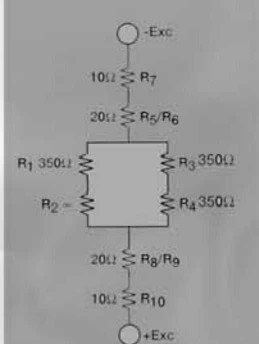
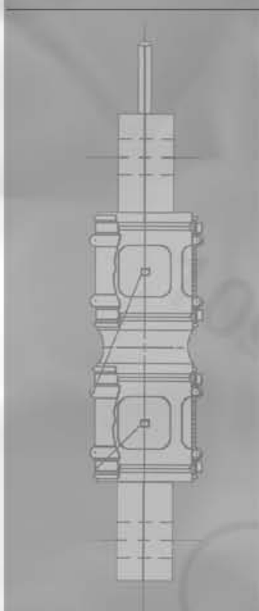
LOAD CELL
HANDBOOK

a comprehensive guide to load cell theory, construction and use





calibration zero balance creep eccentric load tolerance
excitation hysteresis input bridge resistance
non-linearity output repeatability safe overload rating sensitivity
shock load side load temperature effect on rated output

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LOAD CELL HANDBOOK

1.0 INTRODUCTION

A load cell is a device that outputs an electrical signal which is directly proportional to the force that is applied to it. Load cells are used extensively in electronic weighing applications. This review will concentrate on the following subjects:

- DC Circuit Theory
- Load Cell Electrical Theory
- Load Cell Terms
- Troubleshooting
- Load Cell Construction
- Load Cell Types
- Load Cell Selection
- Trimming
- Junction Boxes

2.0 DC CIRCUIT THEORY

OBJECTIVE: *Familiarization with DC circuits, Wheatstone bridge and strain gauges.*

2.1 Electron

An electron is a negatively charged particle that is a part of all atoms. Electrons form orbits around the atom. Electrons found in orbits closer to the atom's center, or nucleus, are held into the atomic structure more closely than those electrons in the outermost orbit. Conductors such as gold, copper and silver have one electron in their outer orbit, also called the valence shell. These valence electrons can easily escape their atom and move randomly to another atom. These electrons are called free electrons. Free electrons bump into other valence electrons, causing more free electrons. Conductors have many free electrons randomly moving from atom to atom.

Insulators are opposite of conductors. Their valence shells contain many electrons which are tightly held to their atoms. Insulators have few free electrons and are very poor conductors of electricity.

2.2 Current and Voltage

Electrical current is the orderly flow of electrons. When electrons flow past a given point at the rate of 6.24×10^{18} (6, 240,000,000,000,000,000) electrons per second, one ampere of current is present. The name given to the number 6.24×10^{18} is a coulomb. So we can say one ampere (Amp) of current is equal to one coulomb passing a given point in one second. The symbol used in electronics for current is A.

In order to move electrons in a conductor to produce current flow, a force must be exerted on the conductor. In electrical circuits this force is a difference in electrical potential between two points and is called voltage. So, current is the actual electron flow and the voltage is the force that causes the electrons to flow. The symbol used in electronics for current is I, and the symbol for voltage is E.

2.3 Resistance

Current flowing through a conductor encounters opposition from the conductor. This opposition to current flow is called resistance. The symbol used to denote resistance is R. The unit of measure for resistance is called the ohm. The symbol used to denote ohms is Ω.

2.4 Direct Current Circuits

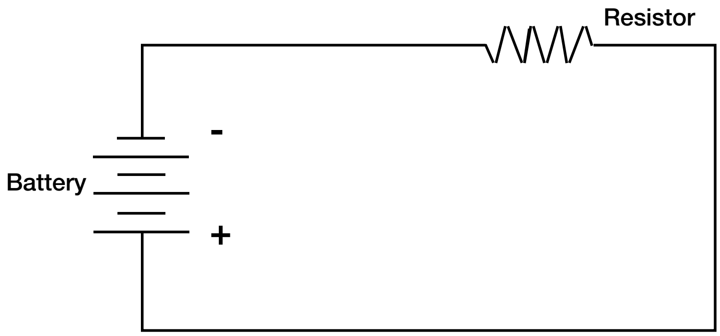
A German physicist named G.S. Ohm developed a definite relationship between voltage, current and resistance in a closed circuit. A circuit consists of a voltage source and a complete path for current flow. The path must start at one side of the voltage source and end at the other side. This gives the circuit a complete, uninterrupted path and also establishes a potential difference between ends of the path since one side of the source has a positive potential and the other side has a negative potential. Mr. Ohm stated, "Current is directly proportional to voltage and inversely proportional to resistance." This relationship is known as Ohm's Law.

As a formula, Ohm's Law looks like this:

$$\text{Current (in amperes)} = \frac{\text{Voltage (in volts)}}{\text{Resistance (in ohms)}}$$

Using the symbols for current, voltage and resistance, this relationship is shown as $I = E/R$. More commonly, Ohm's Law is referred to in the form $E = IR$, or voltage equals current times resistance.

To symbolize a direct current circuit we use the symbol to represent the battery which is the power source. The symbol for resistance is . The diagram of a simple direct current circuit is shown below.



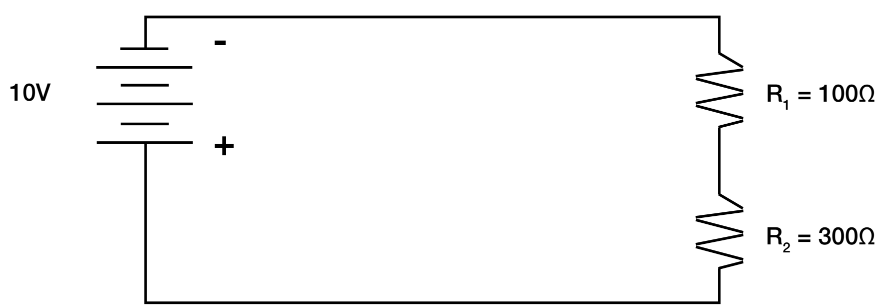
Notice there is a voltage source (battery), a conductor and opposition to the current (resistance). The path is also closed to allow current flow through the circuit.

The resistance is the load or what is being acted upon by the current. It could be a light bulb, heating element or any other type of resistive electrical component, such as a load cell.

Let's take a closer look at Ohm's Law, I = E/R. Since voltage and current are directly proportional, if we increase the battery voltage of our circuit we will also increase the current flow. Also decreasing the resistance will increase current flow as current and resistance are indirectly proportional.

Series Resistive Circuit

A series circuit contains a power source, one or more resistances and only one path for current flow. Let's look at a series circuit with two resistors.



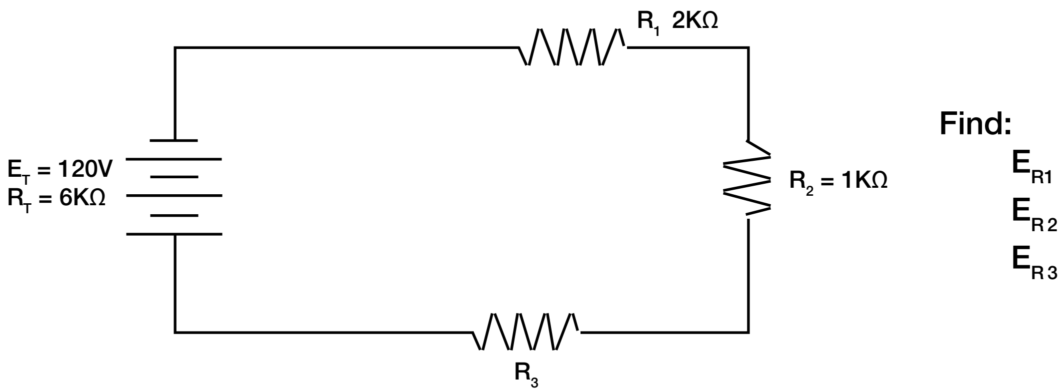
As we look at the circuit we find a 10V power source. There are two resistors in the circuit and only one path for current to flow. So in a series circuit we can say the current in the circuit is constant. No matter where you measure the current in the circuit it will be the same.

The total resistance (R_T) in the circuit is the sum of all resistances. ($R_T = R_1 + R_2$ ...). The total resistance of our circuit is 400Ω. Using Ohm's Law we can find the total current flowing in the circuit: $I_T = E_T/R_T$, $I_T = 10V/400\Omega = .025$ amps or 25 milliamps (mA). Since we know the total current flow we know the current flow through R_1 and R_2 (I_{R1}, I_{R2}). Current flow is constant in a series circuit so $I_T = I_{R1} = I_{R2}$. The sum of the voltage drops in a series circuit are equal to the applied voltage. What is the voltage drop across R_1? Using Ohm's Law the voltage drop across R_1 (E_{R1}) equals the current flowing through R_1 (I_{R1}) times the resistance of R_1.

In a formula it looks like this: $E_{R1} = I_{R1}R_1$

$$E_{R1} = .025A\,(100\Omega) = 2.5 \text{ volts}$$
$$E_{R2} = .025A\,(300\Omega) = 7.5 \text{ volts}$$
$$E_T = E_{R1} + E_{R2}$$
$$E_T = 2.5V + 7.5V = 10V$$

Let's look at another example.



The problem asks to find the voltage drops across each of the resistors. We first need to find the total circuit current, which also equals the current through each of the resistors. Using Ohm's Law:

$$I_T = E_T/R_T$$
$$I_T = 120V/6000\Omega$$
$$I_T = 20 \text{ mA}$$

We also know that $R_T = R_1 + R_2 + R_3$

To find R_3 we can say, $R_3 = R_T - R_1 - R_2$

$$R_3 = 6K\Omega - 2K\Omega - 1K\Omega$$
$$R_3 = 3K\Omega$$

Using Ohm's Law to find E_{R1}, E_{R2} and E_{R3}...

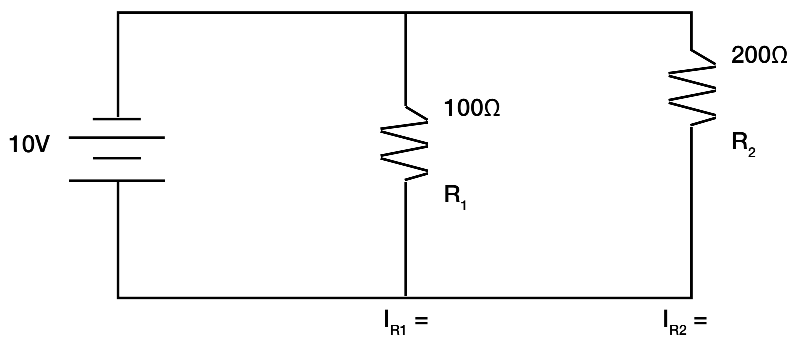
$$E_{R1} = I_{R1} \times R_1$$
$$= .020A \times 2000\Omega$$
$$= 40V$$

$$E_{R2} = I_{R2} \times R_2$$
$$= .020A \times 1000\Omega$$
$$= 20V$$

$$E_{R3} = I_{R3} \times R_3$$
$$= .020A \times 3000\Omega$$
$$= 60V$$

Parallel Resistive Circuit

A parallel circuit contains a power source and more than one path for current flow.



In a parallel circuit the total voltage (E_T) is applied to all circuit branches. Because of this, it is said voltage in a parallel circuit is constant. The total circuit current is the sum of all branch currents.

Total resistance in a parallel circuit is found by finding the reciprocal of the sum of the reciprocals for each resistance. This concept in a formula looks like this:

$$R_T = \frac{1}{1/R_1 + 1/R_2 \ldots}$$

For our circuit:

$$R_T = \frac{1}{1/100 + 1/200}$$

$$R_T = \frac{1}{.015}$$

$$R_T = 66.67\Omega$$

Notice that the total resistance is lower than the lowest individual resistance. For two resistors in parallel total resistance can also be computed by using a formula called "Product Over the Sum." It looks like this:

$$R_T = \frac{(R_1)(R_2)}{R_1 + R_2}$$

$$R_T = \frac{(100)(200)}{100 + 200}$$

$$R_T = \frac{20000}{300}$$

$$R_T = 66.67\Omega$$

If the parallel resistors are the same value, it can be divided by the total number of resistors. For example, if there are 5, 100 ohm resistors in parallel the total resistance would be 100Ω/5 or 20Ω.

In our example circuit we can find total current by using Ohm's Law:

$$I_T = \frac{E_T}{R_T}$$

$$I_T = \frac{10V}{66.67\Omega}$$

$$I_T = 150 \text{ mA}$$

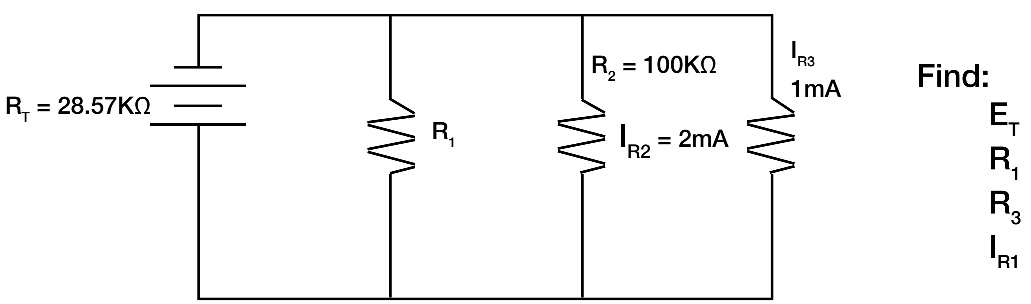
Use Ohm's Law to find I_{R1} and I_{R2}.

$$I_{R1} = \frac{E_{R1}}{R_1} = \frac{10V}{100\Omega} = 100 \text{ mA}$$

$$I_{R2} = \frac{E_{R2}}{R_2} = \frac{10}{200\Omega} = 50 \text{ mA}$$

By adding I_{R1} and I_{R2} we find the total circuit current is 150 mA just as we calculated with Ohm's Law.

Let's look at another example.



Let's start by finding E_T. We know that E_T is the same as the voltage applied to each branch. Since we know R_2 and I_{R2} we can use Ohm's Law to find E_{R2} which is the same as E_T.

$$E_{R1} = R_1 \times I_{R1}$$
$$= 100{,}000\Omega\ (.002A)$$
$$= 200V$$

Since we know E_T we can find R_3.

$$R_3 = \frac{E_T}{I_{R3}} = \frac{200V}{.001A} = 200K\Omega$$

We know E_T and R_T is given. Use Ohm's Law to figure out I_T.

$$I_T = \frac{E_T}{R_T} = \frac{200V}{28.57K\Omega} = 7\ mA$$

Since $I_T = I_{R1} + I_{R2} + I_{R3}$ we can figure out the current through branch resistor I_{R1}.

$$I_{R1} = I_T - I_{R3} - I_{R2}$$
$$I_{R1} = 7mA - 1mA - 2mA$$
$$I_{R1} = 4mA$$

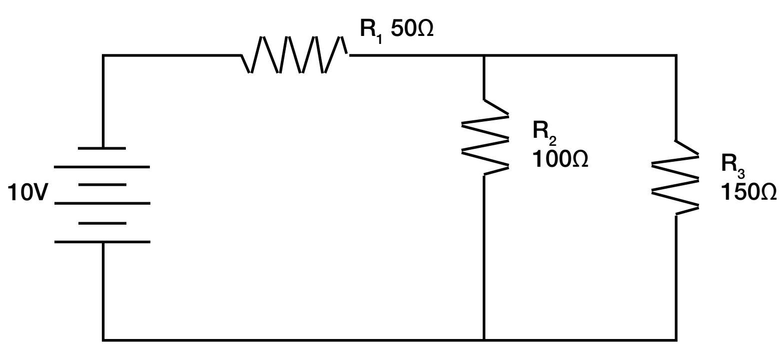
Since we know E_T and I_{R1} we can find R_1 using Ohm's Law.

$$R_1 = \frac{E_T}{I_{R1}}$$
$$R_1 = \frac{200V}{.004A}$$
$$R_1 = 50K\Omega$$

Series-Parallel Circuit

A series-parallel circuit has at least two parallel branches in addition to at least one resistor through which total circuit current flows. The resistor through which all circuit current flows is called the series resistor.

Below is an example of a series-parallel circuit.

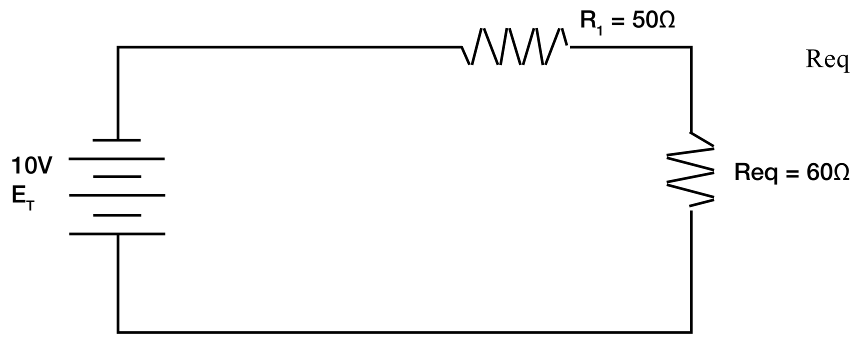


Find:
- R_T
- I_T
- E_{R1}
- E_{R2}
- E_{R3}

To find total circuit resistance, find the equivalent resistance of R_2 and R_3 in parallel.

$$Req = \frac{1}{1/R_2 + 1/R_3}$$
$$= \frac{1}{1/100 + 1/150}$$
$$= 60\Omega$$

The equivalent series circuit is shown below.



