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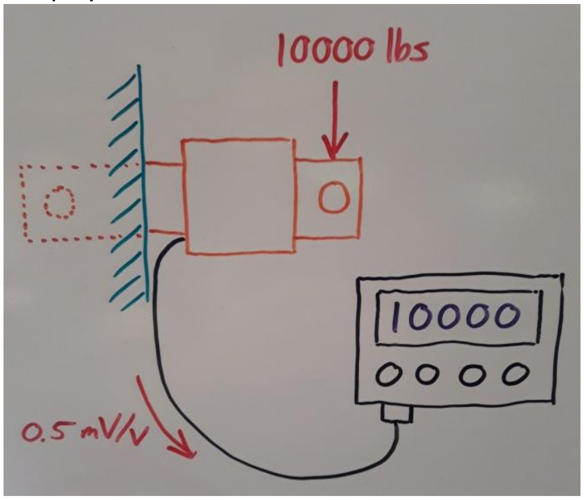
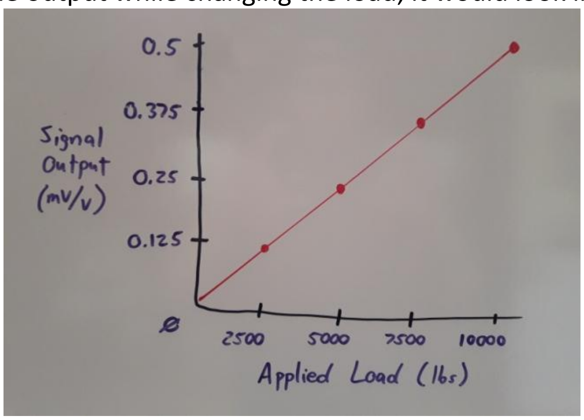
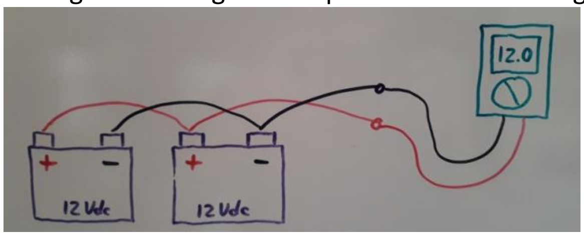
Title:
Multi-Point Scale System Signals

Overview:
- The questions often arise: "How do load cells 'add' together in a scale system?" or, "How does 'negative' load affect a scale?" This Technical Bulletin will use simple diagrams and mathematics as examples to answer these questions.

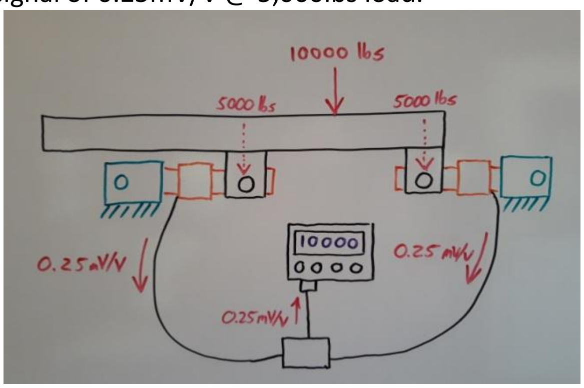
Load Cell Basic Concepts:
- Consider the output of a single load cell. In this example, the cell will have a calibration value of 0.5 mV/V @ 10,000lbs. In other words, when 10,000lbs of load is placed on the cell, it will produce an electrical signal of 0.5 mV/V. The load cell is designed and built to have this amount of signal output at this load, and it is permanently 'set', or calibrated, at the time of its construction. An indicator, or scale head, is used to process the load cell signal so that the weight is displayed.
    - 

- The output of a properly designed load cell is linear, which simply means that if you were to graph the output while changing the load, it would look like a straight line.
    - 

- In a multiple load cell scale system, the cables of the load cells are joined together in a junction box. Another cable exits the junction box and is connected to the indicator. The terminology used to describe this setup is to say that the cells are 'summed' together in the junction box, but that's misleading. The load cell signals are not being added together, they are being averaged, because the cables are connected together in parallel. Think of it as being similar to two 12Vdc batteries being hooked together in parallel - the resulting voltage reading is 12, not 24.

