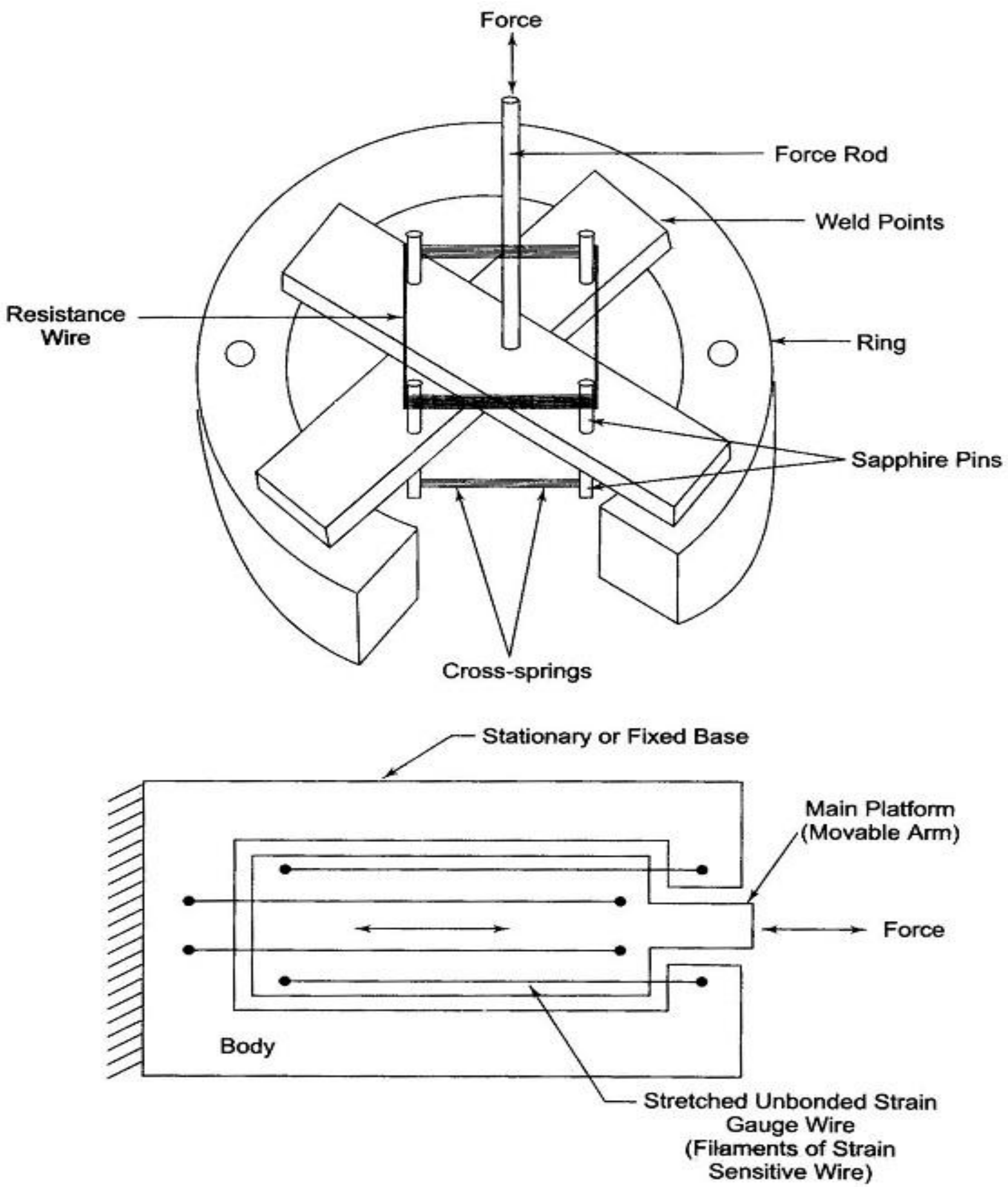


Fig. 13.3 Unbonded Strain Gauge

Unbonded strain Gauge

...typically about 20 mV to 50 mV.