Req = Equivalent Resis-

To find R_T add the series resistances. $R_T = R_1 + Req$

$$R_T = 50\Omega + 60\Omega$$
$$R_T = 110\Omega$$

To find total current in the circuit use Ohm's Law.

$$I_T = \frac{E_T}{R_T}$$
$$I_T = \frac{10V}{110\Omega}$$
$$I_T = .091A \text{ or } 91mA$$

Since total circuit current flows through R_1 we can say $I_T = I_{R1}$. Using Ohm's Law we can figure the voltage drop across R_1.

$$E_{R1} = I_{R1}R_1$$
$$E_{R1} = .091A\,(50\Omega)$$
$$E_{R1} = 4.55 \text{ volts}$$

Since R_1 drops or uses 4.55 volts, that leaves 10V - 4.45V or 5.45 volts to be dropped across the parallel network of R_2 and R_3. Using Ohm's Law we can determine the current flow through R_2 and R_3. The total current in the circuit will divide proportionately between R_2 and R_3. In other words, the total current in the circuit will be the sum of the branch currents I_{R2} and I_{R3}.

$$I_{R2} = \frac{E_{R2}}{R_2}$$
$$= \frac{5.45V}{100\Omega}$$
$$= .0545A \text{ or } 54.5 \text{ mA}$$

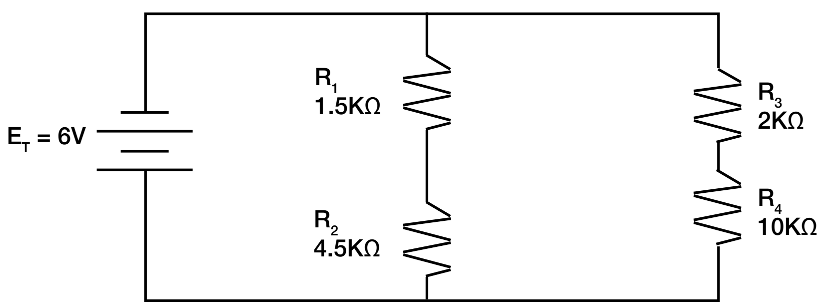
$$I_{R3} = \frac{E_{R3}}{R_3}$$
$$= \frac{5.45V}{150\Omega}$$
$$= .0363A \text{ or } 36.3 \text{ mA}$$

$$I_T = I_{R2} + I_{R3}$$

$$I_T = 54.5 \text{ mA} + 36.3 \text{ mA}$$
$$= 90.8 \text{ mA}$$

Rounding off the 90.8 mA to the nearest whole number, we get 91 mA just as we calculated earlier.

Remember that a series-parallel circuit has to have at least one component through which total circuit current passes. The following type of circuit is sometimes erroneously referred to as a series-parallel circuit.



Using our definition of series-parallel circuits, we can see that total circuit current does <u>not</u> flow through any of the components. This circuit is actually a parallel circuit.

To determine the current flow through $R_1 + R_2$ we need to add these resistances for a total branch resistance of 6KΩ. Using Ohm's Law we can find the current through branch $R_1 + R_2$.

$$I_{R1+R2} = \frac{E_{R1} + {}_{R2}}{R_1 + R_2}$$
$$= \frac{6V}{6{,}000\Omega}$$
$$= 1 \text{ mA}$$

To determine the current flow through $R_3 + R_4$ we add their resistances for a total of 12KΩ. Use Ohm's Law to calculate total current.

$$I_{R3+R4} = \frac{E_{R3+R4}}{R_3 + R_4}$$

$$= \frac{6V}{12{,}000\Omega}$$

$$= .5 \text{ mA or } 500\ \mu\text{A}$$

Total circuit current is the sum of the currents through both branches or $I_T = I_{R3+R4} + I_{R1+R2}$ or 1 mA + .5 mA = 1.5 mA.

To calculate total circuit resistance we can use Ohm's Law again.

$$R_T = \frac{E_T}{I_T}$$

$$= \frac{6V}{.0015A}$$

$$= 4{,}000\Omega \text{ or } 4K\Omega$$

We can also calculate total resistance by using the "reciprocal of the sum of the reciprocals" formula or the "product over the sum" formula. We know the $R_1 + R_2$ branch resistance is 6.0KΩ and the $R_2 + R_4$ branch resistance is 12KΩ.

$$R_T = \frac{1}{\frac{1}{R_1 + R_2} + \frac{1}{R_3 + R_4}}$$

$$R_T = \frac{1}{1/6000 + 1/12000}$$

$$= \frac{1}{3/12000}$$

$$= \frac{1}{1/4000}$$

$$= 4{,}000\Omega \text{ or } 4K\Omega$$

OR

$$R_T = \frac{(6000)(12000)}{6000 + 12000}$$

$$R_T = \frac{72{,}000{,}000}{18000}$$

$$R_T = 4{,}000\Omega \text{ or } 4K\Omega$$

If we want to know the voltage drop across each resistor we can also use Ohm's Law. Let's use R_1. We know that the current flowing through R_1 equals the current flowing through R_2 and the branch made up of $R_1 + R_2$, because these two resistances are in series with each other. Using Ohm's Law we can multiply the resistance of R_1 times the current flow through R_1 (I_{R1}) to find E_{R1} (voltage drop across R_1).

$$E_{R1} = R_1 I_{R1}$$

$$= 1{,}500\Omega\ (.001A)$$

$$= 1.5V$$

Ohm's Law can also be used to find voltage drops throughout the rest of the circuit.

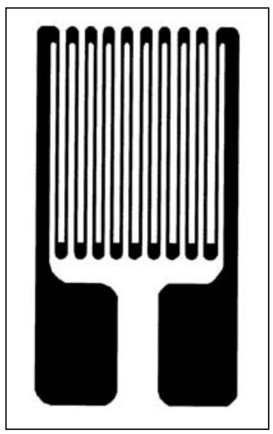
This circuit is the foundation for building a Wheatstone bridge circuit which is the circuit used in load cells. We will explore this circuit in the next section.

2.5 Conductor Size

A conductor or wire has a certain amount of resistance depending on its diameter. The larger the diameter, the lower the resistance. If we stretch the wire we have decreased its diameter, or cross-sectional area, thus increasing its resistance. The opposite is also true. If we compress the wire, its diameter is increased and its resistance is decreased. Since it takes a force to act upon the wire to compress or stretch it, the wire can be configured to measure force. This configuration of wire is called a strain gauge.

2.6 Strain Gauge

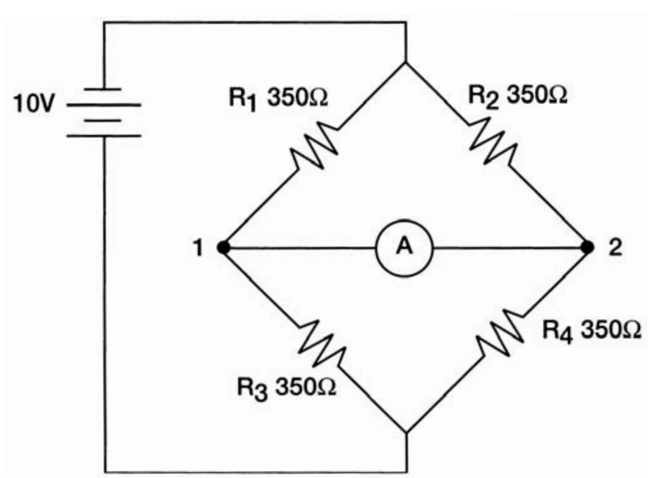
A strain gauge consists of a very fine length of wire that is woven back and forth in a grid and laid on a piece of paper or plastic called its base. A common wire used is a copper-nickel alloy with a diameter of about one thousandth of an inch (.001"). The wire is zig-zagged to form a grid so to increase the effective length of the wire that comes under the influence of the force applied to it. Leads are attached to the ends of the gauge. Strain gauges can be made very small, sometimes as small as 1/64". These gauges are cemented to a strong metal object, commonly referred to as the load receiving element, to make up a load cell. The gauges are configured into a circuit called a Wheatstone bridge.



STRAIN GAUGE
Figure 1

2.7 Wheatstone Bridge

The type of resistive circuit used in load cells is a Wheatstone bridge.

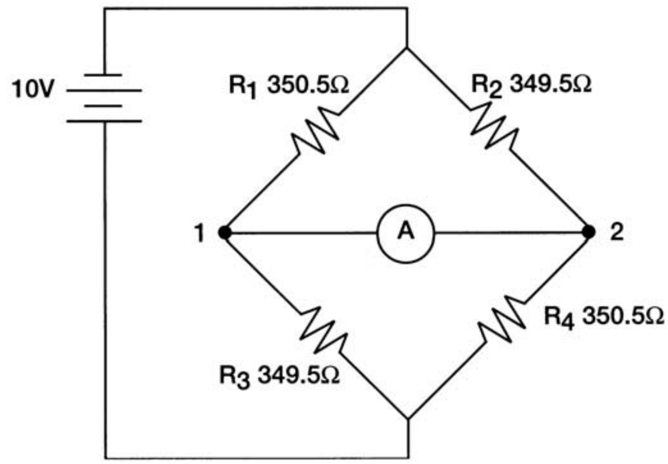


NOTE: All resistors are equal.
A is a symbol for an ammeter,

BALANCED WHEATSTONE BRIDGE
Figure 2

When power is applied to this bridge the current flowing in the R_1/R_3 branch is equal to the current flowing in the R_2/R_4 branch. This is true because all resistors are equal. Since there is no voltage difference between points 1 and 2 there is no current flow through the ammeter. This bridge is in a balanced condition.

Now let's increase the resistance of R_1 and R_4 to 350.5 ohms, and decrease the resistance of R_2 and R_3 to 349.5 ohms.



UNBALANCED WHEATSTONE BRIDGE
Figure 3

As you can see, the bridge becomes unbalanced. There is actually three paths for current flow in this circuit.

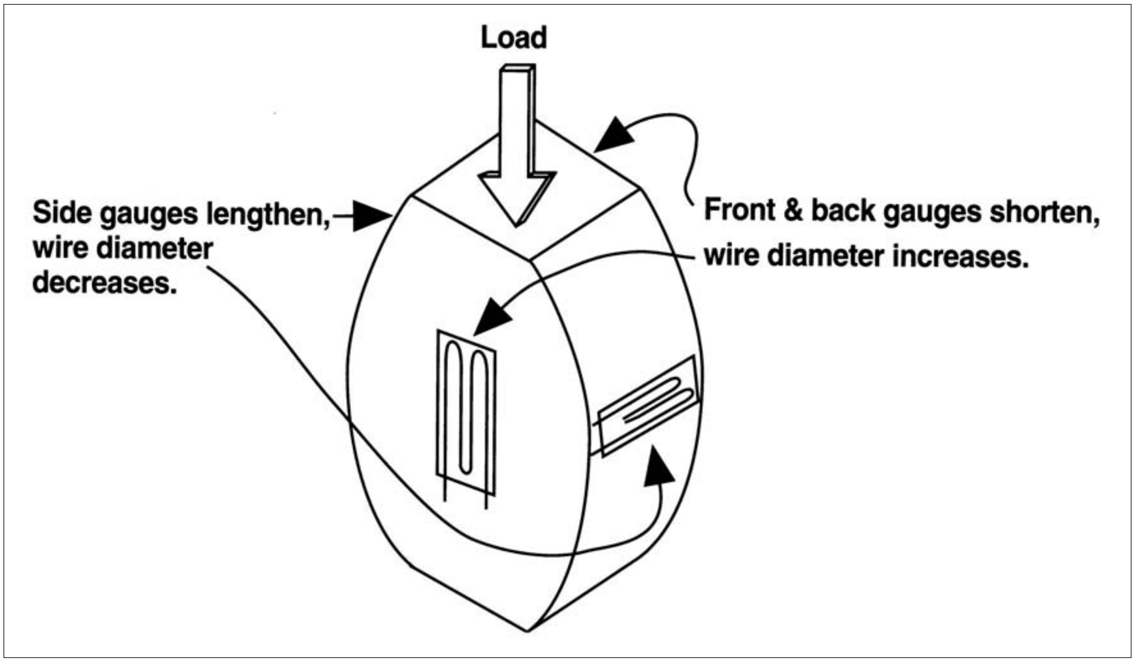
- Path 1 Negative battery terminal through R_2 and R_4 back to the positive battery terminal.
- Path 2 Negative battery terminal through R_1 and R_3 back to the positive battery terminal.
- Path 3 Negative battery terminal through R_2, the ammeter, R_3 and back to the positive battery terminal.

Notice this time there is current flow through the ammeter. This current flow is a result of a potential difference between points 1 and 2. The larger the potential difference the larger the current flow through the ammeter.

2.8 Load Cell

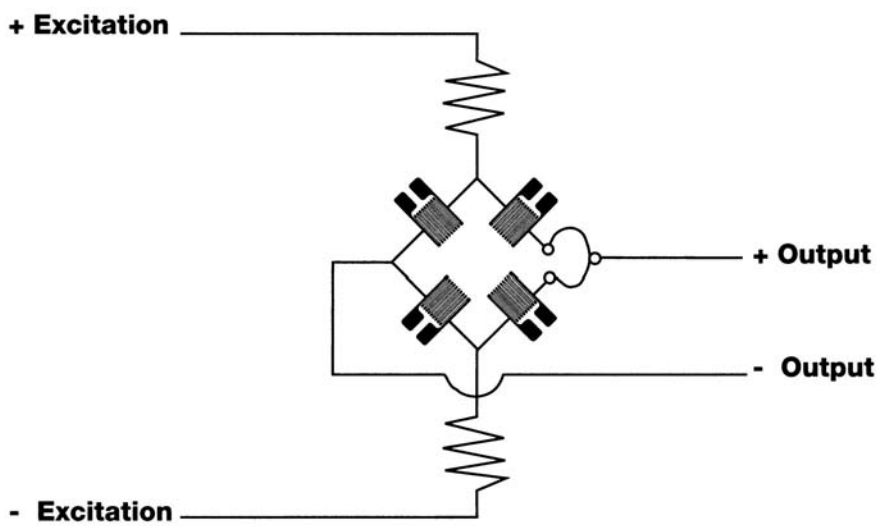
We can take our strain gauge and Wheatstone bridge theories and use them to construct a load cell. We will use a column of steel and glue a strain gauge on each of the four sides of the column. As weight is placed on top of the column, the length of the column would decrease. The column also would become "fatter," or bulge out. Two strain gauges are placed opposite of each other to respond proportionately to the change in length.

Two other gauges are placed on opposite sides of the column and respond to the change in the column's bulge. Since one pair of strain gauges become shorter their wire diameters become larger and their resistance decreases. The other pair of strain gauges are positioned so their wires lengthen, thus decreasing their diameter and increasing their resistance. If we hung the same weight from the bottom of the column instead of compressing the column we would be placing tension on it. The column and strain gauges would act in the opposite direction but still stretch and compress the wires by the same amount. See Figure 4 - Strain Gauge on page 13.



STRAIN GAUGE
Figure 4

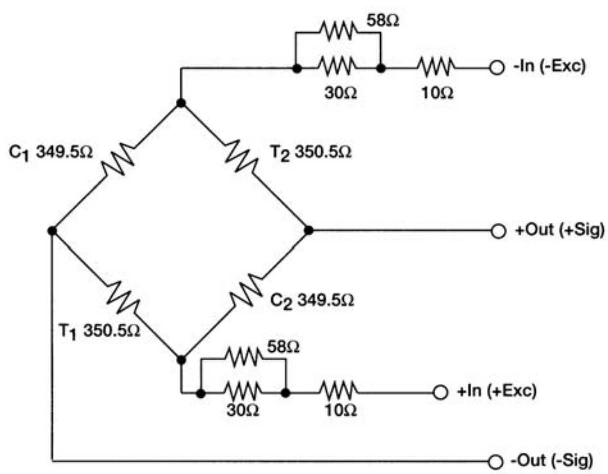
We can wire our strain gauges into a Wheatstone bridge configuration. We can calibrate the ammeter to read in pounds instead of amps. In effect, we actually have a scale. Of course this is a crude, very inaccurate scale. It is intended to show the basic load cell principle. Load cells are made in different shapes and configurations. The strain gauges are strategically placed for peak performance. See Figure 5.



LOAD CELL
Figure 5

3.0 LOAD CELL ELECTRICAL THEORY

OBJECTIVE: *Familiarization with load cell electrical theory.*



The Wheatstone bridge configured above is a simple diagram of a load cell. The resistors marked T_1 and T_2 represent strain gauges that are placed in tension when load is applied to the cell. The resistors marked C_1 and C_2 represent strain gauges which are placed in compression when load is applied.

