FUNDAMENTALS OF LIQUID LEVEL CONTROL

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Liquid level controllers are designed to separate gas, oil and water from the well stream. This is accomplished with the use of process vessels designed to hold fluids long enough to allow the natural gas to be released from the hydrocarbon liquid. Fluids need to be retained for a minimum of one minute for a two-phase separator and three minutes for a three-phase separator, depending on the manufacturer.

The configuration of the liquid level controller and dump valve, assist in controlling the period of time these fluids will remain in the vessel. There are two types of control configurations used in separation vessels:

Throttle control maintains a constant level by matching the liquid discharge rate to inlet flow.

Snap control provides for an accumulation of liquids to a predetermined high level and then releasing the liquids to a predetermined low level. A variety of controllers are included in liquid level control, mechanical, pneumatic, floatless, weight operated and electronic. Each controller has its own unique style of controlling liquids. This paper examines their capabilities and factors to consider in controlling liquid level.

The mechanical level controller is probably the most basic of the three styles of controllers and the easiest to operate. The mechanical level controller is typically limited to low pressure vessels of 500 psi. It is used in two phase top level control or three phase interface control where the water phase float is weighted to float in the liquid interface zone. Common applications include separators, free water knock outs and heater treaters.

The main components of a mechanical level controller include the float, float arm, trunnion, linkage rod, and the lever-operated valve. As a liquid level in the vessels rises, the float is forced upwards, causing the trunnion assembly to rotate. As the trunnion rotates, it pushes the linkage rod down on the lever of the dump valve. This causes the valve to open and discharge the liquids. Mechanical level controllers are throttling action, i.e., they match the amount of liquid entering the vessel with the amount of liquid being removed from the vessel to maintain a constant level. It is up to the operator to match the flow rate thru the vessel with the appropriate sized valve in order to maintain the desired level in the vessel. If the valve is too small, then the vessel will overflow, if the valve is to large, premature damage to the valve can occur. When throttling a valve, industry standard is to operate between 50 and 85 percent flow capacity of the valve. This opens the valve enough to minimize wear on the seat and cage area and allows for the best area of control. The installation of the mechanical level controller is critical with, being the most important factor being the placement of the linkage rod. Being the linkage rod should be as vertical as possible to optimize all the force provided from the trunion and float assembly to operate the valve. A common mistake is to move the linkage rod out to the farthest hole on the trunion arm to increase the closing force. The linkage connection on the float trunnion assembly needs to be installed as close to the assembly as possible to increase closing force. Other factors need to be considered when installing a mechanical level controller such as float size and arm length.

Pneumatic level controllers are the most versatile of the various styles of level controllers. Common applications include separators, free water knock outs, scrubbers, and production units. They have the ability to operate in high-pressure vessels, usually up to 4000 psi, and can work in either snap or throttle control. Pneumatic controllers use a displacer in the fluid instead of a float to generate force that actuates a pilot to open or close a valve. The displacer is typically made from high temperature plastic or stainless steel. As liquid level rises in the vessel, the fluid rises on the displacer and generates force (or makes the displacer lighter). The motion of the displacer is transferred outside the vessel to the controller by the use of a waggle arm. The movement of the waggle arm changes the pneumatic output of the pilot. The pneumatic output of the controller is sent to a pneumatic actuated valve that is able to be positioned by changes in pressure sent to the valve actuator. Typical instrument air pressure for level controllers and valves is 35 psi.

A common configuration for level controllers is snap acting, which allows the liquid in a vessel to accumulate to a pre-determined high level in the vessel then dumps the liquid out of the vessel to a pre-determined low level. The span of the level is determined by two factors, the length of the displacer and the tangent arm (or proportionate band in the pilot assembly).

A method to increase span would be to use a split float, by cutting a float in half and connecting the two pieces with a chain or steel cable. In this instance the span is increased by the length of the cable. The tangent arm also controls the length of the span by acting like a fulcrum, since the movement of the waggle arm is transferred to the pilot with the tangent arm. The further out on the tangent arm, the more travel by the waggle arm is required to actuate the pilot. Pneumatic level controllers are also used in throttle applications. The level controller gives a pneumatic output to position the dump valve so it matches inlet flow. This is done with the use of a valve trim specifically designed for throttle service (often designated as equal percentage). This is the recommended trim to use for precision control or regulation. Do not try to throttle with a snap or quick open trim, because the valve will not provide stable control.

When interfacing two liquids, the pneumatic level controller is the best choice because it has the ability to control the buoyancy of the displacer with the adjustment spring. Interfacing is when the level controller is controlling the lower fluid; usually water with a layer of oil above it. The object is to allow the displacer to sink in the top fluid, yet float in the bottom fluid. This is done by adjusting the spring that makes the displacer buoyant. Interfacing can be difficult, and all pneumatic level controllers have a minimum specific gravity differential for interface? These specifications should be published by the manufacturer. If you are having trouble interfacing due to specific gravity differential, try using a larger displacer. A larger diameter float will have more force per level of submersion.