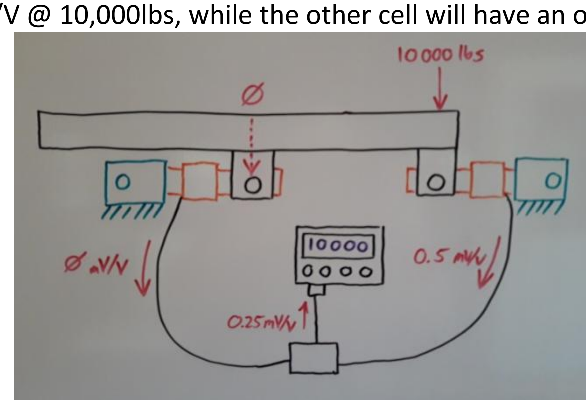
- 

2-Point Scale System - Even Load:

- Consider the example of a 10,000lb load placed on a platform in such a way that it is evenly distributed on two load cells. Based on the graph above, we know that each cell will produce an output signal of 0.25mV/V @ 5,000lbs load.
  - 

- The load cell cables are joined together in a junction box, where the signals are averaged:
  - $\text{Averaged Load Cell Output} = \frac{(0.25+0.25)}{2} = 0.25 \text{ mV/V}$
- The calibration value of the indicator is adjusted so that when it sees an input signal of 0.25mV/V it will display 10,000lbs.

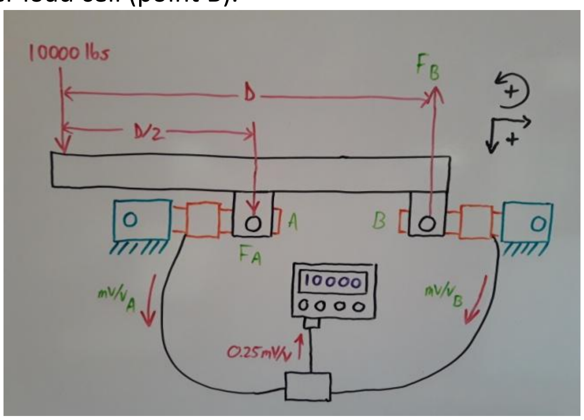
2-Point Scale System - Offset Load:

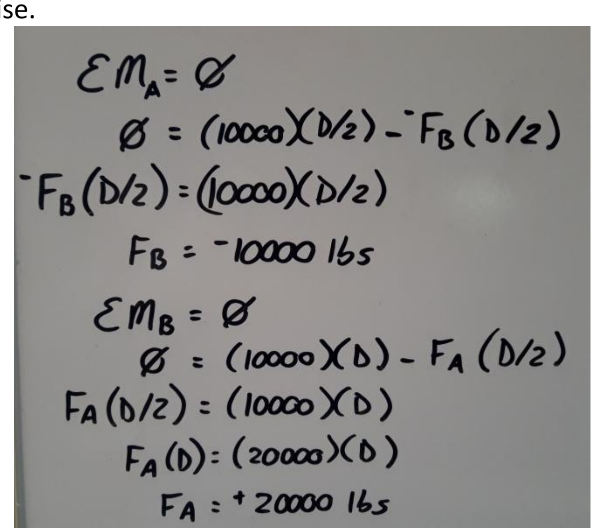
- Next, consider the example of 10,000lbs load placed exactly on top of one of the cells so that the other cell sees no load at all. The cell supporting all of the load will have an output signal of 0.5mV/V @ 10,000lbs, while the other cell will have an output of 0.0mV/V @ 0lbs.
  - 

- The signals are averaged, and the resultant signal is sent to the indicator:

- Averaged Load Cell Output $= \frac{(0.0 + 0.5)}{2} = 0.25$ mV/V
- The setup of the indicator doesn't change because the resultant signal being produced is still 0.25mV/V @ 10,000lbs.