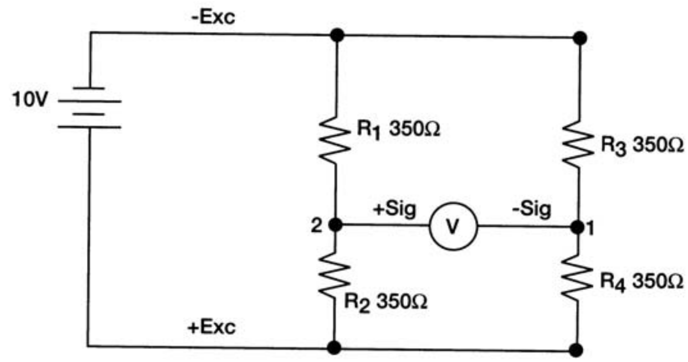
The +In and -In leads are referred to as the +Excitation (+Exc) and -Excitation (-Exc) leads. The power is applied to the load cell from the weight indicator through these leads. The most common excitation voltages are 10 VDC, and 15 VDC depending on the indicator and load cells used. The +Out and -Out leads are referred to as the +Signal (+Sig) and -Signal (-Sig) leads. The signal obtained from the load cell is sent to the signal inputs of the weight indicator to be processed and represented as a weight value on the indicator's digital display.

As weight is applied to the load cell, gauges C_1 and C_2 compress. The gauge wire becomes shorter and its diameter increases. This decreases the resistances of C_1 and C_2. Simultaneously, gauges T_1 and T_2 are stretched. This lengthens and decreased the diameter of T_1 and T_2, increasing their resistances. These changes in resistances causes more current to flow through C_1 and C_2 and less current to flow through T_1 and T_2. Now a potential difference is felt between the output or signal leads of the load cell.

Let's trace the current flow through the load cell. Current is supplied by the indicator through the -In lead. Current flows from -In through C_1 and through -Out to the indicator. From the indicator current flows through the +Out lead, through C_2 and back to the indicator at +In. In order to have a complete circuit we needed to get current from the -In side of the power source (Indicator) to the +In side. You can see we accomplished that. We also needed to pass current through the indicator's signal reading circuitry. We accomplished that as the current passed from the -Out lead through the indicator and back to the load cell through the +Out lead. Because of the high internal impedance (resistance) of the indicator, very little current flows between -Out and +Out.

Since there is a potential difference between the -In and +In leads, there is still current flow from -In through T_2 and C_2 back to +In, and from -In through C_1 and T_1 back to +In. The majority of current flow in the circuit is through these parallel paths. Resistors are added in series with the input lines. These resistors compensate the load cell for temperature, correct zero and linearity.

Let's look at a load cell bridge circuit in mathematical terms to help you understand the bridge circuit in both a balanced and unbalanced condition. Our Wheatstone bridge can either be drawn in a conventional diamond shape or as shown in the diagram on the following page. Either way, it is the same circuit.



We have replaced the ammeter with a voltmeter which will represent the display on our weight indicator. Also, the leads connected to our indicator are designated +Sig and -Sig. These represent our positive and negative signal leads. The 10 volt battery represents our indicator's power supply that provides the precise voltage to excite or power the load cell. The resistance values represent our four strain gauges which make up our load cell.

Since there is no load on our cell, all strain gauge resistances are the same. Using Ohm's Law we can figure the voltage drops at points 1 and 2. Each branch contains 350Ω + 350Ω = 700Ω of resistance. The current flow in the branch is the branch voltage divided by the branch resistance.

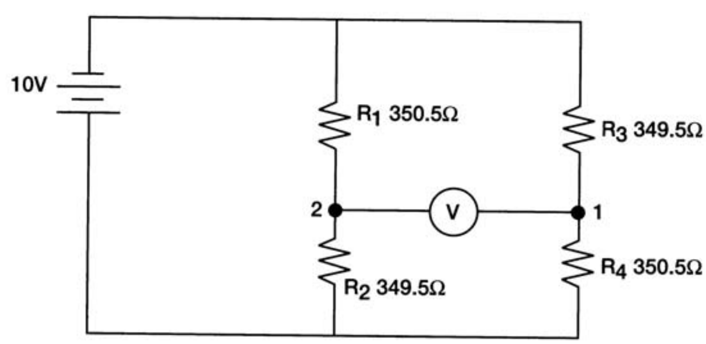
$$I_{R1+R2} = \frac{E_{R1+R2}}{R_1 + R_2} = \frac{10V}{700\Omega} = 14.3 \text{ mA} \qquad I_{R3+R4} = \frac{E_{R3+R4}}{R_3 + R_4} = \frac{10V}{700\Omega} = 14.3 \text{ mA}$$

To figure the voltage at point 1 we can use Ohm's Law.

$$E_{R3} = I_{R3}R_3 = 14.3 \text{ mA} \times 350\Omega = 5V$$

Since all resistances are equal, the voltage at point 2 is also 5V. There is no voltage difference between points 1 and 2 thus a zero reading is displayed on our indicator.

Now let's place a force on our load cell. Our force caused R_1 and R_4 to go into tension, which increased their resistances. R_2 and R_3 went into compression, which decreased their resistances. These changes are depicted in the following diagram.



Notice that the individual branch resistances still total 700Ω so there is still 14.3 mA of current flowing in each branch of our circuit.

However, there is a potential difference between points 1 and 2, thus a reading is displayed on our indicator. Let's calculate the potential difference.

To find the voltage at point 1 we will calculate the voltage drop across R_3. We know the current flow through R_3 is 14.3 mA.

$$
\begin{aligned}
E_{R3} &= I_{R3}\,(R_3) \\
&= 0.0143\text{A}\,(349.5\Omega) \\
&= 4.9979\text{V}
\end{aligned}
$$

To find the voltage at point 2 we will calculate the voltage drop across R_1. Again, we know the current flow through R_1 is 14.3 mA.

$$
\begin{aligned}
E_{R1} &= I_{R1}\,(R_1) \\
&= 0.0143\text{A}\,(350.5\Omega) \\
&= 5.0122\text{V}
\end{aligned}
$$

To find the potential difference between points 1 and 2 we subtract E_{R3} from E_{R1} and find the difference to be .0143V or 14.3 mv.

We see that our bridge has become unbalanced and the potential difference across the bridge is 14.3 mV. The indicator is calibrated so a certain millivolt reading would correspond to a certain weight measurement. As we previously stated the indicator draws current. But its internal resistance is so high that the current it draws is negligible and has no affect on load cell operation.

3.1 Wiring

A load cell may have a cable with four or six wires. A six-wire load cell, beside having + and - signal and + and - excitation lines, also has + and - sense lines. These sense lines are connected to the sense connections of the indicator. These lines tell the indicator what the actual voltage is at the load cell. Sometimes there is a voltage drop between the indicator and load cell. The sense lines feed information back to the indicator. The indicator either adjusts its voltage to make up for the loss of voltage, or amplifies the return signal to compensate for the loss of power to the cell.

Load cell wires are color coded to help with proper connections. The load cell calibration data sheet for each load cell contains the color code information for that cell. Rice Lake Weighing Systems also provides a load cell wiring color guide on the back cover of our Load Cell Product Selection Guide.

3.2 Calibration Data

Each load cell is furnished with a calibration data sheet or calibration certificate. This sheet gives you pertinent data about your load cell. The data sheet is matched to the load cell by model number, serial number and capacity. Other information found on a typical calibration data sheet is output expressed in mV/V, excitation voltage, non-linearity, hysteresis, zero balance, input resistance, output resistance, temperature effect on both the output and zero balance, insulation resistance and cable length. The wiring color code is also included on the calibration data sheet. See a sample calibration data sheet on page 17.

3.3 Output

A load cell's output is not only determined by the weight applied, but also by the strength of the excitation voltage, and its rated mV/V full scale output sensitivity. A typical full scale output for a load cell is 3 millivolts/volt (mV/V). This means that for each volt of excitation voltage applied at full scale there will be 3 millivolts of signal output. If we have 100 lbs applied to a 100 lb load cell with 10 volts excitation applied the load cell signal strength will be 30 mV. That is 10V x 3 mV/V= 30 mV. Now let's apply only 50 lbs to the cell, keeping our excitation voltage at 10 volts. Since 50 lbs is 50% or one half of full load, the cell signal strength would be 15 mV.

Rice Lake Weighing Systems
Calibration Certificate

1.	Model No.	50210-25	
2.	Serial No.	37647	
3.	Capacity	25	lbs
4.	Output	3.0678	mV/V
5.	Excitation	10	Volts
6.	Non-Linearity	< 0.010	% FSO
7.	Hysteresis	< 0.010	% FSO
8.	Zero Balance	-0.0230	mV/V
9.	Input Resistance	375	Ohms Nominal
10.	Output Resistance	350	Ohms
11.	Temperature Effect		
	Output	< 0.0005	% /F
	Zero	< 0.0010	% /F
	Insulation Resistance	5000	Mega Ohms at 50 VDC
	Cable Length	20	ft
	NTEP Certificate No.	****	
	Minimum Dead Load (lb)	****	
	Class	****	
	V min	****	
	n Maximum	****	
	Load Cell Usage	****	
	Safe Load Limit (lb)	****	

Wiring		
Red	+	Input
Green	+	Output
White	-	Output
Black	-	Input
		Shield

4.0 LOAD CELL TERMS

OBJECTIVE: *Familiarization with load cell terminology.*

We know that a load cell is an electromechanical device. It can be called a transducer as it converts one form of energy to another — mechanical force or stress to electrical energy. A load cell has various characteristics that are measurable. These characteristics are determined by the type of metal used, shape of the load cell and how well it is protected from its environment. To understand load cells better there are terms that you need to become familiar with so you can better match the load cell to your application.

CALIBRATION - The comparison of load cell outputs against standard test loads.

COMBINED ERROR - (Nonlinearity and hysteresis) - The maximum deviation from the straight line drawn between the original no load and rated load outputs expressed as a percentage of the rated output and measure on both increasing and decreasing loads.

CREEP - The change in load cell output occurring over time, while loaded, and with all environmental conditions and other variables remaining constant.

CREEP RECOVERY - The change in no load output, occurring with time, after removal of a load which had been applied for a specific period of time.

DRIFT - A random change in output under constant load conditions.

ECCENTRIC LOAD - Any load applied parallel to, but not concentric with, the primary axis.

ERROR - The algebraic difference between the indicated and true value of the load being measured.

EXCITATION - The voltage applied to the input terminals of a load cell. Most load cells have a rated excitation voltage of 10 VDC. There are load cells available that are rated at 15, 20 and 25 VDC and also some that have both AC and DC excitation ratings.

HYSTERESIS - The maximum difference between load cell output readings for the same applied load. One reading is obtained by increasing the load from zero, and the other reading is obtained by decreasing the load from rated load. Hysteresis is measured as percentage of the full scale rated output (% F.S.). Common load cell hysteresis values are .02% F.S., .03% F.S. and .05% F.S.

INPUT BRIDGE RESISTANCE - The input resistance of the load cell. It is measured by placing an ohmmeter across the input or excitation leads. It is usually higher than the output bridge resistance because of the presence of compensating resistors in the excitation circuit.

INSULATION RESISTANCE - The DC resistance measured between the load cell circuit and the load cell structure.

NON-LINEARITY - The maximum deviation of the calibration curve from a straight line drawn between the no load and rated load outputs. It is expressed as a percentage of the full-scale rated output. It is measured on an increasing load only. Common non-linearity values are .02% F.S. and .03% F.S.

OUTPUT - The signal produced by the load cell where the output is directly proportional to excitation and the load applied. The signal must be in terms such as millivolts per volt (mV/V) or volts per ampere (V/A).

OUTPUT BRIDGE RESISTANCE - The output resistance of the cell. It is measured by placing an ohmmeter between the signal or output leads. Common bridge resistances are 350Ω, 480Ω, 700Ω, 750Ω and 1000Ω.

OUTPUT, RATED - The algebraic difference between the output at no load and the output at rated load.

REPEATABILITY - The maximum difference between load cell output readings for repeated loadings under identical loading and environmental conditions.

RESOLUTION - The smallest change in mechanical input which produces a detectable change in the output signal.

SAFE OVERLOAD RATING - The maximum load, in percent of rated capacity, which can be applied without producing a permanent shift in performance characteristics beyond those specified. A common safe overload rating is 150% F.S.

SENSITIVITY - The ratio of the change in output to the change in mechanical input.

SHOCK LOAD - A sudden increase in load usually caused by dropping weight onto the scale. Can cause permanent load cell damage.

SIDE LOAD - Any load acting 90° to the primary axis at the point of axial load application.

TEMPERATURE EFFECT ON RATED OUTPUT - The change in rated output due to a change in ambient temperature. It is usually expressed as the percentage change in rated output per 100°F change in ambient temperature.

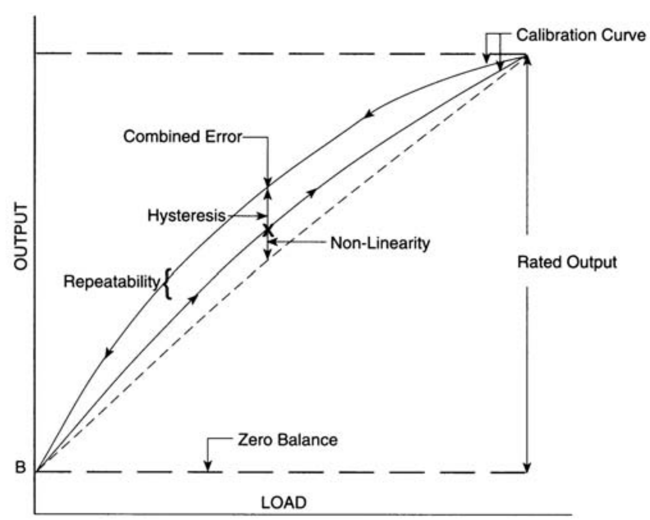
TEMPERATURE EFFECT ON ZERO BALANCE - The change in zero balance due to a change in ambient temperature. It is usually expressed as the change in zero balance in percent of rated output per 100°F change in ambient temperature.

TEMPERATURE RANGE, COMPENSATED - The range of temperature over which the load cell is compensated to maintain rated output and zero balance within specified limits.

TOLERANCE - A magnitude fixing the limit of allowable error or departure from true performance or value.

ULTIMATE OVERLOAD RATING - The maximum load, in percent of rated capacity, which can be applied to a load cell, without producing a structural failure.

ZERO BALANCE - The output signal of the load cell with rated excitation and with no load applied, usually expressed in percent of rated output.



5.0 TROUBLESHOOTING

OBJECTIVE: *Perform physical, zero balance and bridge resistance checks.*

Load cells fail in a variety of ways for a variety of reasons. These reasons may be mechanical, environmental, or electrical. We will discuss these reasons and make physical and electrical load cell inspections. Most load cell failures are caused by incorrect applications or abuse.

Mechanical Failure

The load cell may fail mechanically or physically. If the cell is too small for the application, the excessive weight will cause the cell to distort and not return to its no load shape, thus keeping the strain gauges either in compression or tension. The total weight of the weigh structure (platform, hopper, vessel) plus the weight of the material being weighed must be considered. The number of structural support points also plays a role in load cell weight distribution. Normally the total weight of the structure is divided equally between all the load cells.

Shock loading also can cause mechanical failure. Shock loading occurs when the weight is dropped suddenly onto the scale, which can cause permanent distortion of the load cell. Observe the operators when they are loading the scale. If they are shock loading the scale, the operators require training on proper scale operation and/or larger capacity cells need to be used. Be careful as too large of a cell capacity can decrease load cell sensitivity or output below minimum indicator sensitivity requirements. Non-axial or side loading can also cause mechanical failure besides measurement inaccuracies. Side load can be minimized through proper use of various types of mounting hardware (See Section 8).

Environmental Effects

Most load cells are compensated to operate within a specified temperature range, usually 0° to 150°F. The load cell may operate properly outside these limits. However, the calibration data supplied with the load cell is only valid when the cell is operated within its compensated range.

Moisture has a very negative effect on load cell operation. Moisture can cause no output, overload indications, or most commonly, continuous drift and erratic scale operation. Moisture enters a load cell through cut cables or through pressure. If a non-hermetically sealed load cell is used in a high pressure washdown application, water will be forced in the load cell.

Chemicals can cause corrosion of the load cell. Corrosion can work its way into the strain gauges, especially if the material used to protect against the environment has worn away. A stainless steel load cell may be required to keep the cell from corroding, but may not prevent the penetration of moisture. Some chemicals such as chlorine can even corrode stainless steel.

5.1 Physical Check

The first step to take when troubleshooting a load cell is to check for distortion, cracks or rippling of the metal. All welds should be free of cracks or deep pox marks. Look for crimps, cuts and excessive abrasions on the load cell cable. Moisture can enter anywhere the cable is cut. The moisture will wick its way to the load cell and cause problems such as unstable readings.