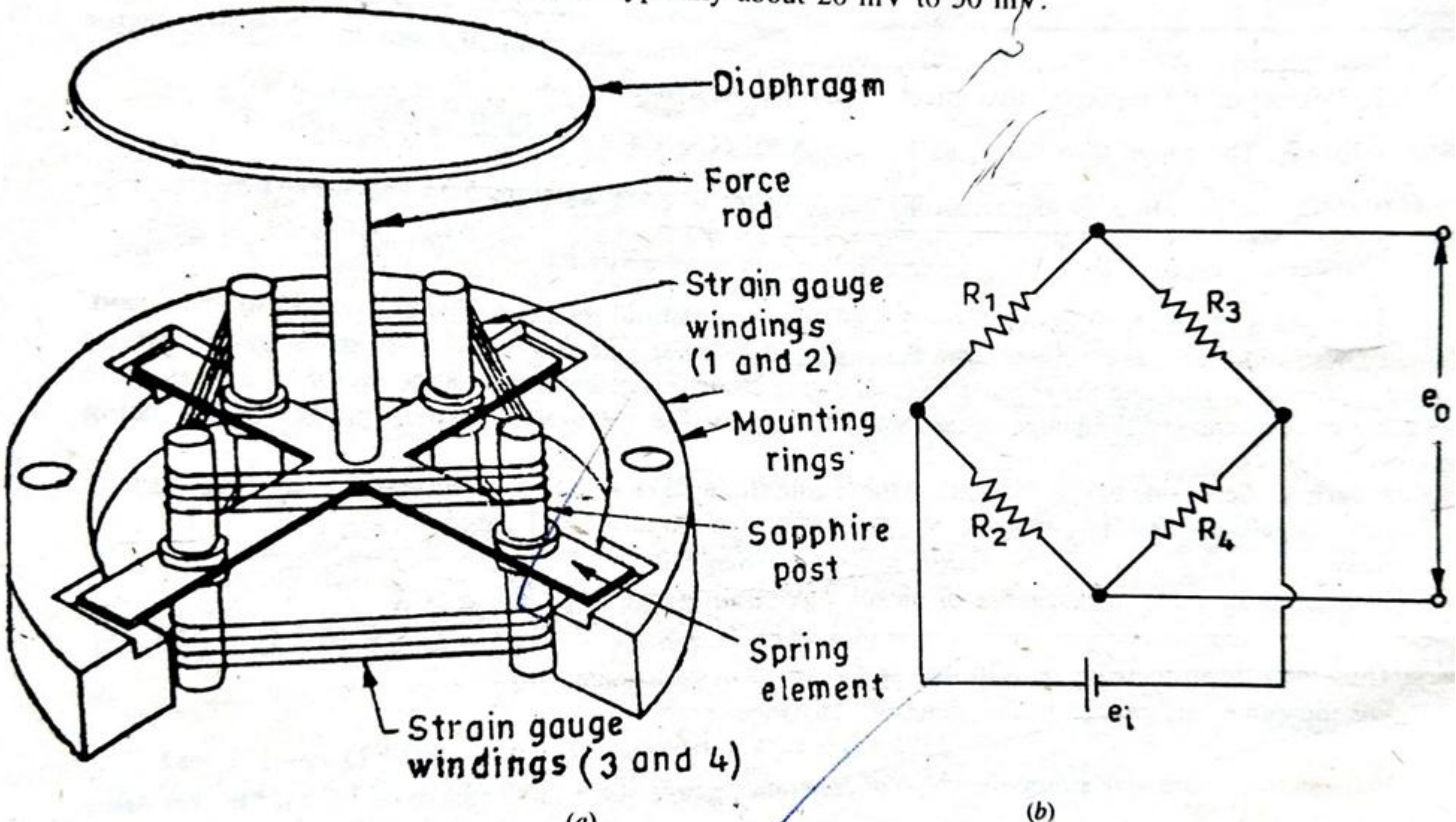
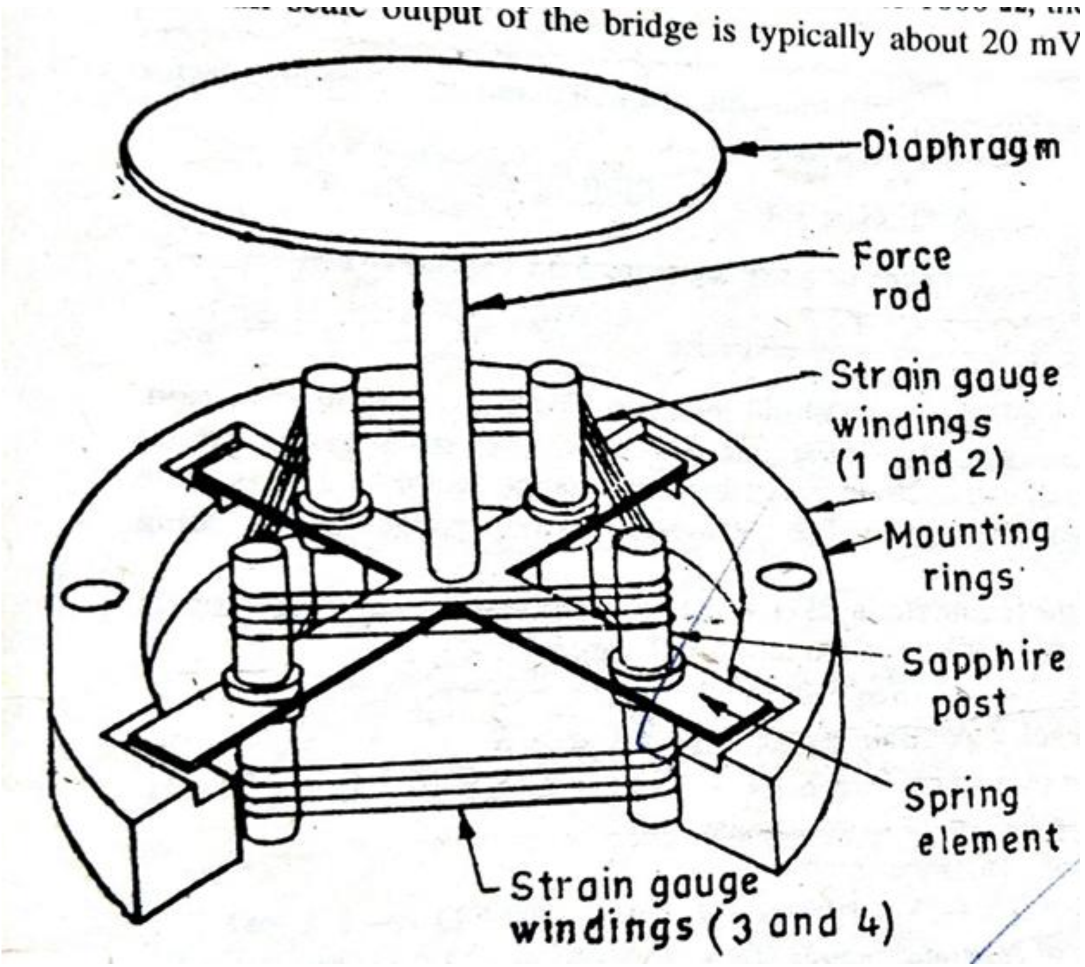
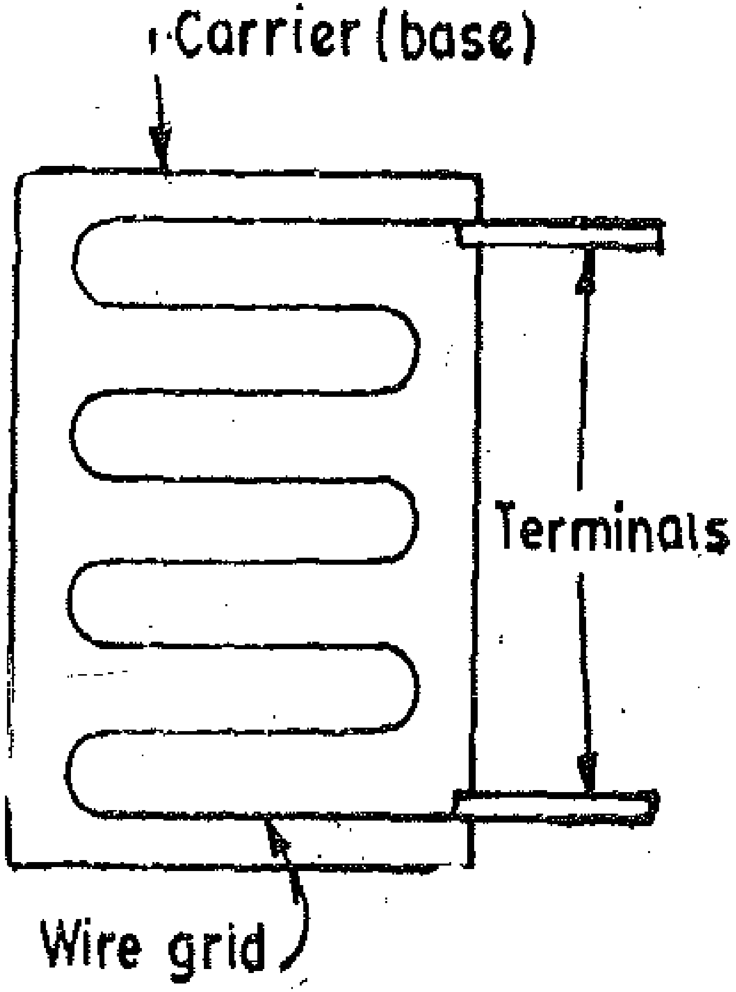


Fig. 5.34. Set up of a unbonded strain gauge and measurement with a wheatstone bridge.

