

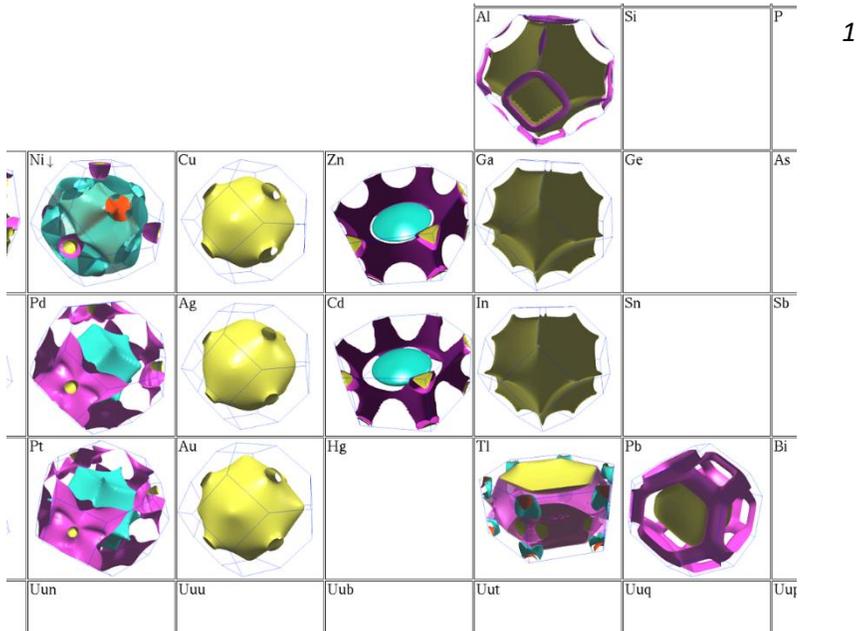
Quartz puller

Review the experimental apparatus used by M.J. Skove at Clemson University for uniaxial stress measurements during 1960's-1970's. Present several examples of results.

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The question and the problem(s)

- What is the effect of uniaxial stress on the electronic properties of materials?

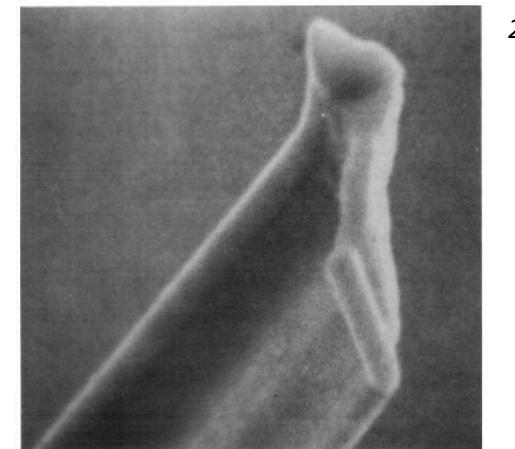


Periodic table of Fermi surfaces.

¹T.-S. Choy, J. Naset, J. Chen, S. Hershfield, and C. Stanton. *Bulletin of The American Physical Society* 45(1):36, (2000)

