3.8 Float Level Devices


**Types**
Switches and transmitters can be mechanically or magnetically coupled and may have single- or multiple-point sensors. Indicators include the tape board gauge.

**Design Pressures**
Level switch units used in vending-machine type applications are usually limited to 100 PSIG (6.9 bars, 0.69 MPa), while magnetically coupled float level indicators can operate up to 1000 PSIG (70 bars, 7 MPa), and special designs can go up to 2000 PSIG (140 bars, 14 MPa).

**Design Temperatures**
Standard level switch units used in vending machine-type applications are usually suited for −40 to 225°F (−40 to 117°C); special designs are available for 500°F (260°C) and higher.

**Float Materials**
Brass, copper, stainless steel, Monel®, Hastelloy®, polysulfone, polypropylene, and other plastics

**Costs**
Vending-machine-quality level switches can be obtained for about $50; the cost of a type 316 stainless-steel industrial float switch ranges from $150 to $500, depending on the type of mounting and area classification. A tape-board-type level indicator costs about $500, and a continuous float level transmitter costs from $2000 to $5000.

**Inaccuracy**
The repeatability of actuation is about 1 in. (25 mm) for level switches and for guide-tube and float-type level indicators. The error in most level transmitters is about 1% of full scale. Consult the manufacturer for guidance if higher precision is required.

**Partial List of Suppliers**
See also the lists of suppliers in Sections 3.7 and 3.18.
Almeg Controls (www.almegcontrols.com/small_h_d.htm) (switch)
American Electronic Components (www.aecsensors.com) (tilt switch)
Applied Geomechanics Inc. (www.geomechanics.com) (tilt switch)
BinMaster (www.binmaster.com) (tilt switch)
Bristol Babcock (www.bristolbabcock.com) (transmitter, pneumatic)
Custom Control Sensors Inc. (www.ccsdualsnap.com)
Custom Switches Inc. (www.custom-switches.com) (switch)
Delta Controls Corp. (www.deltacnt.com) (switch)
Dryden Aqua (www.drydenaquainc.com/Float_switch/float) (tilt switches)
Gauging Systems Inc. (www.gaugingsystemsinc.com)
Gems Sensors Inc. (www.gemssensors.com) (switch)
Harwil Corp. (www.harwil.com) (switch)
Hersey Measurement Co. (www.aaliant.com) (transmitter and switch)
Innovative Components (www.liquidlevel.com/products.htm) (switches and indicators)
ISE Magtech (www.isemagtech.com) (transmitter and switch)
Jo-Bell Products, Div. of Celtech Corp. (switch)
Kelco Engineering (www.pumpshop.au.com/kelco.htm) (tilt switch)
Krohne America Inc. (www.krohneamerica.com) (transmitter and switch)
Magnetrol International (www.magnetrol.com) (switch, transmitter)
Merco Div. of Dwyer Instruments Inc. (www.mercoid.com) (switch)
Montech Systems Inc. (www.monitortech.com) (tilt switch)
MTS Systems Corp. (www.levelplus.com) (transmitters)
National Magnetic Sensors Inc. (www.nationalmagnetic.com) (float switches, reed switch, tape level indicators)
Norriseal (www.norriseal.com) (switch, transmitter, controller)
Nova Controls (www.novacontrols.com) (tilt switch)
Sherman Instruments (www.johnsherman.com/level)
Solartron Mobrey Ltd. (www.solartronmobrey.com)
SOR Inc. (www.sorinc.com) (switch)
TAV Engineering (www.tavengineering.com) (switches)
Techmark Corp. (www.tm-techmark.com) (tilt switch)
Thomas’ Products Ltd. (www.thomasprod.com) (switch)
W. E. Anderson Div. of Dwyer Instruments (www.dwyer-inst.com) (switch)

In addition to this section, other sections in this handbook discuss float-type devices. These include the displacer-type level devices discussed in Section 3.7, the magnetic level gauge covered in Section 3.10, and the various tape level devices discussed in Section 3.18. In addition, the float level control valves, which are covered in Volume 2 of this handbook, also utilize floats for their operation. In addition, floats are combined with capacitance and ultrasonic level detectors.

**INTRODUCTION**

The immersion of a theoretically perfect float would have a perfectly constant immersion depth. The immersion of real floats is not perfectly constant because of the work they have to do to move the mechanical components of the instrument.

The level devices discussed in this section can be functionally grouped into point-sensing level switches and continuous or proportional level devices such as level indicators, controllers, or transmitters. They can be directly connected or can include isolation or seal devices; if they have seals, one can also group them according to the method of sealing used. The older ball-float gauges depended on stuffing boxes for sealing. The newer designs use magnetic coupling or other, more reliable means to separate the pressurized process from the readout.