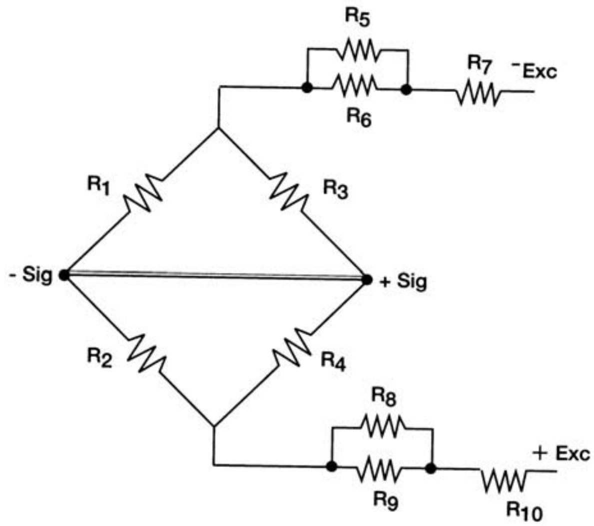
5.2 Zero Balance

As given in our Load Cell Terms section, zero balance is the output signal of the load cell with rated excitation and no load applied. It is expressed in percent of rated output. Zero balance changes usually occur if the load cell has been mechanically overloaded.

With no load on the cell and the cell connected to the indicator, use a millivoltmeter to check the load cell output voltage. At 10 volts excitation a 3 mV/V load cell will output 30 mV at full load. At a 1% tolerance the load cell with no load applied should output less than .3 mV or 300 µV. (.01 x 30 mV = .3 mV). A zero tolerance of greater than 1% may be cause to condemn your load cell. Regauging may be impractical as a mechanical overload usually causes permanent structural damage. Some load cells may operate properly with a shift of up to 10%.

Another balance check may be made which compares one half of the bridge circuit to the other half. With the load cell leads disconnected and no load applied to the cell, perform the following steps.

- Short the signal leads together. This action will yield a circuit that looks like Figure 6.



LOAD CELL CIRCUIT
Figure 6

- Measure and record the resistance between the signal leads and the -Exc lead (measures parallel combination R_1/R_3 in series with -Excitation compensation resistors).
- Measure and record the resistance between the signal leads and the +Exc lead (measures parallel combination R_2/R_4 in series with +Excitation compensation resistors).
- The difference between the above two readings should be zero ohms.

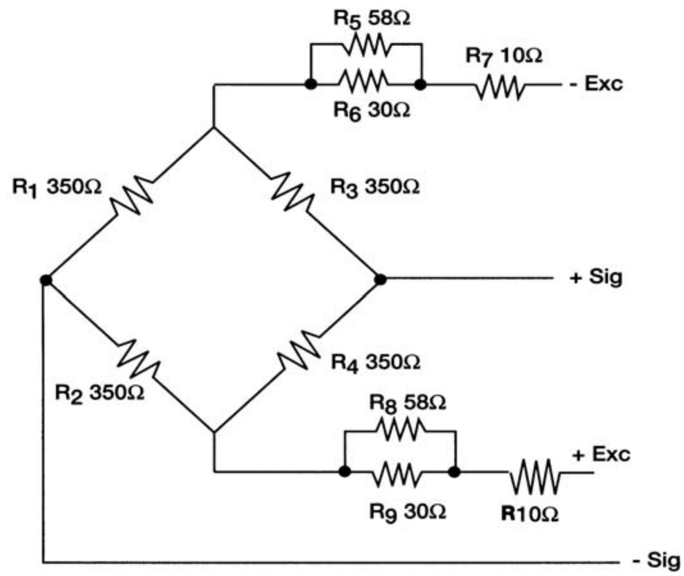
5.3 Bridge Resistance

The bridge input resistance is measured by placing an ohmmeter between the +Exc and -Exc leads. The bridge output resistance is measured by placing an ohmmeter between the +Sig and -Sig leads. The normal resistance readings are found on the load cell calibration data sheet. Your measured readings should be within 1% of the values stated on the calibration data sheet.

You can also take measurements between the following parts of the bridge:

+Exc to +Sig	**+Exc to -Sig**
- Exc to +Sig	**- Exc to -Sig**

The -Exc to +Sig measurement and the -Exc to -Sig measurement should be identical. This is also true of the +Exc to +Sig measurement and the +Exc to -Sig measurement. Any differences in readings indicate damage to the load cell. Let's take a look at some load cell resistance readings and determine if these readings represent a functional load cell or one that is damaged. Figure 7 (on page 22) will represent the type of load cell we are testing.



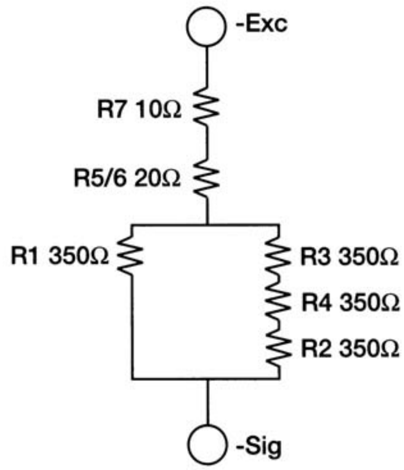
LOAD CELL RESISTANCE READINGS
Figure 7

	Normal Output Resistance	-Sig to +Sig	-Exc to +Exc	+Exc to +Sig	+Exc to -Sig	-Exc to +Sig	-Exc to -Sig
LOAD CELL A	350Ω	350Ω	410Ω	292Ω	292Ω	292Ω	292Ω
LOAD CELL B	350Ω	350Ω	410Ω	292Ω	292Ω	295Ω	295Ω
LOAD CELL C	350Ω	350Ω	410Ω	289Ω	295Ω	289Ω	295Ω
LOAD CELL D	350Ω	∞	410Ω	292Ω	∞	292Ω	∞
LOAD CELL E	350Ω	700Ω	760Ω	380Ω	1080Ω	380Ω	380Ω

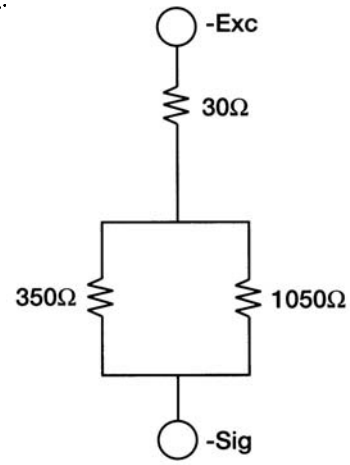
NOTE: An ohmmeter reading of ∞ is an infinity or open reading.

Figure 8

In example A of Figure 8, we see that the input resistance (-Exc to +Exc) is 410Ω. This is the sum of the 350Ω bridge and the equivalent resistance of the resistors placed in the excitation leads. The output resistance is 350Ω. All other resistances are identical. This is a good load cell. Let's examine how the 292Ω was obtained for the bridge resistances. We know that these four resistors are 350Ω resistors. We will look at the equivalent circuit that is being measured when we place our ohmmeter across the -Exc and -Sig leads.



We now simplify the circuit.
R_3, R_4, and R_2 are in series as are R_7 and the equivalent R_5/R_6 parallel combination. We can add these series resistors and simplify our circuit to the following.



The 350Ω and 1050Ω resistors are in parallel. To find the equivalent resistance we will use the formula $R_T = \frac{R_1 R_2}{R_1 + R_2}$.

$$R_T = \frac{350\Omega\,(1050)}{350\Omega + 1050} = \frac{367500}{1400} = 262\Omega$$

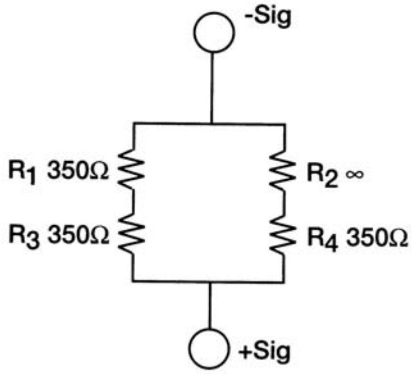
We now add the 30Ω series resistance for a total circuit resistance of 292Ω. The other resistances are calculated in the same manner.

In example B, the +Exc to +Sig and +Exc to -Sig readings are identical as are the -Exc to +Sig and -Exc to -Sig readings. Even though all the bridge resistance values are NOT the same, this load cell will operate properly. Both sides of the bridge are still balanced.

Referring to example C we see that the +Exc to +Sig and +Exc to -Sig readings differ from each other as do the -Exc to +Sig and -Exc to -Sig readings. This load cell is a damaged cell. It was probably mechanically overstressed and failed to fully return to its no load position. This cell should be condemned.

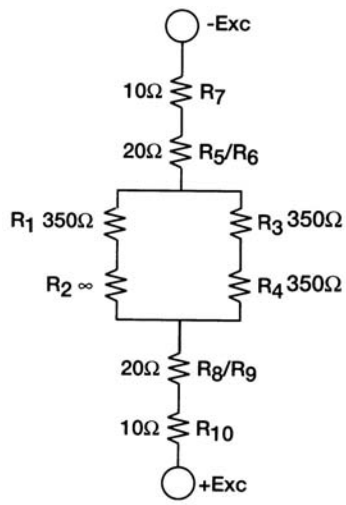
In example D we have some open readings. All the open readings occur whenever we are taking a measurement involving the -Sig lead. In this case the -Sig lead is open or became detached from the strain gauge. Depending upon the cost of the cell, it may be advantageous to have this cell repaired. We will look in depth at the strange readings found in example E. First of all, the problem is an open gauge. In this case it is R_2.

Our -Sig to +Sig measurement is represented by the following diagram (with R_2 open).



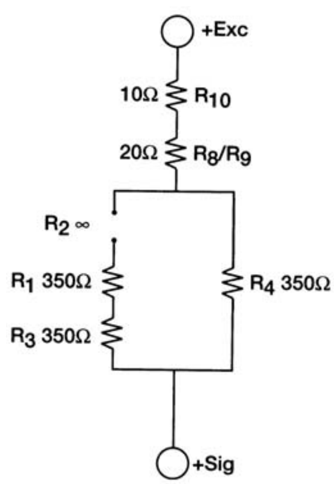
Total resistance is 700Ω ($R_1 + R_3$)

-Exc to +Exc measurement:



Since R_2 is open there is no path to complete our measurement through it. Our ohmmeter will read the sum of all resistances except R_1 and R_2 for a total of 760Ω.

+Exc to +Sig measurement:



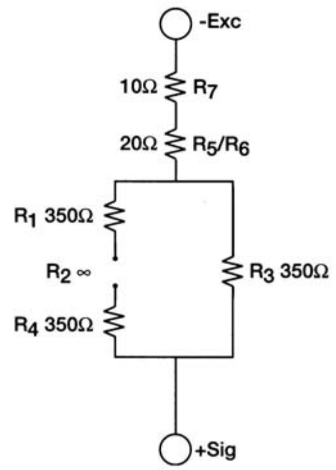
Since R_2 is open

$R_T = R_{10} + R_8/R_9 + R_4$

$R_T = 10\Omega + 20\Omega + 350\Omega$

$R_T = 380\Omega$

-Exc to + Sig measurement:



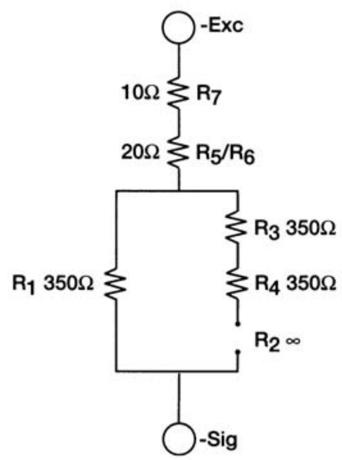
Since R_2 is open

$R_T = R_7 + R_5/R_6 + R_3$

$R_T = 10\Omega + 20\Omega + 350\Omega$

$R_T = 380\Omega$

-Exc to -Sig measurement:



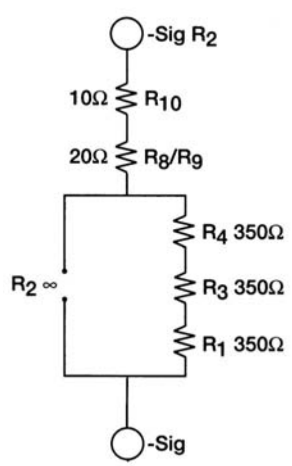
Since R_2 is open

$R_T = R_7 + R_5/R_6 + R_1$

$R_T = 10\Omega + 20\Omega + 350\Omega$

$R_T = 380\Omega$

+Exc to - Sig measurement:



Since R_2 is open

$R_T = R_{10} + R_8/R_9 + R_4 + R_3 + R_1$

$R_T = 10\Omega + 20\Omega + 350\Omega + 350\Omega + 350\Omega$

$R_T = 1080\Omega$

Whenever you are measuring the resistance of your load cell draw a diagram. It may help you see which resistors are actually in your measurement circuit.

You may not know the value of the compensation resistors. This will not keep you from being able to evaluate your load cell. Just remember:

- The +Sig to - Sig reading is the output bridge resistance and should be within 1% of the rated output resistance (normally 350Ω, 700Ω or 1000Ω).
- The +Exc to -Exc reading (bridge input) will normally be larger that the output reading as there are compensating resistors in the excitation circuit. See the calibration certificate for the normal input resistance.
- The -Exc to -Sig and -Exc to +Sig readings should match as should the +Exc to +Sig and +Exc to -Sig readings.

5.4 Resistance to Ground

Resistance to ground or electrical leakage, is often caused by water contamination within the cell or cable. An unstable output is a good indication of water contamination. The resistance between all load cell leads tied together and the load cell metal body should be 1000 megohms or higher. You can measure this very high resistance value with a megohm-meter (often referred to as a “megger”). The megger should not put out over 50 volts to prevent load cell damage. If the cell fails this test, remove the ground wire from the rest of the leads and retest with all leads except the ground wire connected together. If the test is now good (greater than 1000 MΩ), an insulation problem in the cable is suggested.

The Wheatstone bridge configuration amplifies the effects of leakage resistance between the signal leads and ground. A leakage resistance path of one megohm can cause an appreciable shift in zero load cell output. Leakage resistance does not seriously affect the calibration of the instrument but it will cause the instrument to appear to have unstable zero because leakage resistance is not steady.

!Caution:
Do not cut the load cell cable. The load cell is calibrated with a certain amount of cable attached. If the cable is cut, the warranty and calibration data will be void. When returning load cells for credit or evaluation, include the calibration data sheet to avoid a recalibration charge.

6.0 LOAD CELL CONSTRUCTION

OBJECTIVE: *Familiarization with load cell materials and sealing techniques.*

6.1 Materials

6.1.1 Aluminum Load Cells

Aluminum load cell elements are used primarily in single point, low capacity applications. The alloy of choice is 2023 because of its low creep and hysteresis characteristics. Aluminum load cells have relatively thick web sections compared to tool steel cells of comparable capacities. This is necessary to provide the proper amount of deflection in the element at capacity. Machining costs are usually lower on aluminum elements due to the softness of the material. Single point designs can be gauged for costs similar to those of bending beams.

6.1.2 Tool Steel Load Cells

Load cells manufactured from tool steel elements are by far the most popular cells in use today. The cost to performance ratio is better for tool steel elements compared to either aluminum or stainless steel designs. The most popular alloy is 4330 because it has low creep and low hysteresis characteristics. This type of steel can be manufactured to spec consistently, which means that minute load cell design changes don't have to be made every time a new lot or new steel vendor is selected.

6.1.3 Stainless Steel Load Cells

Stainless steel load cells are made from 17-4ph, which is the alloy having the best overall performance qualities of any of the stainless derivatives. Stainless steel cells are more expensive than tool steel load cells. They are sometimes fitted with hermetically sealed web cavities which makes them an ideal choice for corrosive, high moisture applications. Stainless steel load cells that are not hermetically sealed have little advantage over comparable cells constructed of tool steel, other than a higher resistance to corrosion.

6.2 Strain Gauge Protection Alternatives

Environmentally Protected, Non-Washdown

6.2.1 Potted Cell

One method of environmentally protecting a load cell is potting it with a special silicon-based material. This material feels sticky and gelatinous. It easily returns to its original shape after a force is applied to it. This is important as this potting material must not affect the operation of the cell. A 100% silicon material is not used, as this material is very corrosive. The potting material fills the strain gauge cavity and decreases the ability of moisture to reach the strain gauges.

Environmental protection of a load cell is necessary to help keep out unwanted contaminants, such as moisture, which will cause erratic cell operation. When installing load cells, run the cable so it slopes down, away from the cell. Moisture in the cable will work its way to the load cell. It is also good practice to allow the conduit a way to drain moisture out of itself. An environmentally protected cell is not suitable for high moisture, steam, or washdown applications (see hermetically sealed on page 28).

6.2.2 Foam Backed Plate

Some load cell strain gauge cavities are protected by a foam backed plate that is secured over the cavity. This type of protection affords some moisture and foreign object protection but does not protect the cell as well as the potting material of a potted cell.

6.2.3 Neoprene Sleeve

Another type of environment protection is the use of a neoprene sleeve or boot. The boot covers the strain gauge cavity and is secured by clamps. The strain gauge cavity is easily accessed for repair. If the boot is not lubricated, it will crack which will, of course, allow moisture into the cell cavity. It is good practice to lubricate this sleeve during routine inspections.

Washdown

6.2.4. Hermetically Sealed

The hermetically sealed load cell gives the best protection against moisture and other contaminants. The cavity is covered with a metal cap which is sealed by soldering it to the body. A true hermetically sealed load cell also has a welded header where the cable terminal leads are soldered. This prevents water from wicking into the load cell body itself. These cells are the most expensive cells but are required in high moisture and washdown environments.

