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Vented Gas from Wellsite Control Equipment

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Abstract

Common well site control equipment is often designed to continuously vent small amounts of hydrocarbon gas to the atmosphere. While small for individual locations, the collective amount of gas can add up to many tonnes of greenhouse gas emissions each year. Converting emitting equipment to no/low bleed can significantly decrease greenhouse gas emissions with the added benefit of capturing for sales this normally vented gas. This paper addresses methods for determining the magnitude of the emissions, identifying the issues that must be considered when retrofitting a site, and a case study of the application of these techniques at over 4,000 well sites.

Background

Control equipment is used on well sites either to maintain a physical parameter within a range, to start or stop a process, or to provide over-range protection against a parameter reaching unacceptable levels. The parameters typically controlled on well sites are temperature, pressure, rate of flow, and liquid level. Control equipment has sensors and a method to communicate sensor status to other equipment to affect the control. Communications methods can be electronic, hydraulic, and/or pneumatic.

The focus of this paper is on pneumatic liquid level control. Level controllers are made up of a level sensor and a method to send a signal to a valve. A common well site use of level controllers is to direct liquids away from liquid-gas separation equipment. As liquid is separated from the gas stream it collects in a sump. When the liquid-level reaches the control set point, the controller sends a signal to an automatic valve that opens to send the liquid elsewhere.

Pneumatic level controllers can be classified by three parameters: (1) type of displacer-operation; (2) type of signal; and (3) bleed characteristics. Displacers (or floats) are classified by their travel. A *displacement* float is rigidly attached to a moment-arm that travels through an arc as the level changes. Opposite a pivot point on the moment arm is the mechanism that creates the output signal. This very simple and inexpensive device is restricted to applications where a long float-travel is possible. Where long travel is not possible or not desirable a *counter-balanced* float is used. These controllers use a “waggle arm”, “torque tube” or “torque arm” to resist the movement of the float so that the same range of control can be accomplished within a much smaller space. A displacement float will tend to float on the top of the liquid while a counter-balanced float will generally be submerged.

Signal type is either *snap acting* or *throttling*. A snap-acting controller will remain “off” until the liquid reaches its upper set point then it will send an “on” signal to the automatic valve to open. When the level falls to the lower set point the controller will send an “off” signal. A throttling controller will try to maintain a specific level in the vessel by sending a reduced-pressure signal to the automatic valve most of the time. As level rises, the signal strength will increase. As level falls, the signal strength will decrease.

Pneumatic-operated motor valves accept a pressure signal to overcome spring pressure. In level-control service, the valve will be set up to use gas-pressure to open and the spring to shut. The level controller sends the pressure signal when it needs to move the valve towards open and bleeds the pressure off when it needs the valve to move towards closed. This operation can be *continuous-bleed* or *“no-bleed”*. The “no-bleed” controllers do not vent gas while the motor valve is in an intermediate position, but of course they do bleed off stored pressure at the end of the process. Continuous-bleed controllers always vent gas. When the level is in an intermediate position with the motor valve closed the controller is venting the maximum gas that it can pass. At the highest liquid level, the controller is venting the minimum gas that it can pass. At other times the vent-volume is at an intermediate level.

Continuous-bleed, throttling, counter-balanced level controller

These controllers are in very widespread use and similar designs are available from several manufacturers. They represent simple, rugged construction with smooth operation, good reparability, and short float travel.

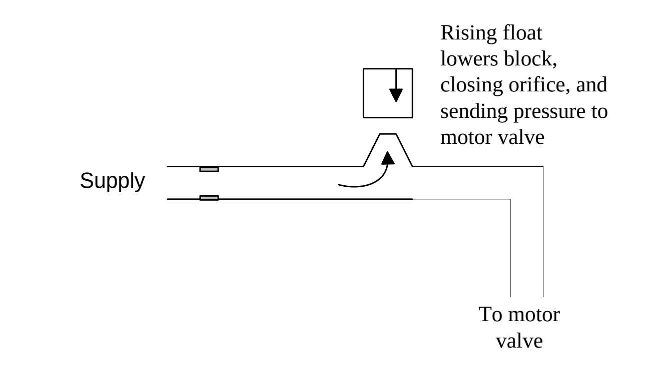

Figure 1: Operation of continuous-bleed, throttling counter-balanced level controller

One manufacturer's controller uses an orifice on the supply gas line and a block attached to the end of the counter-balanced float arm (Figure 1). As the block descends, it begins to seal the orifice, which tends to raise the pressure against the spring tension in the motor valve. If the level continues to rise, the block closes harder on the orifice and sends more pressure to open the motor valve further. As the level drops the float falls and the block rises—releasing the opposing pressure and allowing the spring to shut the valve. This design avoids ever requiring the displacer to overcome a large differential pressure in the instrument gas to operate the motor valve.

