Overview of Liquid Level Gauging and Sensing Methods

Includes a Finite Element Analysis (FEA) using flexPDE

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Liquid Level Gauge and Sensor Device Requirements

1. Simple
2. Inexpensive
3. Do-able
4. Adequate Performance
5. Adaptable

Seven Possible Measurement Methods

1. Pointer and Porthole
2. Ball and Magnet
3. Fluid and Bubble
4. Integrated Current
5. Pump Pulse Counting
6. Ionic Conductivity
7. Electrolytic Elapsed Timer

“Pointer and Porthole” Method of Operation

The gauge has a mechanical pointer or a clearly visible feature that is affixed to or is some part of a liquid containing bladder. As the bladder fills or empties, the pointer or feature moves up or down.

The position of the pointer or feature is observed through a transparent window in the housing. Fiducial marks on or near the window allow semi-quantitative liquid level measurement.

“Ball and Magnet” Method of Operation

The gauge has a magnet attached to some part of a fuel bladder so that as the bladder fills or empties, the magnet position will move some useful distance.

Moving freely inside a tube or slot on the outside of the housing is a small ball bearing. As the magnet moves up or down on the inside of the housing, the ball bearing follows along on the outside.

Therefore, internal magnet position can be “observed” without need for a transparent window in the housing.

Fiducial marks on or near the tube or slot allow semi-quantitative fuel level measurement.

“Fluid and Bubble” Method of Operation

The “Fluid and Bubble” gauge diverts a small amount of the exiting liquid through an auxiliary capillary channel. The capillary channel has a small gas bubble in it near the fluid inflow orifice,

As fuel flows, the small amount of fuel diverted into the gauge tube pushes the bubble along ahead of it, thus indicating total fuel flow.

Fiducial marks on or near the tube holding the bubble allow semi-quantitative fuel level measurement.

“Integrated Current” Method of Operation

Positive displacement liquid transfer pumps are actuated by continuous or pulsed currents. An electronic circuit can integrate the pump driving current or count current pulses over time. The result is a voltage or number that is proportional to the amount of fluid that has been transferred by the positive displacement pump.

“Integrated current” gauges require a separate indicator for the calibrated output voltage. A simple hand held or panel voltmeter can be used for this purpose.

“Pulse Counting” Method of Operation

Positive displacement fluid transfer pumps are often actuated by pulsed currents. A digital electronic circuit can count pumping pulses over time. The result is a “count” that is proportional to the amount of fluid that has been pumped.

“Pulse Counting” gauges require a separate indicator to show the count value. Off-the-shelf “event counters” can total and display a wide range of pump pulse counts.

Pulse counting methods are particularly appropriate for use with a microcontroller.

A Conductivity Method of Operation

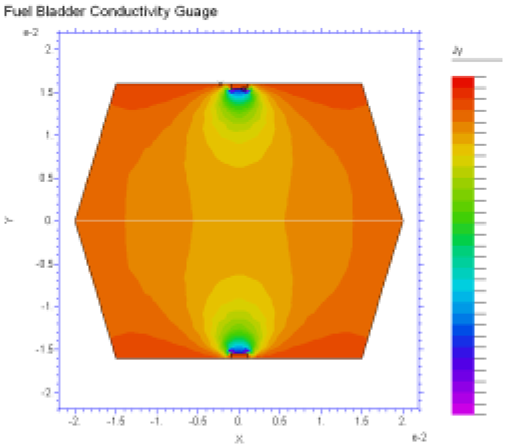
The gauge has two thin foil electrodes which are formed on the inside surface of a liquid bladder. Connection “tabs” are brought out through the bladder edge seal. When a small voltage is impressed onto the electrodes, a small current is passed through the electrolyte between the electrodes. A simple circuit measures the current. A calibration procedure relates the current to the filling state of the fuel reservoir bladder. Several bladders are connected in series for a complete fuel measurement sensor implementation.

The conductivity meter has the feature that it does not require memory to store the value of fuel consumed when power is removed from the gauge electronics.

