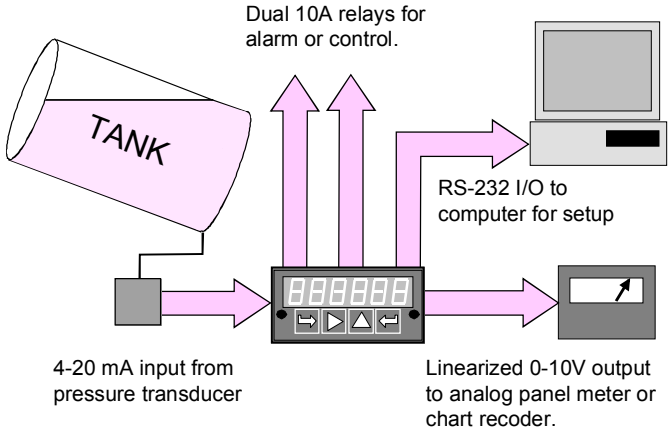
Obtaining tank volume from pressure with irregularly-shaped tanks

The problem: non-linearity between pressure and volume.

A Southeast chemical plant of liquid fertilizers needed a practical way to read out the content of liquid storage tanks based on pressure at the bottom of the tank. The challenge was that the tanks came in a variety of shapes and sizes. Many are cylinders lying on their side and are tilted toward the drain hole to avoid trapping material. Others are horizontal or vertical cylinders with rounded or conical ends.

The laws of physics state that pressure at the bottom of a tank is proportional to the density of the liquid multiplied by the height of the column of liquid above the pressure sensor - regardless of the cross section of the tank. However, the total volume of liquid is the sum of the volumes of individual layers, each of which is proportional to cross-sectional area. And if the tank is irregularly shaped, the cross-sectional area will vary with height.

The challenge is thus that while pressure is easy to measure using commercial pressure sensors with a 0-10V or 4-20 mA output, relating this pressure to liquid volume needs to reflect both the type of liquid and the shape of each individual tank.



Laurel digital panel meters are modular for maximum flexibility at minimum cost and provide a wide range of programmable features to solve application problems. The ability to linearize nonlinear inputs easily is an example of advanced capabilities.

Some uses of Laurel's linearizing meters

- Spline-fit Segmented Linear Error Correction (SLEC) to improve transducer accuracy.
- Extending the usable range of transducers.
- Determining volume of non-linear tanks based on pressure.
- Determining volume of non-linear tanks based on liquid level measured by an ultrasonic level sensor, a resistive sensor, or a float.
- Altimeter readout based on air pressure (the non-linear relationship can be entered as a formula).
- Linearizing non-linear transducers, such as thermistors.
- **Note:** Linearizing capability is also available with Laurel's pulse-input rate meters and totalizers.

The solution: Laurel's linearizing process meter and scale meters.

The plant engineers selected the Laurel Model L40111P extended process meter to scale and linearize the 4-20 mA signal from pressure transducers for readout up to 99,999, and the Model LW40111DCA2 scale meter for readout up to 999,990 (with a dummy right-hand zero). Both models include dual 10A relays, linearized 4-20 mA and 0-10V analog outputs, and an RS-232 interface.

The plant personnel found the scaling and linearizing function very easy to implement. After connecting the Laurel meter to the pressure transducer, they connected the meter via RS-232 to an external PC running Laurel's linearizing software. They then typed in the desired liquid volume reading and pressed the space bar (up to a maximum possible of 240 points) as they added known amounts of liquid as measured by a calibrated flowmeter. Following data entry, Laurel's software would automatically program the meter using multiple non-linear spline-fit segments, which provide much better linear accuracy than linear segments.

The meter's dual 10A relays were used for alarm when tank volume dropped to less than 20% and 10% of tank capacity. This signaled that another tank should be connected.

The 0-10V analog output of each meter became an invaluable bonus, since it was linearized to the display and was proportional to volume, not pressure. Each analog output was used as an input to an electromechanical analog meter which read from 0% to 100%, thereby providing an easy visual indication of tank status.