In fact, the only major drawback to these controllers is the amount of gas they vent. This volume can be calculated by the formula [1]:

$$q = 16330\left[1+\left(\frac{d}{D}\right)^4\right]d^2\left[H\left[29.32+0.3H\right]\frac{T_s G_s H_f}{T_f G_f H_s}\right]^{0.5} \quad \text{........ (1)}$$

This calculation shows that at 6,000 ft. above sea level (i.e., atmospheric pressure of 11.9 psia), 80°F, with 0.70 specific gravity, instrument-gas pressure of 25 psig (75.3 inches of mercury absolute at this elevation), ¼ inch nominal tubing, and a 0.03-inch orifice, you would vent 838 SCF/day. At $2.00/MSCF this amounts to $1.67/day or $612/year. Before the concerns about gas emissions into the environment, most operators considered this a very reasonable cost because the controllers are so reliable and effective.

With increasing concerns about air pollution and the ongoing debate about global warming, our company decided that it was both good citizenship and good business to evaluate methods to reduce this emissions source and sell the gas.

Manufacturer retrofit. The manufacturers of these controllers recognized that there were applications where the continuous-bleed might not be desirable. To serve this market, they each developed retrofit kits to turn the continuous-bleed controllers into no-bleed. Generally we found these kits to be complex, delicate, hard to adjust and repair, and very expensive. The kits were not seen as a viable approach for widespread use, but they certainly are an option for special circumstances.

Initial Experiment. Our first attempt was to invert the controller-head and modify the piping (Figure 2). Inverting the controller head changed it from increasing-level-to-seal to decreasing-level-to-seal operations. In other words the block would be sealing the orifice during the period while the vessel was filling (typically the longest portion of the cycle) and only be off the orifice during the actual motor-valve operation. This modification required the use of an external snap-acting pilot.

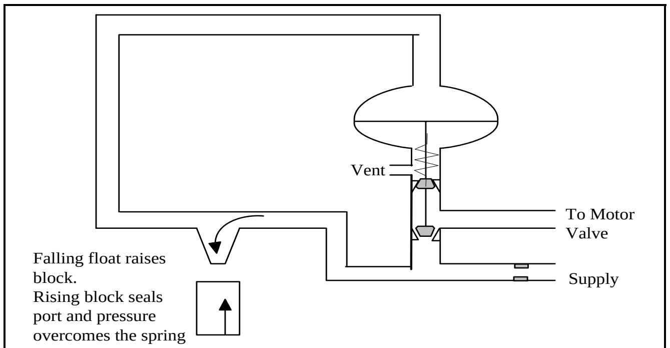

Figure 2: Addition of a pilot to the continuous-bleed, throttling, counter-balanced level controller

Initial results were very promising—the system only vented gas during the actual dump cycle and the amount of vented gas seemed to be smaller than during normal operations. In the inverted configuration, the block is off the orifice during the entire dump cycle so we had to increase control-gas pressure to 35 psig (96.6 inches Hg) to adequately operate the motor valve. With an average well dumping 5 times per hour for 3 minutes each dump, the controllers in this configuration were venting 250 SCF/day

After taking careful measurements it was shown that in an average well the inverted controller would vent 30% as much gas as the original design. For very-high-liquid wells, the higher-pressure gas needed actually exceeds the vented gas from a normal configuration if the dump is open over 50 minutes each hour. This magnitude of improvement was not enough to accomplish the company's goal of making a significant reduction in emissions.

No-bleed, snap acting, displacement level controller

At the other end of the spectrum, is a class of level controllers that don't have a continuous bleed. These controllers "snap" from closed to fully open over a very short portion of the float arc and they rely on a float arm that travels through a significant arc. These controllers tend to be inexpensive, very simple, and quite rugged.

While the vessel is filling, the controller shuts off gas from the instrument-gas system to the motor valve. When the liquid-level in the vessel reaches the set point, the controller opens rapidly and sends gas to the motor valve. When the liquid-level reaches the lower set point, the controller closes off supply and vents the motor valve and piping to atmosphere. The emissions from these no-bleed controllers are based on control-system volume, instrument-gas pressure, and dump frequency.