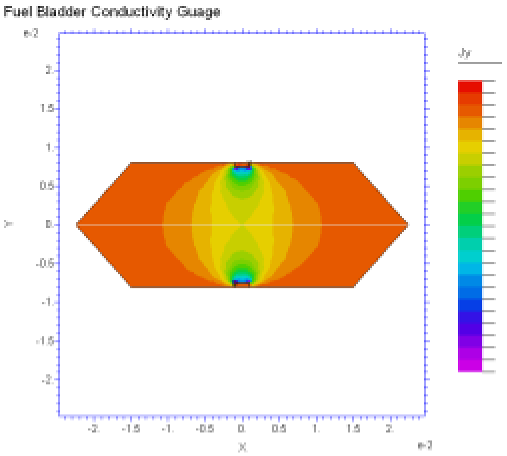
The Finite Element Analysis (FEA) results on the next page shows that adequate performance of a conductivity based fuel gauge is feasible and reasonable.

Conductivity Methods Work When

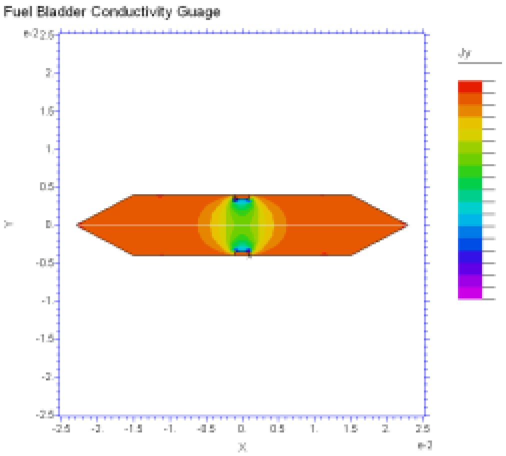
1. Electrolyte is conductive
2. Only moderate accuracy is needed
3. Implementation needs to be simple



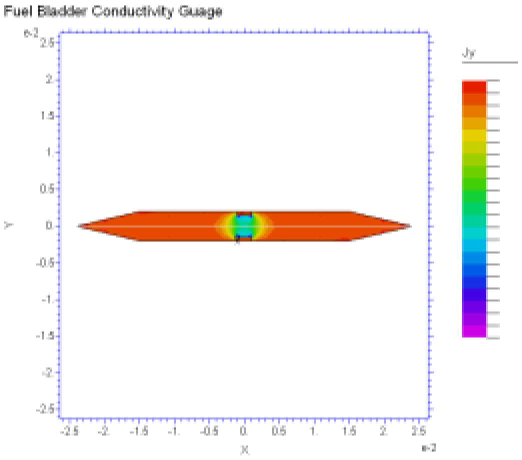
Conductivity Gas Guage 040304A: Grid#2 p2 Nodes=1137 Cells=534 RM
Stage 5 Resistance= 2.075334 Integral= -0.015042



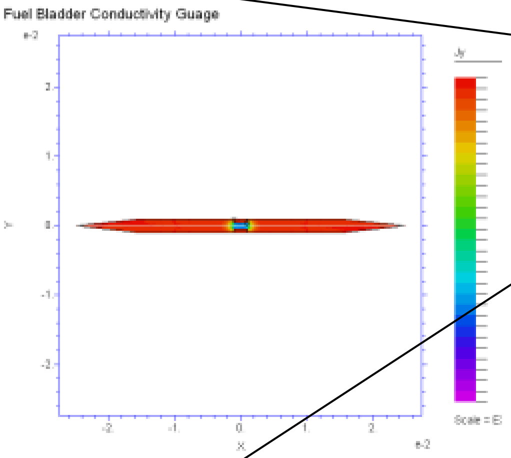
Conductivity Gas Guage 040304A: Grid#3 p2 Nodes=769 Cells=356 RM
Stage 4 Resistance= 1.554615 Integral= -9.715441e-3



Conductivity Gas Guage 040304A: Grid#2 p2 Nodes=621 Cells=284 RM
Stage 3 Resistance= 1.114226 Integral= -6.354709e-3



Conductivity Gas Guage 040304A: Grid#3 p2 Nodes=489 Cells=216 RMS
Stage 2 Resistance= 0.697623 Integral= -4.459542e-3



Conductivity Gas Guage 040304A: Grid#4 p2 Nodes=701 Cells=316 RMS
Stage 1 Resistance= 0.326792 Integral= -3.376934e-3

The calculated resistance starts at 2 Ohms when the bladder is full. It drops to .33 Ohms when the bladder is empty