6.2.5. Welded Seal

A welded seal load cell can be constructed of stainless or alloy steel. The gauge cavity is covered with a metal cap which is sealed by soldering it to the load cell body. Unlike a true hermetically sealed load cell, a welded seal load cell does not have a welded header where the load cell cable enters the load cell. The load cell cable should be run through conduit for acceptable use in mild washdown environments.

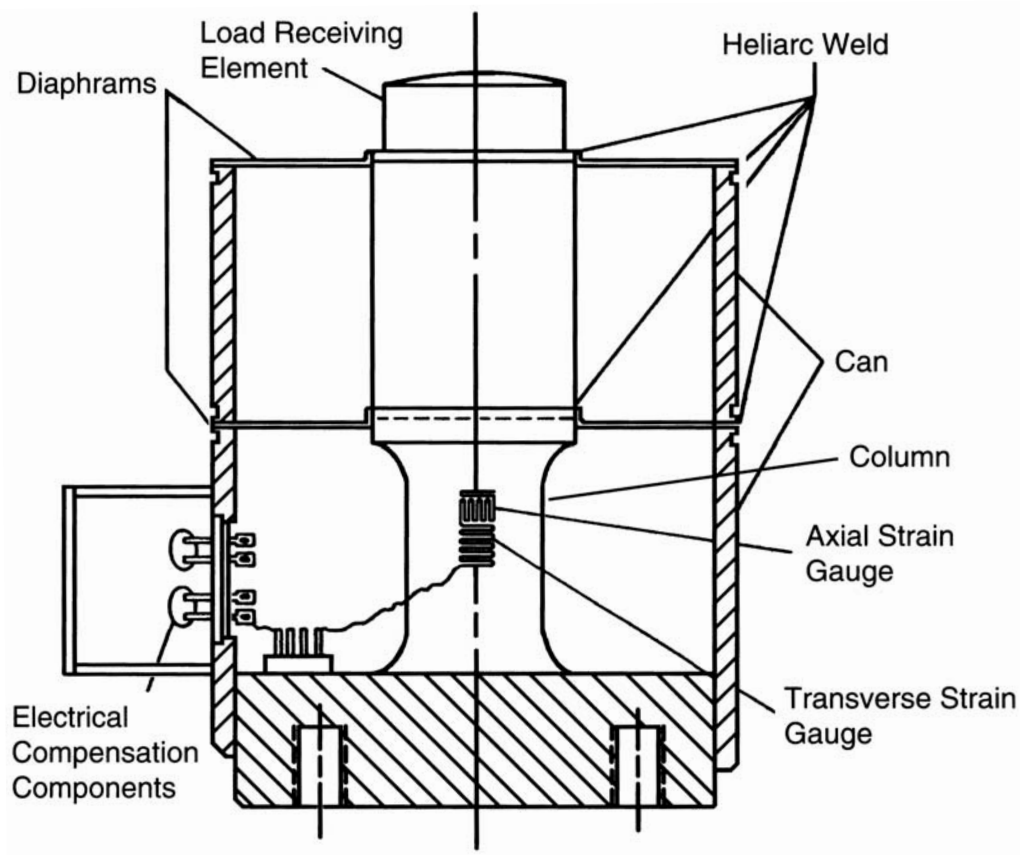
7.0 LOAD CELL TYPES

OBJECTIVE: *Identify load cell types and their applications.*

Load cells are built in various sizes and types for various applications. We will look at the different type of load cells.

7.1 Canister

The canister cell is the earliest load cell design. It is either hermetically sealed or welded to protect the gauges. See Figure 9-- Canister Load Cell.



CANISTER LOAD CELL
Figure 9

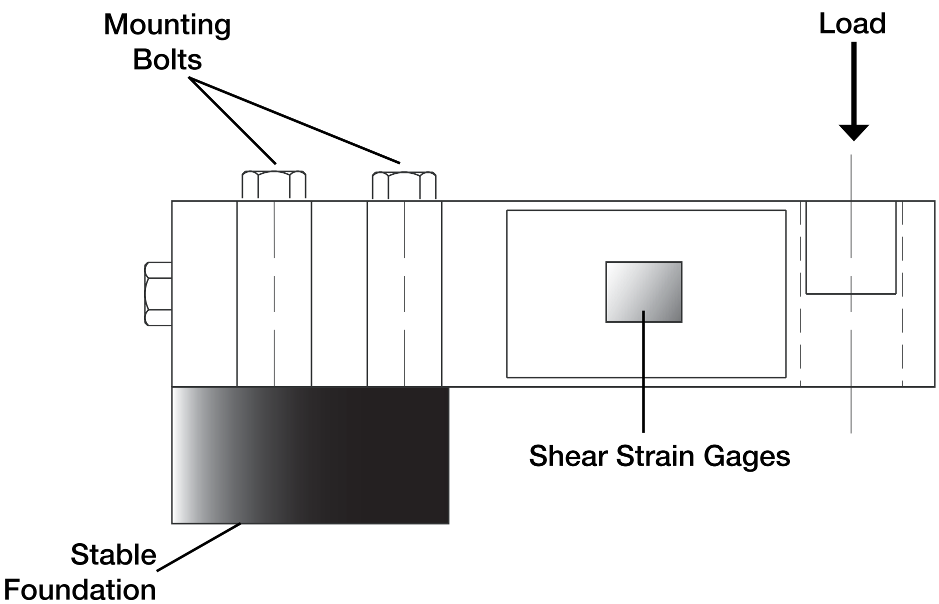
Canister cell popularity is waning as their cost is 2 or 3 times that of a bending beam cell. There are two types of canister construction, single column and multiple column. Single column canisters cannot normally withstand a side load of over 15%. Multiple column canister cells withstand more side load than the single column variety. The canister cell ranges in size from 100 lbs up to 500,000 lbs. The normal safe overload is 150% of full scale (F.S.) but some models are able to withstand a 300% F.S. overload. There is no means through visual inspection or labeling to identify which cells are singular or multiple column. Refer to original manufacturer's specifications or Rice Lake Weighing Systems' Load Cell Product Selection Guide to determine your cell's specifications.

Canister cells are made of high alloy tool steel with an epoxy finish, or stainless steel. Their rated excitation ranges from 10 VDC to 20 VAC/DC. Common bridge resistances are 350Ω and 480Ω.

When replacing a compression type load cell, you should also replace the bearing plate. This plate contacts the load button and applies the load to the cell. Over years of use the point where the bearing plate contacts the load button becomes worn and forms a cup. The new load cell load button will fit into that worn cup and cause side stress on the new load cell. In a few months you will probably be replacing that new load cell. If you fabricate the bearing plate yourself you will need to have it hardened. Some technicians turn the bearing plate over. If the plate is not hardened on the new side it may wear prematurely.

The single ended shear beam cell is designed for low profile scale and process applications. The shear beam cell strain gauge cavity contains a thin metal diaphragm onto which the strain gauges are mounted. Typical shear beam capacities range from 1,000 lbs through 20,000 lbs, although some manufacturers offer shear beams up to 40,000 lbs. One end of the shear beam contains the mounting holes while the opposite end is where the cell is loaded. The cell should be mounted on a flat, smooth surface with high strength hardened bolts. The larger shear beam cells have more than two mounting holes to accommodate extra bolts to keep the hardware from stretching under stress load. See Figure 10-- Single Ended Shear Beam.

Shear beams operate best in a temperature range of +15°F to 115°F. Their maximum safe operating range with minimum performance change is from 0°F to 150°F. Shear beam zero outputs should be frequently checked when operating at high temperatures. These cells may be overloaded statically up to 150% of rated load without damage. Overloads



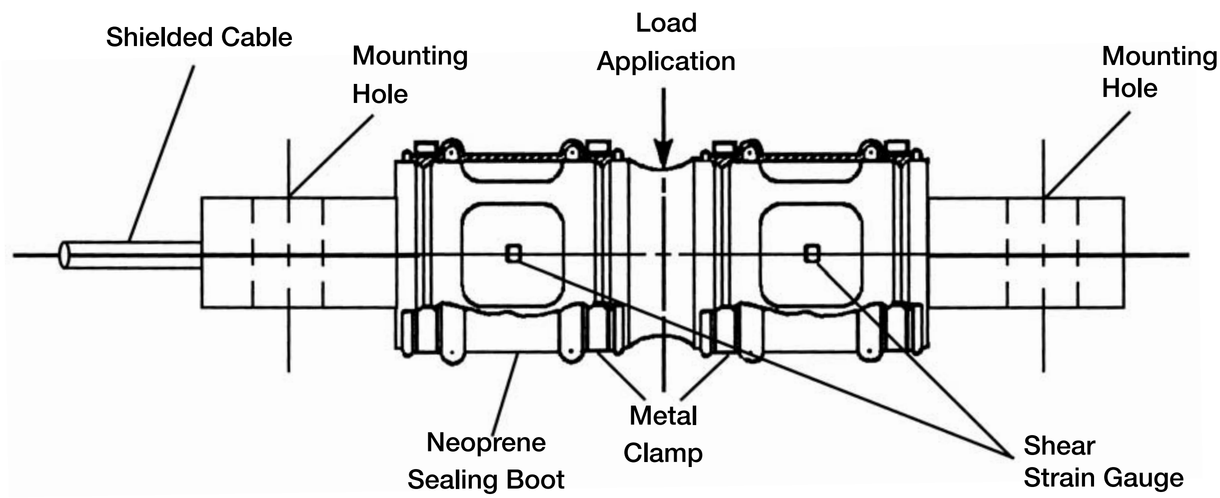
SINGLE ENDED SHEAR BEAM
Figure 10

in excess of the safe overload rating may permanently affect the accuracy and performance of the load. Shock loads having peak values in excess of 120% of rated cell capacity may also affect the calibration and should be avoided.

Shear beams may be constructed of tool steel or stainless steel for use in harsh environments. Just because a cell is made of stainless steel <u>does not</u> mean it can be used in washdown environments.

7.3 Double Ended Shear Beam

The double ended shear beam characteristics are similar to those of the single ended shear beam. The most common bridge resistance for this load cell is 700Ω. It is most commonly used in truck scales and tank and hopper applications. Instead of being secured at one end and the load applied to the other end as in the single ended shear beam, the double ended shear beam is secured at both ends and the load is applied to the center of the load cell. As in all shear beam designs the strain gauges are mounted on a thin web in the center of the cell's machined cavity. See Figure 11 – Double Ended Shear Beam.



DOUBLE ENDED SHEAR BEAM
Figure 11

7.4 Cantilever Beam

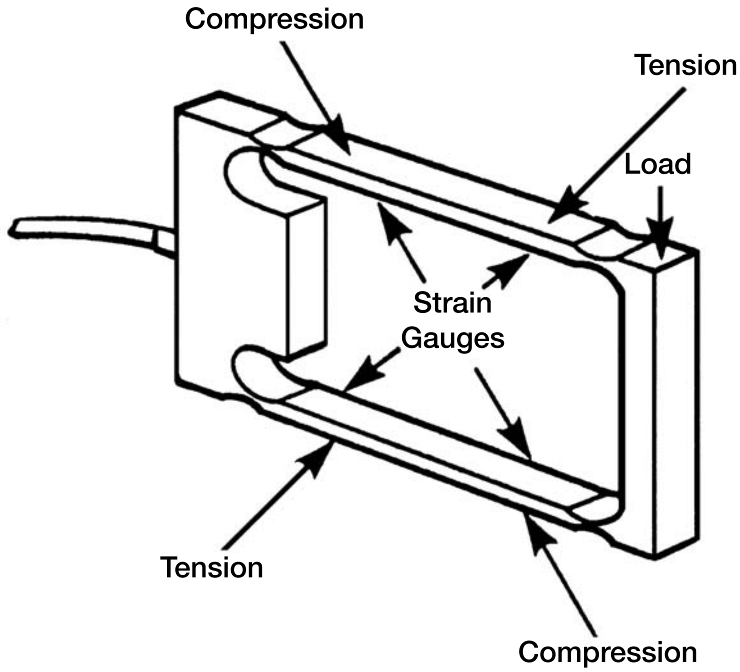
Cantilever beams are similar to shear beams. However, the cantilever beam does not have a thin web located in the strain gauge cavity. The cantilever beam is machined all the way through. The strain gauges are mounted along the inner edges of the cavity. Most cantilever beams have a bridge resistance of 350Ω and either 3 mV/V or 2 mV/V full scale outputs. They range from capacities of 25 lb up to 10,000 lbs. However, there may be a few larger cantilever beams being used. They can be used in tension or compression applications.

7.5 S Beam

S Beam load cells derive their name from their shape which, of course, is the shape of the letter S. The S beam is normally used in tension applications. However, there are S beams available which are bidirectional. They are primarily used for mechanical-to-electronic scale conversions, platform scale and general purpose weighing applications. They vary in size from as low as 25 lbs to as high as 20,000 lbs. When mounting an S beam, remember to include the side from which the cable extends in the dead portion of the system. Movement of the cable in the live part of the system can be a source of weighing errors.

7.6 Platform

The platform load cell is sometimes called a dual-guided cantilever beam cell but is more commonly referred to as a single point cell. They are used in light capacity bench scales. They are most commonly made out of aluminum. Some platform scales have built-in overload stops. Safe overloading of 200% full scale is permissible at the center loading point on some platform load cells. They are commonly made in 2 kg through 1000 kg and 2 lbs through 1000 lb sizes. The bridge resistance is commonly 350Ω. See Figure 12—Platform Load Cell.



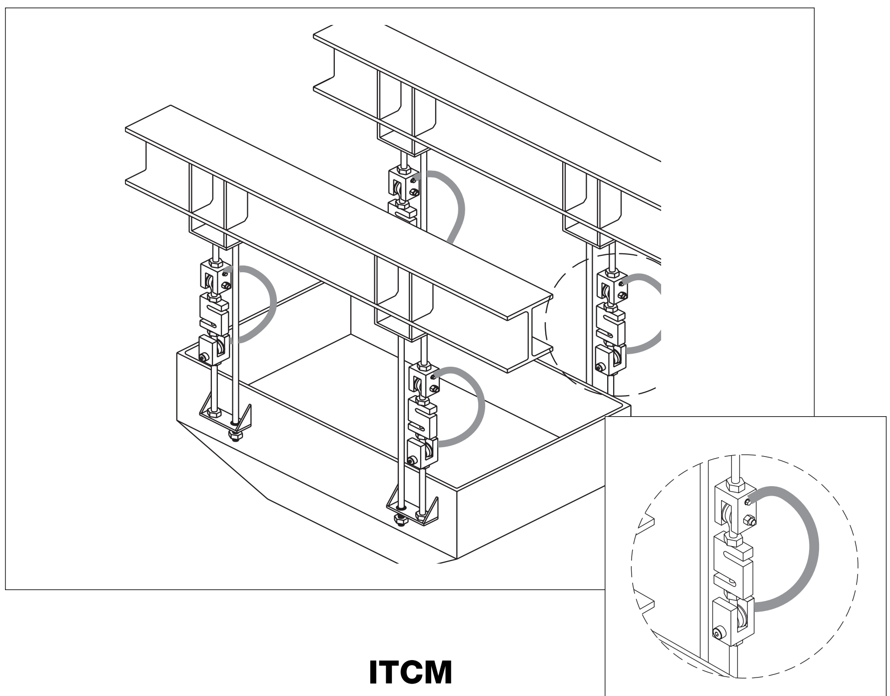
PLATFORM LOAD CELL
Figure 12

8.0 LOAD CELL MOUNTING ASSEMBLIES

8.1 Tank and Hopper Kits

8.1.1 Isolated Tension Cell Mounting Assembly (ITCM)

The ITCM is designed for tank and hopper weighing applications and mechanical scale conversions. It utilizes an S beam load cell mounted between clevis and rod end ball joint assemblies. This construction reduces the overall length to less than half of the traditional tension cell mounts. The clevis mounts with nylon insulating washers and Teflon™-lined rod end ball joints, thus isolating the load cell from stray currents. Additional electrical protection is provided by a bonding strap connecting the two clevis assemblies, routing stray currents around the load cell. Capacities range from 100 lbs through 20,000 lbs per assembly. See Figure 13—ITCM.