The float in float level switches and indicators follows the liquid level or the interface level between liquids of differing specific gravities. The commonly understood difference between the float and the displacer is that floats are allowed to move if level or density changes, whereas the displacers do not move—or move very little. This means that the float devices follow the changes in level more closely, while the displacer follows the changes in density more accurately.

Standard floats for top mounting are spherical or cylindrical; they are spherical or oblong for side-mounted designs. Spherical floats are available from 3 to 7 in. (76 to 178 mm) in diameter. The smaller-diameter floats are used in higher-density materials, and the larger ones are used in liquid–liquid interface detection applications and for measuring the level of lower-density materials. Another reason for using larger floats is to provide additional force for operating the associated instrument.

**FLOAT LEVEL SWITCHES**

Figure 3.8a illustrates a simple device that can be used for level indication or switch actuating in atmospheric tanks or sumps. The ball float has a rod connected to it, and the rod motion is used either to indicate level on a gauge board or to trip any combination of high- and low-level switches for alarm or automatic starting and stopping of lift pumps. For some pump applications, the float and rod may be furnished with the pump and can be factory assembled by the pump manufacturer.

Figure 3.8b illustrates the operation of the magnetically coupled and spring-loaded float switch. The magnet and switch are assembled on a swinging arm that rotates on a pivot. As the liquid level rises, the float rises with it and lifts the attractor. When the attractor reaches its high position, it pulls in the magnet on the swing arm against the nonmagnetic enclosing tube, thus tilting the mercury switch to the right. The spring is selected so as to provide snap-action switching. When the switch tilts, the middle-to-left leg circuit is broken, and the middle-to-right leg circuit is closed.

The magnetic coupling across the enclosing tube isolates the process liquid from the switching elements of the instrument. The swing-arm design can also be arranged to operate one or more dry contact switches. When two switches are...
employed, they can be spaced approximately 1 to 3 in. (25 to 76 mm) apart. One disadvantage is that making changes to the setpoint or the span of this and other float-operated switch designs can be complicated and time consuming.

Figure 3.8c shows some of the external top- and side-mounted float switch designs. The switch operating point is the vessel nozzle elevation. These direct-connected installations usually require that the vessel be depressurized and drained for maintenance. If this would cause a plant shutdown or interfere with normal operations, an external cage (chamber) design can be used. The external chamber can be isolated from the vessel by shutoff valves, which make maintenance possible without draining the vessel—if local safety practices permit.

If ambient temperatures can cause the process fluid to freeze or gel, the external chamber should be heat traced.

Another type of single-point magnetically coupled float switch is illustrated in Figure 3.8d. As the process level rises, the float rises with it, and the float magnet pivots down, which attracts the switch magnet. As it moves up, it changes the state of the electric or pneumatic switch. This design is available with a plastic boot that covers the float magnet and the float pivot point to prevent the buildup of solids or caking at the pivot. If the boot is used, it lowers the pressure and temperature ratings of the switch. The previous discussion on direct versus external cage mounting also applies to this switch design.

### Reed-Switch Designs

Some of the earlier reed-switch-based level switches consisted of several moving parts, which contributed to their potential for maintenance problems caused by corrosion and plugging. Figure 3.8e illustrates one such design, containing a spring-opposed shuttle-and-cam mechanism. Here, the level lifts the float, which in turn rotates a cam counterclockwise, thereby moving the permanent magnet into close proximity with the reed switch. As a result, the switch changes its electrical state.
The main concerns with most such designs are ruggedness, simplicity, and the ability to overcome the resistance of dirt or material buildup that resists float motion. For these reasons, the more successful designs tend to have only one moving component and a relatively large float on a relatively long float arm to maximize the angular momentum generated.

An inexpensive float switch used in vending machine applications is illustrated in Figure 3.8f. This unit is available in polypropylene and in polysulfone materials and can be used from −40 to 225°F (−40 to 107°C) and up to 150 PSIG (10.3 bars, 1.03 MPa) operating pressures.

In another all-plastic level switch, also used in vending machines, the float and reed switch assembly is contained within a housing chamber that is inserted vertically into the process (Figure 3.8g). The process fluid enters this chamber and lifts the float (which contains the magnet) until it actuates the hermetically sealed reed switch within the stem.

It is always wise to inquire into the electrical ratings of a reed switch. Devices that are mounted in the field with long cable runs (possibly in a cable tray) may be exposed to induced currents and high voltages resulting from electrical storms. In such cases, voltage surge protection is needed, because such voltage surges can destroy small switches.

### Float and Guide Tube Designs

The float and guide tube design shown in Figure 3.8h is also a magnetically coupled float switch. In its simplest configuration, a reed switch is positioned inside a sealed, nonmagnetic guide tube at the point where the rising or falling liquid level is to actuate the switch. The float, which contains an annular magnet, rises or falls with the liquid level while it is guided by the tube. In the design shown in Figure 3.8h, the switch is normally open and closes when the float reaches the elevation of the switch.