One final advantage of a pneumatic controller is the ability to add flow measurement of the liquid volumes. Turbine meters are commonly used upstream of the liquid dump valve to measure and report liquid volumes produced over a given time period. The pneumatic controller's ability to operate in snap mode (accumulate then dump) allows for effective rotation of the turbine and provide accuracy typically within ± 1%. However, turbine flow meters are not recommended when level controllers are operated in throttle mode (constant level) because of the potentially low or intermittent rotation of the turbine and resultant lower accuracy.

Electronic level controllers are typically found where gas emissions are not desired, such as locations with sour service or inside enclosures. The electronic level controller is used in conjunction with electric or electro hydraulic valves, RTU, PLC or anything that requires an electronic signal to actuate. There are many types of electronic level controllers but we will discuss the 12v snap acting displacer type. The displacer type electronic level controller is similar to a displacer type pneumatic level controller in that it consists of a spring counterbalanced displacer, a waggle arm to transmit displacer movement and a tangent arm or proportional band to set range and sensitivity. Where a pneumatic type uses a pilot to transfer pneumatic pressure, the electronic type uses proximity switches to send an electronic signal. The electronic type consists of 2 proximity switches: one to turn the electronic signal on and one to shut it off. These proximity switches are set on either side of the tangent arm. The displacer movement is transferred to the tangent arm thru the waggle arm and up the link. The span of the level is controlled by 2 factors, the position of the link connecting the waggle arm to the tangent arm and the location of the two proximity switches. The further out on the tangent arm the link is located, the larger the liquid dump span. The two proximity switches are located on either end of the tangent arm. One of the proximity switches is directly adjustable, offering the ability to move the switch towards the tangent arm to decrease the dump span or away from the tangent arm to increase the dump span. Since only one proximity switch is adjustable, it is only possible to control the range of either the on or off signal-never both at the same time. To adjust the stationary proximity signal indirectly, either move the link on the tangent arm or adjust the displacer counterweight to change the buoyancy of the float

Electronic switches are also commonly used in liquid level control to provide a safety signal when a high or low level is reached. The output signal can activate alarms, solenoid valves or other electrically activated devices.

With an electro hydraulic valve positioner, hydraulic oil is shuttled from the area on top of the diaphragm to the area underneath the diaphragm through a manifold. For a Pressure Opening (PO) valve the volume on the top of the diaphragm acts as a storage space for hydraulic oil at atmospheric pressure. The volume underneath the diaphragm is pressurized to actuate the valve open. An oil reservoir is attached to the top of the valve actuator to allow for hydraulic oil input and visual measurement of the hydraulic oil level. An electro hydraulic valve positioner can be used with either a PO valve or a Pressure to Close (PC) valve. When a signal is received through the control circuit to open a PO valve, the pump is activated and begins to move and pressurize the hydraulic oil out of the top of the diaphragm space through the pump and into the volume underneath the diaphragm. The valve actuator begins to open the valve. For the Discrete (ON/OFF) version (Valve Actuator), the pump continues with pressure being monitored by the pressure transducer until the maximum set point is reached. At that point, the pump is deactivated and the valve remains open. The Discrete version does not have position feedback. Two discrete inputs are monitored for operation. The first discrete input notifies the controller to begin opening the valve by changing from an open contact to a closed contact. The second discrete input notifies the controller to begin closing the valve by changing from an open to a closed contact. When a signal is received through the control circuit to close a PO valve, the solenoid valve is open and begins to allow for the movement and de-pressurization of the hydraulic oil out from underneath the diaphragm through the solenoid valve and into the volume above the diaphragm. The valve will stay in position until a signal is received through the control circuit. Depending on solenoid valve selection, the valve will return to normal state or remain in place.

Floatless level controllers are typically used in smaller vessels where there is not enough room for a float. Nevertheless they can be used in any sized vessel. Floatless level controllers consist of a main diaphragm assembly that transfers movement to a pilot assembly by the use of a waggle arm. Vessel gas pressure is connected to the top side of the main diaphragm assembly and liquid head pressure is connected to the lower half of the diaphragm. The mounting location of the floatless controller is what determines the low liquid set point in the vessel. When the liquid head level in the vessel is even with the main diaphragm assembly, the diaphragm has equal force above and below. This equilibrium results in the pilot having no output. As liquid level increases, the main diaphragm assembly is forced upwords due to liquid head pressure. This upward movement is transferred to the pilot assembly through a waggle arm and actuates the pilot to send pneumatic pressure to open a valve. As the liquid head decreases due to the opening of the dump valve, the main diaphragm assembly is forced downward and the movement is again transferred to the pilot by the waggle arm and results in the dump valve closing. The height of the liquid head is determined by a spring placed in the upper half of the main diaphragm assembly. This spring holds the diaphragm assembly down until liquid head is acquired to force the main diaphragm upwards, the liquid level height is determined by adjustable spring on top of the main sensing diaphragm. Floatless liquid level controllers are available in snap or throttle service and a wide range of control pressures. In throttle mode, the liquid level controller will maintain a pre-determined height above the controllers mounted location. The controller will give a pneumatic output to position the liquid dump valve to match incoming flow.

