WRSGC

August 2-3, 2005
Bloomington, MN

Automation of strain gage measurement on large scale structures

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Christoph Leser
John Christiansen
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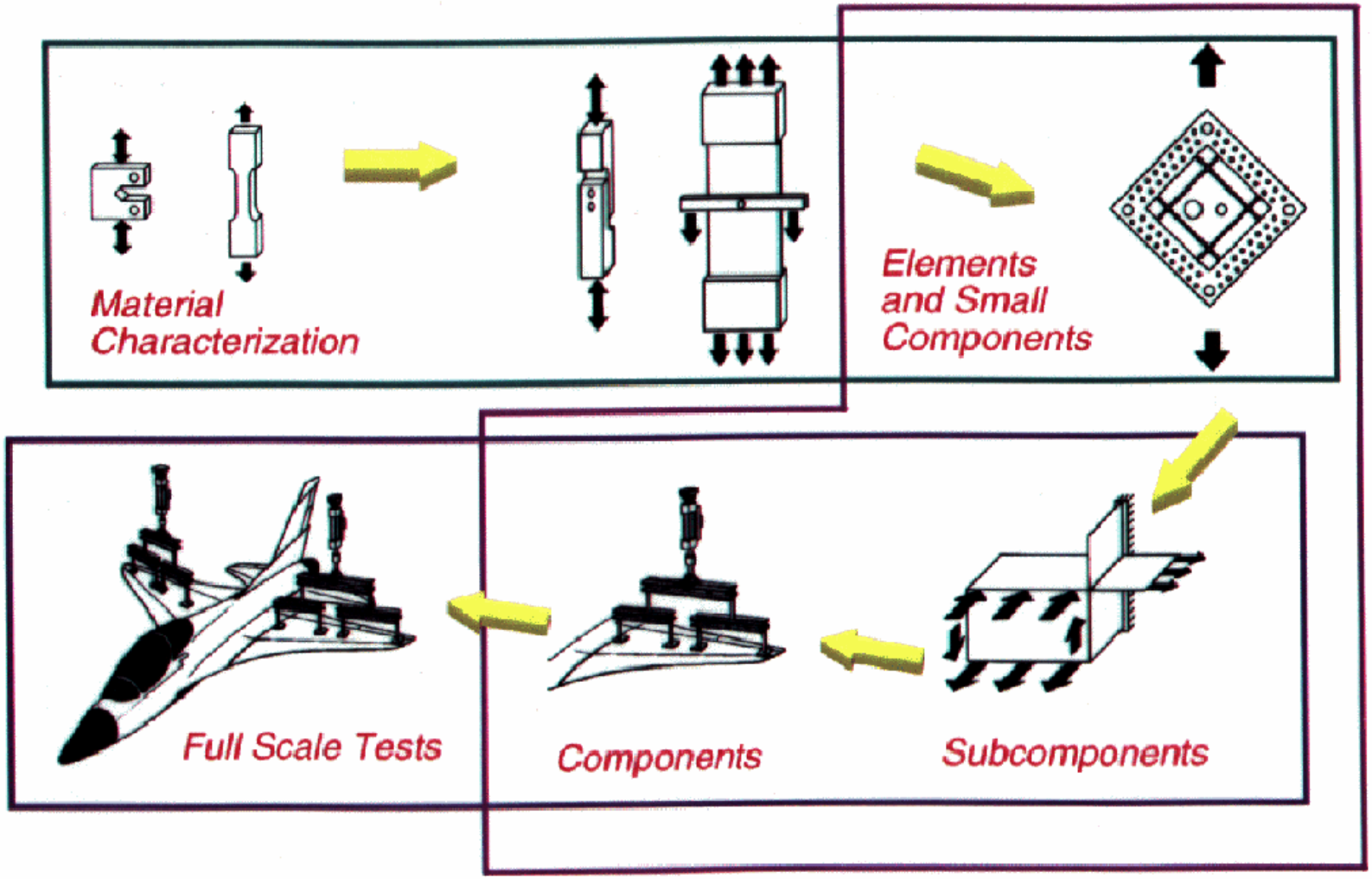
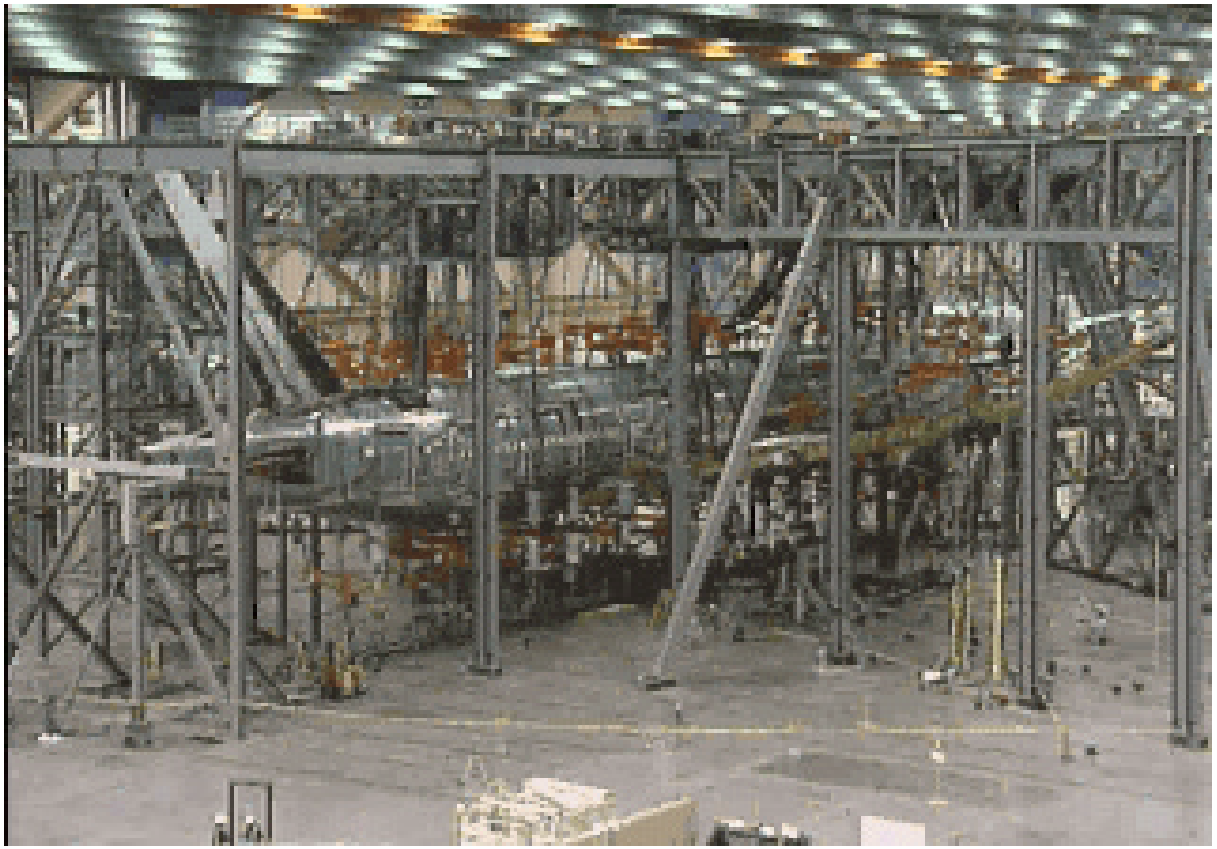
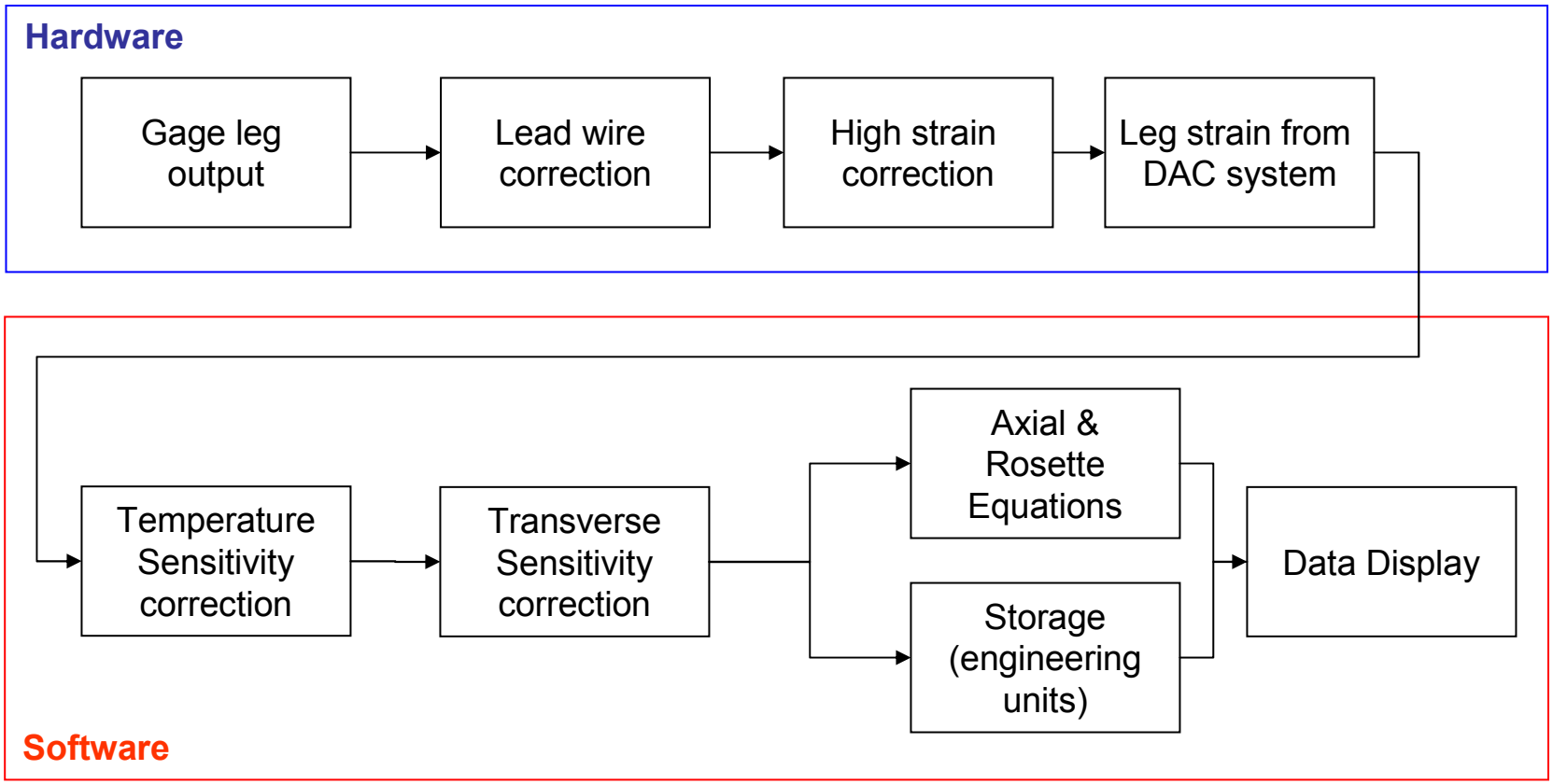
System Development, from Material to Structure