The switch closure can be used to sound an alarm or to initiate logic functions such as starting a pump. The switch will reopen when the float falls, or if it rises and the switch cannot detect whether it was closed by a falling or a rising float. As a solution for answering this question, a mechanical stop can be placed on the guide tube to prevent the float from rising above the elevation of the switch. With the stop installed, the switch will stay closed whenever the level is at or above the switch elevation and will open only when the process level falls. Several mechanically stopped floats can be placed along the same tube to provide multiple switching at different levels.

Figure 3.8i shows this configuration. Two floats and two switches are used to control a sump pump, which is started on high level and stopped on low. When the level in the sump is below the elevation of the level switch low (LSL), both LSL and level switch high (LSH) are open, and the relay coil R is de-energized. When the level rises above LSL, it closes that switch. If it continues to rise, when it also closes LSH, relay coil R is energized, and the relay contacts R1 and R2 are both closed.

Contact R1 is a “hold-in” contact around LSH, whereas the R2 closure starts the pump motor. When the liquid level
Level Measurement
drops below LSH, it will open, but the pump will remain energized, because the still-closed R1 keeps relay R energized. When the level falls below LSL, the opening of that switch will de-energize the relay coil, which in turn sets both R1 and R2 to open. At this point, the pump shuts down, and the system is at the initially described state. By adding more floats and switches to the assembly, more complex control schemes can be devised.

Tilt Switches

Figure 3.8j illustrates two commercially available tilt switch designs: the upper one for liquid and the lower one for solids services. In the liquid level detector switch, a mercury switch is enclosed in a plastic casing and is freely suspended from a cable at the desired level. When the liquid reaches the plastic casing, it tilts it, causing the switch to close (or open) an electric circuit, which in turn actuates a warning device or starts a pump. This device is used in sumps and ponds and is limited to atmospheric pressure and ambient temperature applications. If it is installed outdoors above grade, it should be sheltered by a windscreen.

The second tilt switch design, shown in the lower half of the figure, is used primarily to detect the presence or absence of solids on a conveyor belt. As long as there is material on the conveyor belt, the switch is tilted up. If the feed to the belt is lost, the switch rotates to its vertical position, and the switch contacts change state, thereby enabling alarm actuation, belt shutdown, or other automated actions to be initiated. Other designs are available that use a steel ball. As it changes position, the ball also operates a switch as the housing is tilted. This design is available for corrosive or pressurized services.

Float-Operated Continuous Indicators

The simplest and most direct method of float level measurement is illustrated in Figure 3.8k. The unit shown is basically a tape gauge (detailed in Section 3.18). A tape is connected to a float at one end and to a counterweight at the other, thereby keeping the tape under constant tension. The float

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moves the counterweight up and down in front of a direct reading gauge board, thereby indicating the level in the tank. The installation shown is typically used on water storage tanks, although it can be used in any processes that are left open to the atmosphere. Float and tape materials are selected to suit corrosion requirements. The instrument range is a function of tape length used, which can be up to 100 ft (30 m). For float devices used in closed tanks, refer to Section 3.18.

**Pressurized Tank Applications**

When float-operated devices are used on pressurized tanks, they require a seal between the process and the indicator. In most cases, the float motion is transferred to the indicator by magnetic coupling, but other designs also exist.

Where no external power source is available, the float level indicator shown in Figure 3.8l can be used to obtain remote indication.

When the level of the tank rises, the float moves up, and the float arm rotates around the float arm pivot, thus pulling the push rod down. This, in turn, operates the stroke lever. The stroke lever turns on its pivot, which is sealed inside the bellows. This motion is carried by linkage to the tank side bellows (A and B). As bellows A is compressed, some of its filling liquid is transferred into receiver bellows C. At the same time, as bellows B is expanded, it draws some of the filling liquid from receiver bellows D. The net result of this action of the differential bellows is to change the position of a remote level indicator, which requires no power supply.

These liquid-filled float gauges are available with temperature compensation to eliminate the effect of ambient temperature variations on the measurement. For installations in which the process vapors are not corrosive to copper and the operating pressure is below 15 PSIG (0.1 MPa), the bellows seal shown in the sketch can be eliminated. If the seal is used, it allows the unit to be exposed to 200 PSIG (1.4 MPa) operating pressures while isolating the process vapors from most of the working parts. The bellows seal and other parts that are wetted by the process can be made out of stainless steel, Monel, aluminum, synthetic rubber, or other materials. The capillary tubing between tank side and receiver bellows can be up to 250 ft (76 m) in length.

Figure 3.8m shows another simple level indicator. The float can be placed directly in the tank or mounted in an external chamber that is provided with isolating valves. The maximum level range of the device shown, which uses a standard variable-area flowmeter indicator, is 15 in. (381 mm). This limits its use to narrow-span applications. Another variation, used on home heating oil tanks, is designed with both a pivoted and a rotating arm to allow use of the short indicator scale.

