

# Application of strain gages in Transducers

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## Strain gage applications

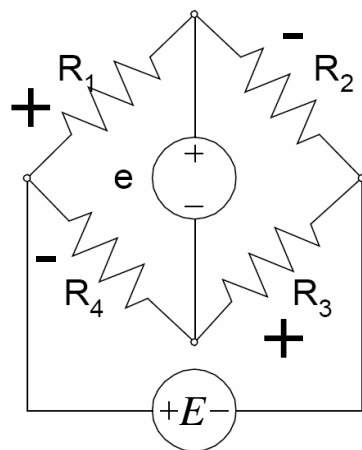
- Strain gage layout for different applications
- Load cell applications
  - ✓ Bending type
  - ✓ Direct stress type
  - ✓ Shear type

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# Strain gage layout for different applications

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## The Wheatstone bridge



$$de = \frac{1}{4} \left[ \frac{dR_1}{R_1} - \frac{dR_2}{R_2} + \frac{dR_3}{R_3} - \frac{dR_4}{R_4} \right] E$$

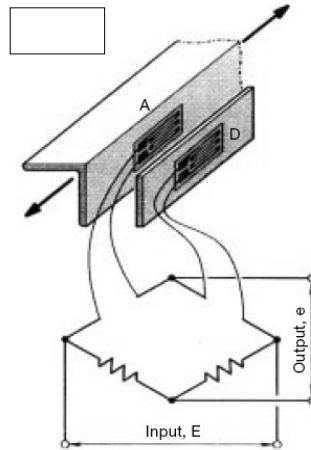
$$de = \frac{GF}{4} [\varepsilon_1 - \varepsilon_2 + \varepsilon_3 - \varepsilon_4] E$$

<http://www.ae.gatech.edu/people/jcraig/ae3145/Lab2/strain-gages.pdf>

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# Temperature compensation

## ➤ Active-dummy method



<http://www.kyowa-ei.co.jp/english/images/whats.pdf>

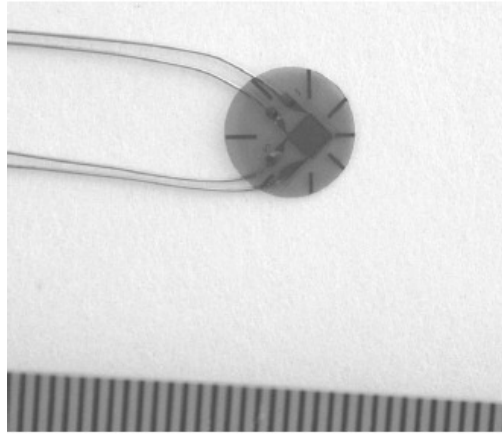
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Table 5. Bridge Configurations for Uniaxial Members

K	Configuration	Notes
1		Must use dummy gage in an adjacent arm (2 or 4) to achieve temperature compensation
2		Rejects bending strain but not temperature compensated; must add dummy gages in arms 2 & 4 to compensate for temperature.
$(1+\nu)$		Temperature compensated but sensitive to bending strains
$2(1+\nu)$		<b>Best:</b> compensates for temperature and rejects bending strain.

<http://www.ae.gatech.edu/people/jcraig/ae3145/Lab2/strain-gages.pdf>

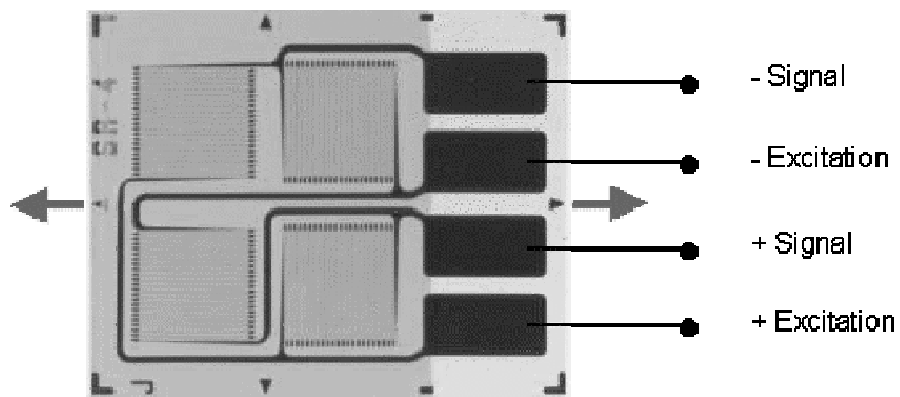
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2 gauge 90 degree rosette

<http://courses.washington.edu/mengr556/Examples%20of%20strain%20gauges.pdf>

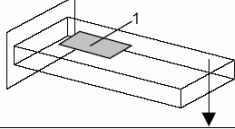
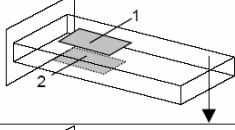
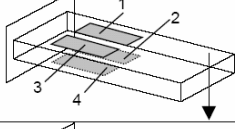
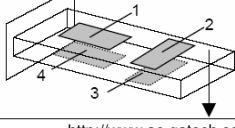
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Full bridge gages for bending beam.

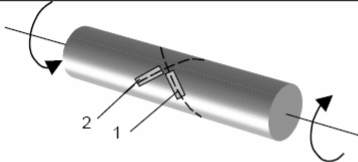
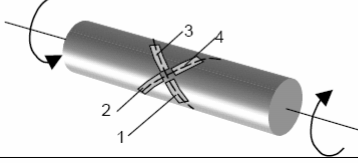
<http://www.blh.de/wiring.htm>

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Table 6. Bridge Configurations for Flexural Members		
K	Configuration	Notes
1		Also responds equally to axial strains; must use dummy gage in an adjacent arm (2 or 4) to achieve temperature compensation
2		Half-bridge; rejects axial strain and is temperature compensated; dummy resistors in arms 3 & 4 can be in strain indicator.
4		<b>Best:</b> Max sensitivity to bending; rejects axial strains; temperature compensated.
$2(1+\nu)$		Adequate, but not as good as F-3; compensates for temperature and rejects axial strain.

<http://www.ae.gatech.edu/people/jcraig/ae3145/Lab2/strain-gages.pdf>

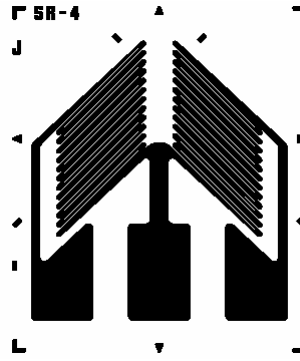
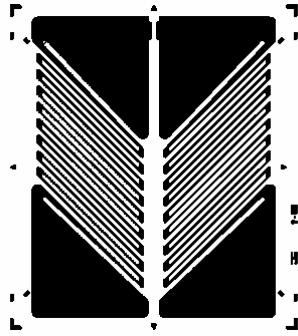
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Table 7. Bridge Configuration for Torsion Members			
No.	K	Configuration	Notes
T-1	2		Half Bridge: Gages at $\pm 45^\circ$ to centerline sense principal strains which are equal & opposite for pure torsion; bending or axial force induces equal strains and is rejected; arms are temperature compensated.
T-2	4		<b>Best:</b> full-bridge version of T-1; rejects axial and bending strain and is temperature compensated.