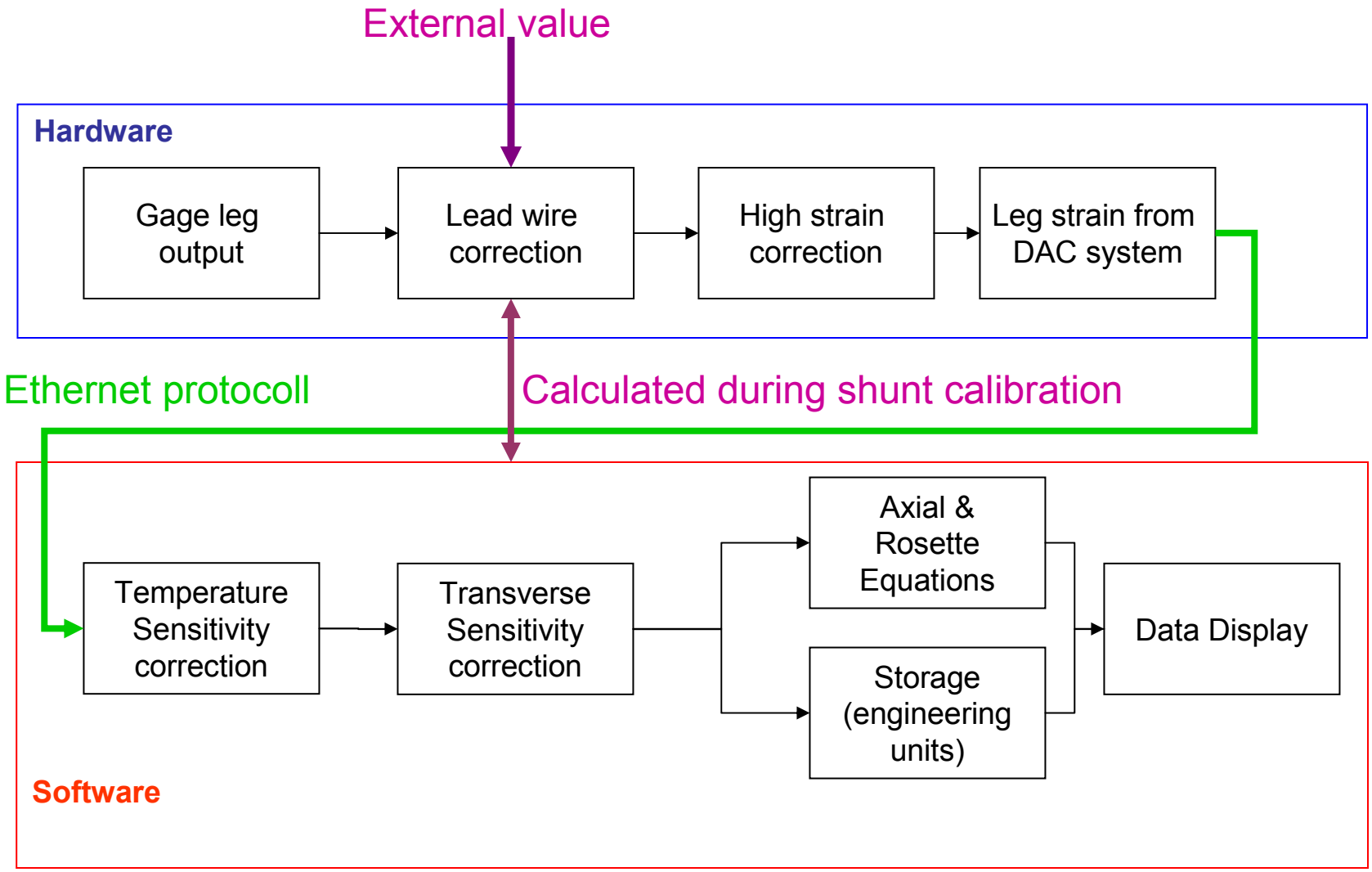
Full Scale Test



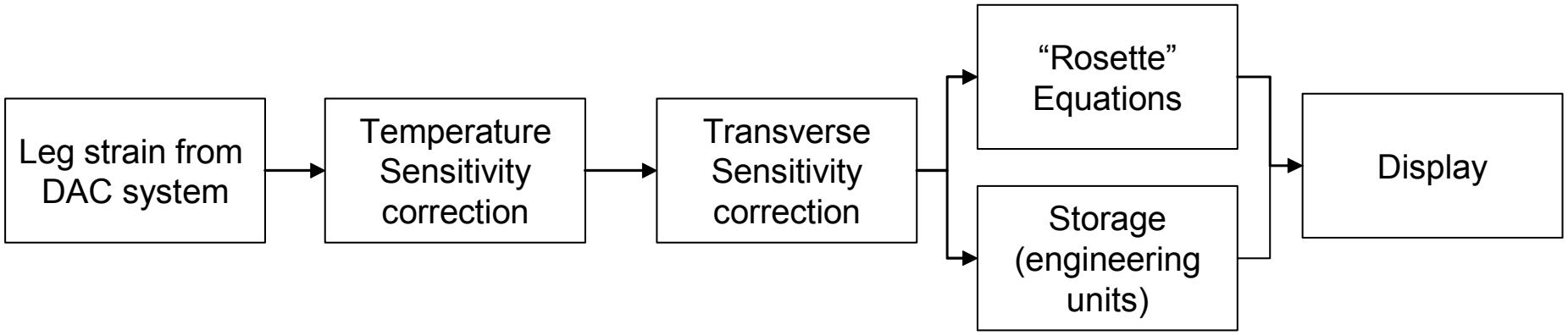
DAC System Schematic

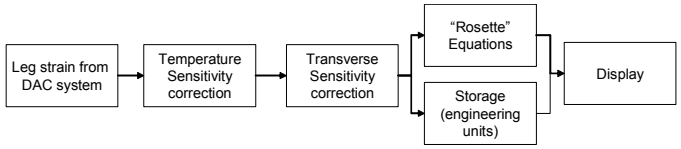


Hardware - Software Interaction



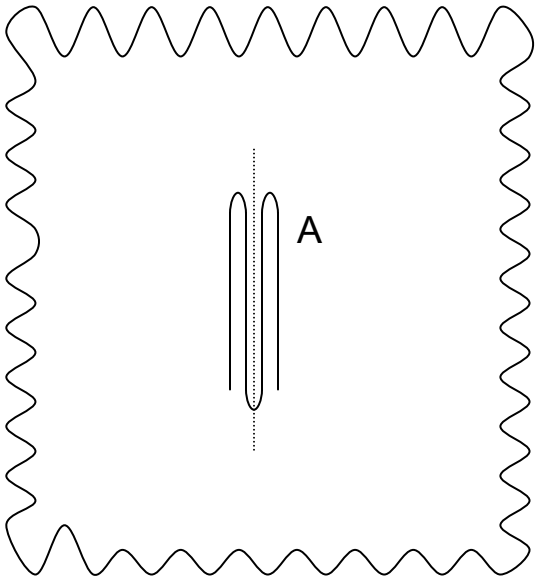
Software Scheme



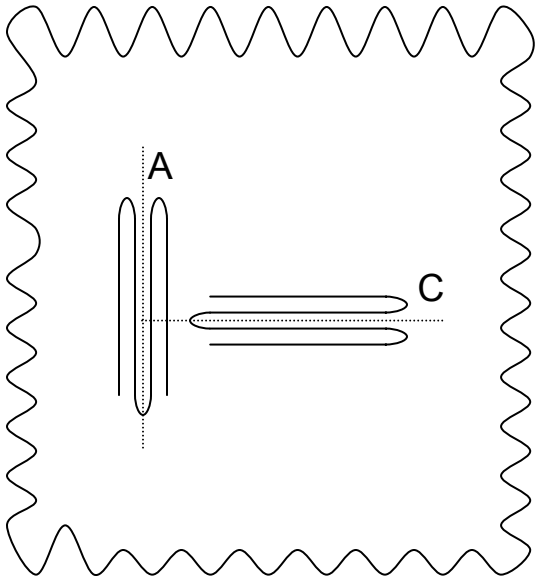


Gages

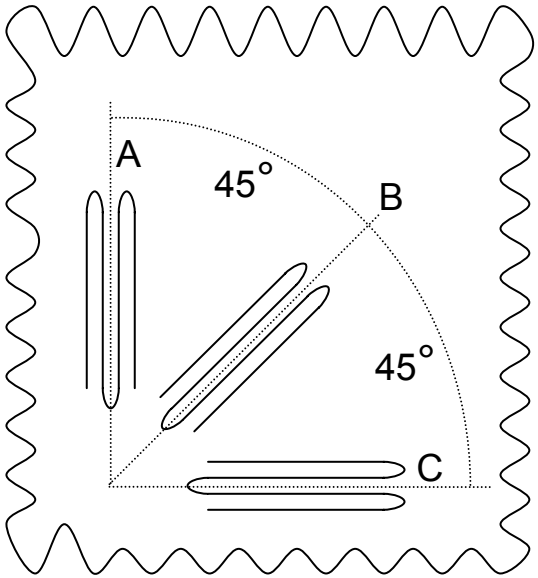
Axial