- A wire stretched between two points in an insulating medium such as air.
- diameter of the wire is about 25 μm
- Copper nickel, chrome nickel, nickel iron
- GF 2 to 4
- Force 2mN
- Length 25m or less



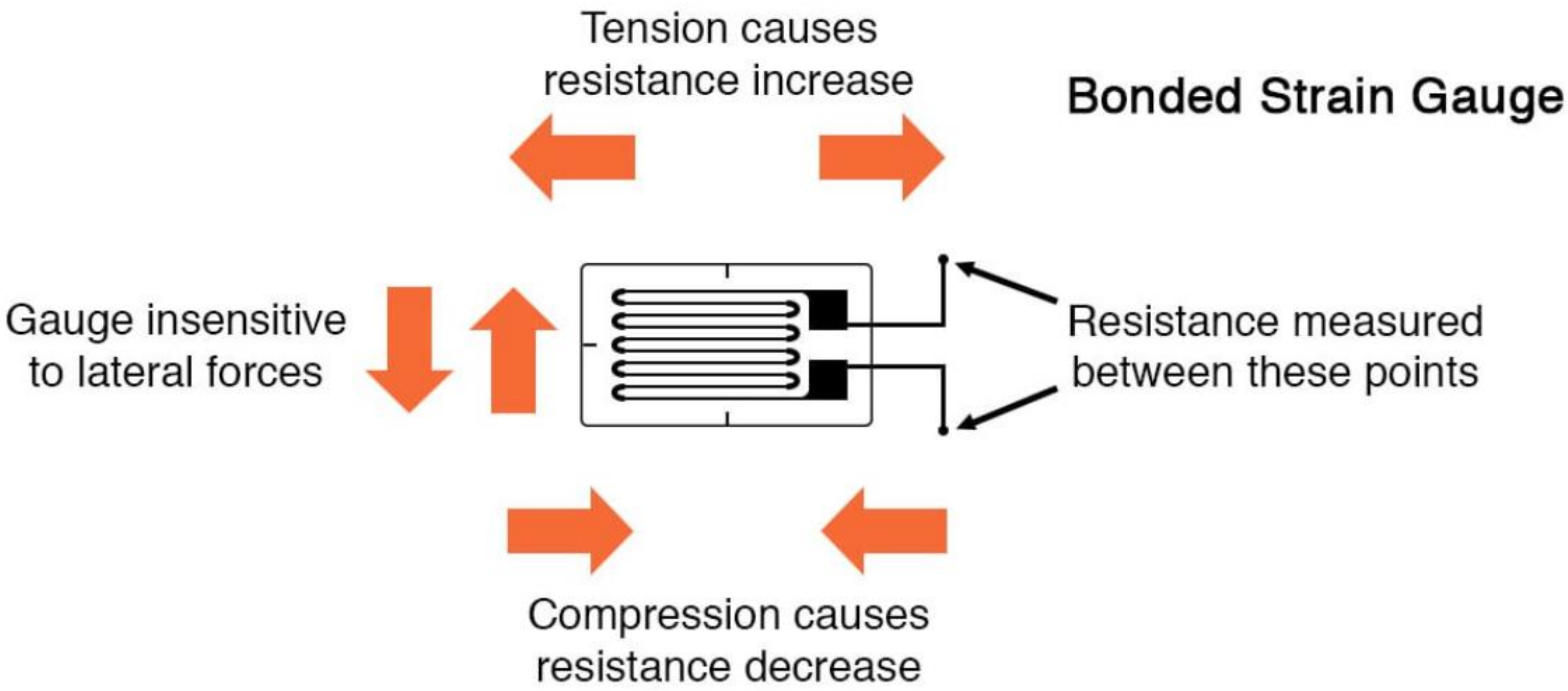
Bonded Strain gauge



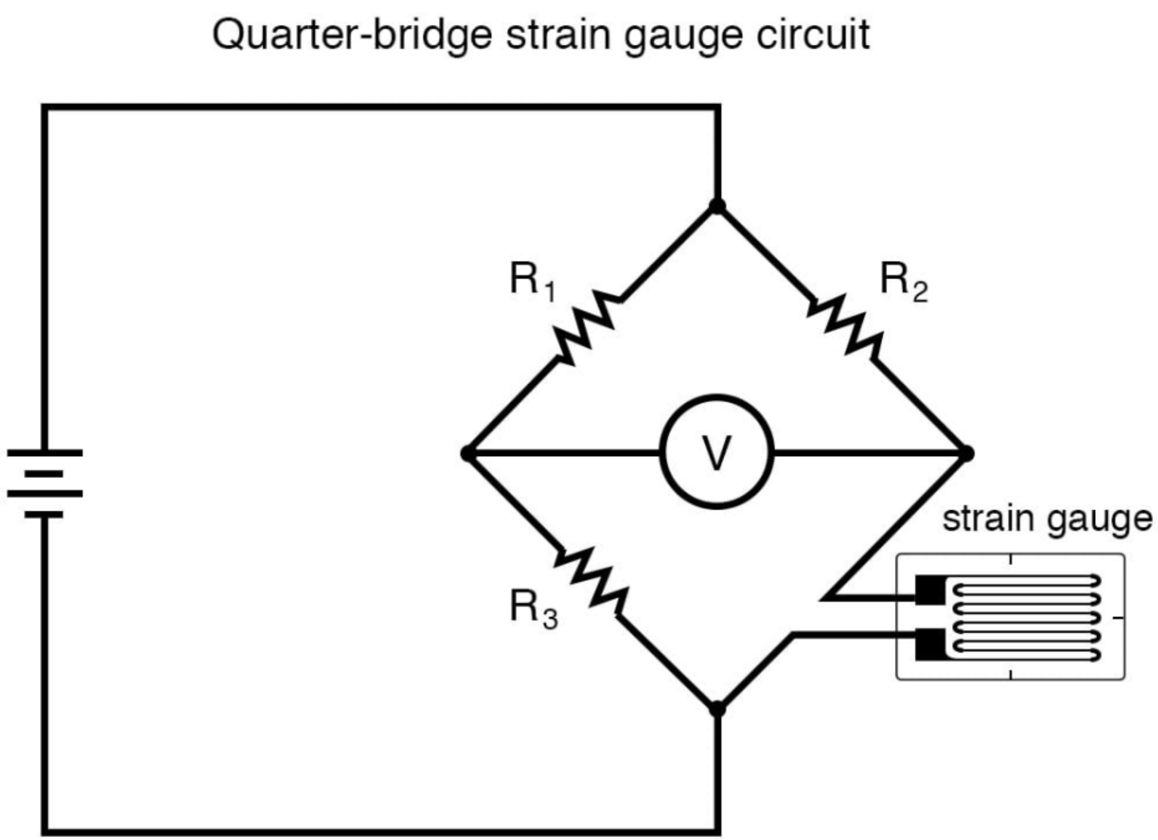
(a) Linear strain gauge.

- A -resistance, wire strain gauge consists of a grid of fine resistance wire of about 25 in diameter or less.
- The grid of fine wire is cemented to a carrier (base) which may be thin sheet of paper or to a very thin Bakelite sheet or to a sheet of Teflon.
- The wire is covered on top with a sheet of thin material so that it is not damaged mechanically.
- The spreading of the wire permits a uniform distribution of stress
- The carrier is bonded with an adhesive material to the structure under study. This permits a good transfer of strain from carrier to wires.