<http://www.ae.gatech.edu/people/jcraig/ae3145/Lab2/strain-gages.pdf>

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- For shear and torque measurement

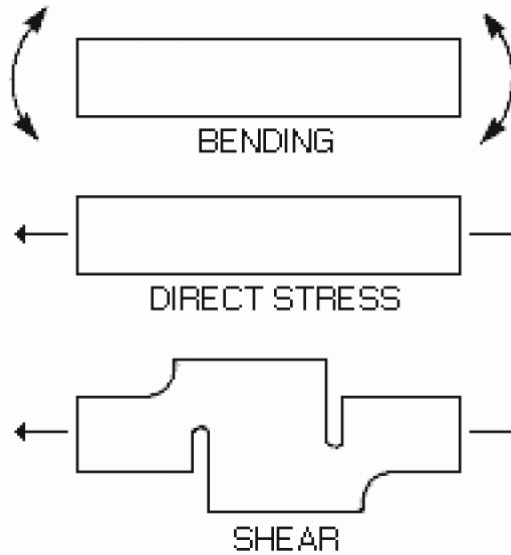


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## Load cell applications

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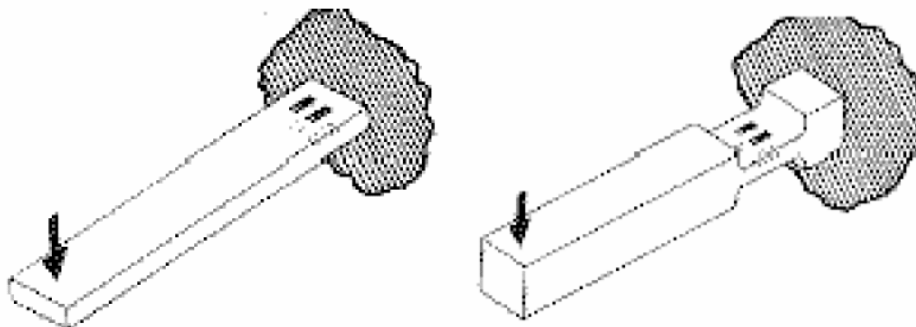
## Basic spring elements



[http://www.vishay.com/brands/measurements\\_group/guide/ta/sGBT/sGBT.pdf](http://www.vishay.com/brands/measurements_group/guide/ta/sGBT/sGBT.pdf)

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## Bending spring



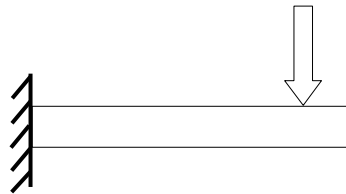
[http://www.vishay.com/brands/measurements\\_group/guide/ta/sGBT/sGBT.pdf](http://www.vishay.com/brands/measurements_group/guide/ta/sGBT/sGBT.pdf)

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## Design considerations

### Off-axis load

- Unpredictable accuracy.



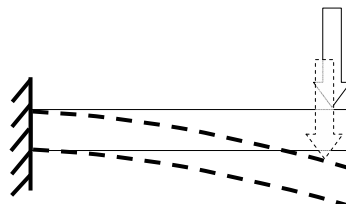
<http://www.sensorland.com/HowPage005.html>

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## Design considerations

### Reduction in moment arm on deflection

- Non-linearity
- Minimized by minimizing the ratio of deflection to length of beam.

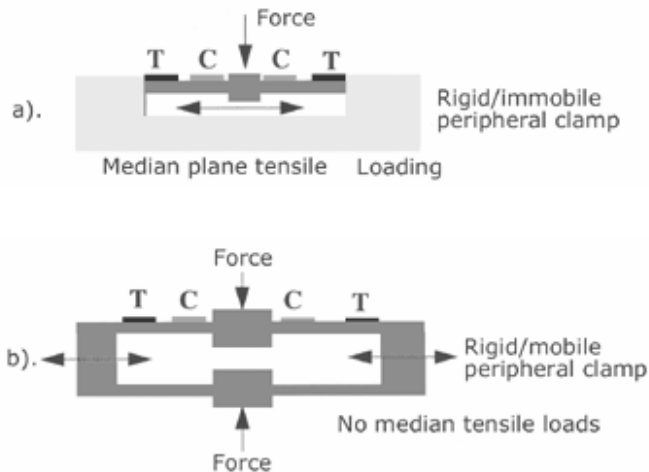


<http://www.sensorland.com/HowPage005.html>

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## Design considerations

### Membrane stress



Effect of Off-axis load alleviated

Deflection doubled.  
Non-linearity exists

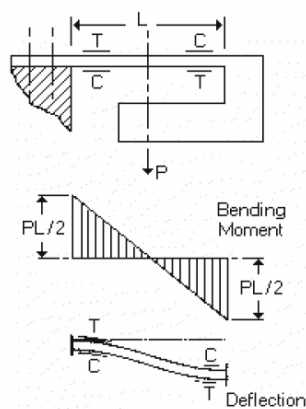
<http://www.sensorland.com/HowPage005.html>

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## Bending spring

a very simple means for producing effectively the same mode of double bending that occurs in either half of the sensing beams.

To function properly, the design must incorporate features to assure that loading can occur only along the intended axis.



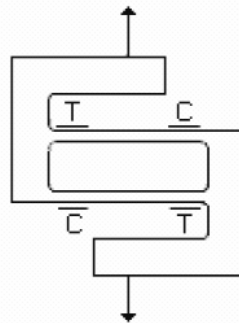
*Reversed bending induced by folded cantilever beam.*

[http://www.vishay.com/brands/measurements\\_group/guide/ta/sGBT/sGBT.pdf](http://www.vishay.com/brands/measurements_group/guide/ta/sGBT/sGBT.pdf)

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## Bending spring

A significantly improved form of the preceding design is shown below, where the load sensing is accomplished with two beams, joined by relatively massive sections at both ends.



*Coupled dual-beam spring element -- basic configuration.*

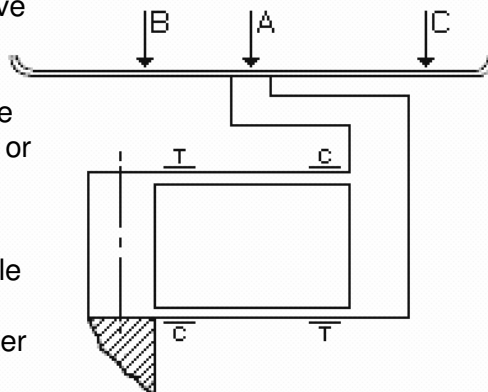
[http://www.vishay.com/brands/measurements\\_group/guide/ta/sGBT/sGBT.pdf](http://www.vishay.com/brands/measurements_group/guide/ta/sGBT/sGBT.pdf)

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## Bending spring

Off-axis insensitive

1. Moving the line of action for B or C to A.
2. Transform the resulting couple to forces in lower and upper arm.



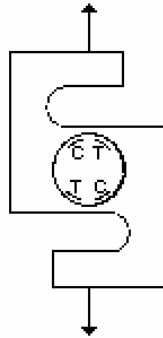
*Dual-beam spring element for reduced sensitivity to off-axis loads.*

[http://www.vishay.com/brands/measurements\\_group/guide/ta/sGBT/sGBT.pdf](http://www.vishay.com/brands/measurements_group/guide/ta/sGBT/sGBT.pdf)

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## Bending spring

A commercial transducer design which represents a simple, elegant, and eminently practical solution to the problem is illustrated below.