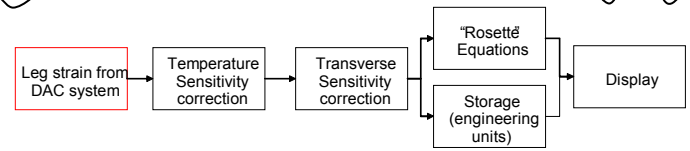


“Tee”



Rectangular





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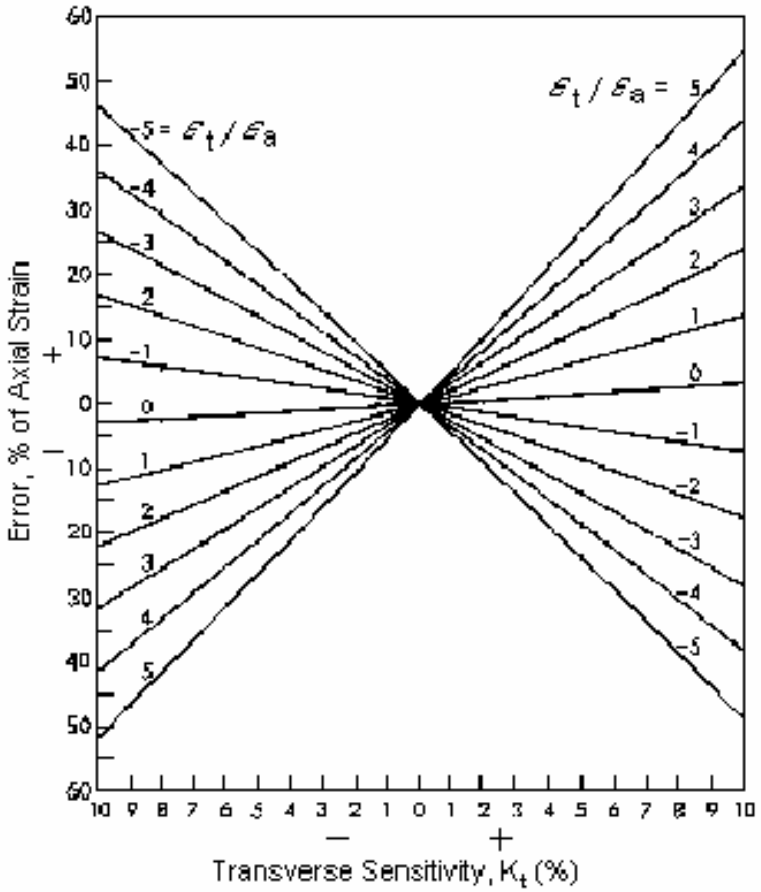
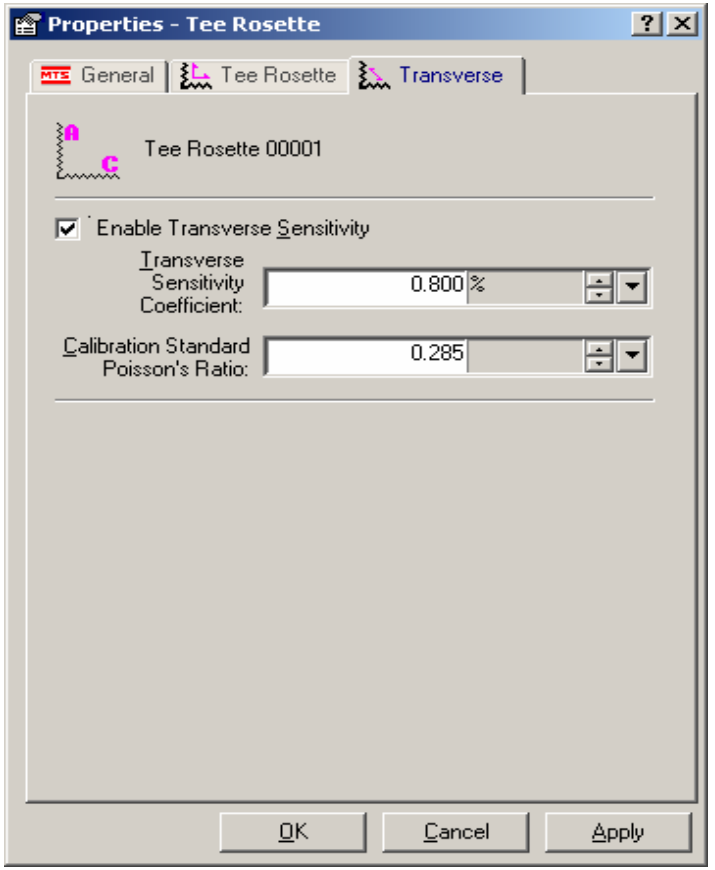
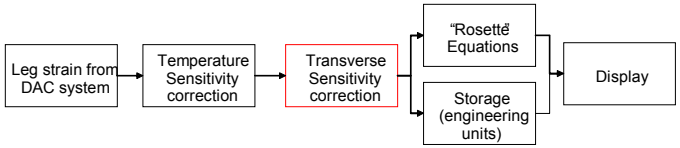
Transverse Sensitivity

$$\varepsilon_A^{TSC} = \frac{1 - \nu k_t}{1 - k_t^2}\left(\varepsilon_A^{ind} - k_t \varepsilon_C^{ind}\right)$$







