LABORATORY #2

Strain Gage Installation and Use

Purpose

This is dual-purpose laboratory a) to become familiar with the basic principles of modern measuring systems involving strain gages, b) to apply elementary solid mechanics and structural analysis principles to convert measurements of strain to displacement or load.

First we are going to learn the principles of operation and installation of strain gages, and then we will use the strain gaged beams built to assemble a load cell (digital Scale), and experimentally estimate the relation between stresses and strains.

Experimental Methods

a) In the first part, an aluminum/steel beam instrumented with a half Wheaston bridge will be callibrated using known weights. Your will have to estimate the weight of the two unknown masses provided. A commercial scale will be available to confirm the measurements and calibrate your "digital scale".
b) In the second part, use well known expressions of solid mechanics and experimentally obtained results to estimate the Modulus of Elasticity (relation between stress and strain) of the material of your beam.

It is your responsibility to engineer these two tasks.

The Strains and Stresses within a cross section of a beam under bending (Moment load) should be used.

CONSTRUCTION of a DIGITAL SCALE

TASK 1: Built a Scale

Use the materials provided to build a scale based on the behavior of a cantilever beam (see Page 3).

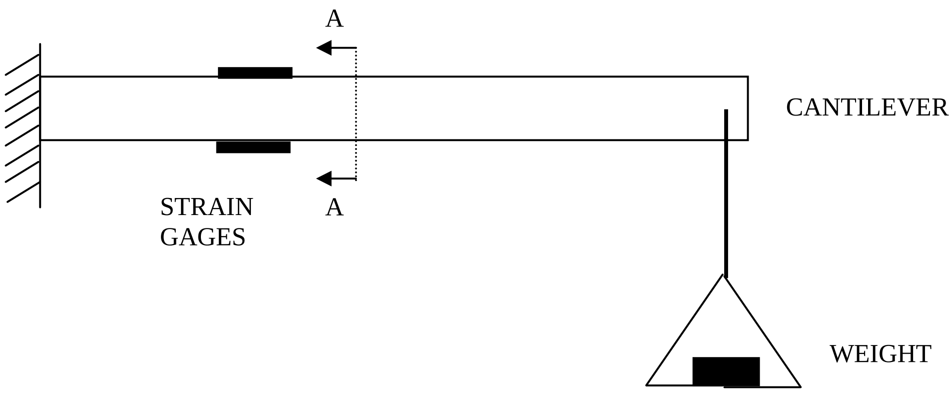
TASK 2: Calibrate the Scale

Use the "known" masses to calibrate your scale.

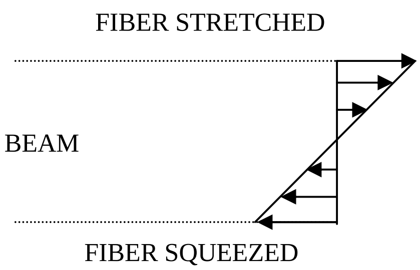
The Merriam Webster Dictionary has the following entry for calibration:

Main Entry: cal·i·bra·tion
Pronunciation: "ka-l&-'brA-sh&n
Function: noun
Date: circa 1859
1 : the act or process of calibrating : the state of being calibrated
2 : a set of graduations to indicate values or positions -- usually used in plural <calibrations on a gauge>

MECHANICS of a CANTILEVER BEAM



CUT A-A



The **stretching or squeezing** of the fibers ***is proportional*** to the **Force/Load/Weight** that the cantilever supports.

The **strain gages** are instruments that measure the stretch/squeeze of fibers. They are connected to a strain gage boxe or to Lab View through a Data Acquisition system that allow us to record the amount of stretching the fibers undergo when a beam is loaded.

THEORY of STRAIN GAGE

Lord Kelvin (1856) first observed that the electrical resistance of a piece of wire is proportional to its length (L) and inversely proportional to its cross-sectional area (A). The operation of electrical-resistance strain Gages is based on this behavior.

Change in length ($\Delta L = L - L_o$) and strain ($\varepsilon = \Delta L / L_o$) of a wire, therefore, could be inferred from measurements of change of the resistance of the wire (usually using a Wheatstone bridge circuitry).