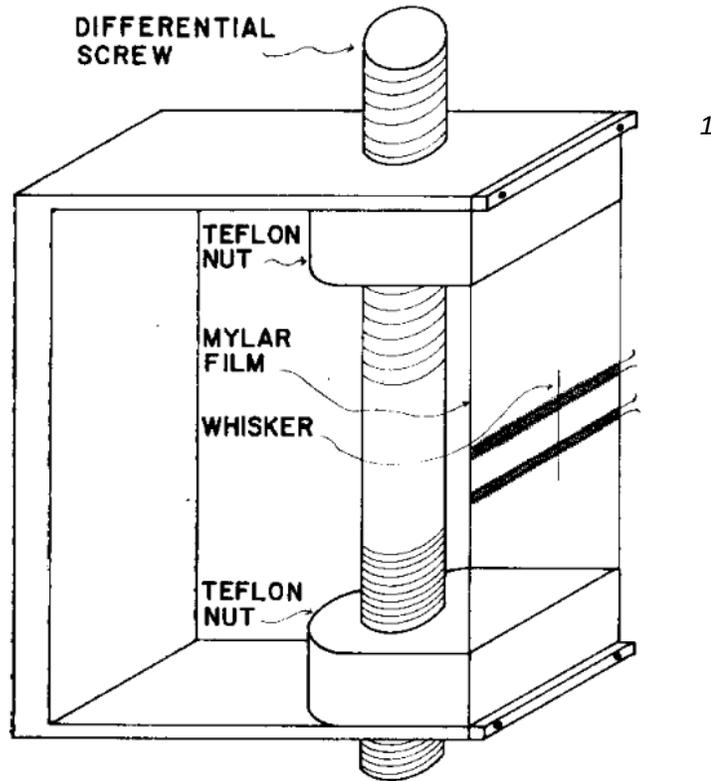
²J. R. Hucke, J. H. Davis, R. B. Lal, D.P. Nicolas. *Journal of Crystal Growth* 16:43, (1972)

- How to apply and measure steady uniaxial stress at low temperatures?
 - pull “hard” and don’t worry about stress applied (calculate stress from known elastic constants and the strain)
 - make apparatus small
- What to do if material breaks too easily?

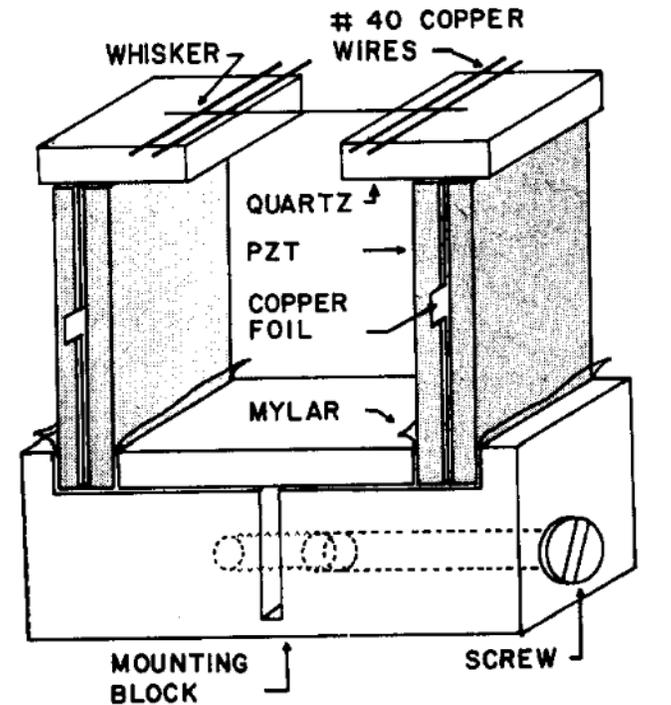


A whisker grown by squeezing technique.

The first two devices of M. J. Skove and associates



Mylar puller. The whisker is mounted on a Mylar sheet that when stretched would also stretch the sample. Mylar is a plastic with high tensile strength. However, it also has large thermal expansion coefficient. The device is about 7 cm high.