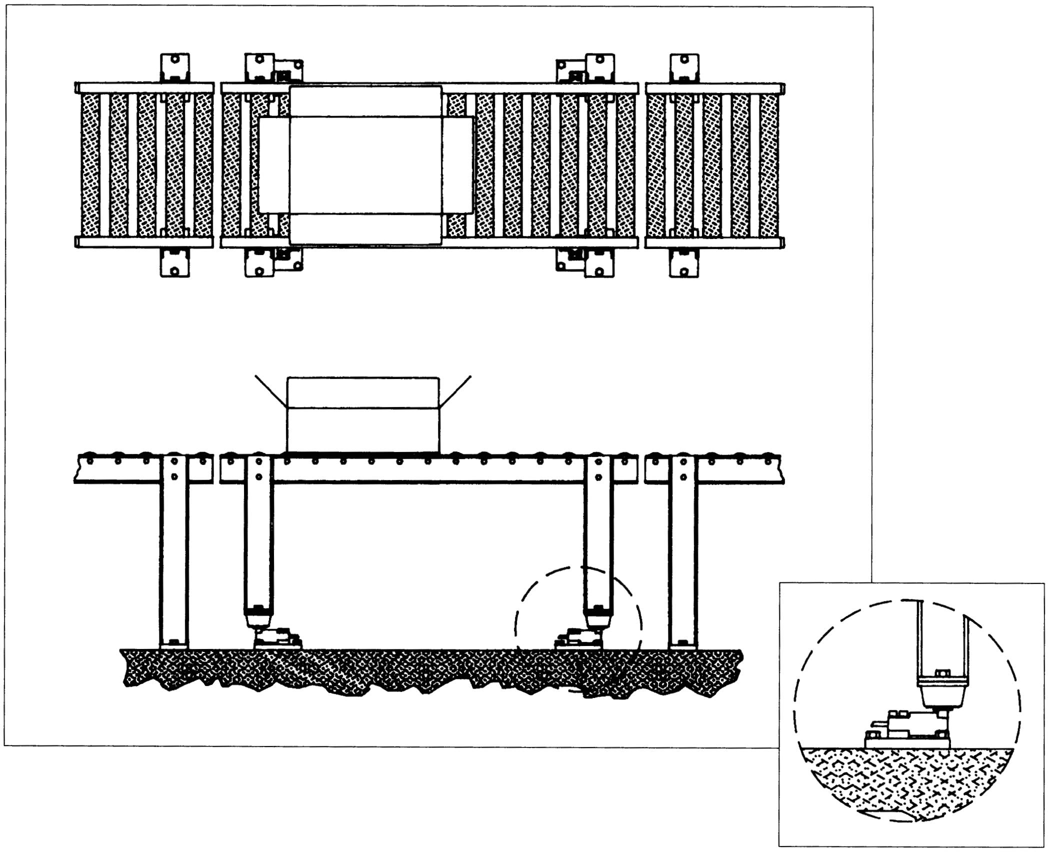
ITCM
Figure 13

- RL20000 NTEP Certified S beam Load Cell
- JB4SS NEMA 4X Stainless Steel signal trim J-box
- 25 ft. of hostile environment load cell cable

8.1.2 RL50210TA Mini Tank Weighing Assembly

The RL50210TA provides a cost-effective alternative for low range weighing requirements. Beside tank and hopper applications, this assembly can be used for small platform scales where shock loading may be a problem and for conveyor/in-motion weighing. The 50 lb, 100 lb, 150 lb and 250 lb assemblies come with a RL50210 cantilever beam load cell. A RL35023 single ended beam load cell is used for the 500 lb to 2500 lb models. Neoprene isolation/compression mounts allow for minor misalignment, thermal expansion and shock absorption. See Figure 14—RL50210TA Tank Weighing Assembly.

- JB4SS NEMA 4X stainless steel signal trim J-Box
- 3 or 4 RL50210 or RL35023 load cells
- Neoprene isolation/compression mounts
- 25 ft. of hostile environment load cell cable



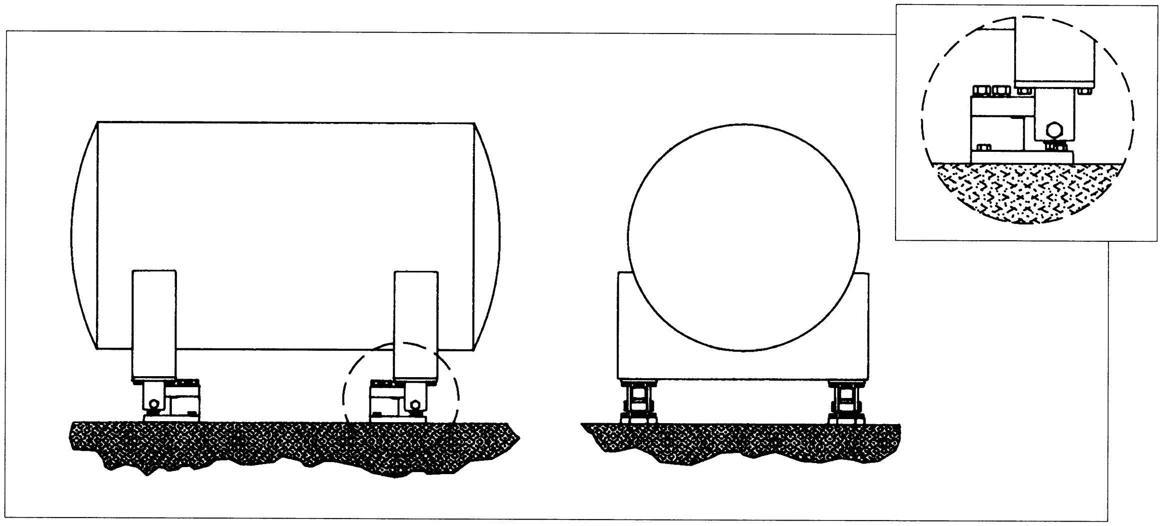
RL50210TA TANK WEIGHING ASSEMBLY
Figure 14

8.1.3 RL1800 Series Mounting Assembly

The RL1800 assembly is designed for medium range capacities (250 lbs - 10,000 lbs). Available in stainless steel or mild steel, the 1K, 2K, 2.5K, 4K, 5K and 10K load cells are NTEP certified (1000-10,000 lbs). The assembly utilizes the RL35023 shear beam load cell. The RL1800 is a center-pivoted, tension loaded design mount. The load is suspended on a high strength bolt. It is self-checking with multi-directional movement. The mount also can be ordered with RL35023S stainless steel NTEP load cells in 1000-10,000 lb capacity. See Figure 15—RL1800 Series Mounting Assembly.

The RL1800 is also compatible with the following load cells:

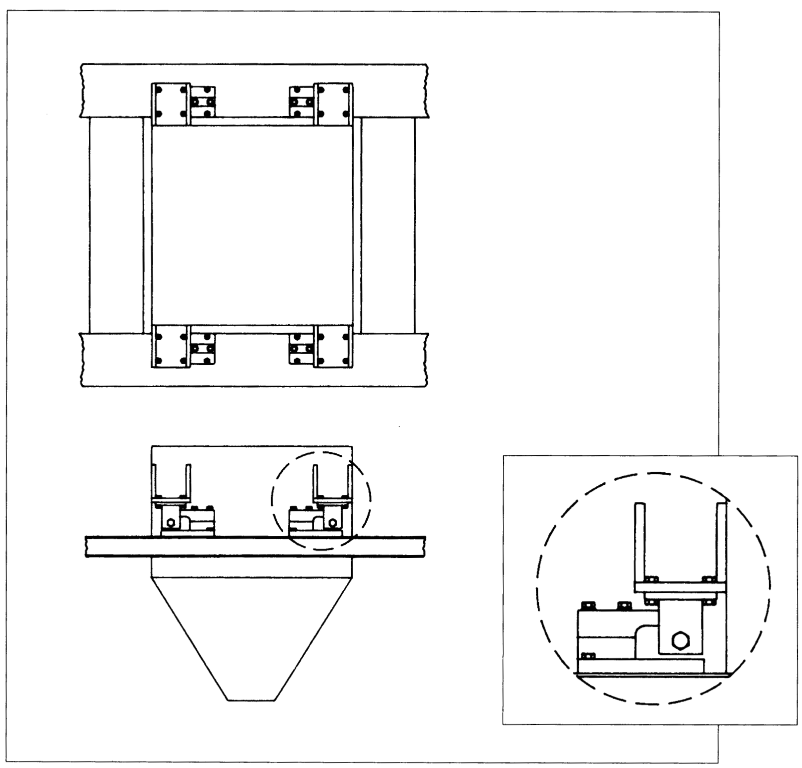
- RL35023
- RL35082
- RL35083
- Sensortronics 65023-5107
- Sensortronics 65023-0113
- Sensortronics 65023S-5113
- Sensortronics 65083
- RTI 5123
- RTI 9123
- Celtron SQB



RL1800 SERIES MOUNTING ASSEMBLY
Figure 15

8.1.4 RL1900 Series Mounting Assembly

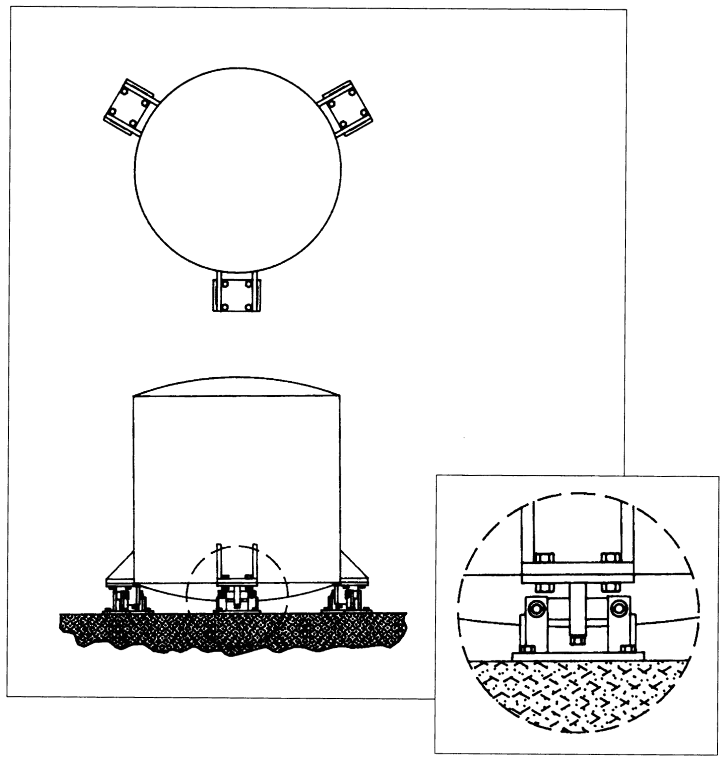
The RL1900 design is similar to the RL1800 except the RL1900 is a stainless steel mount, utilizing a stainless steel, RLSSB welded seal load cell. It is available in capacities of 1K, 2K, 5K and 10K. The RL1900 is also compatible with RTI SSB and HBM SB3 load cells.



RL1900 SERIES MOUNTING ASSEMBLY
Figure 16

8.1.5 RL1600 Series Tank Weighing Assembly

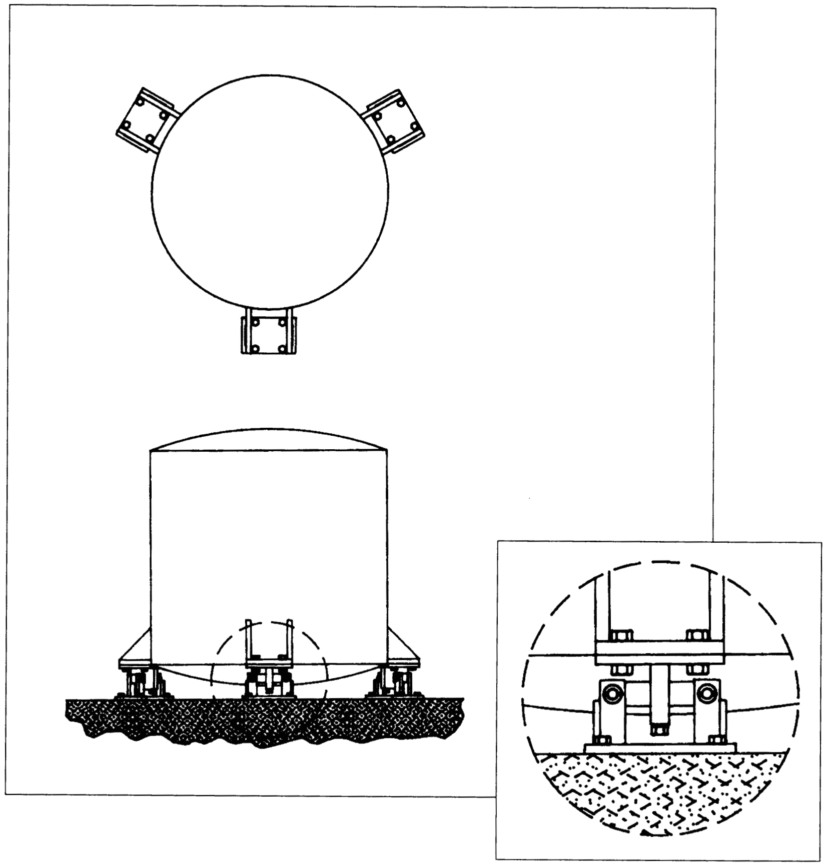
The RL1600 is used for medium to heavy tank and hopper weighing applications. It is available in capacities ranging from 1K through 75K. Its self-checking, easy-to-use design allows the assembly to be bolted directly to the tank leg without requiring additional mounting plates or load buttons. The standard mount is of zinc plated steel construction with a RL75016 double ended shear beam load cell. There is an optional stainless steel model available which utilize the RL75016SS stainless steel load cell or the RL75016WHE hermetically sealed stainless steel load cell. The RL1600 is compatable with Sensortronics 65016, 65016W and 65016WH and Celtron DSR. See Figure 17—RL1600 Series Tank Weighing Assembly.



RL1600 SERIES TANK WEIGHING ASSEMBLY
Figure 17

8.1.6 EZ MOUNT 1 - Tank Weighing Assembly

The EZ MOUNT1 Assembly is a medium to high capacity mount ranging from 5K through 250K. It uses a RL70000 double ended shear beam load cell. The load cells are NTEP ceritified in capacities of 5K-200K. Its sliding pin design compensates for temperature variations. This mount can be bolted directly to the tank and floor. It is a self-checking mount. See Figure 18—EZ Mount 1 Tank Weighing Assembly. Stainless steel mounts using the RL71000HE hermetically sealed load cells are also available.



EZ MOUNT 1 TANK WEIGHING ASSEMBLY
Figure 18

8.1.7 Paramounts®

Paramounts® kits are used for mounting SB4 or SB10 load cells to vessels, tanks, hoppers, platforms and roller tables in light to medium applications. They are useful where thermal expansion and contraction of the weighing vessel are likely, and where dimensional changes caused by loading can occur. Each Paramounts® kit includes:

- One JB4SS Junction Box
- One fixed pin mount with SB4/SB10 load cell
- One side stop mount with SB4/SB10 load cell
- One (or more) free sliding mount(s) with SB4/SB10 load cell(s)
- 25 ft. of load cell cable

Fixed pin mounts allow the top plate to rotate only. Side stop mounts allow the top plate to slide along the cell only. Free sliding mounts allow the top plate to slide freely in all directions. See Figure 19.

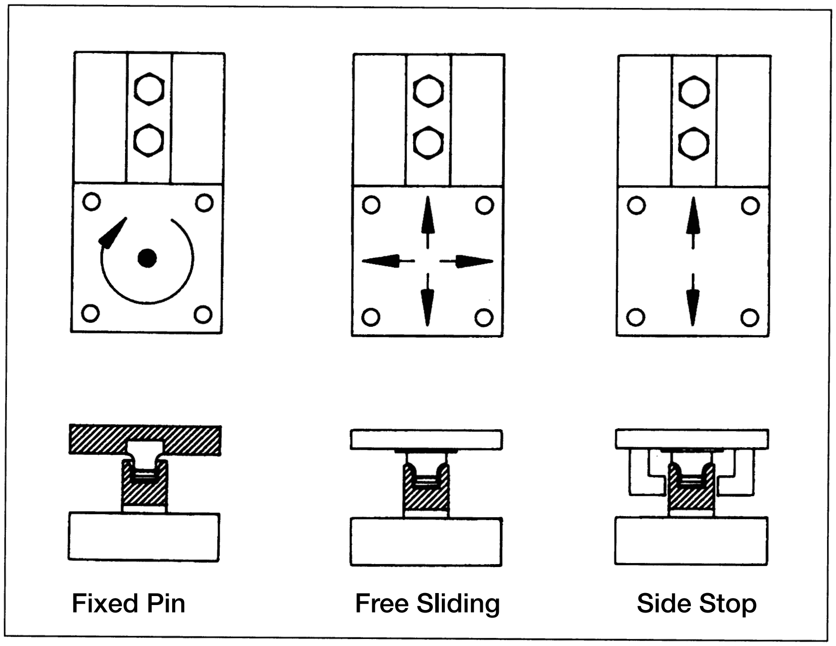


Figure 19

The free sliding and side stop mounts have loading pins with Teflon™ coated top surfaces that slide on stainless steel plates attached to the underside of the top plates. The following figures show some typical applications. See Figures 20-A, B, C, D, and E.