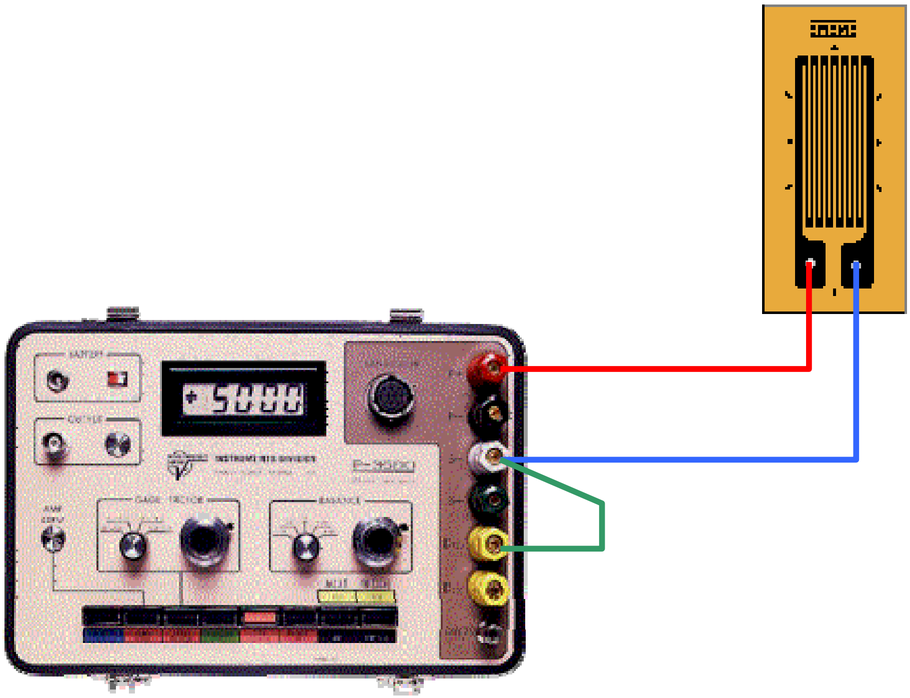
The gage factor (GF) correlates strain and resistance

$$GF = \left(\frac{\Delta R}{R} \right) \varepsilon$$

R: resistance of the un-stretched wire

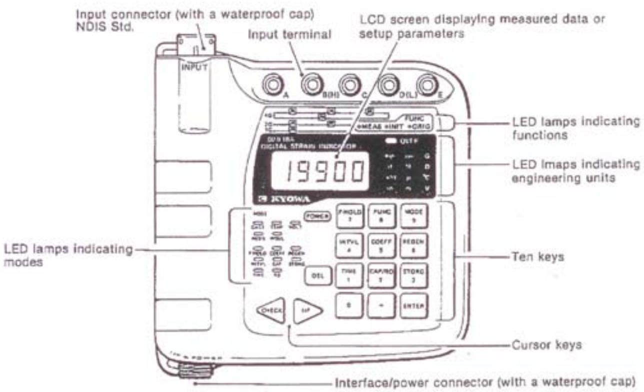
The strain gage manufacturer usually provides gage factor (GF~2.007) and using the equation above the strain can be obtained.

The following pictures depict the strain gage indicator that you will be using and a strain gage.



Operation of the Strain Gage Indicator:

1. Parts and functions



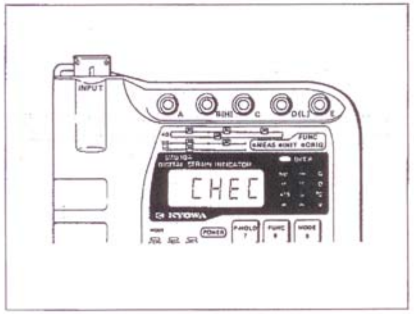
POWER switch / AC adaptor	OFF	ON (Measuring)
Not used (Battery operation)	○ Memory preservation time: 2 months or longer with the fully charged battery	○ Continuous operating time: Normally 10 hours or longer with the fully charged battery and against 120Ω input
Used	○ Normal charging time: 8 hours for full charging	○ Float-charging time: 8 hours for full charging

CAUTION

Charge the battery within a temperature range of 0 to 35°C. Or else insufficient charging or deterioration of the battery can occur. The battery can serve at an ambient temperature in a range from −10 to 50°C while being floating-charged after full charging.

2. Turning the power on

A NiCd battery is incorporated in the instrument. Whenever you intend to perform battery-driven measuring, be sure that you charge the battery for over 8 hours using the AC adaptor.
If the battery capacity goes low during measuring, "LO BAT" appears in the left top area of the LCD screen, and the power automatically turns off several seconds later, thereby preventing overdischarging of the battery.
Should it happen, switch the power to AC using the AC adaptor. The instrument operates while charging the battery (float charging).



① Connect the AC adaptor to the instrument's I/F & POWER connector and to an AC outlet.
② A push of the POWER key turns the power [ON], and another push turns the power [OFF].
③ Once the power has been turned [ON], the instrument activates screen display of "Program Version", CHEC, and "Measuring Mode" in that order, and then undergoes measuring operation.

3. Automatic power-turning-off function

In the battery-powered measuring the automatic power-turning-off function is activated 10 minutes or so after the last key operation, thereby turning the power off automatically. This function prevents the internal battery from discharging.
To cancel the automatic power-turning-off function and thus to continue measuring, proceed with the key operation as follows.

