3.5 Diaphragm Level Detectors


---

**Service**
Level transmitter in water wells, open tanks with immersed sensor; tank-mounted diaphragm pressure transmitter and repeaters; level switch for solids in bins and silos

**Design Pressure**
Switches, atmospheric; transmitters, submersible to 500 PSI (3.5 MPa); others to 5000 PSI (35 MPa)

**Temperature**
−40°F (−40°C) to 180°F (80°C) typical

**Wetted Materials**

**Ranges**
Single point for solids; up to 700 ft of water for the transmitters

**Inaccuracy**
Single points are repeatable to about 1 in. (25 mm) on solids; transmitters are accurate to 0.5 to 1.0%, based on pressure. Level inaccuracy depends on the specific gravity of the liquid.

**Cost**
Switches, $150 to $500; submersibles, $350 to $600; tank mounted, $1000 to $2500

**Partial List of Vendors**
AMETEK-Gulton Statham Products (www.ametekpower.com)
AMETEK-PMT Products (www.ametekusg.com)
Anderson Instrument Co. (www.andinst.com)
Barton Instrument Systems LLC (www.barton-instruments.com)
Bindicator (www.bindicator.com)
Delta Controls Corp. (www.deltacnt.com)
Druck Inc. (www.druck.com)
Fisher-Rosemount Systems (www.emersonprocess.com)
Foxboro Eckardt GmbH, an Invensis Co. (www.foxboro-eckardt.com)
Honeywell (www.acs.honeywell.com)
Kimray Inc. (www.kimray.com)
King Engineering Corp. (www.king-gage.com)
Monitor Technologies LLC (www.monitortech.com)
Monitrol Bin Level Mfg. Co. (www.monitrolmfg.com)
Pressure Systems (www.pressuresystems.com)
Scientific Technologies Inc. (www.automationsensors.com)
Sensotec Inc. (www.sensotec.com)
Vega Messtechnik AG (www.vega-g.de)
Viatran Corp. (www.viatran.com)
Yokogawa Corp. of America (www.yca.com)
All diaphragm detectors operate on the simple principle of detecting the force exerted by the process material against the diaphragm. The designs discussed below include diaphragm switches for liquid and solid services and diaphragm devices for continuous liquid level detection and transmission in tanks or wells.

**DIAPHRAGM SWITCHES FOR SOLIDS**

For solid service, diaphragm switches can be selected from a number of design variations. Devices with mercury switches can be used with materials having a bulk density of more than 30 lb/ft$^3$ (48 kg/m$^3$), whereas units with microswitches are used for lower-density services. Some of the most sensitive diaphragm switches will actuate with as little as 6 oz (171 g) of force on the diaphragm. The differential of a single diaphragm can be as high as 8 in. (200 mm), meaning that the switch will close its circuit when the solids rise to the top of the diaphragm and will open the circuit when they drop 8 in. The lower the solid density, the larger the diaphragm area required. Units are available with 4- to 10-in. (100- to 250-mm) diameter diaphragms. As illustrated in Figure 3.5a, there are three ways to install these detectors. They can be suspended on a support pipe to provide for quick adjustment of the switch position, they can be mounted on the inside wall of thick-walled silos, or, as is most commonly done, they can be externally mounted on thin-walled bins and silos. The mounting location should always be selected to guarantee the free flow of solids to and from the diaphragm area.

As shown in Figure 3.5a, diaphragm-type switches for solids can serve several purposes. Switch 1 protects against overfilling, switch 2 signals low supply level, and switch 3 indicates choke-up in the screw conveyor. Diaphragm 4 detects overfeeding the elevator boot, and diaphragm 5 detects plugging of the elevator discharge spout. Diaphragm switches 6 and 7, in the storage silo, will signal extreme level conditions. Switch 6 can interlock the material feed and shut it down when the storage silo is full.

In newer designs, the diaphragm itself is vibrated by built-in piezoelectric elements and, when the solids level rises up to the diaphragm, the resulting load on the diaphragm decreases the amplitude of vibration. This change in amplitude is used to trigger the level switch. This solids level switch (Figure 3.5b) is smaller, lighter, and more sensitive than the earlier designs, and its stainless-steel diaphragm (in an ABS resin body) is more rugged than the rubber diaphragms of the direct pressure-sensing units. The vibration

---

**FIG. 3.5a**

Use of diaphragm switches in solid services.
of the diaphragm at 200 to 400 Hz reduces the probability of material sticking to the diaphragm and it also increases its sensitivity. The switch will actuate when it is 50% covered by materials with specific gravities exceeding 0.5, such as flour (0.48 to 0.55), polyethylene pellets (0.56), rice (0.58), PVC pellets (0.76), or wheat (0.77). On lighter materials, such as instant coffee (0.22) and copier toner (0.49), the diaphragm will actuate when it is 80% covered. To eliminate cycling, a 1- to 3-sec time delay is provided.