The weight operated floatless level controller is a throttling valve that combines the motion of the mechanical trunnion with the principle of a floatless level controller. Applications include oil or water in low pressure vessels such as heater treaters, water knockouts, and gunbarrels. The weight operated level controller is unique in that it is the only self contained level controller. The design integrates the valve's seat with the differential diaphragm used to control the hydrostatic or liquid head level. Like the floatless level controller, a diaphragm is balanced with vessel gas pressure above and the hydrostatic head pressure and vessel gas pressure below.

The weight of the hydrostatic head provides the force to push the diaphragm up. The hydrostatic head pressure pushing up on the diaphragm is opposed by the use of a weight mounted on a trunion shaft. The further out on the trunion shaft arm that the weight is located, the greater the hydrostatic head level required to push the diaphragm upward. When hydrostatic head pressure builds to a point that it is greater than the weight, the diaphragm is forced upwards. When this happens, the seat is actually attached with the diaphragm of the valve so the valve opens. As long as hydrostatic head level provides enough force to counteract the weight the valve will remain open and allow flow. When flow decreases, the force on the diaphragm once again becomes balanced by vessel pressure only and the weight forces the diaphragm back down and seats the valve. The valve seat is directly related to the position of the balancing diaphragm, and the position of the diaphragm will be directly related to the amount of fluid entering the vessel in order to maintain a constant liquid level. The fluid level in a vessel that utilize valves is set by either a spillover connection and or a water leg with a siphon nipple. The weighted valve only controls the height in the spillover pipe or water leg jacket, not the fluid height in the vessel. Installation is critical for proper operation of the weight operated valve. The maximum liquid level can only be established from the installation height of the valve. Standard liquid level is 4 feet but extra weights and longer lever arms can be used to maintain a higher level. A bucket filled with rocks hanging off the trunnion arm or bungee cord holding the arm should not be used to increase liquid level (this has been observed). The equalizing vessel gas pressure line must not be shared with any other equipment because this can cause an unbalance across the main diaphragm and cause the valve to open prematurely or bounce. This equalizing gas line must also be installed so it slopes down from the diaphragm, to prevent any condensation in the gas stream from accumulating on top of the diaphragm. During winter months the condensation can freeze, causing damage and possible failure to the valve. However, with the proper installation the weight operated level controller is very durable and efficient for holding a constant liquid level.

Turbulence is a common problem for level controllers, as it creates instability in the system and results in inaccurate level control. Violent swirling, foaming, and bubbling in the separator causes floats to bounce and could result in hysteresis in diaphragms and displacers to be knocked off the waggle arm connections. Some vessels have diverter plates or even baffles to help turbulent flow. If this does not solve the problem or your vessel is not equipped with either, then an external float cage is always a good solution. The external float cage is offered for horizontal or vertical displacers and is designed to mount on the exterior of the vessel. The float cage requires two connections, vessel gas pressure on the top and the vessel liquid pressure in the bottom. The external cage needs to be mounted at the level of desired control. This allows a displacer type level controller to be installed out of the turbulent vessel but can still read and control the level in the vessel.

All of the level controllers discussed have their own unique qualities. The mechanical level controller is for throttle service and is difficult to interface. However the mechanical level controller usually requires the least amount of maintenance and is the easiest to operate. The mechanical level controller is for low pressure only and is not suggested for interface applications. The pneumatic level controller offers both snap and throttle action, used for high pressure vessels and is the recommended controller for interfacing. An external float cage can be used in turbulent vessels to improve stability of the controller. The pneumatic level controller requires dry supply gas and vents to atmosphere. The floatless level controller is recommended for smaller vessels and must be mounted at the lowest control point. The floatless level controller does not interface and is possibly the hardest to operate.
The weight operated level controller is the only all-in-one controller and valve. This makes installation easy by mounting the controller to the liquid outlet line. The weight operated level controller does not interface and is for low pressure vessels. The electronic level controller is used for applications were supply gas is either not available or not able to be vented. Many times the electronic level controller is operated with a solar panel and battery making remote installation possible. Activity of the controllers can be monitored and controlled from a RTU or PLC. As with all electronic devices it is susceptible to lightning and other outdoor elements. When choosing a level controller it is always important to know your vessel pressure limits, liquid flow rates, mode of and if supply gas will be available. These few facts will help your manufacturer in selecting the right controller for you.