*Coupled dual-beam spring element -- compact, low-compliance design.*

[http://www.vishay.com/brands/measurements\\_group/guide/ta/sGBT/sGBT.pdf](http://www.vishay.com/brands/measurements_group/guide/ta/sGBT/sGBT.pdf)

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## Bending spring



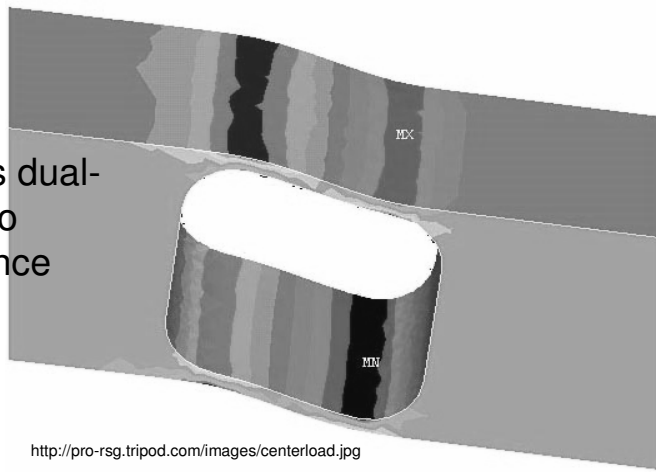
<http://news.thomasnet.com/images/large/2004/11/457720.jpg>

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## Bending spring

Deflection will cause a decrease in moment arm in a bending spring, giving rise to non-linearity.

Previous dual-beam too compliance

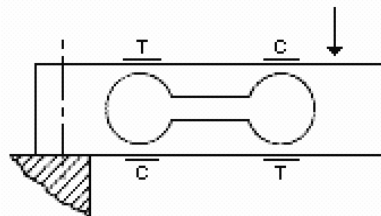


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## Bending spring

Another dual-beam configuration with no loss in sensitivity but improved stiffness (thus less non-linearity caused by shorted moment arm associated with deflection.)

Previous dual-beam too compliance

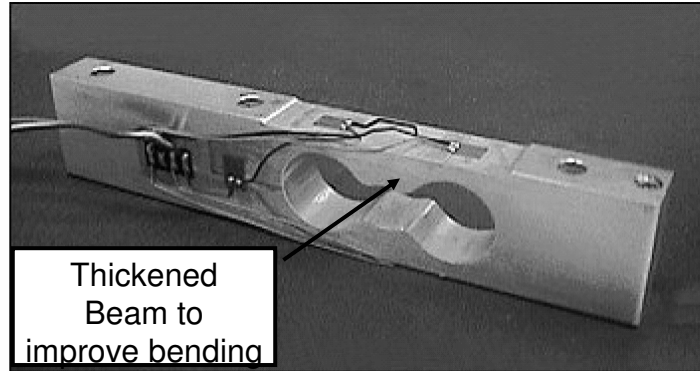


*Popular "binocular" spring element, widely used in low-capacity scale applications.*

[http://www.vishay.com/brands/measurements\\_group/guide/ta/sGBT/sGBT.pdf](http://www.vishay.com/brands/measurements_group/guide/ta/sGBT/sGBT.pdf)

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## Bending spring

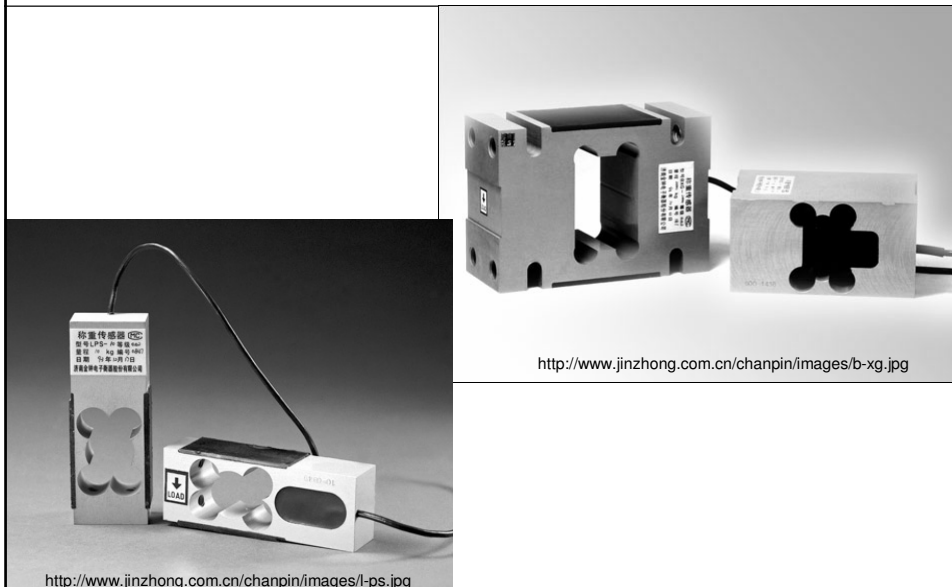


Representative spring element with gages installed and wired (prior to application of protective coatings).

[http://www.vishay.com/brands/measurements\\_group/guide/ta/sGBT/sGBT.pdf](http://www.vishay.com/brands/measurements_group/guide/ta/sGBT/sGBT.pdf)

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## Bending spring

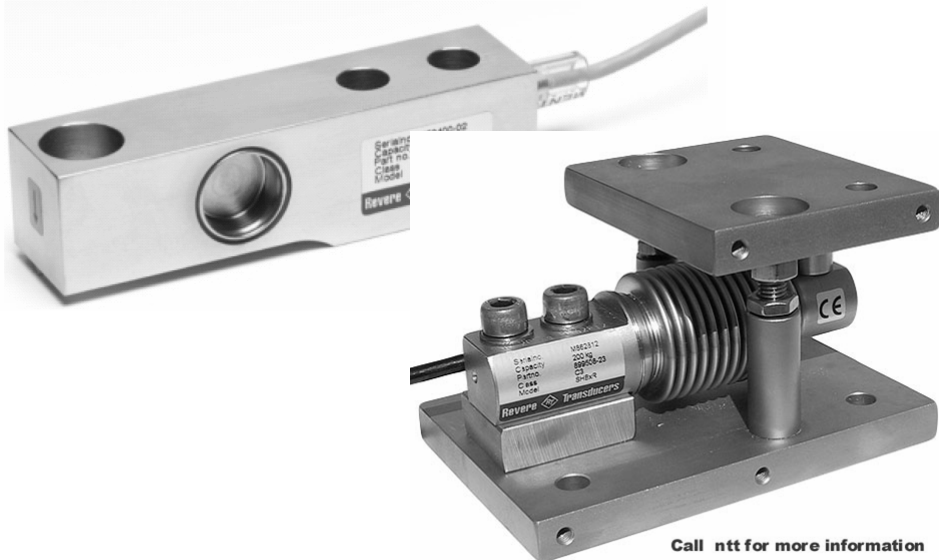


<http://www.jinzhong.com.cn/chanpin/images/b-xg.jpg>

<http://www.jinzhong.com.cn/chanpin/images/l-ps.jpg>

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## Bending spring

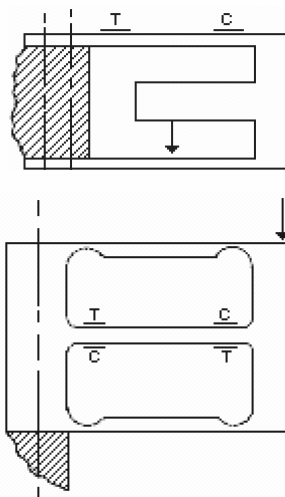


<http://www.ntt.dk/bending.htm>

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## Bending spring

Two methods  
to eliminate  
direct stress  
in sensing  
beams



Loaded at  
center

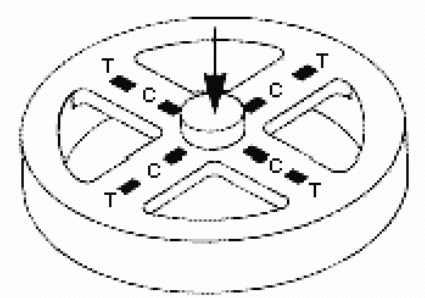
Sensing  
element as  
neutral axis.