**DIAPHRAGM SWITCHES FOR LIQUIDS**

*Figure 3.5c* shows how diaphragm switches can be used to detect liquid level by sensing the pressure of a captive air column in a riser pipe beneath the diaphragm. An 8-in. (203-mm) head of liquid above the inlet of the riser pipe generally compresses the air sufficiently for switch actuation. The unit can handle a maximum of 60 ft (18 m) of liquid. The diaphragm is in contact with the captive air but not with the process. The liquid rises in the dip pipe enough to compress the enclosed mass of gas to match the level-caused pressure outside the dip pipe minus the liquid rise inside the dip tube. Physical dimensions are important. Sensitivity increases as the wetted portion of the dip tube increases and decreases in proportion to the enclosed air volume. These units can be used only on atmospheric tanks and should be considered only for applications where low cost is desired and accuracy is not a critical consideration.

**DIAPHRAGM-TYPE LEVEL SENSORS AND REPEATERS**

*Figure 3.5d* illustrates two versions of the continuous level detector, both limited to atmospheric tanks and to applications where low cost is more important than quality or accuracy of measurement. The diaphragm box unit, shown on the left side of the sketch, is similar in operation to the previously discussed riser pipe diaphragm switches except that the diaphragm isolates the captive air from the process fluid. The unit consists of an air-filled diaphragm box connected to a pressure detector via capillary tubing. Correct function depends on a large volume displacement by the diaphragm, with negligible spring constant. As the level rises above the slack diaphragm, the liquid head pressure compresses the captive air spring. The air pressure in the capillary tubing is sensed by a pressure element and displayed as an indication of level.

A one-to-one pressure repeater is illustrated on the right side of *Figure 3.5d*. With this unit submerged in the vessel, the static head of the liquid exerts an upward force on the diaphragm that increases as the level rises. The air supply pressure on the other side of the diaphragm opposes the upward force. The force caused by the rising level moves the diaphragm toward a bleed orifice, thus restricting its flow to atmosphere and causing the air pressure to build up until it equals the static head pressure. When the forces on the two sides of the diaphragm are equal, the unit is in equilibrium. The speed of response of the unit is changed by an adjustable restriction that, if opened, will increase sensitivity by allowing...
more air to flow onto the diaphragm. Air supply to the unit should be regulated at a pressure of 3 to 5 PSIG (0.2 to 0.3 bar) in excess of the maximum hydraulic head to be repeated.

The pressure repeater can be submerged, as shown in Figure 3.5d, or mounted on a nozzle near the bottom of an atmospheric tank (Figure 3.5e). These flange-mounted units are available with stainless-steel diaphragms and steel or stainless-steel bodies. They can operate with up to 160 PSIG (11 bars) air supply and can repeat hydrostatic pressures up to within 5 PSI (0.35 bars) of the air supply pressure. The air consumption of these repeaters is under 0.2 scfm (5.7 slpm). Other repeater designs, such as the extended diaphragm version, are discussed in the following section (Section 3.6), because they are used to complement differential pressure transmitters in level-measurement applications.

**ELECTRONIC DIAPHRAGM LEVEL SENSORS**

Most diaphragm-type pressure detectors and pressure transmitters can also be used to detect level by measuring the weight of a column of liquid in an atmospheric tank. In the unit shown in Figure 3.5f, the pressure applied to the diaphragm is transferred to a fill fluid that also fills the inner cavities. A straight-axis, twisted Bourdon tube is cantilevered from the process side to convert pressure of the fill fluid to proportional, rotary motion at its free end. A rotary variable differential transformer (RVDT) detects the rotation and converts it to an electrical signal. This particular sensor is available with ranges from 0 to 100 in. (0 to 2.5 m) of water column up to 0 to 300 PSIG (0 to 20.7 bars) and has a 150% overpressure protection over its range. Other means of transduction include strain gauges bonded directly to the diaphragm, silicon diaphragms with the strain gauges etched and diffused into the side away from the process, and capacitive sensing of the diaphragm by an internal parallel plate.

Diaphragm-type electronic pressure transmitters are available in all stainless-steel sanitary designs and are used in the food industry. They are available with 0–20 to 0–100 ft (0–6 to 0–30 m) ranges and with 4- to 20-mA DC output signals, and they are suited for process temperatures between 25 and 225°F (–4 and 107°C). They can provide level measurement accuracies (assuming constant specific gravity) of 0.5% of full-scale reading.
Diaphragm-type electronic transmitters can also be submerged to detect levels in wells or in open water bodies. They are available with ranges up to 700 ft (213 m) and can be connected by cable to their readout instruments. Accessories generally supplied for these lake and well installations include digital readouts with a variety of packaging types, battery/solar cell power packs, power supplies for various line power voltages, multiple high- and low-level current relays, and optional analog (4- to 20-mA DC) or digital (RS-232, HART, Honeywell protocols) outputs.

**Bibliography**


Koeneman, D. W., Evaluate the options for measuring process levels, *Chemical Eng.*, July 2000.


Lerner, J., Continuous level measurement: an introduction to 16 basic types, *Control*, November 1990.


---

**FIG. 3.5e**

Pressure repeater for mounting on 4-in. (200-mm) tank nozzles. (Courtesy of Siemens Energy and Automation.)

**FIG. 3.5f**

Electronic diaphragm level sensor with twisted bourdon/RVDT transduction.