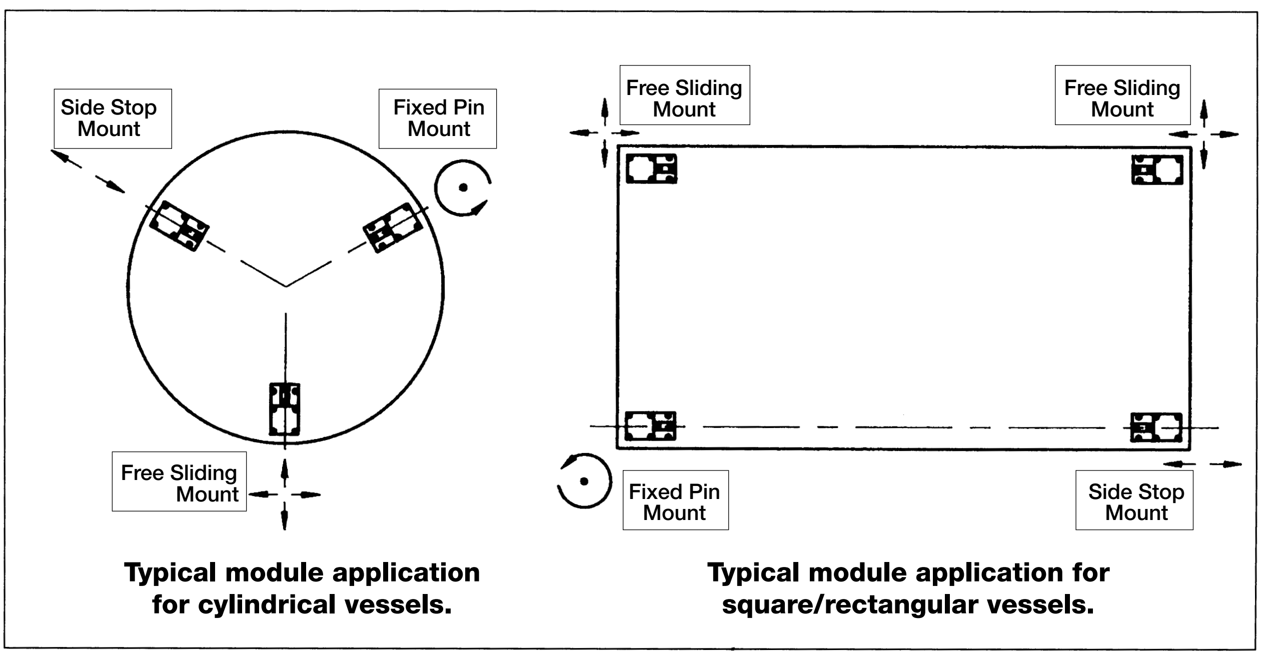


Figure 20-A

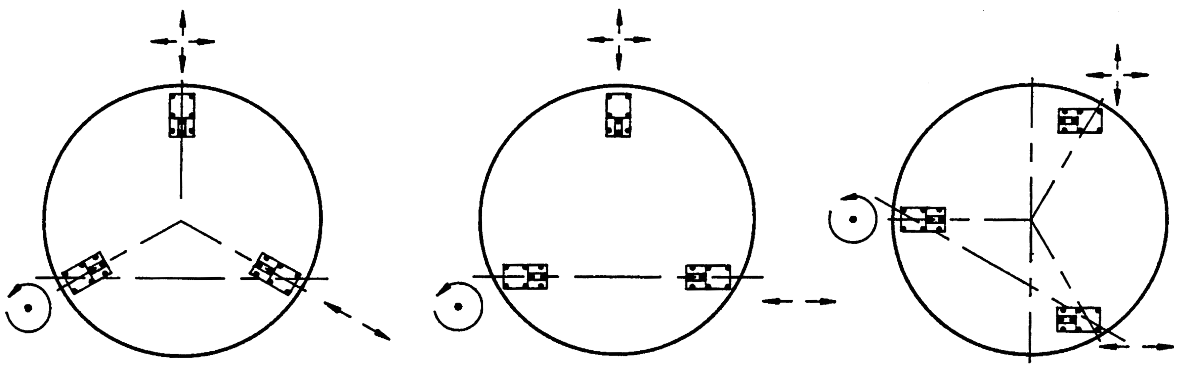
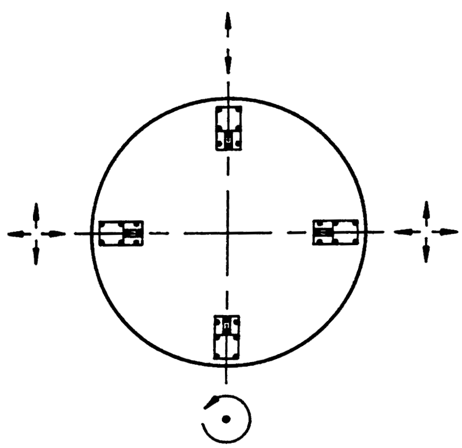
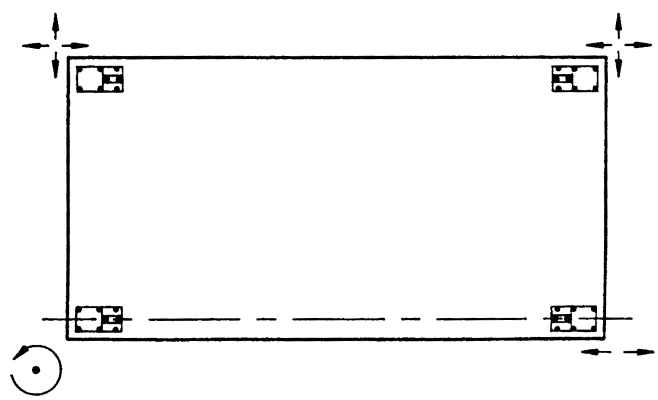


Figure 20-B



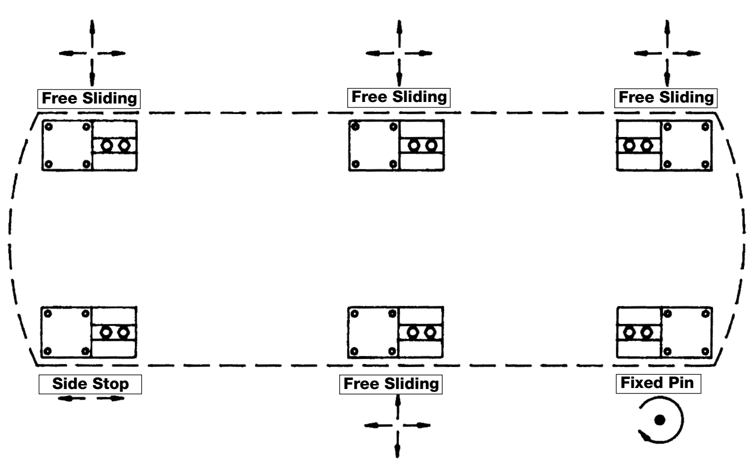
Four load cells
on round vessel

Figure 20-C



Four load cells on
rectangular vessel

Figure 20-D



Six load cells on rectangular vessel

Figure 20-E

Paramounts® are available in capacities of 1 kilonewton (225 lbs) through 100 kilonewton (22,500 lbs). The SB4/SB10 cells are hermetically sealed and made of stainless steel. A jacking screw allows the EMPTY vessel to be lifted clear of the load cell for maintenance. The cell outputs are matched to ±.07%. It should not be necessary to trim the load cell outputs because of their closely calibrated outputs. The trimming capability of the EL604ET J-box is disabled by the presence of shunt wires. A Paramounts® Installation Manual is available.

8.2 MVS

The MVS Assembly unilink suspension design checks lateral assembly movement while allowing controlled floating of the scale deck. The need for check rods, links, and expansion assemblies is eliminated. The MVS is designed to be used with the RL75058 and Sensortronics load cell model 65058A, or optional stainless steel model RL75060 (ordered separately), which is a double ended shear beam design. Besides truck scale applications, the MVS can be used for track and horizontal tank applications. Its capacities range from 10K through 125K.

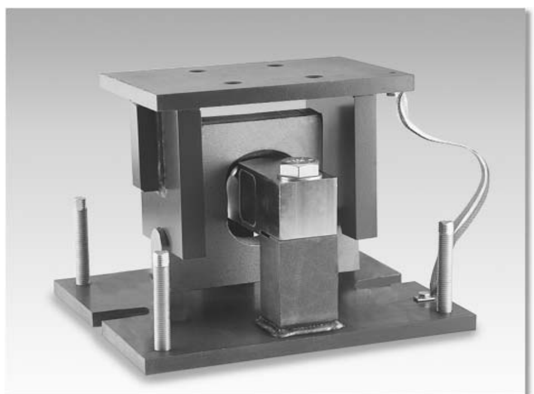


Figure 21

8.3 TransLink

The Translink load cell mount is used for heavy capacity tank and truck weighing applications. The mount is made of fabricated and hardened tool steel in capacities of 25,000 lb to 100,000 lb. The pendulous action of the links allows self-centering of the weighing platform, and the platform has free movement in all directions in the horizontal plane. Install platform bumpers to prevent overtravel.

The mount is compatible with four different tool steel, double ended shear beam load cells. The RL75040 and the Sensortronics 65040A load cells are environmentally protected styles, whereas the RL75223, RTI 5223, and Sensortronics 65040S load cells are welded seal styles.

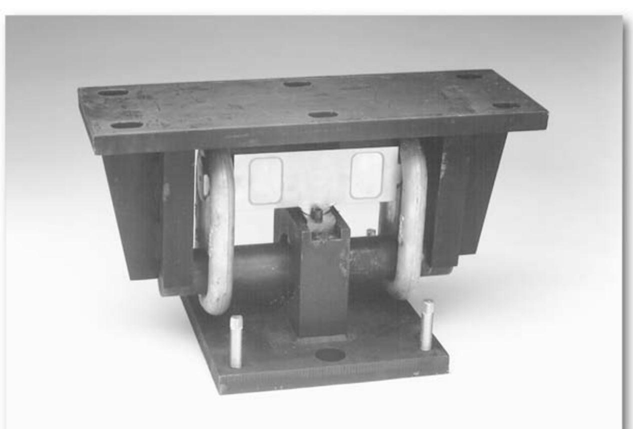


Figure 22

9.0 LOAD CELL SELECTIONS

OBJECTIVE: *Select proper load cell size and determine output sensitivity.*

9.1 Mechanical to Electronic Conversion

It is sometimes necessary to convert a mechanical scale indicator (balance beam or mechanical dial) to an electronic indicator. The electronic indicator provides a direct weight readout and output signals which can be sent to a number of types of peripheral equipment, such as printers, computers, data loggers, programmable controllers and remote displays. The cost of the electronic indicator and load cell may be more economical than maintaining that mechanical dial.

9.1.1 Determine Scale Multiple

You must first determine the scale multiple or pull at the point of the load cell installation. The load cell is normally installed in the steelyard rod, which connects the transverse lever to the balance beam or cabinet dial tare lever. Figures 23 and 24 show locations of the steelyard rod.

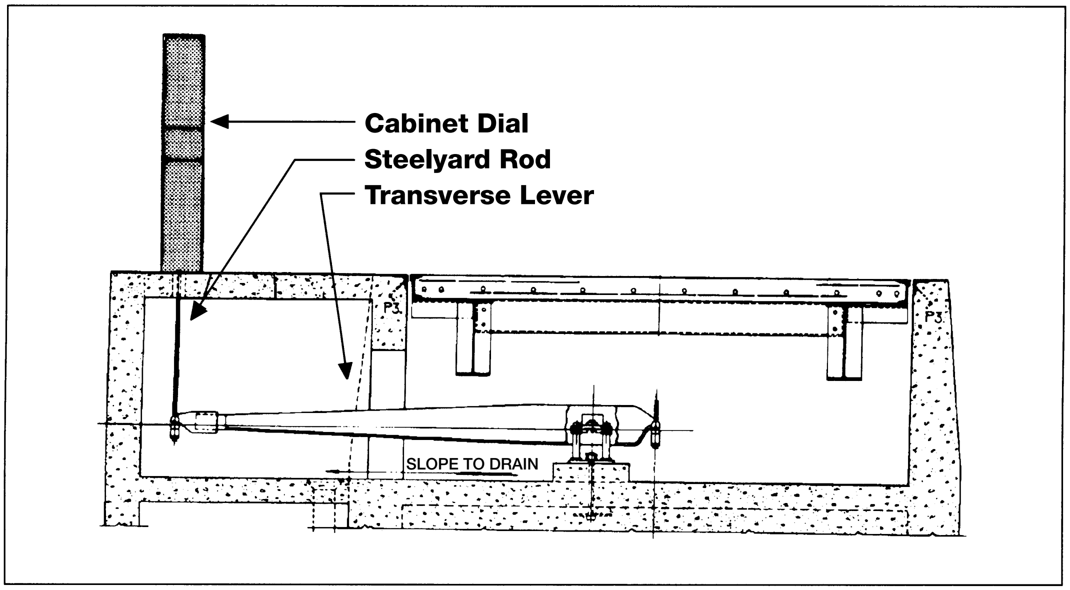


Figure 23

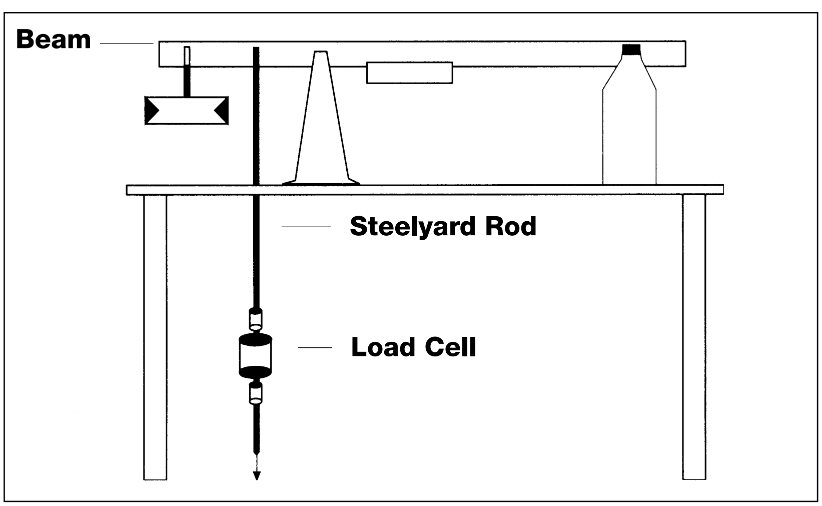


Figure 24

You may have an information sheet for your scale that gives you the scale multiple. However, with most old scales this sheet is no longer available. You still can determine the multiple by using the following procedure.

- Balance the scale at zero
- Hang a 1 lb weight on the steelyard rod
- Rebalance the scale and read the new value

The new value is the scale multiple. The multiple is typically 20:1 or 25:1 on dormant scales and 400:1 on motor truck scales.

9.1.2 Load Cell Size

Now that you know the scale multiple, you must determine the proper load cell size. If you choose a load cell that is too light, you may overload it. If you choose a cell that is too heavy, its output may be insufficient to maintain a proper and stable indicator reading. The load cell size equals the sum of the live load (scale capacity) plus the dead load (weight of weighbridge and levers) divided by the scale multiple

$$\text{Load Cell Size} = \frac{\text{Live Load (LL)} + \text{Dead Load (DL)}}{\text{Scale Multiple}}$$

If the required load cell size falls between commonly manufactured load cell sizes, then choose the next higher load cell size.

Let's use the following example and determine the proper load cell size.

Live Load = 5000 lbs
Dead Load = 1000 lbs
Scale Multiple = 20

Using our formula:

$$\begin{aligned} \text{Load Cell Size} &= \frac{\text{LL} + \text{DL}}{\text{multiple}} \\ &= \frac{5000 \text{ lbs} + 1000 \text{ lbs}}{20} \\ &= \frac{6000 \text{ lbs}}{20} \\ &= 300 \text{ lbs} \end{aligned}$$

Three hundred pounds (300 lbs) is not a common load cell size. The next higher common load cell is 500 lbs. You don't want to select a cell lower than 300 lbs as it would be overloaded.

If the scale is to be used in a Legal-for-Trade application where NTEP is a requirement, then consult RLWS' publication "What is Handbook 44 & What is NTEP" for guidance in selecting a suitable load cell.

9.1.3 Microvolt Per Graduation

So now we know how large our load cell has to be. But will the selected load cell develop enough signal to provide a stable indicator display? The analog input sensitivity or microvolt per graduation (µV/grad) rating of indicators vary, depending on manufacturer and indicator gain settings. Typical µV/grad ranges are from 1 µV/grad to 30 µV/grad. The µV/grad rating tells us how much signal it takes to change the display by one graduation . See the manufacturer's manual for your particular indicator. Using our previous example, let's figure our µV/grad sensitivity.

Live Load = 5000 lbs
Dead Load = 1000 lbs
Scale Multiple = 20
Load Cell Size = 500 lbs

With 5000 lbs of live load on the scale having a multiple of 20, the live load felt by the load cell is 250 lbs.

$$\text{Live Load on Cell} = \frac{\text{LL}}{\text{multiple}}$$

$$= \frac{5{,}000 \text{ lbs}}{20}$$

$$= 250 \text{ lbs}$$

The live load, 250 lbs, comprises 50% of our total load cell capacity of 500 lbs.

If our 500 lb load cell is rated at 3 mV/V, it will output 3 mV for each volt of excitation voltage applied at full load. If we apply 15 volts of excitation, the load cell will output 45 mV, with 500 lbs applied (3 mV/V x 15V = 45 mV).