*Triple-beam design for isolation of sensing beam from externally applied couples.*

[http://www.vishay.com/brands/measurements\\_group/guide/ta/sGBT/sGBT.pdf](http://www.vishay.com/brands/measurements_group/guide/ta/sGBT/sGBT.pdf)

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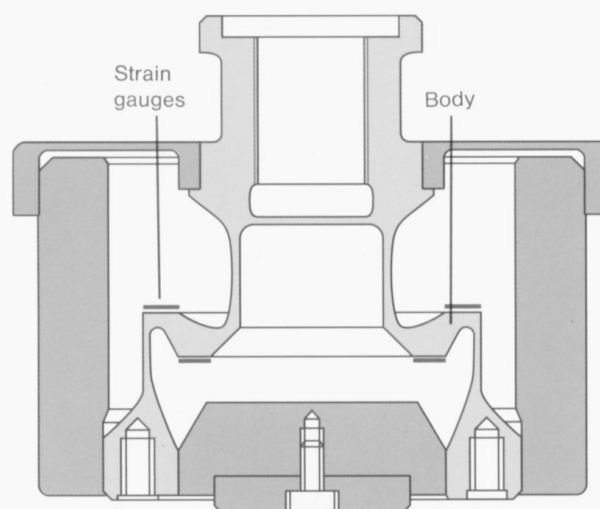
## Bending spring



*Wheel-shaped spring element, adaptable to low-profile transducers.*

[http://www.vishay.com/brands/measurements\\_group/guide/ta/sGBT/sGBT.pdf](http://www.vishay.com/brands/measurements_group/guide/ta/sGBT/sGBT.pdf)

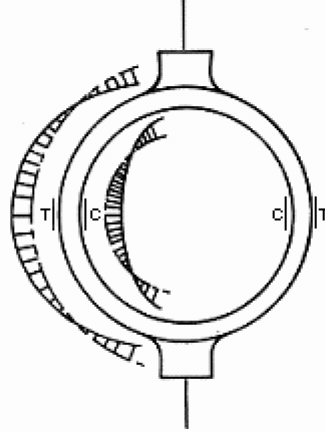
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From Schenck catalogue

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## Bending spring

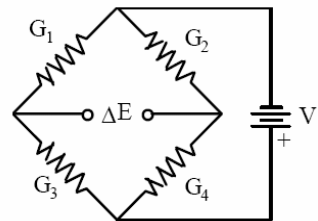
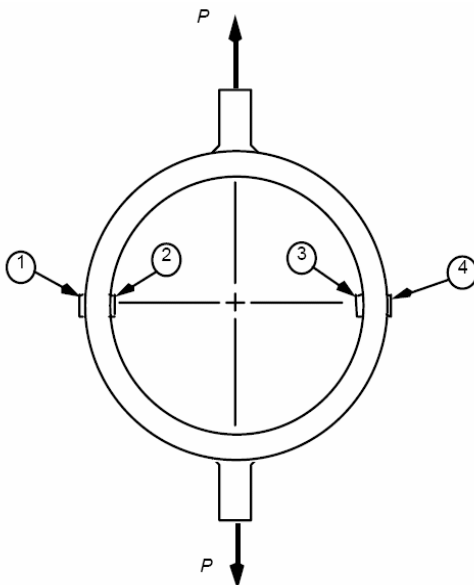


*Simple ring configuration, based on classical Morehouse proving ring principle*

[http://www.vishay.com/brands/measurements\\_group/guide/ta/sGBT/sGBT.pdf](http://www.vishay.com/brands/measurements_group/guide/ta/sGBT/sGBT.pdf)

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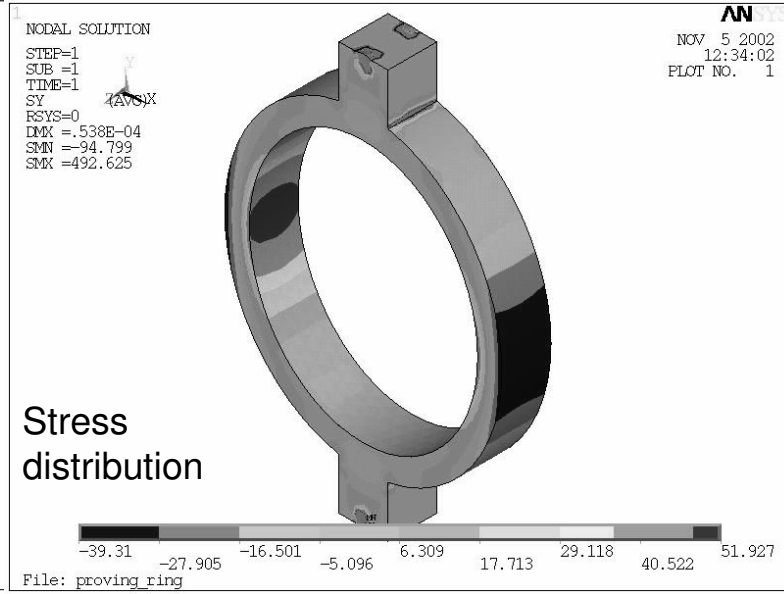
## Proof ring



<http://courses.washington.edu/mengr556/lab4.pdf>

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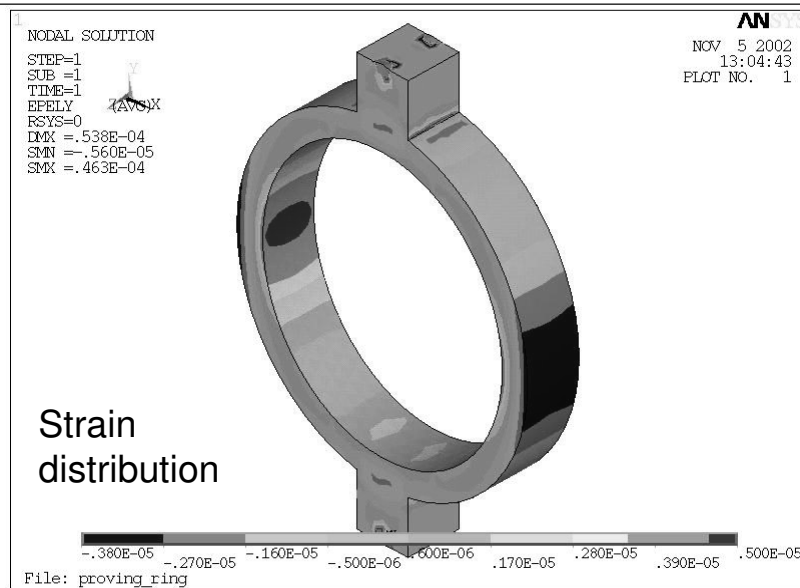
# Proof ring