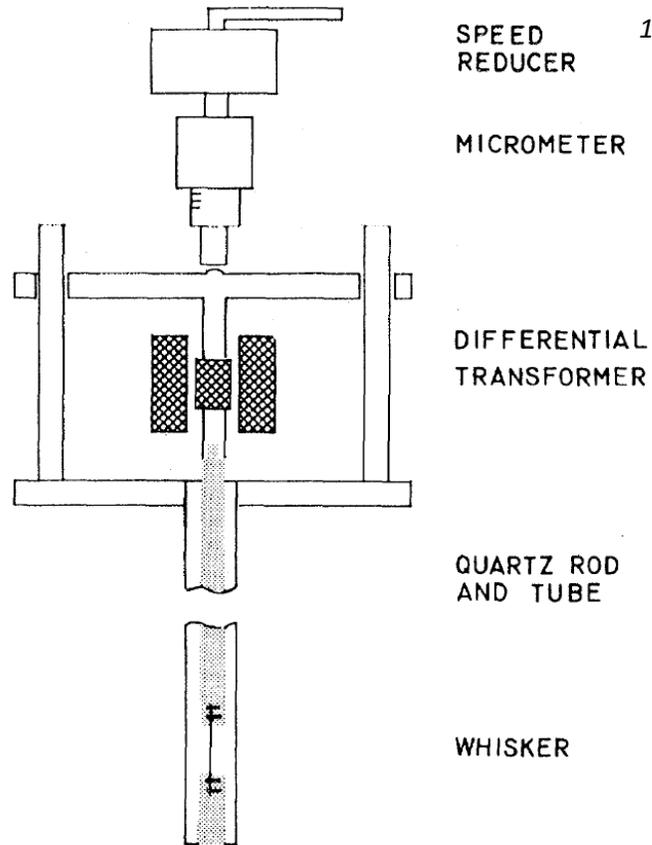
Piezoelectric puller. The whisker is mounted top of the two piezoelectric bimorphs. Bimorphs would deform under applied voltage and thus strain the whisker. However, it also has large thermal expansion coefficient. The device is about 3 cm high.

¹ E. P. Stillwell, M. J. Skove, and J. H. Davis. *Review of Scientific Instruments* 39:155 (1968)

The good and the bad

	Mylar puller	Piezoelectric puller
advantage(s)	<p>small enough to cool in a Dewar</p> <p>the strain is determined by turning the screw (applying and measuring at the same time)</p>	<p>small enough to fit in a Dewar or in a magnetic field</p> <p>can measure the stress applied if the characteristics of the piezoelectric crystals used are well known</p>
limitation(s)	<p>large thermal expansion of the Mylar film (order of magnitude larger than in metals)</p> <p>the strain is determined by turning the screw</p>	<p>difficult to calibrate (applied quantity is voltage; each bimorph is different; hysteresis)</p>

Quartz puller

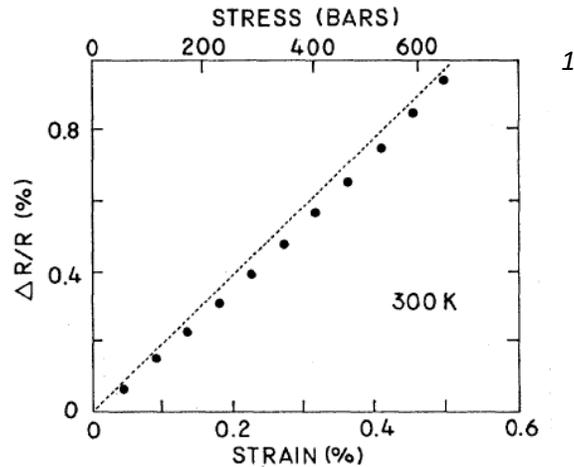


The third device was constructed to check the results obtained by the first two when it became apparent that there was a large discrepancy between these results and those obtained by others who measured the change in length of an In crystal as it passes through the superconducting transition temperature.