Since only 50% of our load cell is being utilized by the live load, then the live load millivolt output will be 22.5 mV or 22500 µV. (45 mV x .5 = 22.5 mV). To determine the µV/grad of our load cell, divide the live load microvolt output by the number of graduations for which our indicator is programmed. We will program our indicator for 5000 graduations to weigh 5000 lbs in l lb graduation sizes.

$$\mu\text{V/grad} = \frac{\text{Live load output } (\mu\text{V})}{\text{Programmed Graduations}}$$

$$= \frac{22{,}500 \ \mu\text{V}}{5{,}000}$$

$$= 4.5 \ \mu\text{V/grad}$$

This signal is sufficient for most indicators. Check your indicator manual to be sure your load cell output is adequate for your indicator.

The following formula can also be used to figure µV/grad.

$$\mu\text{V/grad} = \frac{\text{Load cell rating (mV/V) x Excitation Voltage (V) x grad size (lb/grad)}}{\text{Scale ratio x load cell size}}$$

$$= \frac{3 \text{ mV/V (15V) (1 lb/grad)}}{20 \ (500)}$$

$$= \frac{4{,}500 \ \mu\text{V(1 lb/grad)}}{10{,}000 \text{ lbs}}$$

$$= 4.5 \ \mu\text{V/grad}$$

9.2 Tank and Hopper

We have previously selected a load cell for a mechanical - electronic conversion. Now we will select load cells for an electronic weighing system utilizing a tank. We will use three load cells for our configuration. The following information about our system is known:

Live Load = 10,000 lbs
Dead Load = 2,000 lbs
Scale Capacity = 10,000 lbs x 2 lbs

Load Cell Output = 3 mV/V
Excitation = 10V

To figure out our total system weight at capacity we add the live load and dead load.

Total System Weight = LL + DL
= 10,000 lbs + 2,000 lbs
= 12,000 lbs

The weight will be shared equally by all the cells, so each cell will handle 4,000 lbs (12,000 lbs ÷ 3). The cells we have available are 5,000 lb load cells, so the total load cell capacity is 15,000 lbs. Given 10 volts of excitation and a full capacity load cell output of 3 mV/V, our load cells will output 30 mV at full load (15,000 lbs). Our live load is 10,000 lbs. At 10,000 lbs our load cell will output 20 mV. This is calculated by finding the ratio of live load to load cell capacity and multiplying this ratio by our full scale millivolt output.

$$\text{Live Load Output} = \frac{\text{Live load}}{\text{Load cell capacity}} \times \text{Full Scale mV/output}$$

$$= \frac{10{,}000 \text{ lb}}{15{,}000 \text{ lb}} \times 30 \text{ mV}$$

$$= 2/3 \times 30 \text{ mV}$$

$$= 20 \text{ mV}$$

To determine our µV/grad sensitivity we will divide the live load signal by our scale resolution. Since our scale capacity is 10,000 lbs x 2 lb graduations, our resolution is 5000 graduations.

$$\mu\text{V/grad} = \frac{20 \text{ mV}}{5000 \text{ grads}}$$

$$= \frac{20{,}000\ \mu\text{V}}{5000 \text{ grads}}$$

$$= 4\ \mu\text{V/grad}$$

Using our formula method, our calculations are as follows:

$$\mu\text{V/grad} = \frac{\text{load cell rating (mV/V) x Excitation voltage (V) x grad size (lb/grad)}}{\text{No. of load cells x load cell size}}$$

$$= \frac{3 \text{ mV/V} \times 10\text{V} \times 2 \text{ lb/grad}}{3 \times 5000}$$

$$= \frac{60{,}000\ \mu\text{V lb/grad}}{15{,}000 \text{ lbs}}$$

$$= 4\ \mu\text{V/grad}$$

Using either method, our load cell output sensitivity is 4 µV/grad.

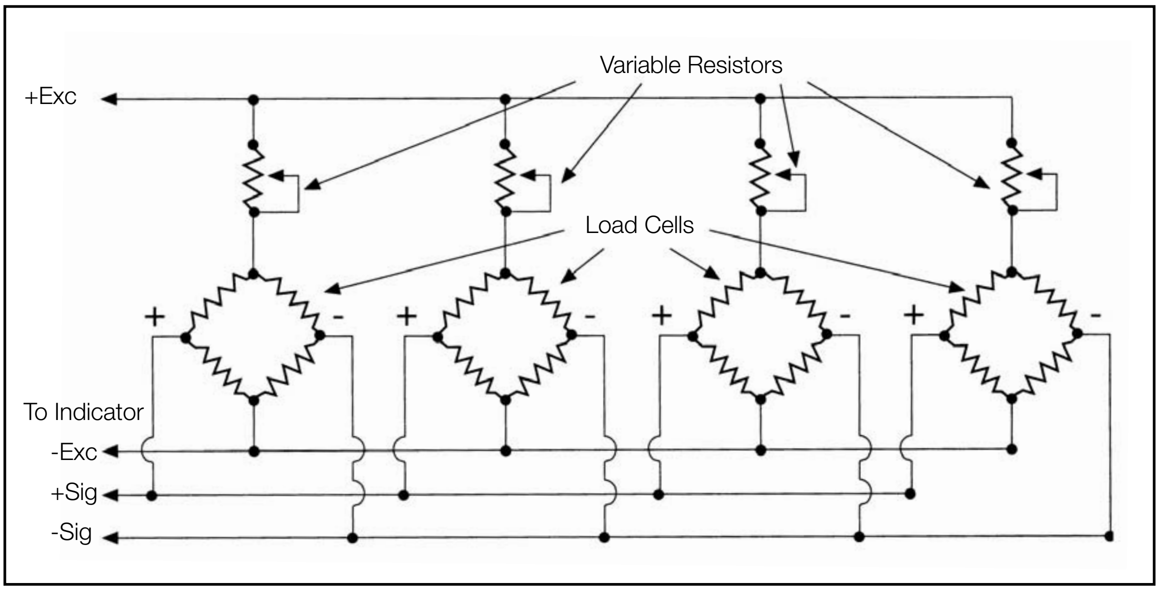
10.0 LOAD CELL TRIMMING

OBJECTIVE: *Perform excitation and signal load cell trimming.*

When using load cells in parallel it is essential to match their outputs. It is much cheaper to manufacture load cells with outputs that are not exactly matched and trim them in the field than to manufacture load cells with outputs that are exactly matched. A device called a junction box is used to tie the multi-cell system leads together to provide a single entry point for load cell excitation and a single exit point for the load cell system signal. Variable resistors are also provided to trim or adjust the load cell signal. Each load cell has a different sensitivity than others parallel to it. When weight is placed on the scale, the load cells do not react with the same output. By trimming these cells their outputs are matched to give accurate measurements. We will discuss two trimming methods: excitation trim and signal trim.

10.1 Excitation Trim

This is the oldest method of load cell trimming. With excitation trimming, series resistance is added to the excitation circuit of the load cell. This method reduces the amount of excitation voltage that is dropped across the load cell. By adjusting these variable series resistances (potentiometers) the load cell outputs can be matched. A junction box diagram is shown in Figure 25.



EXCITATION TRIM JUNCTION BOX
Figure 25

Since the potentiometer is in series with the excitation inputs, the sum of the voltages dropped across the potentiometer and load cell is equal to the applied excitation voltage. Most excitation trim J-boxes are three-stage devices. In parallel with the potentiometer, there is a low value resistor which limits current flow through the potentiometer to limit its range. This also reduces the thermal affect and noise of the potentiometer. Also, a jumper wire is installed around the potentiometer to keep it out of the circuit when trimming of that particular cell is not desired. It is better to trim a cell as little as necessary, as the less resistance introduced into the circuit the better.

There is a method of pretrimming load cells utilizing excitation trim. This method allows pretrimming load cells to within ±2 graduations without even touching a test weight. You will need an adjustment screwdriver, calculator and/or pencil and paper, a wire snippers, digital volt meter and the calibration data sheet for each load cell. For greater accuracy it is recommended that your volt meter have at least a 4 1/2 digit display.

We will pretrim a six cell truck scale.

- Refer to each load cell calibration data sheet and write down each of the load cells mV/V rated output at full load.

CELL #	SERIAL #	FULL LOAD mV/V
1	65059	3.005
2	66078	2.995
3	64098	3.002
4	65077	2.990
5	66002	3.014
6	65034	2.987

- The next step is to determine our reference cell. The reference cell is always the cell with the lowest mV/V output. In our case, the reference cell is Cell 6 at 2.987 mV/V. The lowest cell is considered the reference cell because with excitation trimming we can only add resistance in the excitation circuit and lower the voltage seen by the load cell. We cannot raise the lower cells to meet the cells with higher outputs. So we can say the reference cell is the fixed point of our system.

- Connect the indicator and junction box that you will be using in your system to the load cells you want to trim. Allow 20 minutes for the system to come to operating temperature.

- Turn all potentiometers fully clockwise to reduce the resistance value of the pot to its lowest value. It is not necessary to turn the lowest cell (reference cell) potentiometer since it will remain jumped out of the circuit. There will be a slight audible click when the pots are at their fully clockwise positions.

- Cut the jumper wires from around all the potentiometers except the reference cell potentiometer. This allows the potentiometer to add resistance as you adjust it.

- Divide the rated mV/V output of the reference load cell by the mV/V outputs of the remaining cells.

Cell #		
1	2.987/3.005	= .9940
2	2.987/2.995	= .9973
3	2.987/3.002	= .9950
4	2.987/2.990	= .9990
5	2.987/3.014	= .9910

Since we are dividing the mV/V reading of the lowest cell by others that are higher, our readings should be less than 1.0000. If you get a number greater than 1.000, refigure your math.

- Using the digital volt meter, measure the excitation voltage present at the reference cell excitation leads. We will say that the measured value is 14.95 volts.

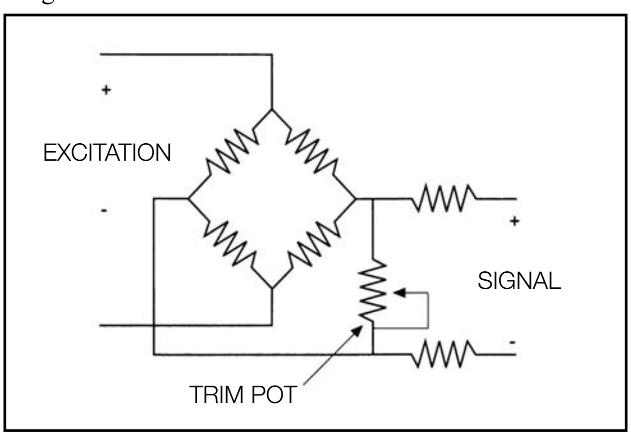
- Take each reading obtained when dividing the reference cell by each of the other cells and multiply them by the reference excitation voltage.

Cell #					
1	.9940	x	14.95	=	14.86
2	.9973	x	14.95	=	14.91
3	.9950	x	14.95	=	14.88
4	.9990	x	14.95	=	14.94
5	.9910	x	14.95	=	14.82

These calculated voltages must be present across each respective load cell excitation terminal before each load cell can output the same amount of signal. Place the voltmeter leads on Cell 1 and adjust its potentiometer for 14.86 VDC. Then place the volt meter leads on Cell 2s excitation terminals and adjust the potentiometer for a 14.91 VDC reading. Repeat this procedure for each of the load cells. Before disconnecting your system be sure to mark the junction box as to what cells go where so you can put them back in the same junction box terminals when permanently installing the system at the job site. You must use the entire cable supplied by the load cell manufacturer. Shortening this cable can slightly alter the load cell output. This junction box pretrimming system will not eliminate the need to use test weights but it will minimize the number of passes needed to calibrate the system and save time and effort for movement of test weights.

10.2 Signal Trim

Signal trimming first appeared as an alternative to excitation trimming for use with indicators with gated or chopped power supplies. Since the signal lines are static (not chopped), the trimming resistor is placed in the signal or output load cell circuit. The signal strength is very low as compared to the excitation voltage strength (15 mV vs. 15 volts). If the trim resistor is placed in series with the output the system will be very non linear and unstable. Instead, the trim resistor is placed in parallel with the output. This parallel resistance is relatively high (40KΩ to 200KΩ). It takes a large resistance change to make a small output signal change. Thus low cost resistors and potentiometers can be used with little concern for temperature coefficient and drift as long as the noise characteristics of the resistor are low. A signal trim diagram is shown in Figure 26.



SIGNAL TRIMMING OF LOAD CELLS
Figure 26

Cermet pots and metal filmed non-inductive wire wound resistors are excellent for signal trim components. To leave this system as it is will cause an interaction problem between cells in a multiple load cell system. The adjusting of one load cell will affect the other load cell outputs. To prevent this interaction, a series resistor is placed in each of the signal leads between load cell and indicator. These resistors must be stable and very well matched. Typical isolation resistance values are 2.5KΩ ± 0.1%. The temperature coefficient should be no more than 10 parts per million (PPM) or .001%, with 5 PPM being more acceptable. If these resistors are not matched the system will be very non-linear.

Besides being able to trim the system easily, there is almost no interaction between zero and span. This factor outweighs the cost of the resistors. Since there is very little zero span interaction and excellent temperature stability, single pass calibration is attainable along with fine trimming resolutions. Although signal trimming was developed to be used with chopped power supplies, it is becoming more popular for all multiple load cell applications.

10.3 Junction Box Care

Some of the causes of junction box troubles are:

- Aging
- Shock and impact loading
- Water
- Animals

Aging can cause load cell parameters to drift, thus retrimming may be necessary. Shock and/or impact loading can cause a zero shift and unstable readings, if not total load cell mechanical failure. Water, both in the form of liquid and humidity, can be the cause of erratic junction box performance. Scales can become erratic during wet periods and then correct themselves during dry weather. Humidity promotes fungus growth on circuit cards. This fungus is electrically conductive and can be very corrosive. Coatings are available to protect the circuit board from contaminants.

NEMA 4 junction boxes are not designed for immersion. Unless the boxes are properly sealed and fittings tightened, these boxes will not provide the protection for which they are designed. If a silicone based sealant is used, be careful as it gives off acetic acid as it cures. This acid will corrode plating and discolor solder. A vent is necessary if silicone is used. Place desiccant in metal boxes that are used in humid areas or areas subject to wide temperature variations. Rice can also be used but fill the bag only half full as rice expands when it absorbs moisture. Change the desiccant about every six months. If chemicals, salt or water are likely to be used around the junction box, consider using a non-metallic junction box. They sweat less, won't corrode, and are less likely to support fungal growth.

Cables sometimes are an overlooked source of problems. Animals, especially rodents, can chew away cable insulation. Moisture then gets into the cable and wicks its way to the load cell, causing an apparent calibration shift from winter to summer and erratic performance. For outdoor use, the cable should be contained in a sheath. If rigid conduit is used, slope the conduit to drain the water away from the load cell. Do not allow it to droop, which can cause water to settle in the conduit. Metallic conduit also acts to reduce the effect of electric transients.

Before replacing an existing J-box, consider these points.

- Is the scale properly mounted?
- Have you checked for mechanical friction and binding?
- Are any of the load cells suspected of drift or damage?
- Have any cables been underwater, crushed or abraded?

A new junction box will not cure the above problems. Electronic scales must be properly installed to decrease binding and friction. Quality installation provides quality performance. Load cell cables are the arteries of the system. If the cables are damaged or internally damp, the scale will not perform properly. Do not change the J-box unless you have checked for other problem causes.

Appendix A - Units of Measure

Voltage, current and resistance are electrical properties. These properties each have their own units of measure as shown in the chart below.

UNIT	MEASUREMENT OF	ABBREVIATION
Volt	Voltage	V
Ohm	Resistance	Ω
Ampere	Current	A

Instead of writing out 25 volts, we can write 25V; l ampere can be written as lA; and 100 ohms can be written as 100Ω. Often times these units are too large or small for easy use. For these cases, we can use prefixes to further qualify each unit of measure. Refer to the chart below for the most common prefixes.

PREFIX	SYMBOL	VALUE	FACTOR
Mega	M	1,000,000	10^6
Kilo	K	1,000	10^3
Centi	c	.01	10^{-2}
Milli	m	.001	10^{-3}
Micro	µ	.000001	10^{-6}

Whole number symbols are represented by upper case letters while fractional number symbols are represented by lower case letters. The symbol for micro is the Greek letter "µ" NOT a lower case "u." Resistance readings can range from millionths of ohms to several million ohms. Let's look at an example of 60,000 ohms and find another way to write it. The prefix for 1000 is kilo and its symbol is K. The symbol for ohms is Ω. So we can write 60,000 ohms as 60KΩ. Essentially, we made our value 1000 times larger. (Ohms to kilohms).

When working with electronic weighing systems, it is very common to find very low current and voltage levels. A common value is 3 mV. We can also write 3 mV as:

.003 volts
3 mV
3×10^{-3} volts

NOTE: 10^{-3} is the same as .001, 1/1000, $1/10^3$ or 1/ (10 x 10 x 10)

It is sometimes desirable to convert millivolts (mV) to microvolts (µV). Millivolts are 1000 timers larger than microvolts. So to change millivolts to microvolts we need to multiply the number of millivolts by 1000. For example:

3 millivolts = 3 x 1000 microvolts
3 mV = 3000 µV

These two numbers both represent the same quantity values.

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