Resistance Strain gauge bridges

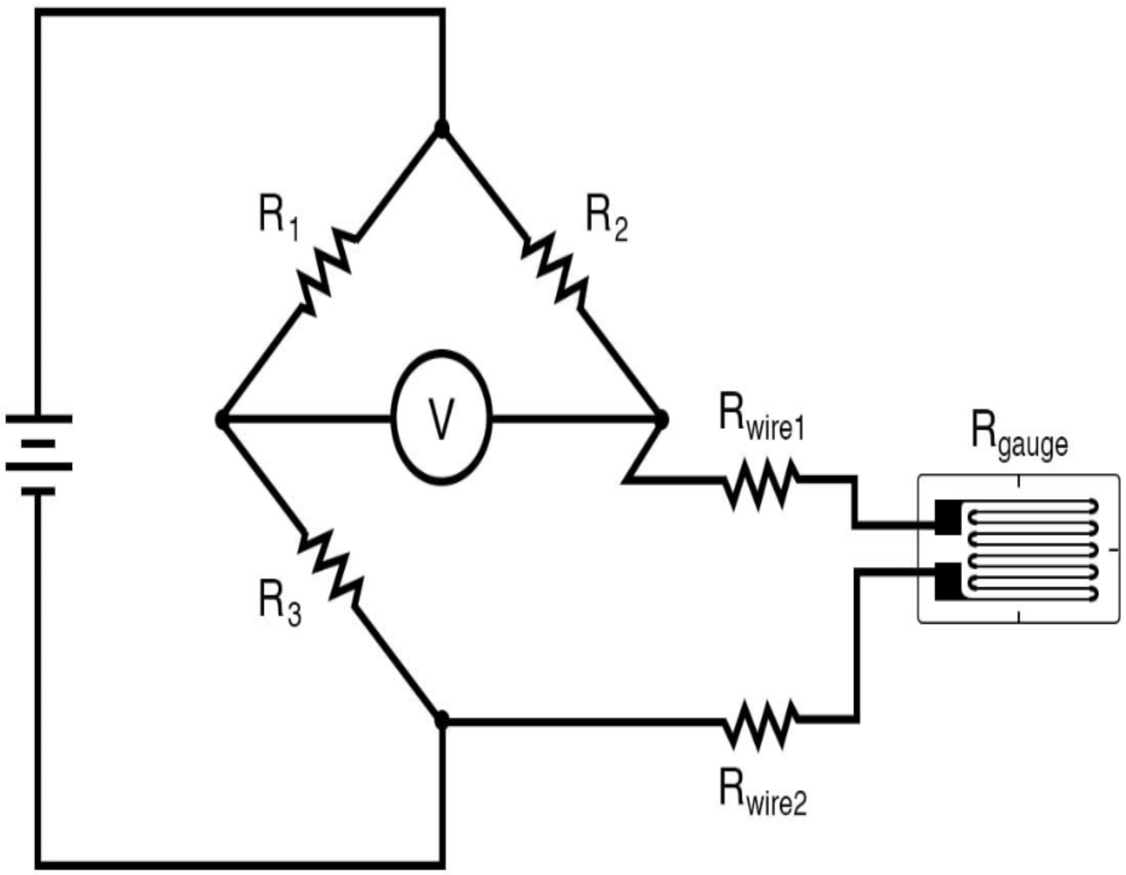


- a strain gauge bridge circuit indicates measured strain by the degree of *imbalance*, and uses a precision voltmeter in the center of the bridge to provide an accurate measurement of that imbalance

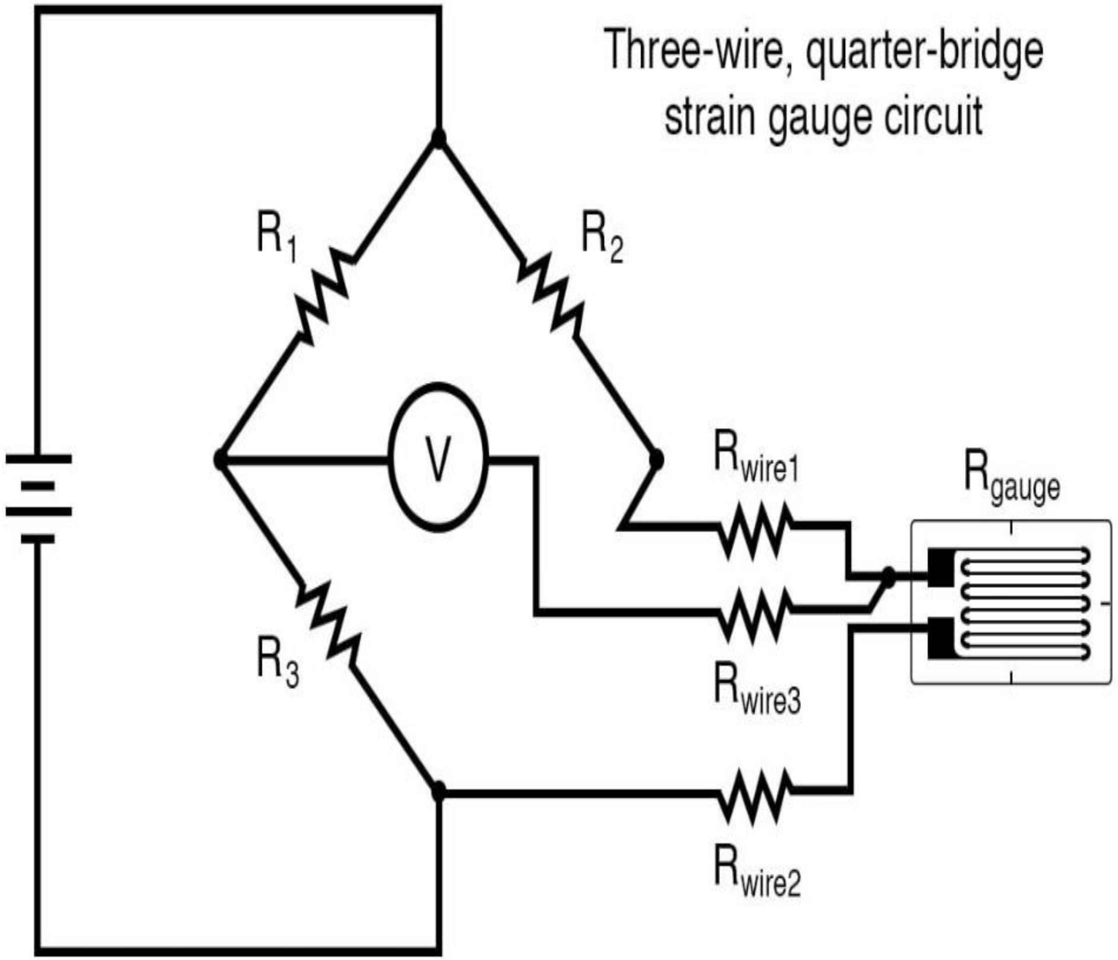


- Typically, the rheostat arm of the bridge (R_2 in the diagram) is set at a value equal to the strain gauge resistance with no force applied. The two ratio arms of the bridge (R_1 and R_3) are set equal to each other. Thus, with no force applied to the strain gauge, the bridge will be symmetrically balanced and the voltmeter will indicate zero volts, representing zero force on the strain gauge.
- As the strain gauge is either compressed or tensed, its resistance will decrease or increase, respectively, thus unbalancing the bridge and producing an indication at the voltmeter. This arrangement, with a single element of the bridge changing resistance in response to the measured variable (mechanical force), is known as a *quarter-bridge* circuit