Equations
(LaFever, 1992)

Hooks Law, etc.

$$\sigma_A = E_{(\mathrm{T\ or\ C})}\varepsilon_A$$

Single

$$\sigma_A = E\varepsilon_A$$

Back to Back

$$\sigma_A^1 = E\varepsilon_A^1$$

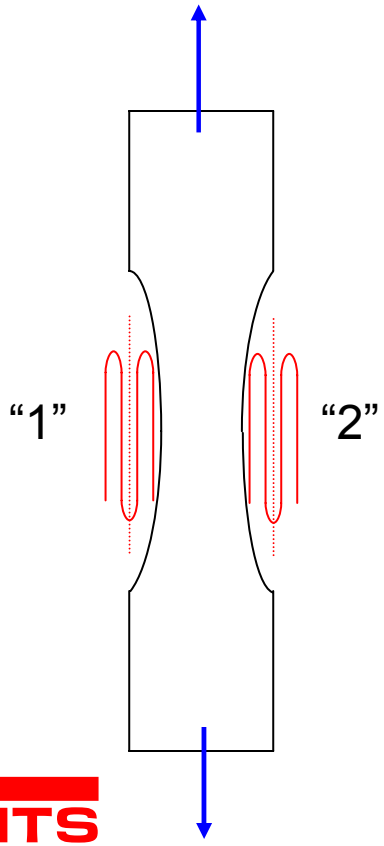
$$\sigma_A^2 = E\varepsilon_A^2$$

$$\varepsilon_{avg} = \left(\varepsilon_A^1 + \varepsilon_A^2\right)/2$$

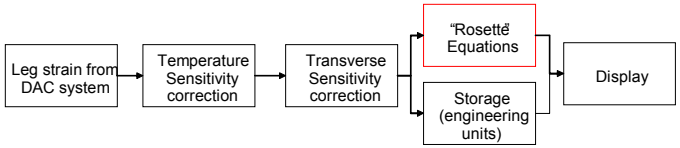
$$\sigma_{avg} = \left(\sigma_A^1 + \sigma_A^2\right)/2$$

$$\sigma_{bnd} = \left(\sigma_A^1 - \sigma_A^2\right)/2$$

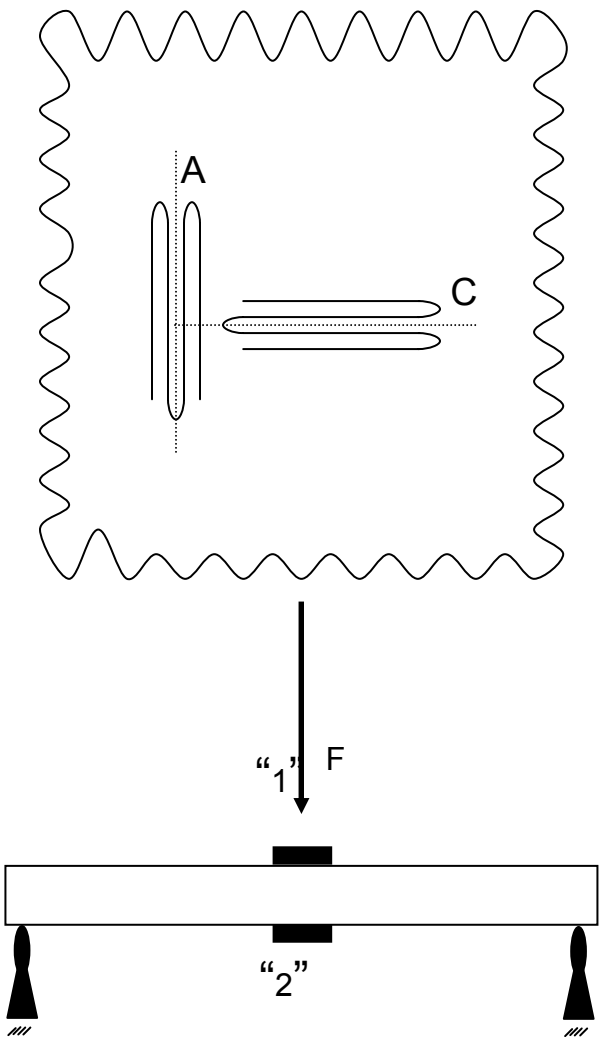
$$\varepsilon_{bnd} = \left(\varepsilon_A^1 - \varepsilon_A^2\right)/2$$



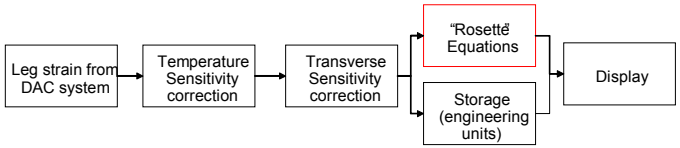
Axial Gage



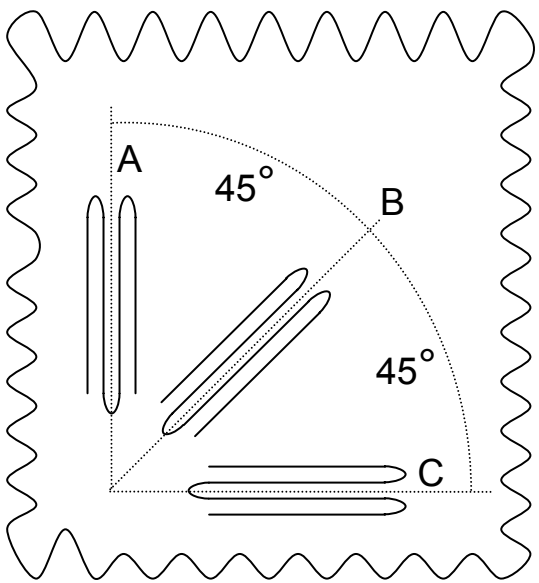
“Tee” Rosette

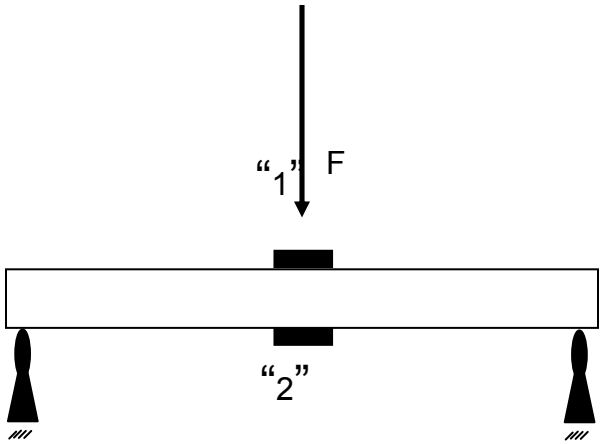


Measured	SA1	Strain A1
Measured	SA2	Strain A2
Measured	SC1	Strain C1
Measured	SC2	Strain C2
1	GB1	Shear Strain 1
2	GB2	Shear Strain 2
3	FA1	Stress A1
4	FA2	Stress A2
5	FC1	Stress C1
6	FC2	Stress C2
7	TB1	Shear Stress 1
8	TB2	Shear Stress 2
9	SAavg	Average Strain A
10	SCavg	Average Strain C
11	GBavg	Average Shear Strain
12	FAavg	Average Stress A
13	FCavg	Average Stress C
14	TBavg	Average Shear Stress
15	SAbnd	Bending Strain A
16	SCbnd	Bending Strain C
17	GBbnd	Bending Shear Strain
18	FAbnd	Bending Stress A
19	FCbnd	Bending Stress C
20	TBbnd	Bending Shear Stress