Materials of construction are either steel or stainless steel, with glass indicating tubes used on nonhazardous, low-pressure services only. In other installations, metal tubes are used with magnetic coupling to drive the scale indicator. This design can be used for operating pressures to 1200 PSIG (8 MPa) and temperatures to 800°F (427°C). The rotameter design can be used for local indication and can be equipped with high and low alarm switches and electronic or pneumatic transmitters.

**Magnetically Coupled Indicators**

Continuous level indication can be obtained by placing many closely spaced switches inside a guide tube and detecting which ones are being held closed by the magnet as it is lifted with the ball float (Figure 3.8n). In this design, a voltage divider
Level Measurement

The network is configured by connecting resistors R1, R2, ..., Rn in series across the power supply. Since the resistors have equal value, the voltage drop across each one will be equal. If the magnet in the ball float closes the third switch from the top, for example, the voltage between R2 and R3 will be impressed on R0, causing a very small current to flow through the ammeter. As the level continues to fall and closes the fourth switch, R4 is inserted into the circuit, and the voltage to R0 will be reduced.

The ammeter scale may display the level in percentage or in engineering units. Resistor R0 is specified at a high value so that current flow through the meter is small in comparison with that in the divider. The switches can be placed with a minimum spacing down to 0.25 in. (6 mm), which is the resolution for this type of indicator. As can be expected, replacement of faulty switches is difficult, so the guide tube normally includes spare (redundant) switches installed at each point. Maximum length available for this design is 10 ft (3 m) if the assembly is furnished with the metal guide tube. However, it is possible to obtain a flexible, plastic-jacketed assembly that can be furnished in longer coils. The plastic jacketed assemblies are field installed into stainless steel or other nonmagnetic guide tubes. Solar-powered versions of this design are also available.

Figure 3.8o shows how the magnetically coupled float and guide tube design can be used for manual gauging or to operate a direct-reading dial. The sketch to the left shows the same magnet-carrying float and guide tube as described earlier. But here, instead of switch closures, the magnet is used to reposition a gauging rod. As the level moves the float up, the rod projects farther out of the tank, thus indicating the rising level. When the gauge is not in use, the rod can be pushed down to the bottom of the well, and the opening can be capped. This feature makes the gauge attractive for use on transportation tankers.

Given the right geometry, this system can also be installed from the bottom so that the reading can be made from under the tank. As shown on the right side of the sketch in Figure 3.8o, this design is also available with a direct-reading tape-driven indicator. This unit eliminates the need for the operator to climb on top of the tank. The major drawback of this design is that, if the pipe that contains the tape is ruptured, a spill can result unless some other form of spill protection is provided.

Another magnetically coupled float design is shown in Figure 3.8p. This gauge has been installed on a fair number of stationary and mobile liquefied petroleum gas and anhydrous ammonia tanks. The vertical motion of the float is converted to a dial reading.
DENSITY MEASUREMENT

Hydrometers are discussed in detail in Section 6.3 but, also being float operated, they are mentioned here. In a hydrometer (Figure 6.3a), a calibrated float with a small-diameter upper section is placed in the process fluid and sinks to a level where the buoyancy and its weight are in balance. One version is calibrated to detect the composition of automobile radiator cooling liquid. Another version is calibrated to measure the state of charge of a lead-acid battery. Others can be calibrated for the specific gravity ranges of various liquids and mixtures.

CONCLUSION

Float-operated devices are widely used in utility services and as alarm switches. In some applications, the size of the float may limit its use; in other designs, the associated support and guide tubes cannot be accommodated. Other limitations include that the immersed magnets will accumulate pipe scale and other ferrous metal particles from the process. These buildups will eventually interfere with the proper operation of such switches.

In all areas of instrumentation, it is safe to assume that trash, dirt, and solids will always accumulate in unwanted places. Many of the float-operated designs have moving parts exposed to the process and therefore should not be used in dirty or plugging services. The ball float switch designs are relatively inexpensive and reasonably reliable. For these reasons, they are used (selectively) in industrial processes and routinely in a wide array of applications outside of the industrial area.

Applications of float level instruments include the protection of pumps and compressors by detecting the presence or the absence of liquids in pipes and vessels. Pneumatically operated level switches avoid the problems associated with the availability of electrical power or the issues of electrical hazards. Independent level alarm and interlock switches are used to back up other level measurements for overflow protection and other safety purposes. The large number of float level device suppliers is an indication of the wide variety of available designs, and the user is advised to search for the most current sources and designs.

Bibliography

Flashlight, sunlight power tank level indicator, Design News, July 9, 1979.
Level measurement and control, Meas. Control, April 1991.