Wire resistance compensation



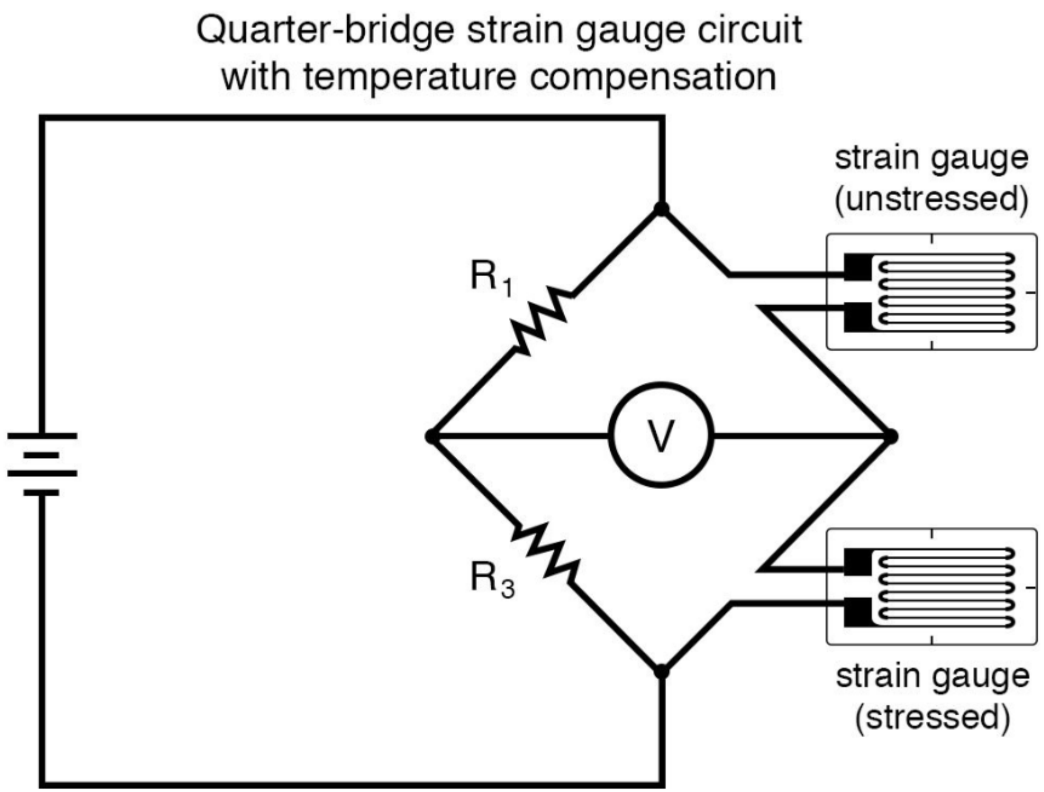
- As the distance between the strain gauge and the three other resistances in the bridge circuit may be substantial, wire resistance has a significant impact on the operation of the circuit. To illustrate the effects of wire resistance, I'll show the same schematic diagram, but add two resistor symbols in series with the strain gauge to represent the wires:
- The strain gauge's resistance (R_{gauge}) is not the only resistance being measured: the wire resistances R_{wire1} and R_{wire2}, being in series with R_{gauge}, also contribute to the resistance of the lower half of the rheostat arm of the bridge, and consequently contribute to the voltmeter's indication. This, of course, will be falsely interpreted by the meter as physical strain on the gauge.



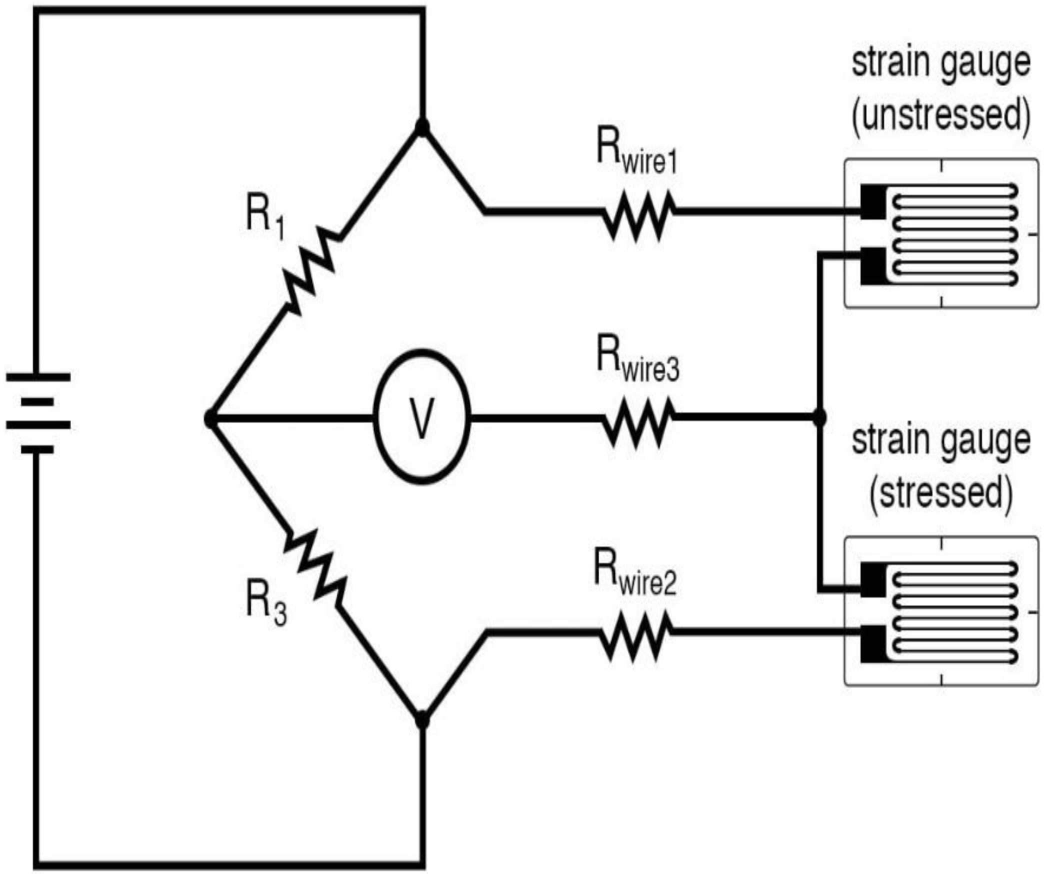
- In this configuration, it can be minimized with the addition of a third wire, connecting the right side of the voltmeter directly to the upper wire of the strain gauge:
- Because the third wire carries practically no current (due to the voltmeter's extremely high internal resistance), its resistance will not drop any substantial amount of voltage. Notice how the resistance of the top wire (R_{wire1}) has been "bypassed" now that the voltmeter connects directly to the top terminal of the strain gauge, leaving only the lower wire's resistance (R_{wire2}) to contribute any stray resistance in series with the gauge. Not a perfect solution, of course, but twice as good as the last circuit!