- Besides allowing for **uniaxial stress measurements at liquid helium temperatures in whiskers** like previous devices:
 - Quartz has very small thermal expansion coefficient.
 - Smaller strain increments possible than with differential screw.
 - Possibility of comparing the input (strain, voltage in dif. transformer) and the output (voltage drop on the whisker) in a lock-in.
- Disadvantages and problems:
 - works only for whiskers
 - stress is calculated using elastic constants of the material, not measured
 - mounting points of the sample (glued to the quartz rods) are a significant source of uncertainty

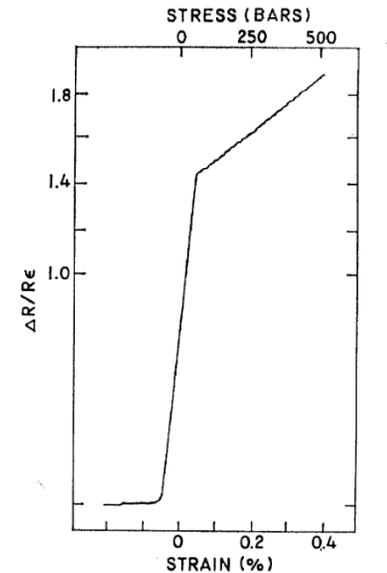
What was measured?

- Resistance as a function of strain and temperature.
- Elastoresistance, $\frac{\delta R}{R\epsilon}$, as a function of strain and temperature.



Relative change in resistance of an In whisker ($\langle 101 \rangle$ orientation) as a function of strain at room temperature.

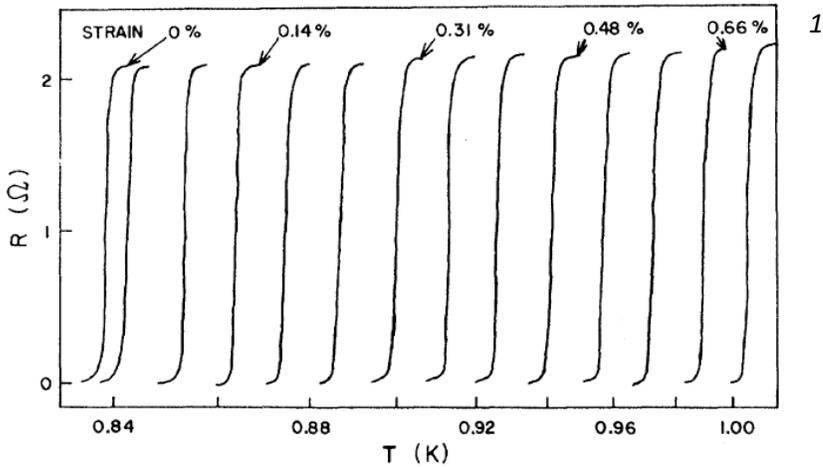
Elastoresistance of an In whisker as a function of strain at room temperature. Pure geometric effect would give a constant value of 1.96.



- Much better if extracted by “oscillatory technique” (comparing the voltage drop and strain in a lock-in).

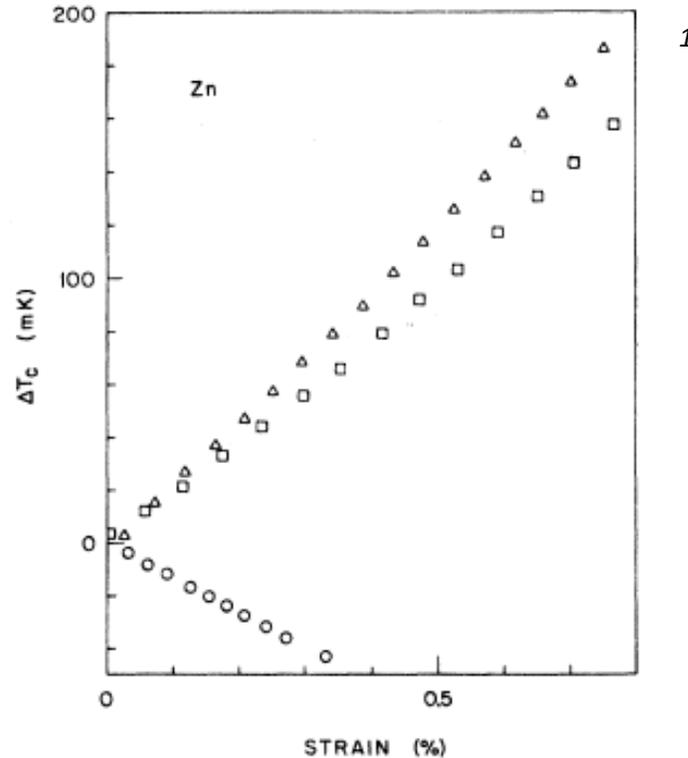
¹D. R. Overcash, M. J. Skove, and E. P. Stillwell. *Phys. Rev.* 187:570 (1969)