Rectangular Rosette

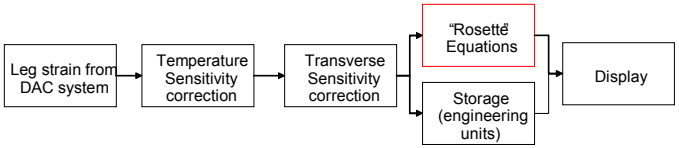




1 . Measured . 6

1 . Calculated . 50

Measured	SA1	Strain A1
Measured	SA2	Strain A2
Measured	SB1	Strain B1
Measured	SB2	Strain B2
Measured	SC1	Strain C1
Measured	SC2	Strain C2
1	GAC1	Shear Strain along A1 & C1
2	GAC2	Shear Strain along A2 & C2
3	GMAX1	Max Shear Strain 1
4	GMAX2	Max Shear Strain 2
5	SMAX1	Max In-Plane Principal Strain 1
6	SMAX2	Max In-Plane Principal Strain 2
7	SMIN1	Min In-Plane Principal Strain 1
8	SMIN2	Min In-Plane Prinicpal Strain 2
9	FA1	Stress A1
10	FA2	Stress A2
11	FC1	Stress C1
12	FC2	Stress C2
13	TAC1	Shear Stress along A1 or C1
14	TAC2	Shear Stress along A2 or C2
15	FMAX1	Max In-Plane Principal Stress 1
16	FMAX2	Max In-Plane Principal Stress 2
17	FMIN1	Min In-Plane Principal Stress 1
18	FMIN2	Min In-Plane Principal Stress 2
19	TMAX1	Max Shear Stress 1
20	TMAX2	Max Shear Stress 2
21	ANG1	Angle 1
22	ANG2	Angle 2
23	SAavg	Average Strain A
24	SBavg	Average Strain B
25	SCavg	Average Strain C
26	GACavg	Average Shear Strain along A & C
27	GMAXavg	Average Max Shear Strain
28	SMAXavg	Average Max In-Plane Principal Strain
29	SMINavg	Average Min In-Plane Principal Strain
30	FAavg	Average Stress A
31	FCavg	Average Stress C
32	TACavg	Average Shear Stress along A or C
33	FMAXavg	Average Max In-Plane Principal Stress
34	FMINavg	Average Min In-Plane Principal Stress
35	TMAXavg	Average Max Shear Stress
36	ANGavg	Average Angle
37	SAbnd	Bending Strain A
38	SBbnd	Bending Strain B
39	SCbnd	Bending Strain C
40	GACbnd	Bending Shear Strain along A & C
41	GMAXbnd	Bending Max Shear Strain
42	SMAXbnd	Bending Max In-Plane Principal Strain
43	SMINbnd	Bending Min In-Plane Principal Strain
44	FAbnd	Bending Stress A
45	FCbnd	Bending Stress C
46	TACbnd	Bending Shear Stress along A & C
47	FMAXbnd	Bending Max In-Plane Principal Stress
48	FMINbnd	Bending Min In-Plane Principal Stress
49	TMAXbnd	Bending Max Shear Stress
50	AGNbnd	Bending Angle



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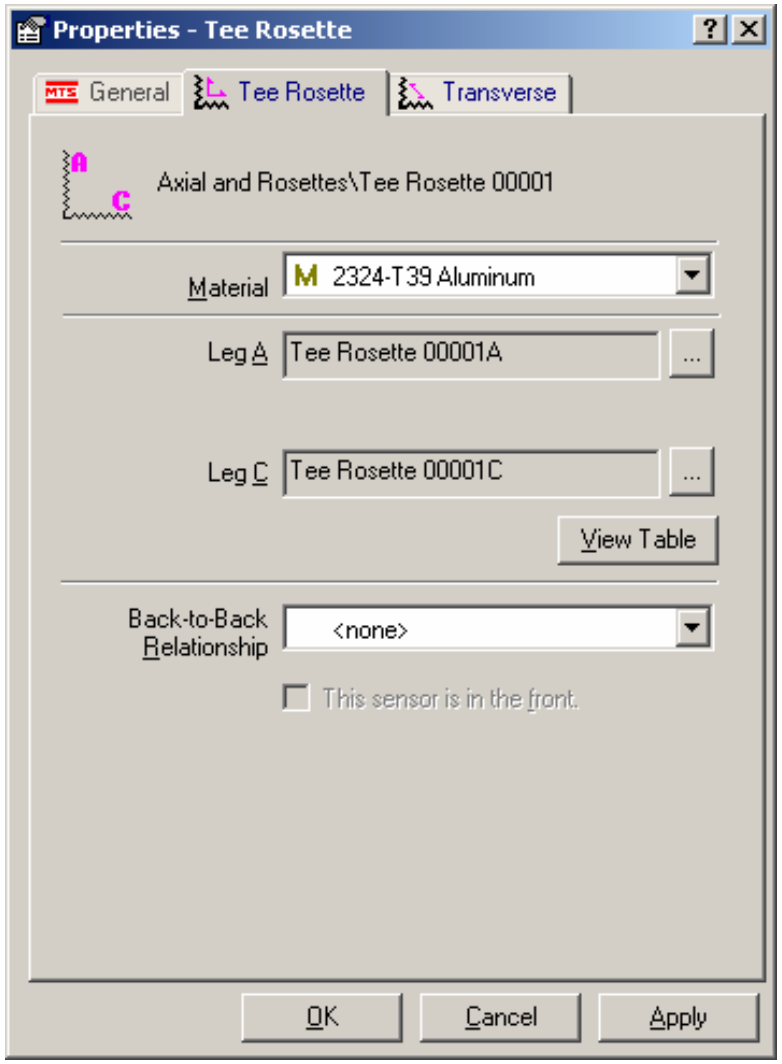
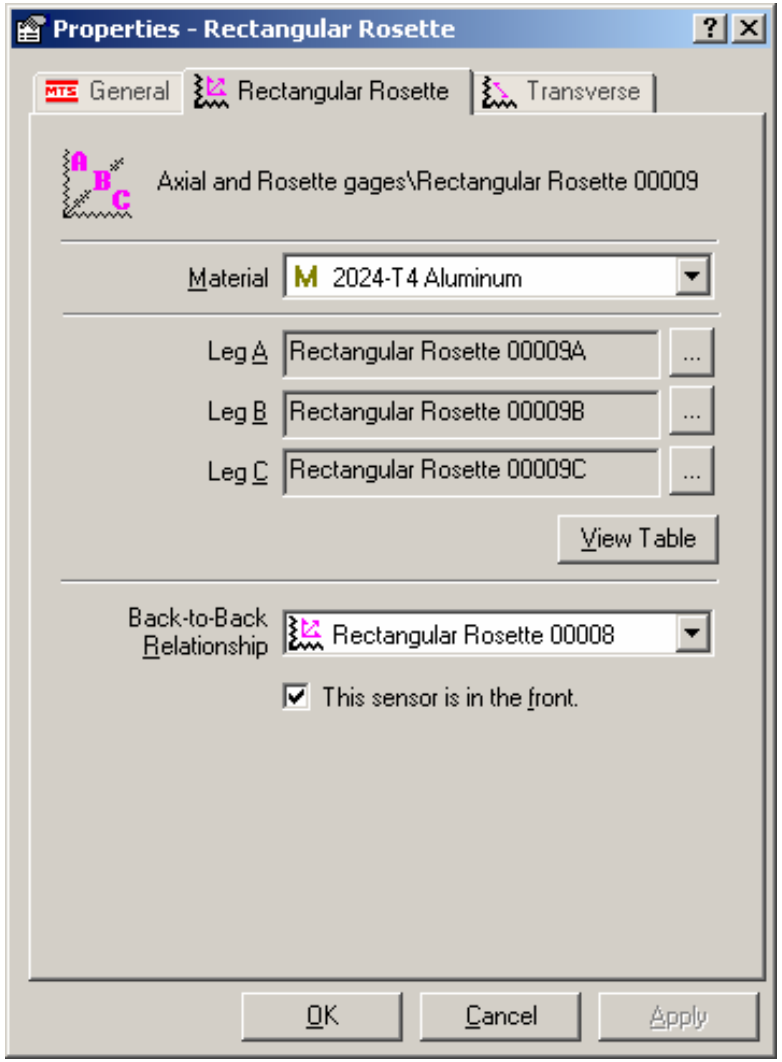
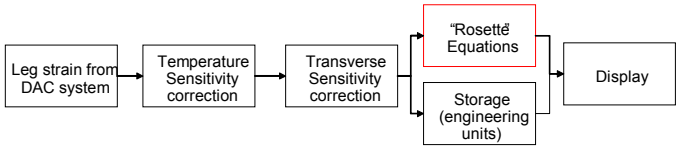
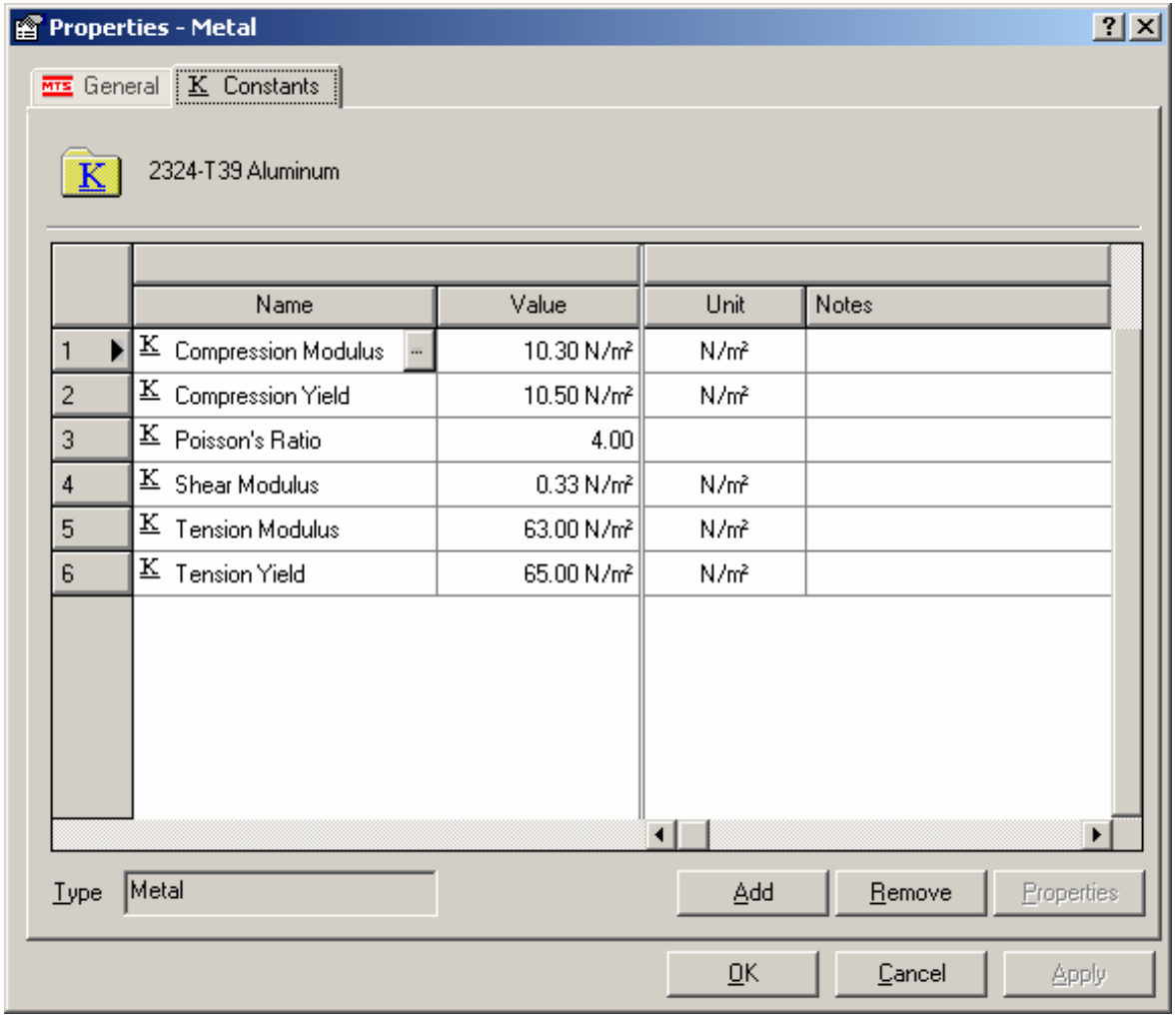
Setup