The volume of the system can be calculated by:

$$VentVol = \frac{\pi}{4}\left(D^2_{tubing} L_{tubing} + D^2_{ValveBonnet} L_{ValveTravel}\right) * \frac{P_f T_s Z_s}{P_S T_f Z_f} \text{ .... (2)}$$

With 10 feet of standard-wall ¼ inch tubing, a motor valve with an 11-inch bonnet and ¾ inch travel, operating at 25 psig and 60°F (assuming no change in compressibility at these pressures and temperatures), the system will vent 0.1 ft^3 per dump. If an "average" location dumps 5 times per hour, then you would vent 12 SCF/day—a savings of over 98%. Using the same cost of gas that we used in the Continuous-Bleed example the cost of the vented gas falls to \$0.025/day or \$9.29/year for a savings of over \$600/year for each site. With an installed cost of about \$400 going to these controllers would payout in 8 months.

Level-Controller Replacement Project

The project was based on changes to the well site equipment on over 4,000 gas wells in New Mexico, Colorado, and Wyoming. These wells were drilled between 1950 and 1999. Each well was equipped using the specifications that were current when that well was drilled. Consequently, there were 20-30 different vessel designs for two phase (i.e., gas and water) and three phase (i.e., gas, water, and hydrocarbon liquids) fluid streams. The specific gravity (relative to water) of the liquids also varies from about 0.5 to 1.05.

The project evaluation began with the assumption that a simple, inexpensive, no bleed, snap acting, displacement level controller could work for all 4,000 wells and all of the vessel designs.

Complicating issues. As the project progressed through the analysis and authorization stages it became very clear that a cookie-cutter approach was not going to address all of the issues.

Dirty fluids. We immediately found wells with very dirty fluids that would foul any displacement-type level controller. In fact, even the counter-balanced controllers would not work consistently on these wells because solids builds up around the float until it cannot travel even the very short distances that those controllers need. For the very dirty fluids we were able to find an exotic magnetic-coupled level controller that was quite expensive but very effective with very low emissions.

Liquid-liquid interface. Another group of wells had been equipped with separators that used a gravity-separation column to route water and oil. The controller needed to float on the interface between the oil and water. The float material had to be designed very specifically for the exact fluid gravity that the well produces. The best solution we found to this problem was the no-bleed conversion kit for the original controller from the separator's manufacturer. While the kit was expensive it was purported to provide the same magnitude of emission-reduction that we were looking for while maintaining the function of the separator.

Very light crude. When a well produced very light crude, the float on the preferred controller would not float. Attempts to replace the float with a lighter material were unsuccessful and we had to switch to a different no-bleed controller that had an adjustable counter-balance and a higher price.

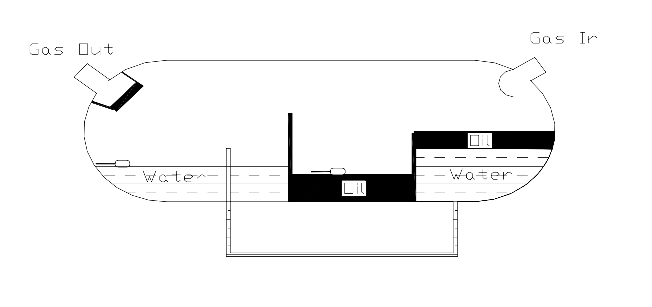

Figure 3: Typical three-phase separator

Weir Nipple. Some of the three-phase separators rely on the maintenance of a very precise level on the oil-water interface (Figure 3). These vessels expect an inventory of oil to be maintained floating over a carefully controlled water level. If the water level rises, then the vessel will lack the retention time to allow proper separation. If the water level falls, then the vessel can lose its water seal and start dumping oil into the water tanks or water system. This precise water level is maintained with a "weir nipple". Rising water level in the water-oil separation section is automatically moved through the weir pipe and out the top of the weir nipple into the water section. Rising water in the water section causes the water controller to open and dump the section. Rising oil in the water-oil section spills over the weir into the oil section. When enough oil has accumulated in the oil section to reach the oil-controller set point, that controller will open and dump the oil to an oil tank for sales. The design depth of oil on top of the water in the water-oil section is about 1-2 inches. The water-controller must maintain a water level somewhere below the height of the weir nipple or else the water level in the water-oil section will rise. If the water-controller set point is above the weir height (i.e., 1-2 inches above the weir nipple height) then both water and oil will dump out the oil section and contaminate the oil sales. Since the no-bleed, snap-acting, displacement level controller is not adjustable, it seems to be a poor choice for this application. In fact, most of these separators had the water-controller boss located low enough that the preferred controller works fine. On some vessels we fabricated an offset piece to lower the float on the preferred controller and this worked. On the few vessels where the boss was just, too high we were able to find an adjustable no-bleed, snap-acting, counter-balanced controller that would work.