Resistance Change in Temperature

- An unfortunate characteristic of strain gauges is that of resistance change with changes in temperature.
- quarter-bridge circuit as shown (either with two or with three wires connecting the gauge to the bridge) works as a thermometer just as well as it does a strain indicator.
- If all we want to do is measure strain, this is not good. We can transcend this problem, however, by using a “dummy” strain gauge in place of R_2, so that *both* elements of the rheostat arm will change resistance in the same proportion when temperature changes, thus canceling the effects of temperature change:



- Resistors R_1 and R_3 are of the equal resistance value, and the strain gauges are identical to one another. With no applied force, the bridge should be in a perfectly balanced condition and the voltmeter should register 0 volts. Both gauges are bonded to the same test specimen, but only one is placed in a position and orientation so as to be exposed to physical strain (the *active* gauge). The other gauge is isolated from all mechanical stress and acts merely as a temperature compensation device (the *"dummy"* gauge). If the temperature changes, both gauge resistances will change by the same percentage, and the bridge's state of balance will remain unaffected. Only a differential resistance (difference of resistance between the two strain gauges) produced by physical force on the test specimen can alter the balance of the bridge.

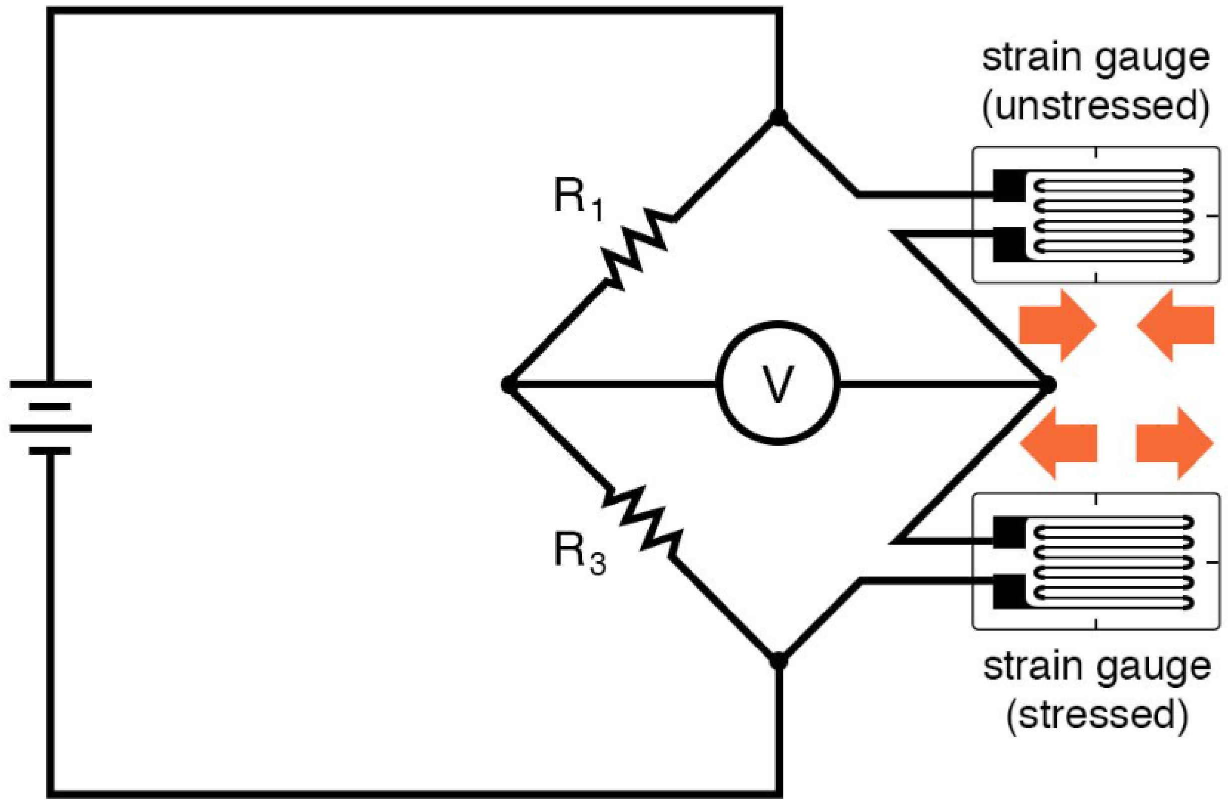


- Wire resistance doesn't impact the accuracy of the circuit as much as before, because the wires connecting both strain gauges to the bridge are approximately equal length. Therefore, the upper and lower sections of the bridge's rheostat arm contain approximately the same amount of stray resistance, and their effects tend to cancel:

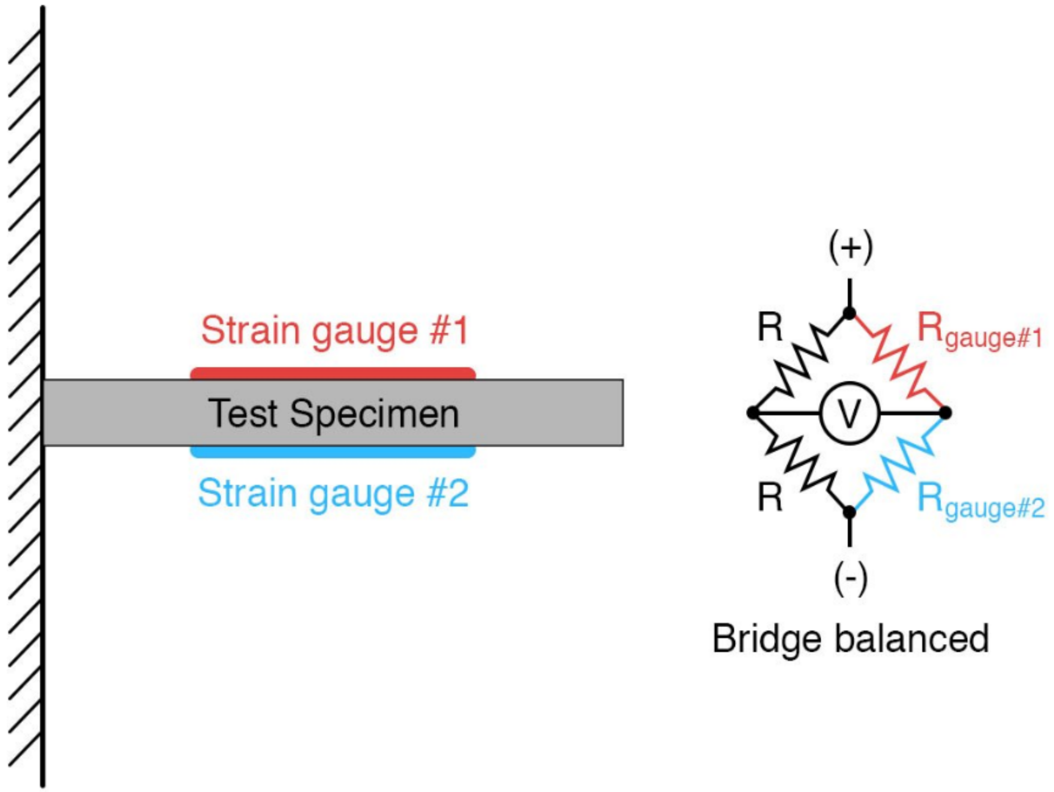
Half Bridge Circuits

- Even though there are now two strain gauges in the bridge circuit, only one is responsive to mechanical strain, and thus we would still refer to this arrangement as a *quarter-bridge*.
- If to take the upper strain gauge and position it so that it is exposed to the opposite force as the lower gauge (i.e. when the upper gauge is compressed, the lower gauge will be stretched, and vice versa), we will have *both* gauges responding to strain, and the bridge will be more responsive to applied force. This utilization is known as a *half-bridge*.
- Since both strain gauges will either increase or decrease resistance by the same proportion in response to changes in temperature, the effects of temperature change remain canceled, and the circuit will suffer minimal temperature-induced measurement error:

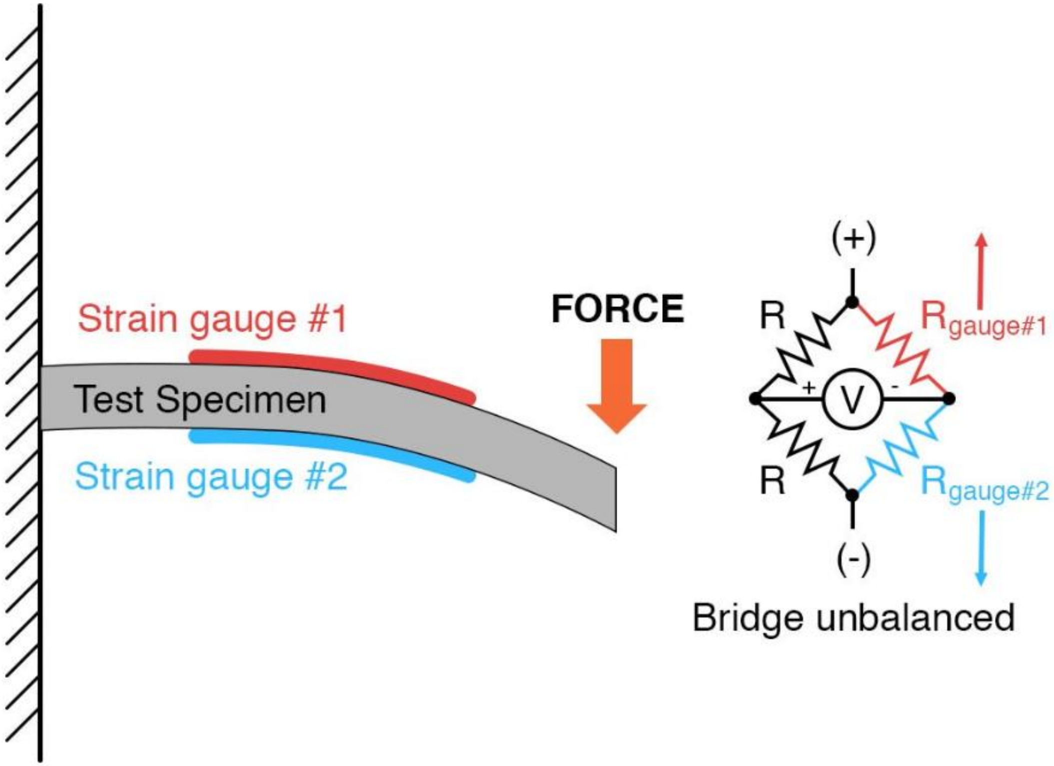
Half-bridge strain gauge circuit



An example of how a pair of strain gauges may be bonded to a test specimen so as to yield this effect



ino force applied to the test specimen, both strain gauges have equal resistance and the bridge circuit is balanced