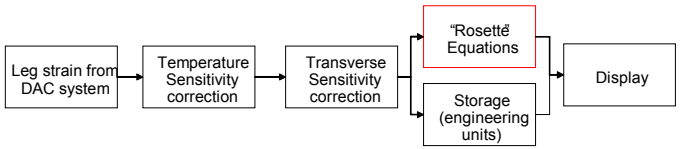

Properties - Tee Rosette
General
Tee Rosette
Transverse
Axial and Rosettes\Tee Rosette 00001
Material
2324-T39 Aluminum
Leg A
Tee Rosette 00001A
Leg C
Tee Rosette 00001C
View Table
Back-to-Back Relationship
<none>
This sensor is in the front.
OK
Cancel
Apply


Properties - Rectangular Rosette
General
Rectangular Rosette
Transverse
Axial and Rosette gages\Rectangular Rosette 00009
Material
2024-T4 Aluminum
Leg A
Rectangular Rosette 00009A
Leg B
Rectangular Rosette 00009B
Leg C
Rectangular Rosette 00009C
View Table
Back-to-Back Relationship
Rectangular Rosette 00008
This sensor is in the front.
OK
Cancel
Apply


Leg strain from DAC system
Temperature Sensitivity correction
Transverse Sensitivity correction
"Rosette" Equations
Storage (engineering units)
Display

Materials Database





Storage

Only leg strains stored in binary format for efficiency

RosetteTest1-A_export Inp1 1.txt - Notepad

File Edit Format View Help

```
Test Name:          RosetteTest1-A
Data Set Name:      VTI Scan Index Recorder (8/1/2005 1:22:27 PM)
Scan Type(s):       All Scan Types
Signal ID:          Input 1
                    Test Chan Key    D1          D2          D3          D4          D5          D6
                    Test Chan Name   Left Front A  Left Front B  Left Front C
Left Rear A         Left Rear B      Left Rear C   Right Rear A  Right Rear B
                    Test Chan No     1           2           3           4           5           6
                    Chan Type
                    Units    µStrain µStrain µStrain µStrain µStrain µStrain µStrai
Scan Index          Date     Time
  1          01-Aug-2005     '13:20:17.397   -129.396102905273          12.37074661254
11.8975763320923            9.29820156097412          12.6382541656494          11.759
114.157814025879            12.3592147827148          12.8607025146484          10.824
  2          01-Aug-2005     '13:20:17.497   -129.430313110352          12.36446857452
11.9639778137207            9.33093643188477          12.5158700942993          11.787
114.147026062012            12.3974370956421          12.900691986084 10.85173988342
  3          01-Aug-2005     '13:20:17.597   -129.507690429688          12.32666683197
11.9072484970093            9.30294513702393          12.5724124908447          11.739
114.110389709473            12.3410797119141          13.0160074234009          10.862
  4          01-Aug-2005     '13:20:17.697   -129.499969482422          12.31350803375
11.9315214157104            9.29866695404053          12.5116386413574          11.764
114.169151306152            12.195912361145 12.8388481140137          10.79528999328
  5          01-Aug-2005     '13:20:17.797   -129.470123291016          12.32499313354
11.9109687805176            9.29308700561523          12.5316333770752          11.819
114.163948059082            12.3152265548706          12.9305429458618          10.767
  6          01-Aug-2005     '13:20:17.897   -129.539520263672          12.33736133575
9.29197120666504            12.4898309707642          11.8289442062378          6.2247
12.225205214478             12.8693046569824          10.7777824401855
  7          01-Aug-2005     '13:20:17.997   -129.42529296875           12.41101455688
11.946494102478 9.31875419616699          12.4744396209717          11.82066726684
```