Results – superconducting transition temperature change with strain

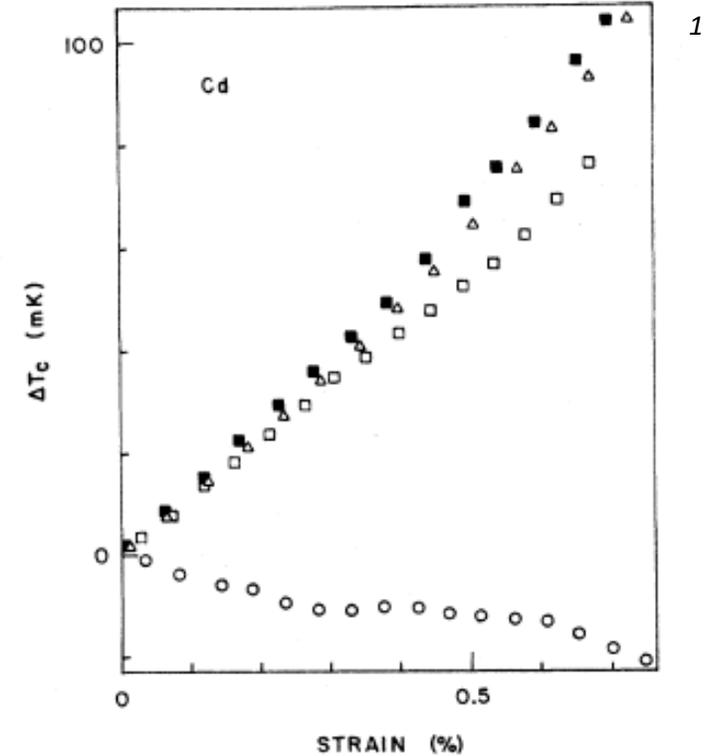


Resistance of Zn whisker ($\langle 1\bar{2}13 \rangle$ orientation) near superconducting transition for different values of strain.

Probing the Fermi surface topology!

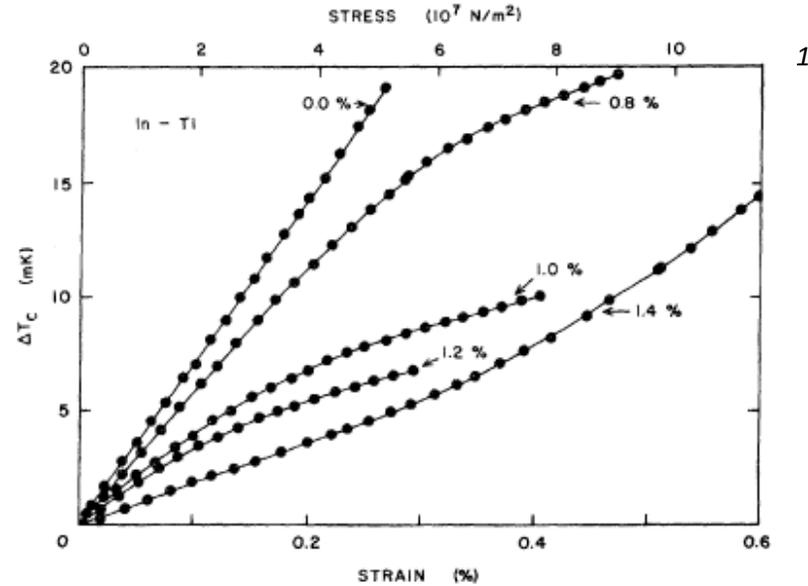


Change in superconducting transition temperatures of Zn as a function of strain for whiskers of different orientation ($\langle 1\bar{2}13 \rangle$ triangles, $\langle 10\bar{1}1 \rangle$ squares, $\langle 1\bar{2}10 \rangle$ circles).