The exact numbers will be a little different than calculated but, the results shouldn’t be to different

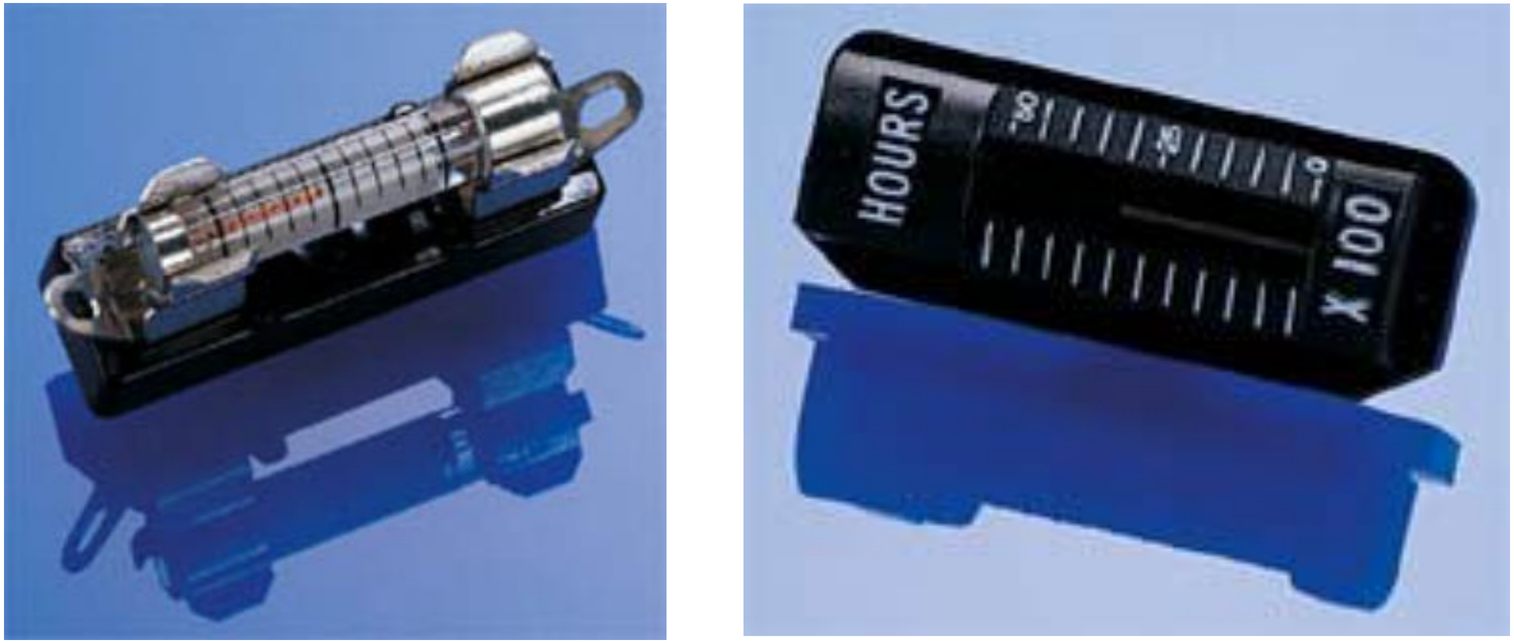
This set of illustrations shows the vertical component of sensor current flux as a bladder is emptied

“Electrolytic Elapsed Timer” Method of Operation

“Electrolytic Elapsed Timer” devices exploit simultaneous electrolysis and electro-deposition in a capillary tube filled with mercury except for a small electrolyte filled gap.

When a small pulsed or continuous current is passed longitudinally through the lumen of the capillary, mercury is “removed” from one side of the short electrolyte filled gap and simultaneously deposited on the other side. The result is a very slow movement of the gap along the capillary tube lumen. The total distance traveled by the small gap is proportional to the integral of the current over time.

Fiducial marks on or near the capillary allow semi-quantitative fuel level measurement.



Here are pictures of small, commercially manufactured, electrolytic elapsed time indicators

Summary Regarding Liquid Level Gauging

1. Several methods are possible to implement
2. They are relatively easy to build and test
3. They have a reasonable operating range
4. They have reasonable accuracy
5. Most methods are not very expensive