Export leg strain + derived values in XML, ASCII

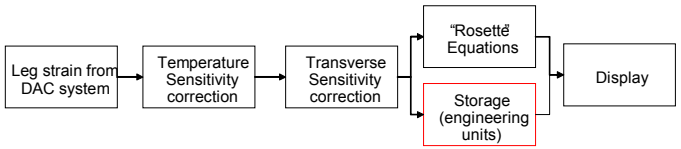
MTS® Data Display - [List View 1 -> Test Station 1: RosetteTest (Continuous)]

File Edit View Tools Window Help

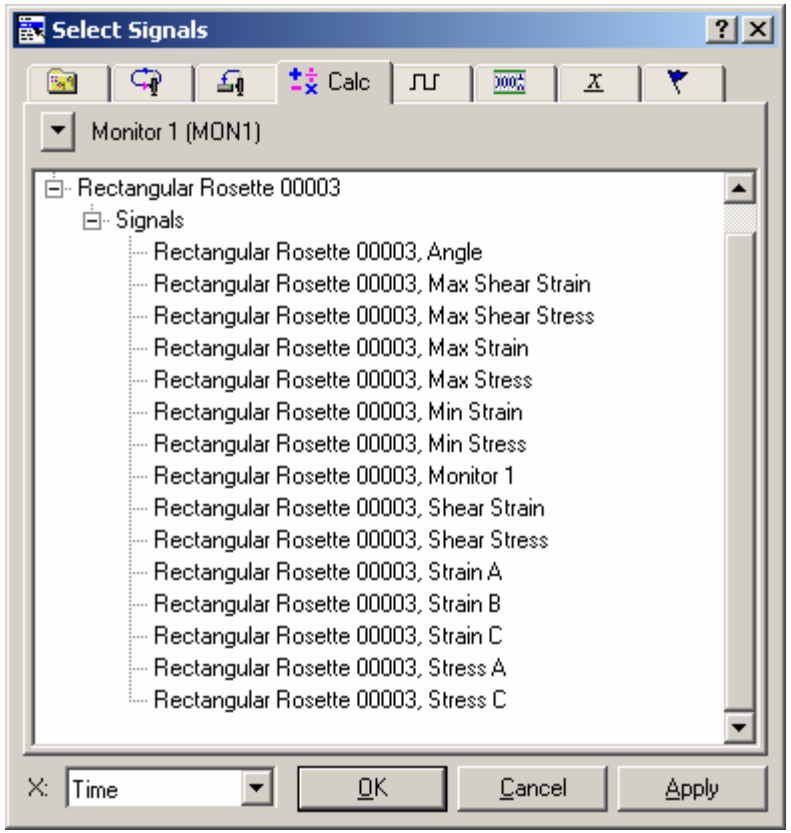
Test Station 1: RosetteTest (Continuous)

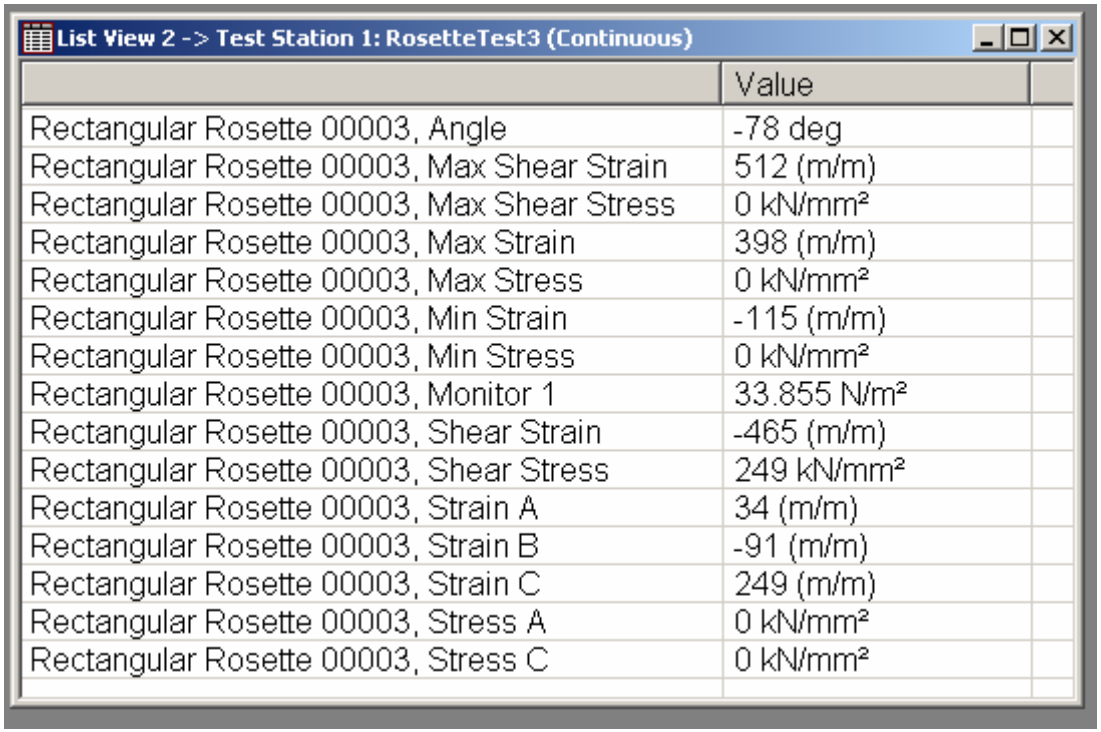
	SA	SB	SC	SMAX	SMIN	GAC	TAC	ANG
Rectangular Rosette 00027	-4.52	-96.91	28.94	122.60	-98.18	-218.23	28.94	-85.64
Rectangular Rosette 00028	22.22	62.56	28.81	62.71	-11.68	74.09	28.81	87.46
Rectangular Rosette 00029	-34.71	-0.36	29.50	29.58	-34.79	4.49	29.50	47.00
Rectangular Rosette 00030	60.97	26.32	-2.10	61.12	-2.26	-6.22	-2.10	-42.18

