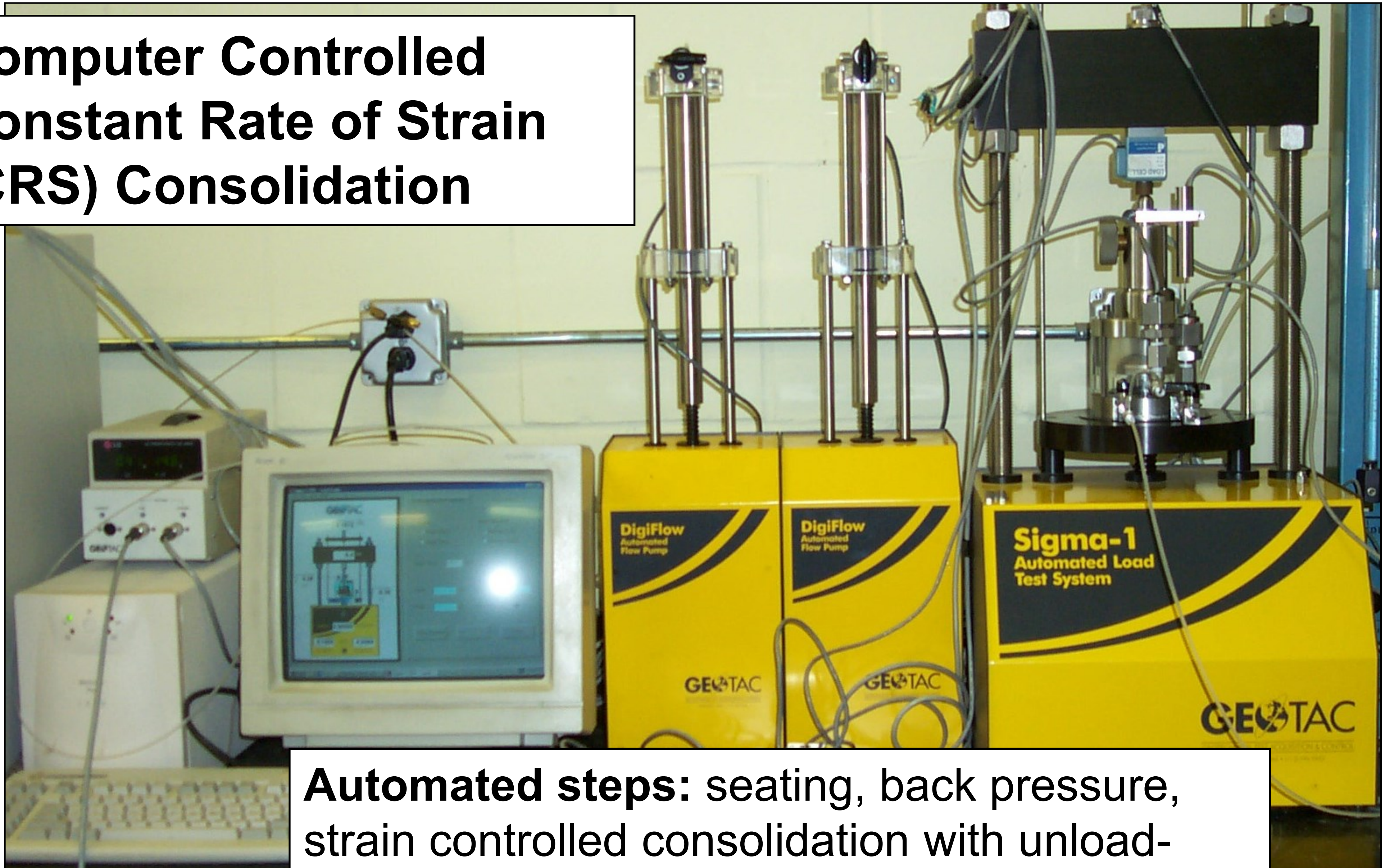




Obtain σ'_p and compressibility data as per regular oedometer test


Load Frame - TruePath Triaxial Test System
Setup File Tools Help
Temperature
0.0 °C
-0.2027 inch
21.49 lbs
9.86 lbs
43.52 psi
Position
0.6769 inch
Speed
0.00004 inch/min.
Volume
-3.674 mL
Flow
-0.0011 mL/m
43.63 psi
49.91 psi
Volume
32.300 mL
Flow
0.0000 mL/m
GEOTAC
Seating
Back Pressure
Consolidation
Shear
View Graphs
Cursor Behavior Plot Appearance
Axial Strain versus Vertical Effective Stress
Axial Strain (%)
0.0
1.0
2.0
3.0
4.0
10.0
Vertical Stress Sigma1 (psi)
Cursor Coordinates
X - 3.2808 6.5668
Y - -0.3318 -0.6682
Select Graph
Compression Curve
Slope -0.1024
Properties
Target Vertical Effective Stress 20.0 psi
Direction
Loading
Unloading
Strain Rate 0.1 %/hour
Elapsed Time 0:04:11:48
Current K (σ3/σ1) 0.50
Creep
Current Vertical Stress 12.68 psi
Stop
Graph
Done
C:\Documents and Settings\Geotech Grad Student\Desktop\True
Start
Load Frame - TruePath T...
View Graphs
12:57 PM

Computer Controlled Constant Rate of Strain (CRS) Consolidation



Automated steps: seating, back pressure, strain controlled consolidation with unload-reload and creep stages (if required)

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Remarks regarding computer control

1. Pumps, motors, instrumentation & software continuously improve
2. With IP address, remote access and control possible
3. Instantaneous electrical (power) back up critical
4. Be aware of any "automated" decisions software makes
5. Temperature control is critical, especially for stress path cell
6. Sometimes the systems just go "crazy"
7. Need experienced personnel for trimming/specimen setup

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