[http://courses.washington.edu/mengr556/FEA\\_ring.html](http://courses.washington.edu/mengr556/FEA_ring.html)

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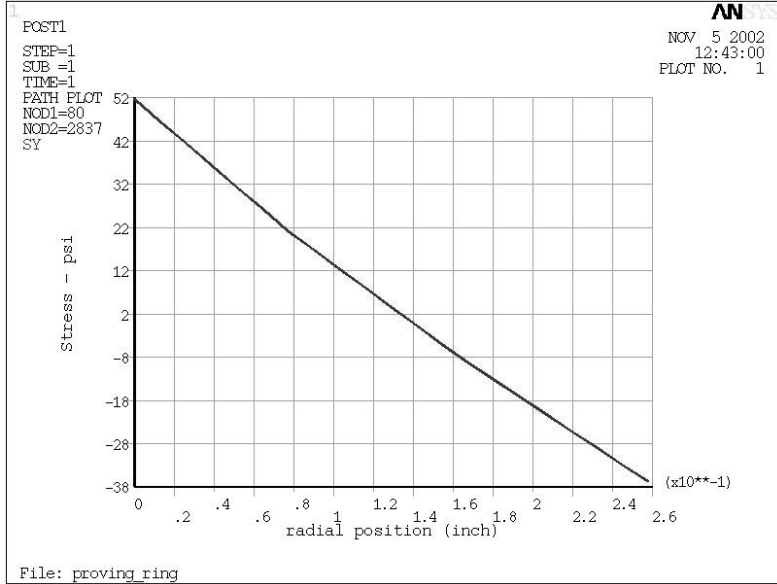
# Proof ring



[http://courses.washington.edu/mengr556/FEA\\_ring.html](http://courses.washington.edu/mengr556/FEA_ring.html)

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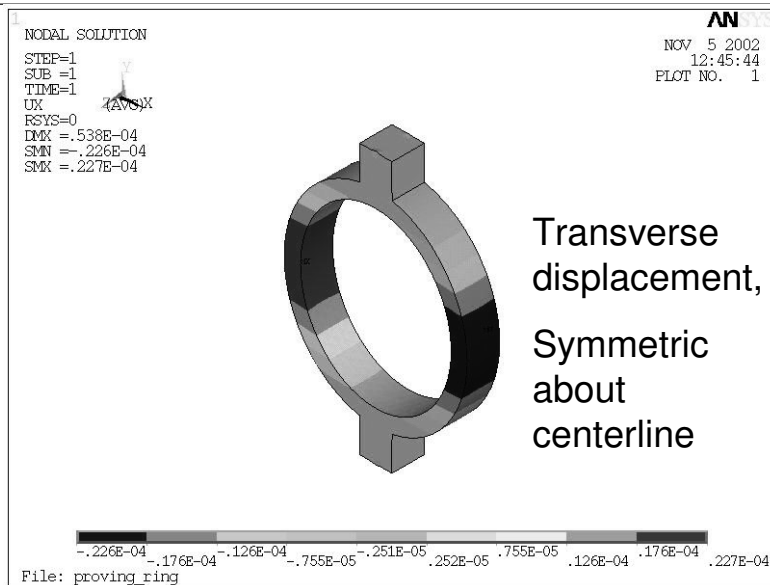
# Proof ring



[http://courses.washington.edu/mengr556/FEA\\_ring.html](http://courses.washington.edu/mengr556/FEA_ring.html)

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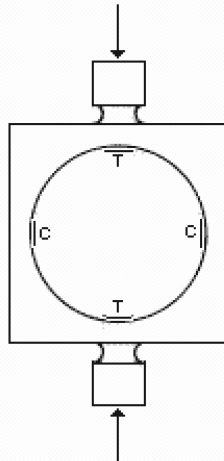
# Proof ring



[http://courses.washington.edu/mengr556/FEA\\_ring.html](http://courses.washington.edu/mengr556/FEA_ring.html)

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## Bending spring

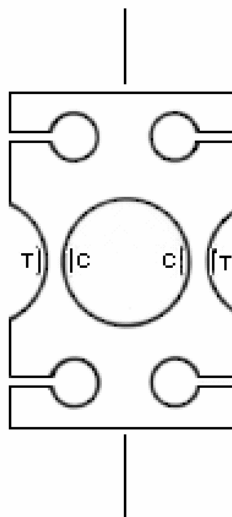


*Improved ring design for low compliance, less sensitivity to off-axis loads, and reduced manufacturing cost.*

[http://www.vishay.com/brands/measurements\\_group/guide/ta/sGBT/sGBT.pdf](http://www.vishay.com/brands/measurements_group/guide/ta/sGBT/sGBT.pdf)

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## Bending spring

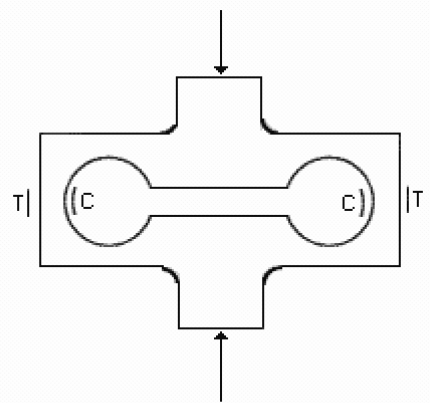


*Complex spring-element geometry derived from ring concept.*

[http://www.vishay.com/brands/measurements\\_group/guide/ta/sGBT/sGBT.pdf](http://www.vishay.com/brands/measurements_group/guide/ta/sGBT/sGBT.pdf)

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## Bending spring

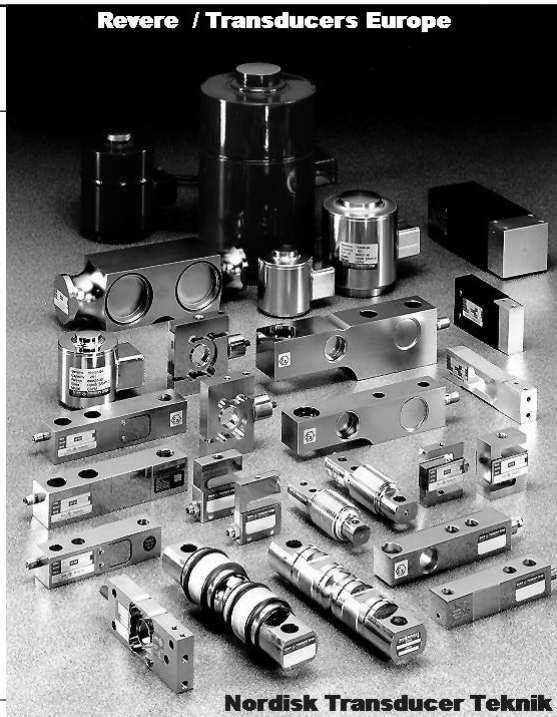


*Variation of ring design, similar in appearance to "binocular" spring element, but very different in operating characteristics.*

[http://www.vishay.com/brands/measurements\\_group/guide/ta/sGBT/sGBT.pdf](http://www.vishay.com/brands/measurements_group/guide/ta/sGBT/sGBT.pdf)

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## Revere / Transducers Europe

