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Load Cell Testing

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This project tested the concept of using load cells to measure the amount of propane in a stationary tank. The goal of the project was to see if a cost-effective load cell system could be installed that would accurately measure product quantities, including quantities delivered.

The answer to this question is no. When the unit was installed, the investment in the measuring system was about $2,500, which is considered to high for propane applications. However, a system could be engineered to weigh propane tanks that would cost less than $1,000 installed. This would require low cost cells and better tank brackets.

The hardware for the current test included 4 load cells, a load cell adder, a load cell conditioner and a display. The test was to see if electronic meters could measure volume in the a tank easily and accurately. Usually tank volume is measured by float gauges that are magnetically coupled to a dial gauge or a liquid level gauge. These methods are limited in their accuracy (5%-10%), whereas load cells are inherently more accurate (+/-0.03%) since no correction is required to account for product volume and precision strain gauges are used in the cells. For example, on a 1,500-gallon storage tank load cells can measure the amount of propane in the tank to within one gallon. This potential led to the development of this test to see how easy it would be to set up the load cells on a stationary vertical tank.

Background

Load cells use strain gauges to measure mechanical strain – the change in length per unit of length. The strain gauge is a small electrical resistance element about the size of a stamp or smaller on a flexible backing such as Mylar that changes electrical resistance as it is stretched. The metal etch on the strain gauge stretches; as it stretches it becomes thinner, which increases the electrical resistance due to the smaller cross-sectional area. The resistance is directly related to strain. Strain gauges are a well-developed technology and have been used extensively in the aerospace industry for 40-50 years. They are very exact for measuring the change in length - strain in an object. When placed on a bar of known size and dimensions the force on the bar can be determined from the strain.

Strain is a function of the force exerted on an object and the modulus of elasticity of the material, and the modulus of elasticity of the material is a physical property – a constant for most purposes. The force on a simple object such as a rectilinear beam is easy to determine from the strain and an analysis of the beam.

In weighing applications, the force (tank weight) is applied vertically down onto 4 load cells, which in this test are beam-type load cells. The cells are loaded as a cantilever beam where the stress-strain relationship is well understood from basic mechanics of materials (stress = Mc/I). The units are simple, rugged and long-lasting, as there are no moving parts in the cell, however they do require temperature compensation because electrical resistance is a function of temperature. As a result, the load cells do require some complex electronics to calibrate and use. This equipment is the summer and conditioner.

In addition, accurate installation ensuring proper alignment of the load cell and load points is important, because any out-of-vertical loading on the cell will alter the accuracy by changing the stress on the strain gauge. If the load is off-center, accuracy is reduced.

Load cells are available in capacities ranging from 1 oz. to 50,000 lbs., and prices range from $70 to more than $1,000. Omega, Inc., produces 500 different load cells. One company quoted quantity discounts of 25 percent, which is not a very large price break considering the simplicity of the design. Our test required extensive technical support because the documents furnished with the load cell were not informative on key set up issues.

The cells used in the AFRED test cost $350 each, and four were used in a cross-pattern layout to measure the tank weight on each of the tank legs. To save cost on the project we used bare load cells attached to the frame. A simpler approach would have been to use cells that are in a weighing fixture. This would have saved installation time, but would have cost 100% more.

Load cell precision

Load cells are available for use in a wide variety of commercial applications. They are used to weigh trucks, tanks, and in market and postal scales because of their high precision. Since load cells are temperature-compensated and can be calibrated for each setup, the accuracy of each cell used in this project was +/-0.03%. For the 1,500 gallon tank used in this project, 0.03% accuracy means that the weight of the propane in the tank is measurable at +/- a little less than one gallon of propane. For cylinder-filling applications the measurement is accurate to within about 1/20 gallon of propane

Load cell setup

The weighing system used in the test used 4 cells each placed on the main load frame. The cells were bolted to the frame using special brackets that

constrained the lateral movement of the tank (wind loads). These brackets are shown in the photos attached to this report. The use of 4 load cells required the use of a summing box that added the input from 4 cells together and produced an output that looks like one cell. From the summing box the conductors were run to a smart display. The display accounted for the tare weight of the tank and was able to read the amount of propane added to the tank and could be programmed to read out in gallons using a factor such as 4.21 lbs per gallon.

