Measuring Level in Highly Dynamic Petroleum Processes

Getting an accurate level reading where there is fluid boiling and off-gassing makes for quite a challenge. Here are two examples plus advice on bridle configurations.

John Yerkovich, Wayne Buhler, Sr.

Questar Pipeline Co. operates a facility that processes 120 million cubic feet of natural gas per day, where it chills the gas to remove some of the heavier hydrocarbons in liquid form. This increases the value of the gas and yields a salable product in the heavier gas liquids.

When the plant was built, the levels in the processing vessels were measured using guided wave radar level transmitters installed in bridle on the sides of the tanks. But in some parts of the plant it turned out to be impossible to get true level readings.

Questar called on Emerson Process Management, which found a way to measure the level despite fluid boiling and off-gassing, by replacing the guided wave radars with newer models and using the transmitter’s implied length output to find the true levels. This discussion will explain the process of solving the problem.

Problem 1: The receiver/economizer

A good example of the problem showed up in the receiver economizer (Fig. 1), which is supposed to be kept 50% filled with liquid propane at 55 psig. The process operated in cycles and control was a challenge, because it involved interacting loops for flow, level, and pressure. When the pressure dropped, the fluid would begin to boil, and the radar’s level reading would increase very rapidly—more rapidly, in fact, than was physically possible. The level would fail high and the plant would trip.

Questar consulted with Steve Newton, Emerson’s local level specialist, on several occasions. He would help tune the process for

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Fig. 1: When the pressure in the economizer dropped, the fluid would begin to boil, and the radar device’s level reading would fail high and trip the plant.
Problem 2: The chiller was also affected. As the pressure dropped, the fluid would boil and the GWR readings would lose their level, fail high, and trip the plant.

The Rosemount 5300 GWR has probe end projection as a standard feature, as well as a more powerful transmitted pulse and the ability to track rapid changes, but the units originally fitted did not, so implementing the new method involved simply replacing the GWR heads and programming the new units appropriately. The 5300 uses the same antenna as the existing 3300, so the change was simple.

With the erratic level reading stabilized, it was possible to tune the level loop properly, removing much of the damping that had been put in to try to cope with the rapidly-changing level signal. As shown in Fig. 4, the process now controls to within about 10% to 15% of setpoint and there are no more plant trips.

Problem 2: The chiller

A problem similar to that in the receiver economizer was also present in the chiller (Fig. 5), which holds liquid propane at –32 °F. This unit has a level setpoint of 50% measured by a GWR on a bridle. As the pressure dropped, the fluid would boil and the GWR would lose its level, fail high, and trip the plant.

A close look at the sight glasses on the affected vessel showed that over the course of a cycle the liquid propane would make a sudden drop in level and then begin to boil vigorously, filling the sight glass with bubbles and driving the surface—such as it was—out the top.

It was obvious why the radar gauges could not get good readings; in fact graphs of the radar signals showed that when this happened the liquid surface seen by the radar would simply vanish, and the level reading with it. This is actually a fairly common problem in gas plants and refrigeration applications—anywhere a liquid can suddenly begin evolving large amounts of gas in bubble form. The question was what to do about it.

The strength of the reflected pulse depends on the dielectric constant of the liquid to be measured, so water (dielectric constant = 80.4) gives a strong signal, but propane (dielectric constant = 1.6) gives a much weaker signal. And if there is no good surface there will be no corresponding reflection at all. The situation clearly called for a different method.

There is a technique with GWR devices called probe end projection that infers the level of the liquid by measuring other parameters. Since hydrocarbons have a greater dielectric constant than air, they reduce the speed at which the pulse travels along the probe, delaying the return from the tip and making the probe appear to be longer than it really is (Fig. 3). The more hydrocarbons present—whether in the form of liquid or bubbles—the longer the probe appears to be. By measuring that apparent length increase and then back-calculating—using the actual length of the probe and the known dielectric constant of the hydrocarbons—it’s possible to derive a reading of the amount of hydrocarbons present. Instead of a noisy reflection disturbed by every bubble, the output signal is a steady representation of the actual level.

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In this case, as with the receiver economizer, the solution was to replace the GWR with a type 5300 set to use probe end projection, then retune the loop. The result is shown in Fig. 6.

As a result of the new radar gage installations, nuisance level alarms have been significantly reduced. The plant can be left unattended through weekends and after normal operating hours.

Other considerations
There are a number of other factors that can affect the accuracy of radar level measurement in difficult applications:

- **Bridle diameter**—Small-diameter bridles (less than 2-in.) can exhibit gas lift, in which the liquid surface is lifted due to expanding gasses in the bridle, as well as bubbles traveling up the bridle, giving a false surface level, an unstable surface, and rapid apparent level changes. If enough off-gassing is present it can act like an air pump, similar to an aquarium pump, moving liquids from the lower process connection, up the bridle, and out the top process connection. Using a larger-diameter bridle (4-in.) will reduce this effect to mere burping, rather than lifting the entire fluid column. The large diameter also gives the radar a more stable surface from which to reflect signals.

- **Bridle temperature**—It’s a good idea to keep the temperature of the bridle as close as possible to that of the vessel. Since a bridle has much less mass than a vessel, it heats and cools much faster with changes in ambient temperature, and shows different levels for that reason. If the tank is cold, for example, and the contents not boiling, but the bridle is warm because it is exposed to the environment, the fluid has less density and is likely to boil and give false level readings. The answer is to insulate the bridle.

- **Multiple levels**—A single bridle (or sight glass) with two process connections should not be used in a vessel containing multiple fluids (perhaps oil above water, with air or vapor on top), because the interfaces between the fluids may not show up in the bridle, or if they do they will be at the wrong heights. It is much better under these conditions to install two bridles, one above the other, to show the top level surface and the interface independently.

- **Three process connections**—Attempting to get an accurate reading on multiple interfaces by using a bridle with three connections to the vessel might seem to be a way around having to use two bridles (each with its own radar), but it requires care in placing the connections. The distance between the connections should not exceed the anticipated thickness of the upper layer. In addition, this arrangement can lead to some uncertainty about the level of the top layer.

- **Four process connections**—This method tends to work better than three connections, as it gives less chance of trapping fluids. The distance between the connections should, as before, be roughly equal to the anticipated upper product thickness.

- **Direct vessel mounting**—Putting the radar gauge directly in the vessel eliminates the inaccuracies found with bridle connections. This method will give accurate readings of the level and interface as it is actually occurring in the vessel. The disadvantage of this method is that the fluids may not be separating as well as they would in a still bridle environment. Sometimes installing the radar in the vessel inside a stilling well with multiple holes can solve both issues.

John Yerkovich is an automation services supervisor for Questar Pipeline Co. Wayne Buhler, Sr., is a sales engineer for Emerson Process Management.