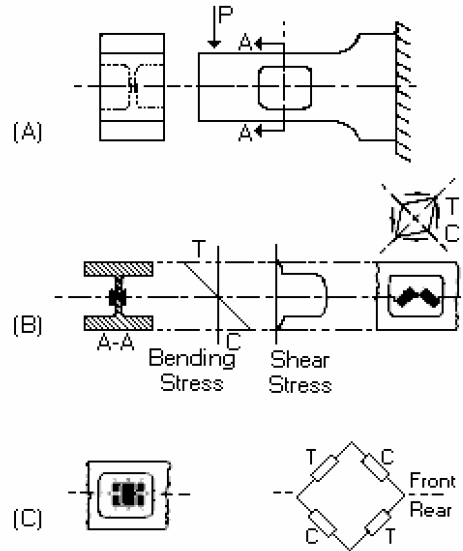


<http://www.ntt.dk/rteprogram.JPG>

Nordisk Transducer Teknik

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## Shear web type

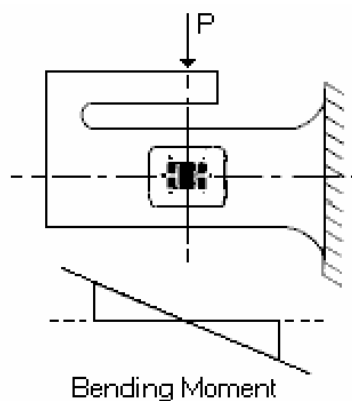


*Principle of the shear-web load cell, with stress distribution and circuit*

[http://www.vishay.com/brands/measurements\\_group/guide/ta/sGBT/sGBT.pdf](http://www.vishay.com/brands/measurements_group/guide/ta/sGBT/sGBT.pdf)

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## Shear web type

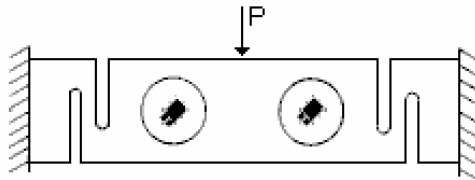


*Shear-web spring-element with zero bending moment at the gaged section*

[http://www.vishay.com/brands/measurements\\_group/guide/ta/sGBT/sGBT.pdf](http://www.vishay.com/brands/measurements_group/guide/ta/sGBT/sGBT.pdf)

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## Shear web type

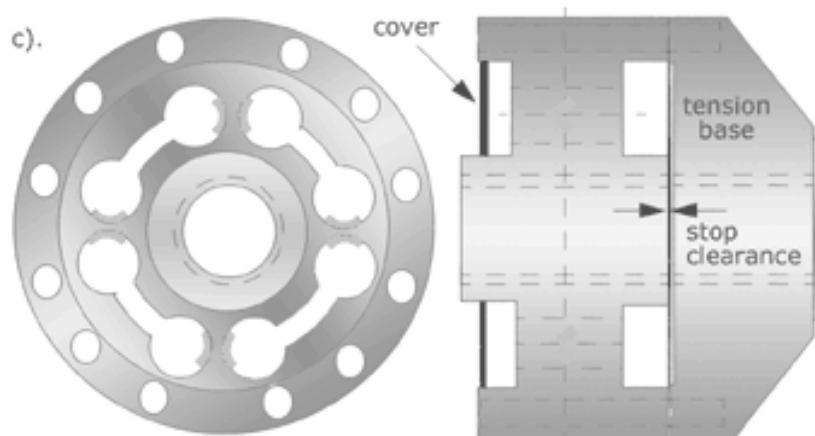


*Dual shear webs in a beam configuration designed to cancel the effects of the off-axis and side loads.*

[http://www.vishay.com/brands/measurements\\_group/guide/ta/sGBT/sGBT.pdf](http://www.vishay.com/brands/measurements_group/guide/ta/sGBT/sGBT.pdf)

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## Shear web type

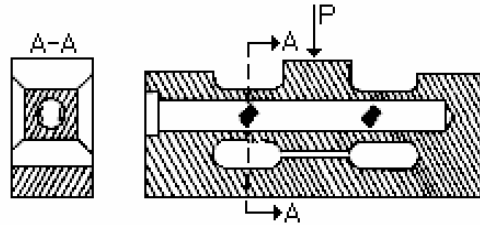


Spring element in wheel form, with radial webs subject to direct shear.

<http://www.sensorland.com/HowPage005.html>

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## Shear web type

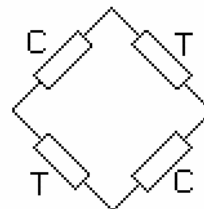


*Shear webs formed by drilling a longitudinal hole in the load-sensing beam.*

[http://www.vishay.com/brands/measurements\\_group/guide/ta/sGBT/sGBT.pdf](http://www.vishay.com/brands/measurements_group/guide/ta/sGBT/sGBT.pdf)

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## Direct stress spring



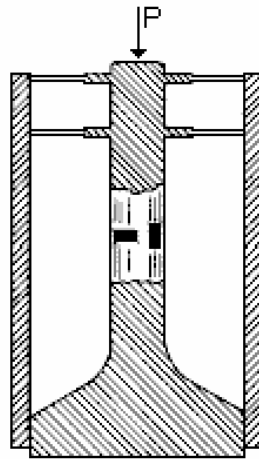
$$T = -\nu \times C$$

*Principle of the column load cell.*

[http://www.vishay.com/brands/measurements\\_group/guide/ta/sGBT/sGBT.pdf](http://www.vishay.com/brands/measurements_group/guide/ta/sGBT/sGBT.pdf)

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## Direct stress spring



*Representative design for a column load cell.*

[http://www.vishay.com/brands/measurements\\_group/guide/ta/sGBT/sGBT.pdf](http://www.vishay.com/brands/measurements_group/guide/ta/sGBT/sGBT.pdf)

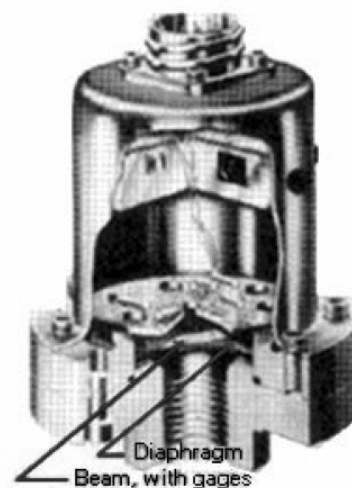
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## Direct stress spring

(a)



(b)



*Representative contemporary strain gage transducers:*

*(a) Cutaway load cell (courtesy of Eaton Corp./Lebow Products)*

*(b) Cutaway drawing of pressure cell (courtesy of Viatran Corp.).*

[http://www.vishay.com/brands/measurements\\_group/guide/ta/sGBT/sGBT.pdf](http://www.vishay.com/brands/measurements_group/guide/ta/sGBT/sGBT.pdf)

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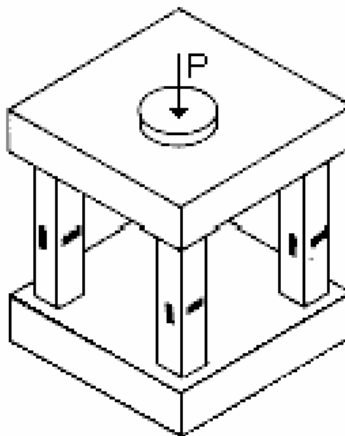
## Direct stress spring