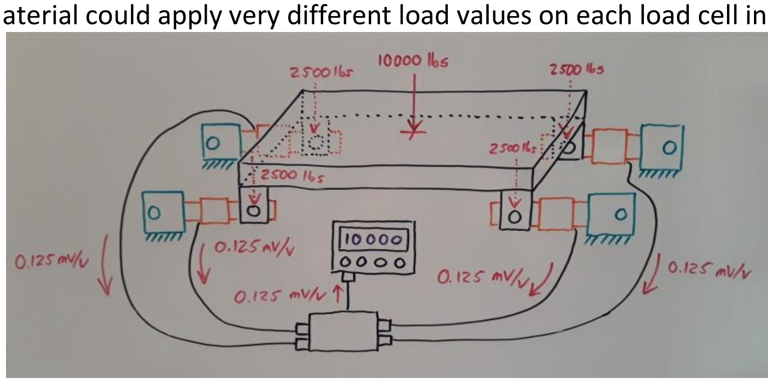
2-Point Scale System - Negative Load:

- Finally, consider the example of 10,000lbs load placed in a cantilevered position on the platform so that it is not above either load cell. Intuitively, one can see that the platform wants to tip or pivot counterclockwise around one of the load cells (point A), and that it is going to pull up on the other load cell (point B).
  - 

- In order to determine the output signal of each load cell, we first must calculate the load being applied to them (F_A and F_B). Because the platform is being held firmly in place and kept from rotating, we say that it is 'static', which makes the mathematics much easier. A rotating or moving platform is 'dynamic', and would be a more difficult problem to solve.
- The first step in determining the loads being applied to the cells is to calculate the 'Sum of the Moments' at points A and B. A moment is nothing more than a torque, which is a force being applied some distance away from the point in question. Because the platform is static, the sum of the moments is equal to zero - in other words, the torque trying to make the platform rotate counterclockwise is being balanced by an equal-and-opposite torque trying to make it rotate clockwise.
  - 

- From the calculations above, we can see that the load being applied to load cell A is 20,000lbs, and the load applied to B is -10,000lbs (down is positive). That means that the output of load cell A is 1.0mV/V @ 20,000lbs, and the output of B is -0.5mV/V @ 10,000lbs (being analog devices load cells are capable of producing negative output).
- It should be noted that load cell A is being 'crunched' like a nut in a nutcracker, and is overloaded by twice its calibration value. This would be called '100% overload' - the percentage refers to the load above and beyond the acceptable maximum capacity.
- Once again, the signals are averaged in the junction box and sent to the indicator:
  - $\text{Averaged Load Cell Output} = \frac{(1.0 + (-0.5))}{2} = 0.25 \text{ mV/V}$
- Even in this cantilevered loading condition, the indicator will still display 10,000lbs. This works out well 'theoretically' on paper, but given the numerous factors that come into play in a scale system, it's hard to say how such a system would behave in real life.

4-Point Scale System - Even Load:

- A four point load cell scale system would behave exactly the same way as the two point system, with the exception that the load position has another degree of freedom that must be taken into account to determine the distribution. One can see how a hopper full of grain or other 'fluid' material could apply very different load values on each load cell in the system.
  - 

- The load cells signals are also averaged in the junction box and sent to the indicator in the same manner:
  - $\text{Averaged Load Cell Output} = \frac{(0.125 + 0.125 + 0.125 + 0.125)}{4} = 0.125 \text{ mV/V}$
- What does change is the calibration value of the indicator, because now it needs to display 10,000lbs when it sees a smaller 0.125mV/V signal.

Summary:

Understanding the natural characteristics of a single load cell can help one determine the correct behavior of a multi-point scale system.

References:

www.northstarloadcell.com