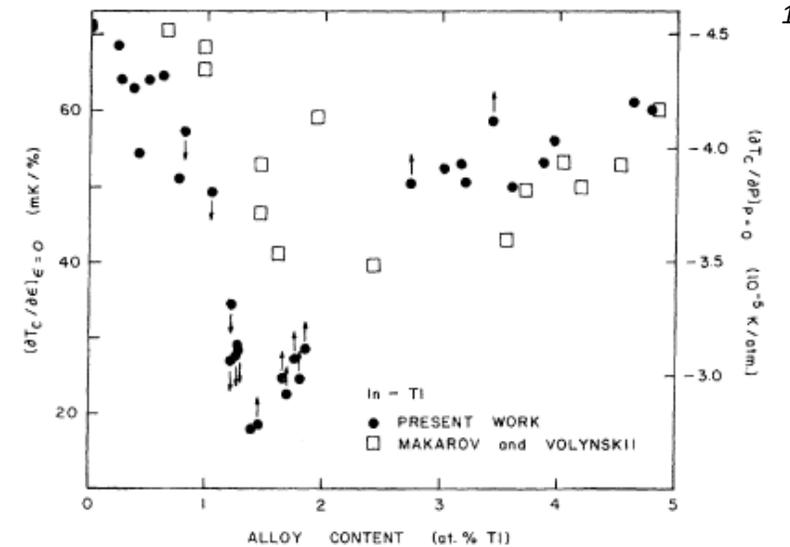


Change in superconducting transition temperatures of Cd as a function of strain for whiskers of different orientation ($\langle 10\bar{1}2 \rangle$ full squares, $\langle 1\bar{2}13 \rangle$ triangles, $\langle 10\bar{1}1 \rangle$ squares, $\langle 1\bar{2}10 \rangle$ circles).

Results – T_c as a function of strain and composition



Change in transition temperature vs strain for In-Tl whiskers ($\langle 101 \rangle$ direction) from 0 to 1.4 at.% Tl.



Initial slope of the change in transition temperature-vs-strain curve vs alloy content for In-Tl samples. Arrows indicate direction of curvature of the change in transition temperature vs strain curves. Results are compared with hydrostatic pressure data².

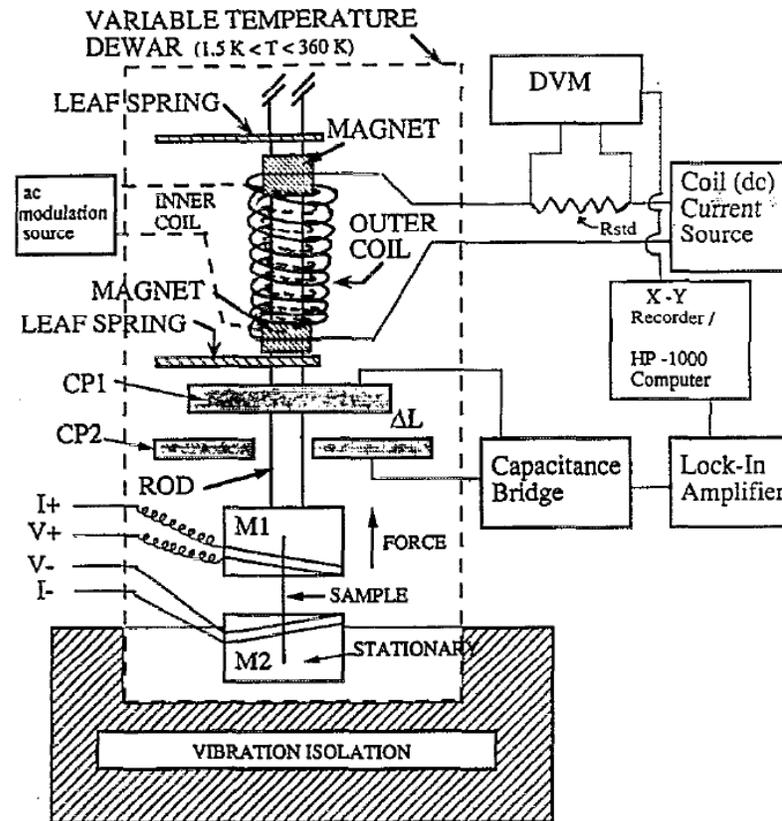
¹J. W. Cook, Jr., W. T. Davis, J. H. Chandler, and M. J. Skove. *Phys. Rev. B* 15(3):1357 (1976)