<http://www.pcm-uk.com/newpdfs/BiDirectionalBolts-0505.pdf>

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## Direct stress spring

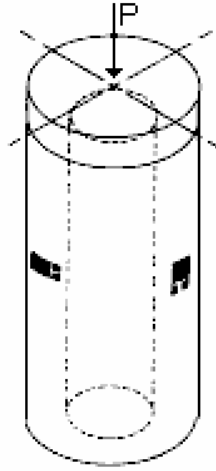


*Four-column load cell for increased capacity.*

[http://www.vishay.com/brands/measurements\\_group/guide/ta/sGBT/sGBT.pdf](http://www.vishay.com/brands/measurements_group/guide/ta/sGBT/sGBT.pdf)

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## Direct stress spring

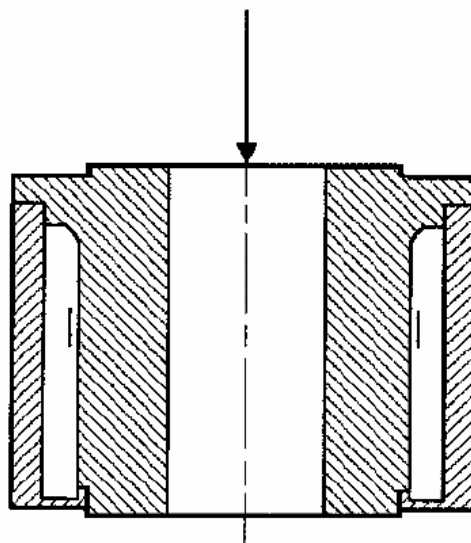


*Hollow cylindrical load cell is less sensitive to bending moments.*

[http://www.vishay.com/brands/measurements\\_group/guide/ta/sGBT/sGBT.pdf](http://www.vishay.com/brands/measurements_group/guide/ta/sGBT/sGBT.pdf)

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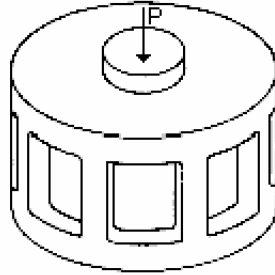
## Direct stress spring



<http://www.blh.de/pdf/g/306p21.pdf>

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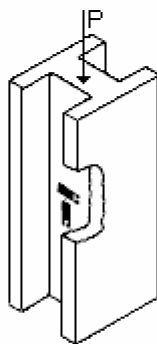
## Direct stress spring



*Slotted-cylinder, multiple-column configuration for high-capacity, low-profile applications.*

[http://www.vishay.com/brands/measurements\\_group/guide/ta/sGBT/sGBT.pdf](http://www.vishay.com/brands/measurements_group/guide/ta/sGBT/sGBT.pdf)

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*H-section column, with gages close to the load axis, has reduced sensitivity to bending moments..*

[http://www.vishay.com/brands/measurements\\_group/guide/ta/sGBT/sGBT.pdf](http://www.vishay.com/brands/measurements_group/guide/ta/sGBT/sGBT.pdf)

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## Bridge completion

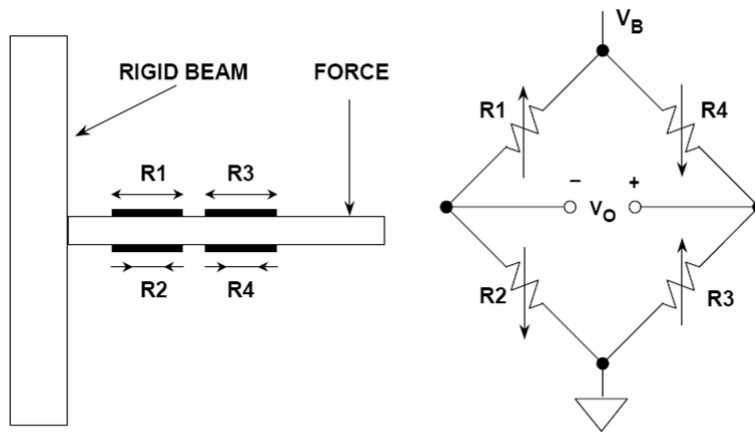
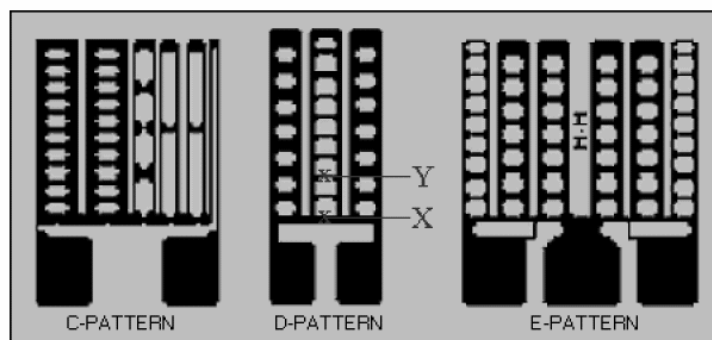


Figure 4-27: A beam force sensor using a strain gage bridge

[www.analog.com/library/analogDialogue/archives/39-05/Web\\_Ch4\\_final.pdf](http://www.analog.com/library/analogDialogue/archives/39-05/Web_Ch4_final.pdf)

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## Bridge completion

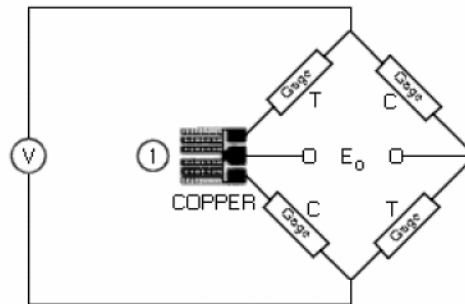


Bondable adjustable (ladder) resistor patterns used for bridge output adjustment and compensation.

[http://www.vishay.com/brands/measurements\\_group/guide/ta/sGBT/sGBT.pdf](http://www.vishay.com/brands/measurements_group/guide/ta/sGBT/sGBT.pdf)

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## Bridge completion

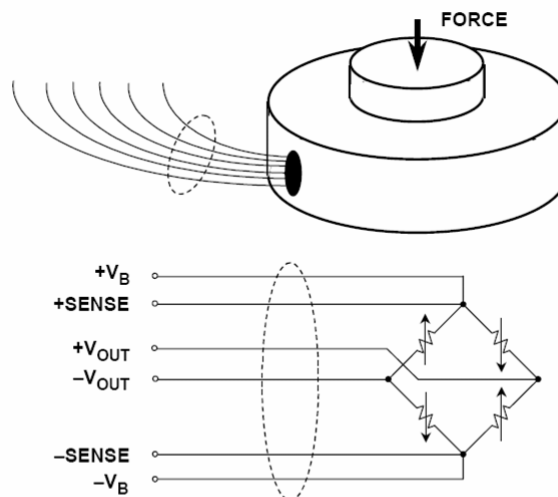


*High-TCR copper resistor (#1) inserted in corner of bridge circuit, and adjusted to maintain bridge balance over the opening temperature range.*

[http://www.vishay.com/brands/measurements\\_group/guide/ta/sGBT/sGBT.pdf](http://www.vishay.com/brands/measurements_group/guide/ta/sGBT/sGBT.pdf)