Calibration
Calibration of the cells proved to problematic. Calibrating of one cell at a time was not a practical option, since all four needed to be installed at one time when the tank was lifted up in the air. This degraded the accuracy was slight, but the accuracy was still quite high.

Problems encountered
Cell selection. The cheapest cell that was suitable was selected for the project. This cell required the development of the mounting configuration, which included lateral load analysis from wind forces and fabrication of the stabilizing bars for the system. Other cells had easier mounting configurations, but cost twice as much.

Electrical connections. Load cells are considered safe because of the low voltage of the units. However, the display operates at line voltage (120 V) and had to be located 25 feet (7.6m) away from the unit to meet code requirements. This required installing additional protected and shielded wiring. After the project was installed, a low-voltage display was located that would have simplified the installations and cost 1/3 as much.

Communication of weight to remote locations.
The display unit contained a 4-20 milliamp current output, which is suitable for input to a wireless transmitter to remote site. The communication system was selected but not installed due to the difficulty of calibrating the load cells. The communication system contained the following components from Onset Computer Corporation:

- HOBO Micro Station data logger with 4-20milliamp sensor $278
- Radio modem batter powered with a range of 3 miles line of sight $599.
- Base station connected to the computer $250
- Yagi high-gain antenna kit for a range of up to 5 miles $275
- HOBOware data logging software $95.

The total price for this setup was $1,498, which was too high for the project.

This equipment allows reading the tank capacity on any PC up to 5 miles away (line of sight). In an urban environment the distance will probably be in the range of 2-3 miles. If longer distances are needed, then a remote cell phone/pager

system was available for about the same price from SolarStream. The cell phone system required a monthly fee of $10.00 for the pager connection. The advantage of this system is that alarms can be set up to be sent via text messages to the phones, so that every time a tank went down to 30 percent or 20 percent capacity a text message could be sent to the subscriber, who could be a dealer or an owner.

An important feature of this system is that a log of the tank contents is kept for about one or two years depending on the configuration of the logger. This could provide a management tool for a customer or the propane dealer. For example, for a chicken farm the producer could have alarms sent to his or her office and the gas supplier when the tank reached certain levels.

Recommendations

This project was more complicated than originally anticipated due to the capabilities of the load cells and electronics. Many phone calls to manufacturers and suppliers were made on the load cells and conditioning communication electronics. A wide range of options needed to be sorted out to find a system that would work effectively.

The original goal of the project was to find a cheap way to accurately measure a tank load. Load cells definitely have this potential, but the standard hardware that is available off the shelf proved to be too expensive except for critical applications. For example, the load cell selected for the AFRED tank cost $350, and installing four of them and the associated conditioning electronics brought the price for the setup to $2,500 excluding labor. This was much more than originally anticipated.

The important question is: Can a tank setup that uses only one or two load cells be developed? This could reduce the cost of an installation considerably. Under the best of cases, the price for a weighing system would be approximately $1,000 for single-order purchasers. This price is still too high for many applications. For quantity purchases of a weighing system specifically designed for propane containers and using low-cost cells, the cost would be much lower. I estimated it could be as low as 15 percent to 30 percent of the cost of the systems currently available in catalogs.

AFRED's system setup in Austin has a great deal of flexibility because of the components selected. This level of flexibility would not be needed for most practical systems and this would reduce the cost even more. Also less accurate, lower-cost load cells are available that could be suitable for propane weighing.

AFRED's 1,500 gallon vertical tank


Load cell installation at the foot of the tank. Four load cells were installed.


Lateral bracing on the legs of the tank


Remote meter and conditioner for cells

Digital display of tank weight (not converted to gallons)