Controller located too near bottom. Another issue was that sometimes the level controller sits too close to the bottom of the vessel. After the controller sends a "close" signal to the motor valve and while the motor valve is responding the vessel blows dry. This can cause free gas in systems designed for liquids, extra gas emissions, and the expulsion of bottom-sludge into liquid lines. This problem went away when we lowered the instrument-gas pressure to the minimum required for the motor valve and throttled the supply needle valve to cause the motor valve to open slowly and close quickly.

Long controller boss. Some vessels use very long controller bosses to protect the float against being subjected to turbulent flow and the accompanying spurious operation. These long bosses have a large-enough inside diameter for the short float travel that counter-balanced controllers need, but displacement floats need more room to travel. We were able to use our preferred controller on many of these vessels by installing a float-arm extension. The extension pushed the float out of the end of the boss and was able to adequately travel. We had some concern that extending the float out of the boss would cause problems with flow turbulence, but we have not seen these problems.

Small boot. At the other extreme, some vessels have the controller sitting in a small-diameter boot. The standard-length float arm pushes the float against the far wall and prevents the float from moving. This was avoided by using a shorter float arm. The shorter float arm has not caused any problems.

Project Approach. For this project we looked at the predominate vessel in each operation. We determined that in the Greater Green River Basin operation in Wyoming, the predominate vessel was a vertical separator that required the level controller to float on a liquid-liquid interface.

In the coal bed methane operation in the San Juan Basin of southern Colorado, the wells (known locally as "Type II Coal") produce copious amounts of coal along with the gas and water. Gas volumes are relatively low (i.e., 200-800 MCF/d) and water volumes are very high (60-500 bbl water/day) which causes the well to move a lot of coal to the surface. In this situation we determined that the exotic controllers would be required