2005/07/28 10:09:01.434 - VTI SM #940 Rate: 1.0 Hz

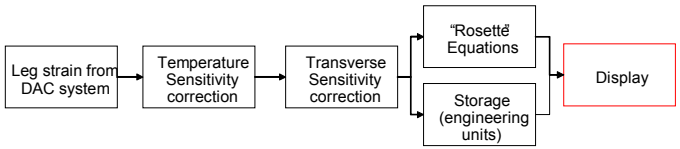


Display



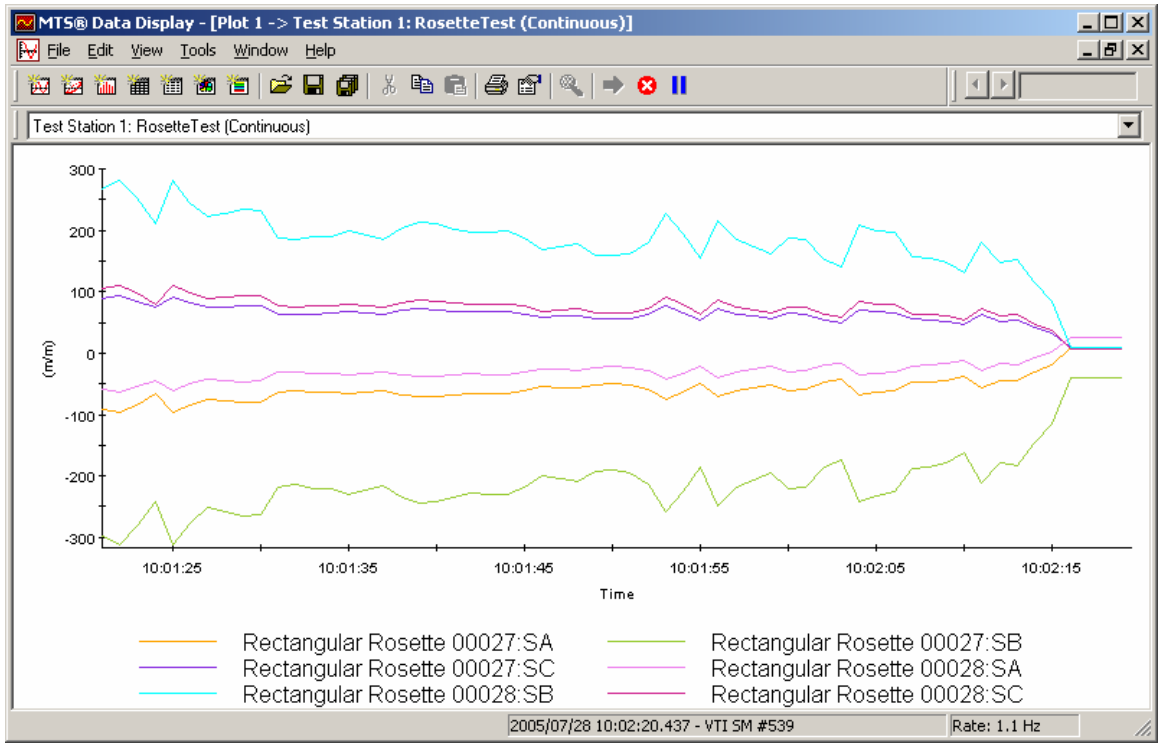


	Value
Rectangular Rosette 00003, Angle	-78 deg
Rectangular Rosette 00003, Max Shear Strain	512 (m/m)
Rectangular Rosette 00003, Max Shear Stress	0 kN/mm²
Rectangular Rosette 00003, Max Strain	398 (m/m)
Rectangular Rosette 00003, Max Stress	0 kN/mm²
Rectangular Rosette 00003, Min Strain	-115 (m/m)
Rectangular Rosette 00003, Min Stress	0 kN/mm²
Rectangular Rosette 00003, Monitor 1	33.855 N/m²
Rectangular Rosette 00003, Shear Strain	-465 (m/m)
Rectangular Rosette 00003, Shear Stress	249 kN/mm²
Rectangular Rosette 00003, Strain A	34 (m/m)
Rectangular Rosette 00003, Strain B	-91 (m/m)
Rectangular Rosette 00003, Strain C	249 (m/m)
Rectangular Rosette 00003, Stress A	0 kN/mm²
Rectangular Rosette 00003, Stress C	0 kN/mm²

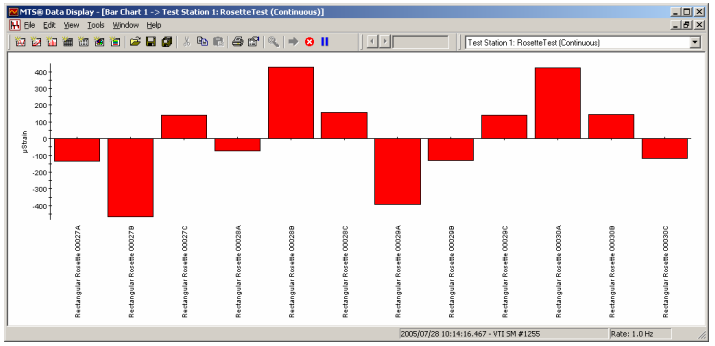


Display

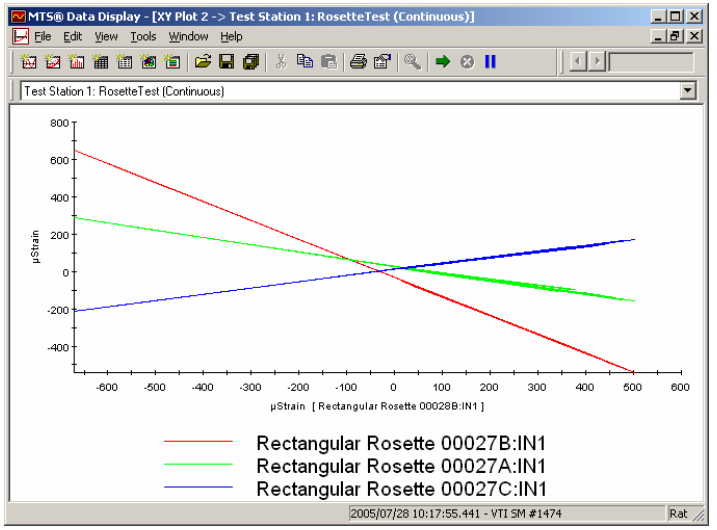
Time trace

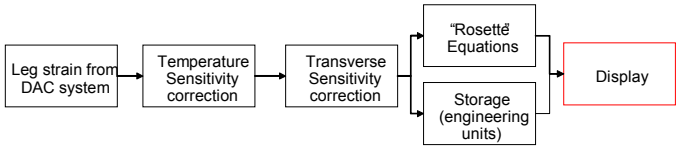


Bar Chart

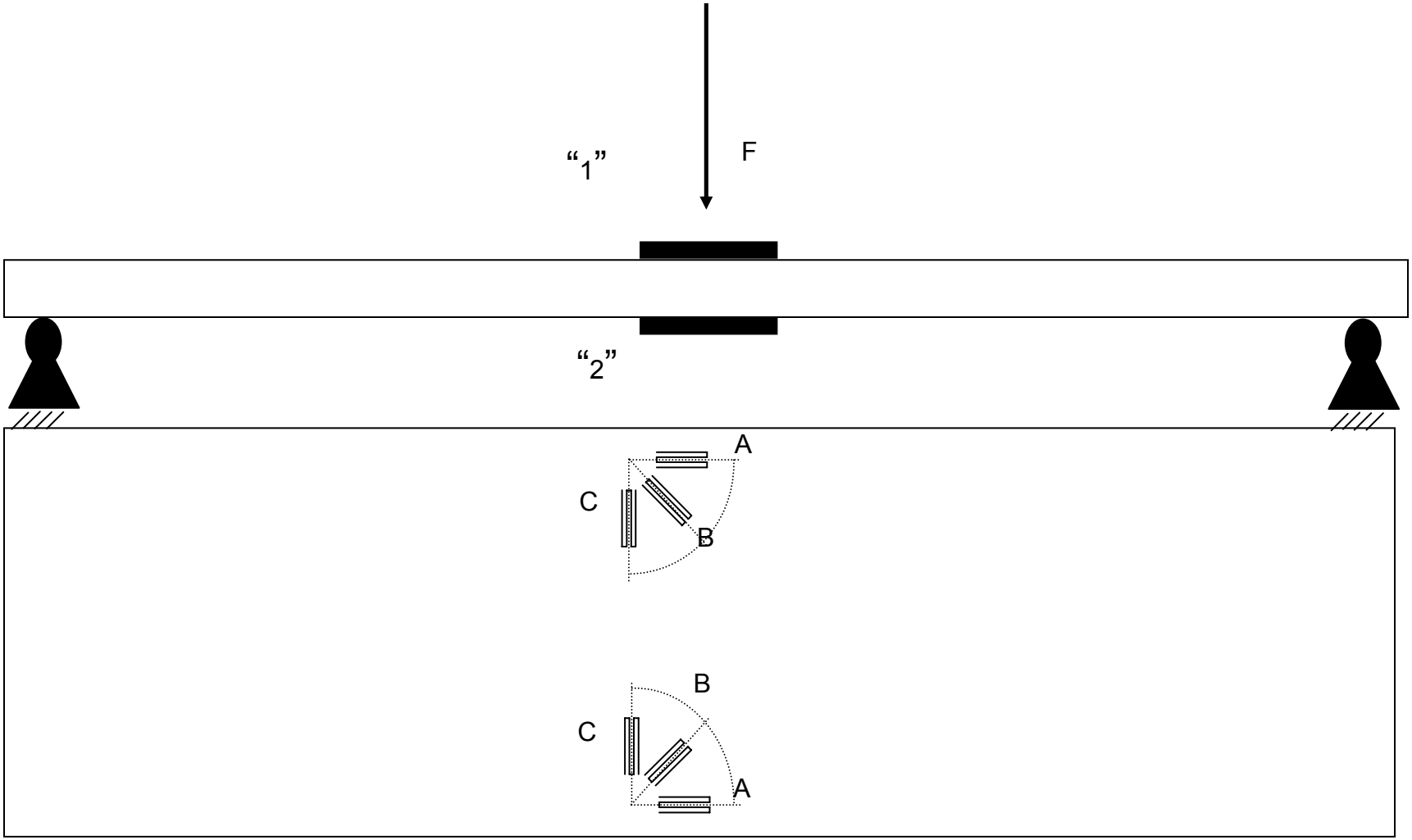


X-Y plot





Experimental Setup



Demo