²V. I. Makarov and I. Y. Volynskii. *Zh. Eksp. Teor. Fiz.* 61:1928 (1971)

Thank you! Questions?

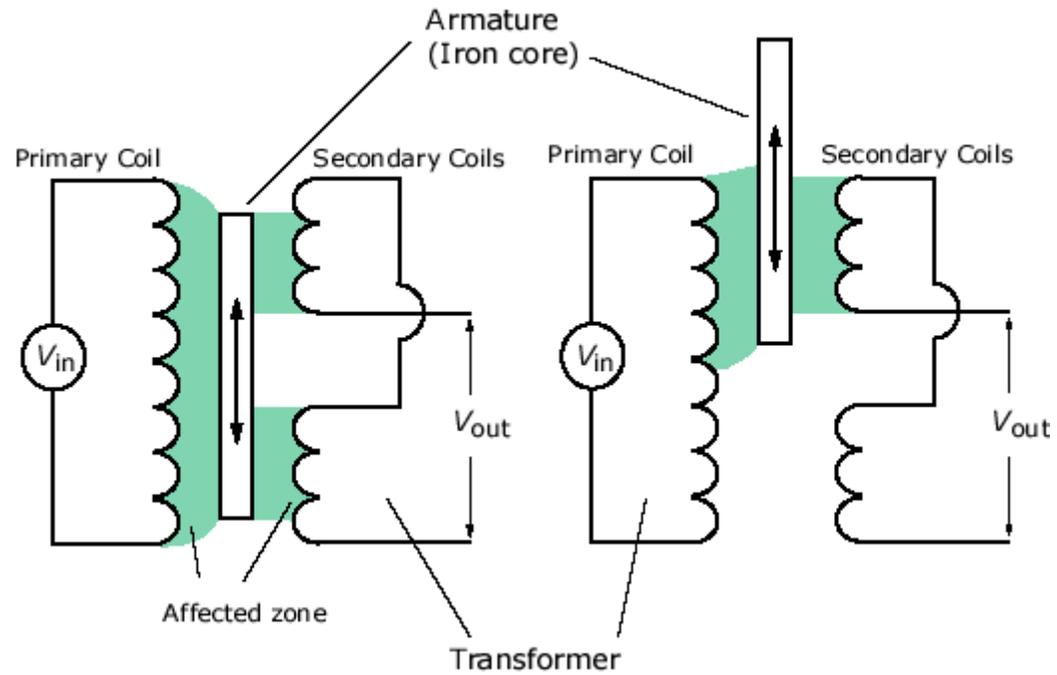
Modernized quartz puller – possibility of measuring stress and strain at the same time

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¹M. J. Skove, T. M. Tritt, A. C. Ehrlich, and H. S. Davis. *Review of Scientific Instruments* 62:1010 (1991)

Linear variable differential transformer



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¹<https://www.cpi-nj.com/lvdt-sensor-technology/>