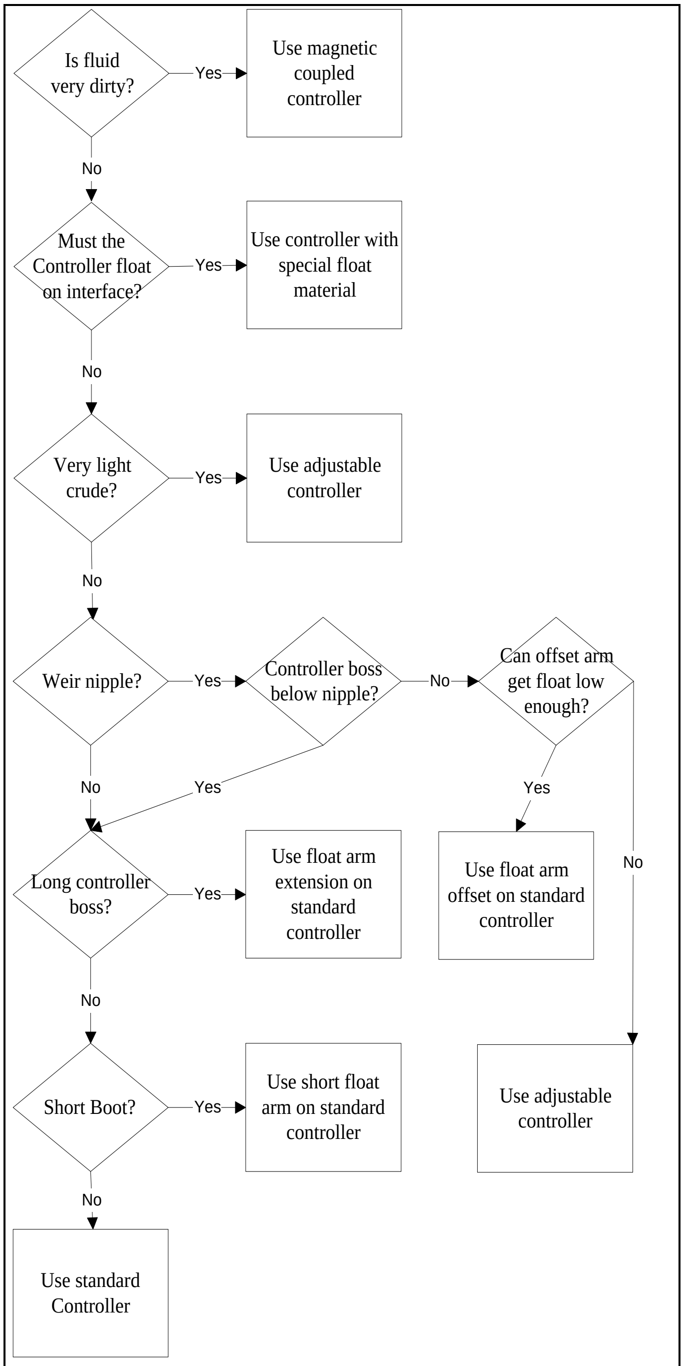

Figure 4: Decision Tree

In the conventional gas production from the San Juan Basin in northern New Mexico there was a wide variety of vessels and requirements, but there was a predominance of vessels that would allow the use of the inexpensive no-bleed, snap-acting, displacement level controller. Finally, in the San Juan "fairway" coal bed methane in New Mexico and extreme southern Colorado, the inexpensive controllers would be the preferred choice because gas volumes were so high (1,500-

6,000 MCF/d) and water volumes were so low (2-40 bbl water/day) that coal production was more manageable.

Because of time constraints to complete the project during 1999 we designed the project in the San Juan based on statistical samples of wells. To improve the effectiveness of the installation process we developed a decision tree (Figure 4) to evaluate the various options. The intention of this exercise was to quickly exclude the vessels that would not be suitable for the inexpensive no-bleed, snap-acting, displacement level controller. Further we wanted to identify the vessels that would be able to use this controller with minor modifications.

Results. The San Juan Basin represented almost 3,300 controllers. The Wyoming operations represented another 1,600 no-bleed conversion kits. The project looked at 4,900 controllers on over 4,000 wells and was able to use the inexpensive controllers on over 1,300 of them.

The project schedule was built to accomplish the project within 1999. This schedule was somewhat hampered by starting late in the year (which increases risks of weather delays), but we were able to accomplish over 95% of the project within the project schedule. The straggler wells were completed early in 2000.

	Wyoming	San Juan	Total
Well Count	1,560	2,760	4,320
Controller Count	1,560	3,300	4,860
Expected Cost	\$780K	\$933K	\$1,713K
Actual Cost	\$760K	\$666K	\$1,426K
Annual Savings	\$878K	\$1,240K	\$2,118K
Tonnes of CH_4/yr	8.5K	12.0K	20.5K
Tonnes of CO_2 Equiv	178.5K	252K	430.5K

Table 1: Project Results Summary

The 20.5K tonnes of methane that is no longer being vented is equivalent to about 2.9 MMCF/d of extra gas sales. Since this number is less than 0.3% of our daily gas production it is not visible on production curves and it is very difficult to verify that the project actually achieved the total savings expected. With the demonstrated savings, this project will payout in the first year. On individual wells, it is possible to verify the emissions reduction. That reduction is evident by less frequent episodes of explosive gas in separator buildings, by reduced “hissing” sounds around the separators, but not by increased daily gas sales. Reducing the “hissing” noise from the continuous-bleed controllers has been a big help in allowing the lease operators to attack the next emission-reduction project—repairing all control-equipment leaks.

Nomenclature

q = *Gas rate, SCF/day*
d = *Orifice diameter, inches*
D = *Pipe/tubing inside diameter, inches*
P = *Pressure, psia*
H = *Pressure, inches of mercury*
T = *Temperature, Rankin*
G = *Specific gravity relative to air*
L = *Length, feet*
Z = *Compressibility*
P_s = *Standard pressure, 14.73 psia*
H_S = *Standard pressure, 29.99 in Hg*
T_s = *Standard temperature, 520 Rankin*
G_s = *Standard Specific Gravity, 0.6*

Subscripts

s = *Standard conditions*
f = *Flowing conditions*

References

1. GPSA Engineering Data Book, 10th Edition, 1987, Volume 1, Page 3-10, Equation 3-12