Power [OFF]

0 + POWER .... While holding down 0 key, push POWER key for 3 seconds.

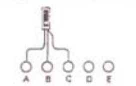
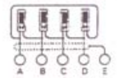
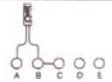
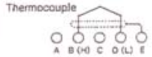
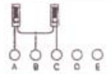
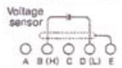
POFF .... This appears on the screen, and the automatic power-turning-off function is cancelled.

Note that once the power has been turned off, the cancellation of the automatic power-turning-off function is disabled.

CAUTION

The automatic power-turning-off function is invalid if the AC adaptor is in use.

4. How to connect with incoming signals

Signal type	How to connect	Signal type	How to connect
• 1-gage method (3-wire system)		• 4-gage method • Strain-gage transducer	
• 1-gage method (2-wire system)		• Thermocouple	
• 2-gage method		• Voltage	

- The input terminals and the matching input connectors have same signs.
- When using the input connectors, also connect them to the matching pins having same signs.
- F and G pins of the input connectors are open.
- The applicable plug is P12-7 (TAJIMI PRC03-12A10-7M10).

For multipoint measuring using strain gages or strain-gage transducers, use the SS-R or NS-H switch box and switch measuring points manually.

5. Simple way of measuring

You can carry out measuring in a simple manner depending on the setup as follows.

Mode	1-gage 120Ω (SMD-10A); 4-gage 350Ω (SMD-20A)
Function	Original
Coefficient calculation	0.000E0 (does not calculate); no decimal point; unit μ (10^{-6})
Storage data	Clear
Sampling	0.5 seconds

Power [OFF]

- DEL + POWER .... Activate the setup by operating the keys as follows. Hold down [DEL], then push [POWER] key for 3 seconds.
- A-CL .... All the parameters in the memory are then cleared, and the setup is activated.
- 01.00 .... The program version number appears (for about 3 seconds). The numer shown at left denotes Version 1.
- CHEC .... Self-test on the internal circuitry is carried on (for about 3 seconds).
- (SMD-10A) 1G 120 / (SMD-20A) 350 .... The current mode name appears (for about 3 seconds).

Measuring state / Measuring state

To modify the simple measuring setup, follow the instructions given below, relating to mode, function, coefficient calculation, data storage and sampling.

CAUTION

Once the simple measuring setup is established, all measurement data stored are forever lost.

6. Setting a measuring mode [MODE]

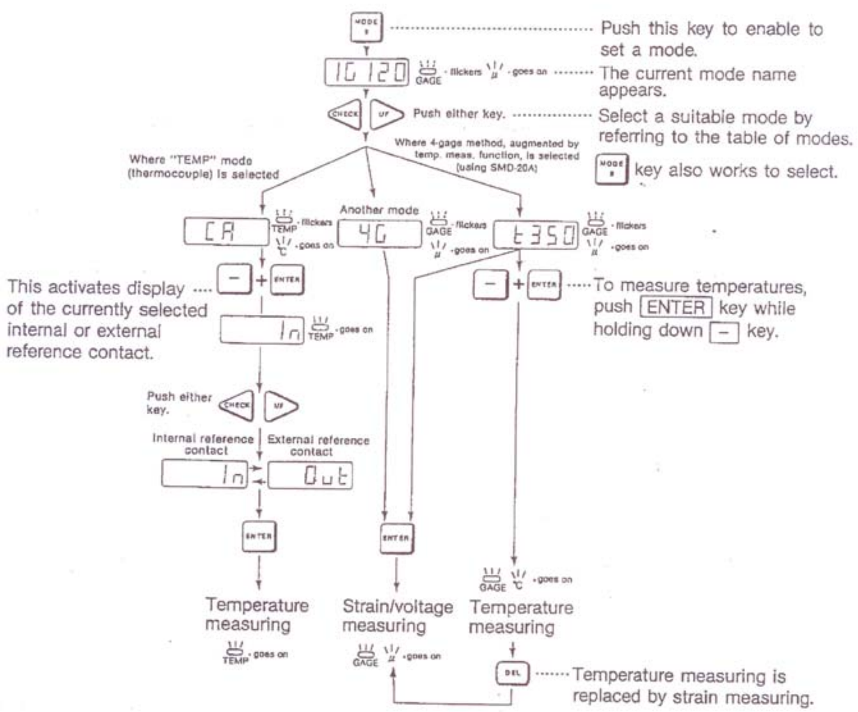
6-1 Kinds of measuring mode.

The two models provide their respective measuring modes as follows.