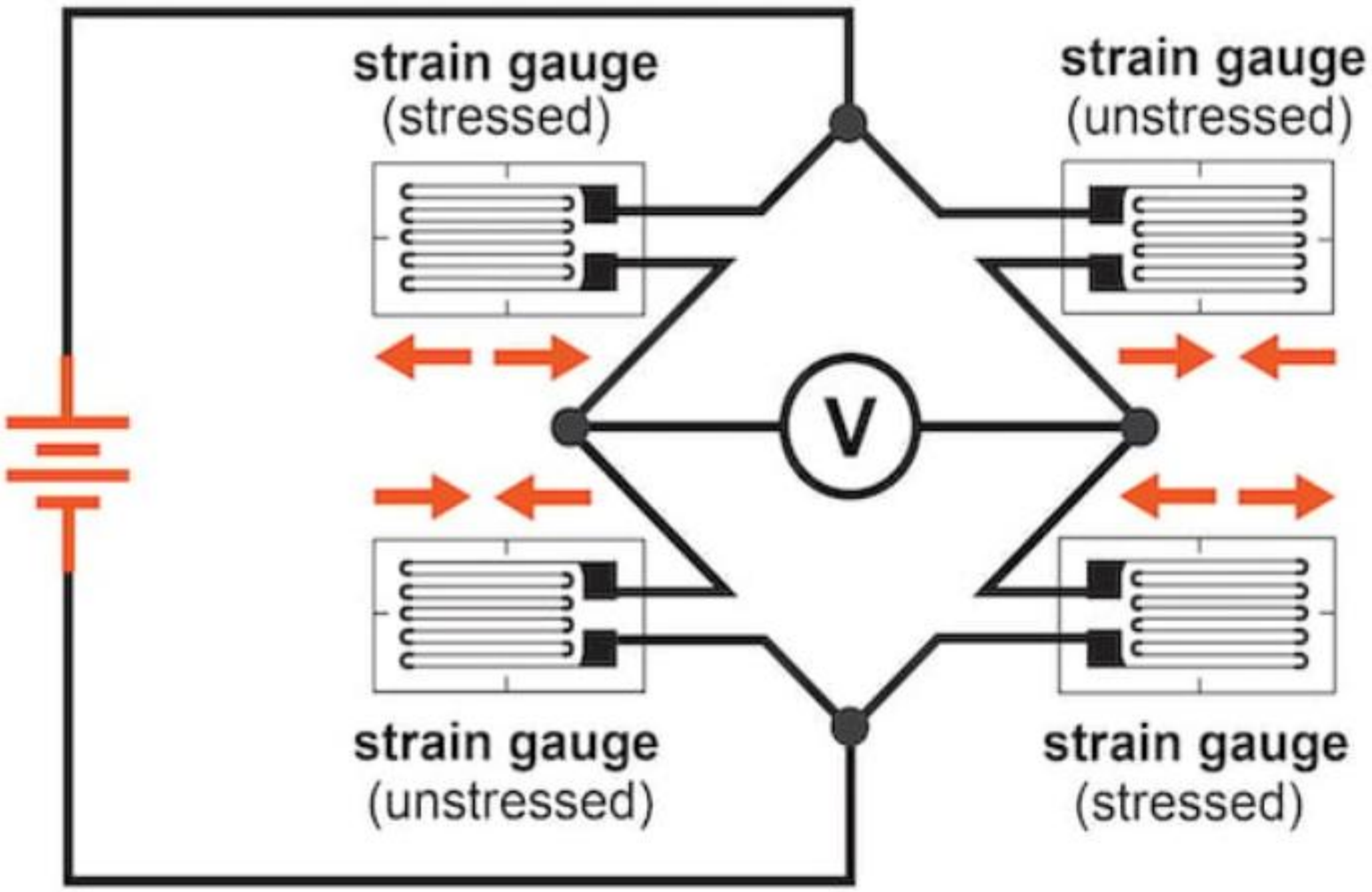


- when a downward force is applied to the free end of the specimen, it will bend downward, stretching gauge #1 and compressing gauge #2 at the same time:
-

Full-Bridge Circuits

- In applications where such complementary pairs of strain gauges can be bonded to the test specimen, it may be advantageous to make all four elements of the bridge “active” for even greater sensitivity. This is called a *full-bridge* circuit:
- When possible, the full-bridge configuration is the best to use. This is true not only because it is more sensitive than the others, but because it is *linear* while the others are not.
- Quarter-bridge and half-bridge circuits provide an output (imbalance) signal that is only *approximately* proportional to applied strain gauge force. Linearity, or proportionality, of these bridge circuits, is best when the amount of resistance change due to the applied force is very small compared to the nominal resistance of the gauge(s). With a full-bridge, however, the output voltage is directly proportional to an applied force, with no approximation (provided that the change in resistance caused by the applied force is equal for all four strain gauges!).
-

Full-bridge strain gauge circuit



RTD

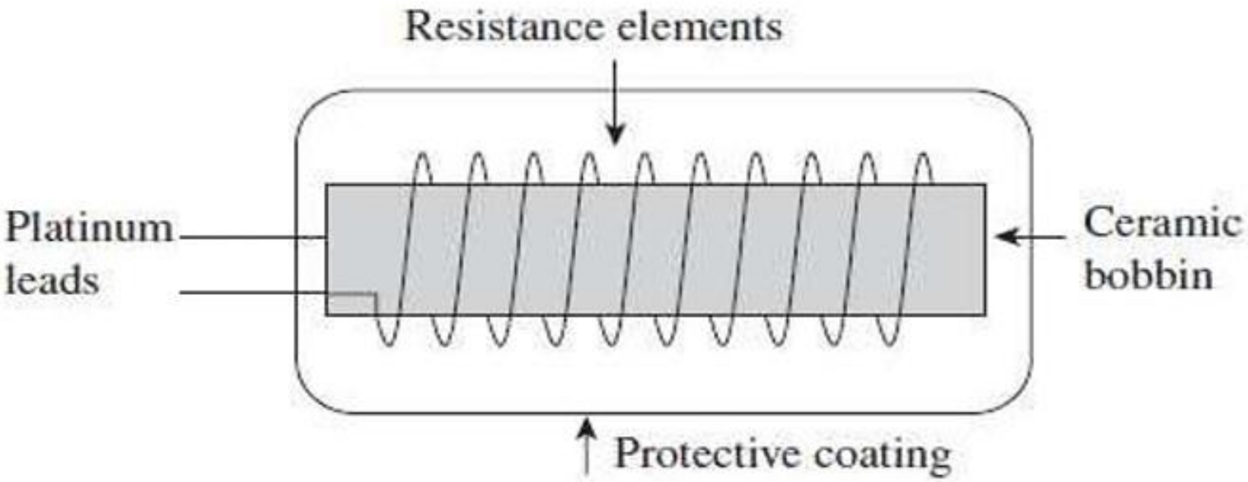


Fig. 15.5 Wire-wound RTD

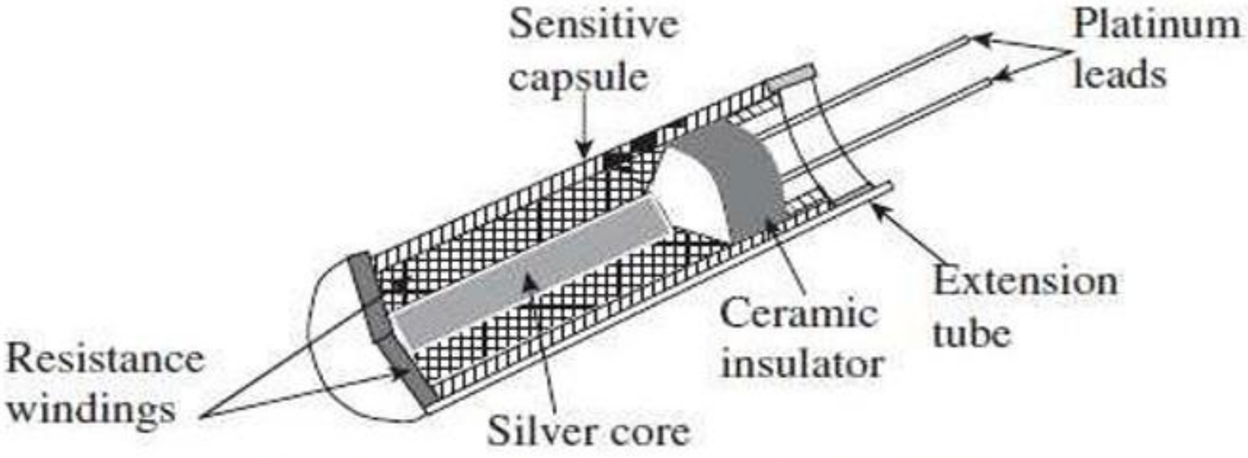


Fig. 15.6 General construction of an RTD

Desirable Properties of Materials Used in Resistance Thermometers (RTDs)

- The material should have a suitable resistivity to allow fabrication in convenient sizes without excessive bulk (which can slow response time).
- It should have a high and stable temperature coefficient of resistivity, ensuring an approximately linear output over the temperature range.
- The material must be corrosion-resistant and chemically stable.
- It should not undergo phase changes within the temperature range of operation.
- The material should be available in a pure and uniform form to ensure reproducible and consistent results.

Salient Features of Resistance Thermometers (RTDs)

- High accuracy and precision — laboratory-grade RTDs can measure temperature within ±0.01°C.
- Designed for fast response and high sensitivity, allowing close control in processes where small temperature variations must be maintained.
- Interchangeable — RTDs of the same type can be replaced without recalibration or compensation.
- Rugged construction ensures reliability in industrial environments.
- Self-heating effect may occur when current passes through the element, slightly changing the measured temperature.
- Lead wire resistance can introduce measurement errors, especially in long cables.
- Bulky size in some designs may cause slower thermal response.
- Conduction effects through the leads or surrounding medium may affect temperature measurement accuracy.