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## Bridge completion

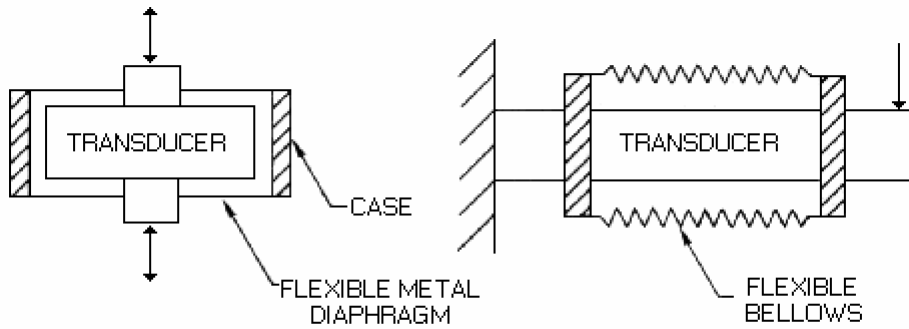


**Figure 4-28:** A load cell comprised of 4 strain gages is shown in physical (top) and electrical (bottom) representations

[www.analog.com/library/analogDialogue/archives/39-05/Web\\_Ch4\\_final.pdf](http://www.analog.com/library/analogDialogue/archives/39-05/Web_Ch4_final.pdf)

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## Environmental Protection



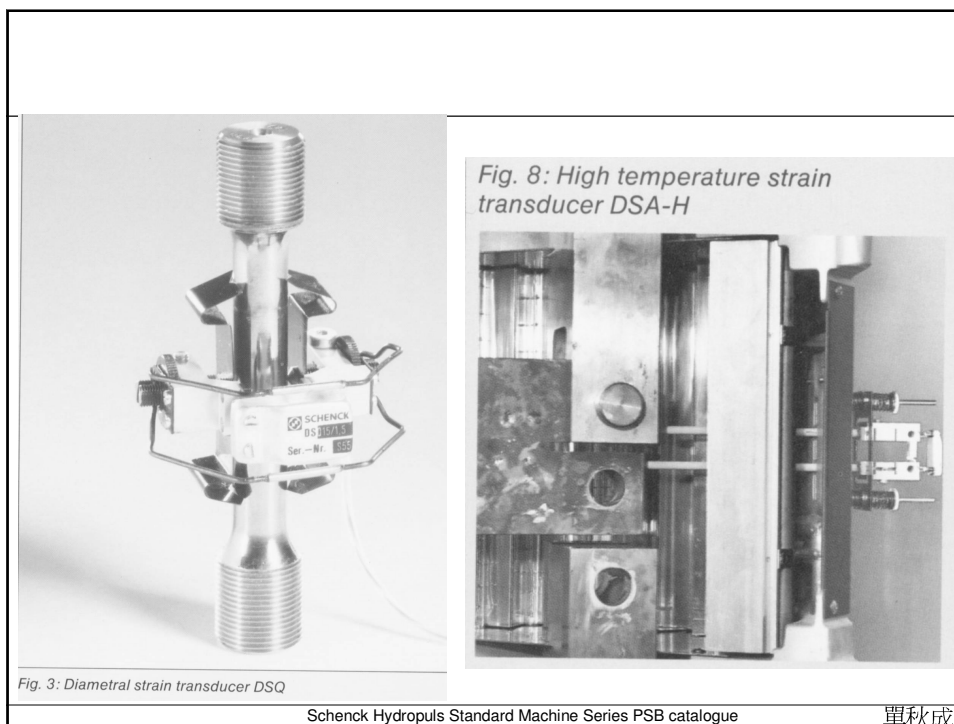
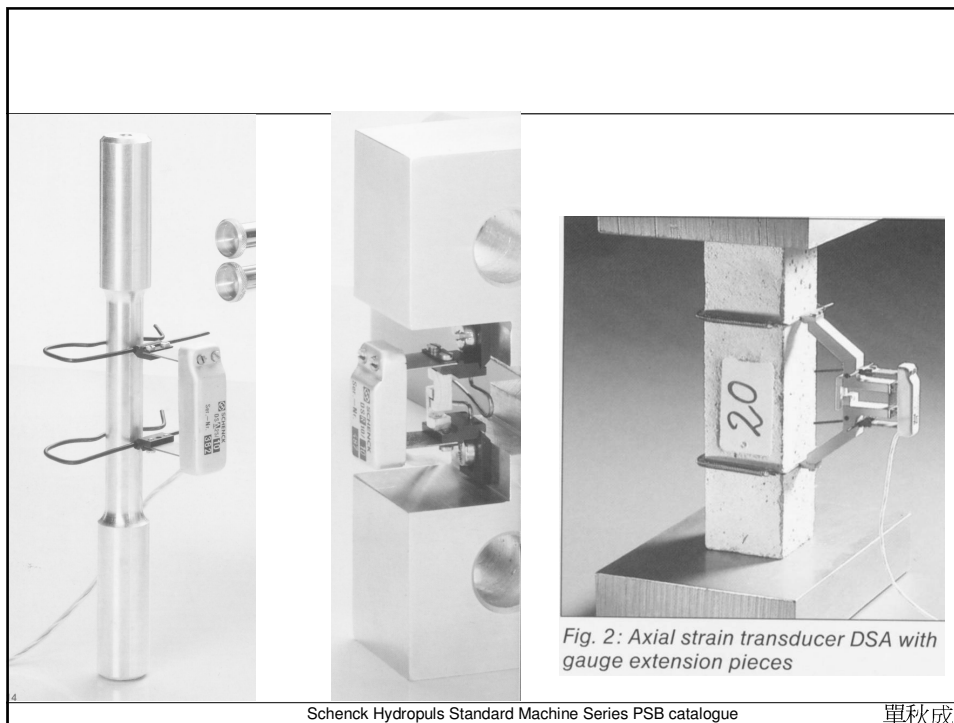
*Typical hermetic seal designs for environmental protection of transducer gage installations.*

[http://www.vishay.com/brands/measurements\\_group/guide/ta/sGBT/sGBT.pdf](http://www.vishay.com/brands/measurements_group/guide/ta/sGBT/sGBT.pdf)

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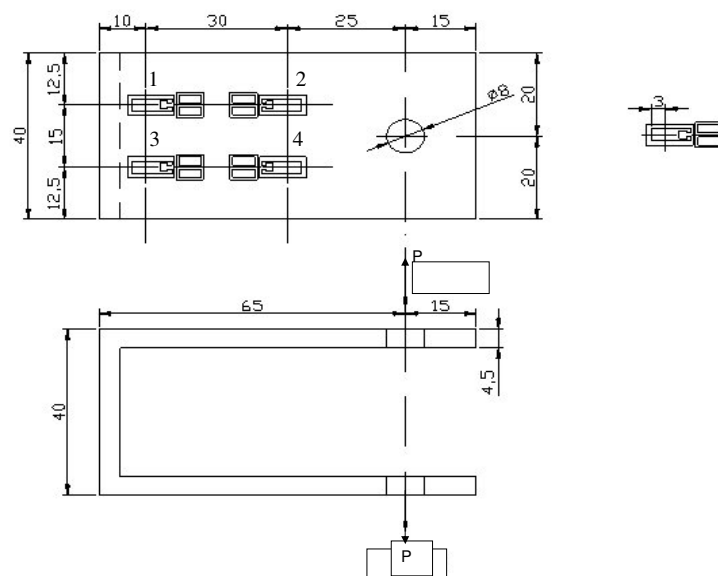
## Clip gages

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# END

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