Mode renewal	SMD-10A (constant voltage bridge excitation for general measuring)				SMD-20A (constant current bridge excitation for civil engineering measuring)			
	Mode LED	Mode display	Unit	Sensor	Mode LED	Mode display	Unit	Sensor
I/F	GAGE	1G 120	μ	1-gage method, 120Ω	GAGE	120	μ	4-gage method, 120Ω
		1G240	μ	1-gage method, 240Ω		350	μ	4-gage method, 350Ω
or		1G350	μ	1-gage method, 350Ω		t 120	μ	4-gage method, 120Ω with temp. meas. function
MODE 9		2G	μ	2-gage method		t350	μ	4-gage method, 350Ω with temp. meas. function
		4G	μ	4-gage method				
	TEMP	CA	°C	Thermocouple K (CA)	TEMP	CA	°C	Thermocouple K (CA)
		CC	°C	Thermocouple T (CC)		CC	°C	Thermocouple T (CC)
		CrC	°C	Thermocouple E (CRC)		CrC	°C	Thermocouple E (CRC)
		IC	°C	Thermocouple J (IC)		IC	°C	Thermocouple J (IC)
CHECK		n	°C	Thermocouple N		n	°C	Thermocouple N
	VOLT	volt	mV	Voltage, mV	VOLT	volt	mV	Voltage, mV
		volt	V	Voltage, V		volt	V	Voltage, V

To renew a mode, push [I/F] key or [MODE] key (and you will go to a mode presented below) and [CHECK] key (and you will go to a mode presented above).

6-2 Setting a measuring mode



8. Setting the coefficient calculation function

Use the coefficient calculation function in order to convert a voltage or a strain quantity in a physical quantity (an engineering value) for direct reading, or in order to correct a gage factor. A suitable unit can be selected from units provided. Two methods are available to set the coefficient calculation function. One is to enter a coefficient directly. The other is to enter a capacity/rated-output, then let the instrument calculate a coefficient internally.

8-1 Setting the function with a coefficient [COEFF]

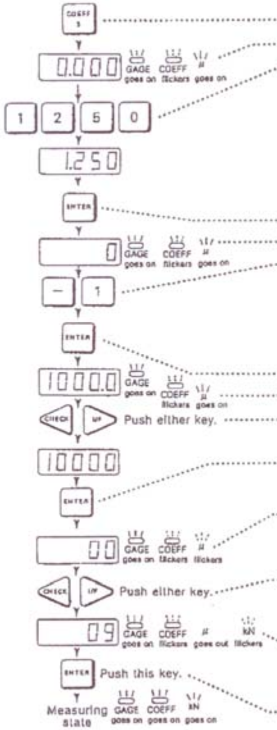
Using ten keys, key in a coefficient, which was preliminarily obtained, for further internal calculation.
Key in [coefficient (mantissa)], [coefficient (exponent)], [place of the decimal point to express a physical quantity], and [unit] in that order.

How to find a coefficient:
Example: To directly read in kN, using a load cell of 500kN (50.99tf) capacity

Coefficient = Capacity / (rated output x bridge voltage)
= 500(kN) / (2000μv/v x 2v)
= 0.1250
= 1.250×10^{-1}

where: Rated output, 2000μv/v; SMD's bridge voltage, 2V

A coefficient is expressed by an exponent. So you key in 1.250 as a mantissa, and −1 as an exponent (1 digit).



Push this key to enable to set a coefficient.

The mantissa of the current coefficient flickers.

Example: 1.250

Using ten keys, key in the mantissa (up to 4 digits) of a coefficient to be registered. The decimal point is fixed.

Example: +1.250E − 1

• Mantissa, 4 digits; Fixed decimal point, ±00.001 to ±9.999

Push this key to enter a mantissa.

Example: The exponent of the current coefficient appears.

Example: ±0 to ±5

Using ten keys or ◁ ▷ , key in a one-figure number as the exponent of a coefficient to be registered.

• Key in 0 if conversion in physical value is not needed.

Push this key to enter the exponent.

The current place of the decimal point appears.

Move the decimal point to a suitable place.

Push this key to place the decimal point.

The number of the current unit flickers, and the matching LED flickers.

The unit LED lamp light moves.
(Refer to the table of units, page 12.)

The LED lamp on the selected unit flickers, and the unit number flickers.

The unit is entered to complete the setting. To cancel calculating a coefficient, key in (0.000) for a mantissa.

Example: Coefficient to correct a gage factor in strain measuring

Correction coefficient = 2.00/Ks = 2.00/2.10 = 0.952

where Ks: 2.1 (in case of a gage factor of 2.1)
(Because a gage factor of 2.0 is adopted for SMD, perform this correction if accurate measurement is necessary.)

Example: Coefficient to directly read in stress (kPa)
(Measuring of simple stress)

Correction coefficient $= (2.00/Ks) \times E \times 10^{-6}$
$= (2.00/2.10) \times 206 \times 10^{6} \times 10^{-6}$
$= 196$

where Ks : Gage factor, 2.1 (Perform same correction as above)
E : Young's modulus, 206×10^{6} kPa
10^{-6} : Strain

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