Water Level Monitoring in Riserless Pumped Wells

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Introduction

The Riserless Pump System (illustrated in Figure 1) was introduced by Australian inflatable packer manufacturer, AGE Developments, to allow the casing itself to be used as the riser for an electric submersible pump by sealing and supporting the pump in the casing with an inflatable packer.

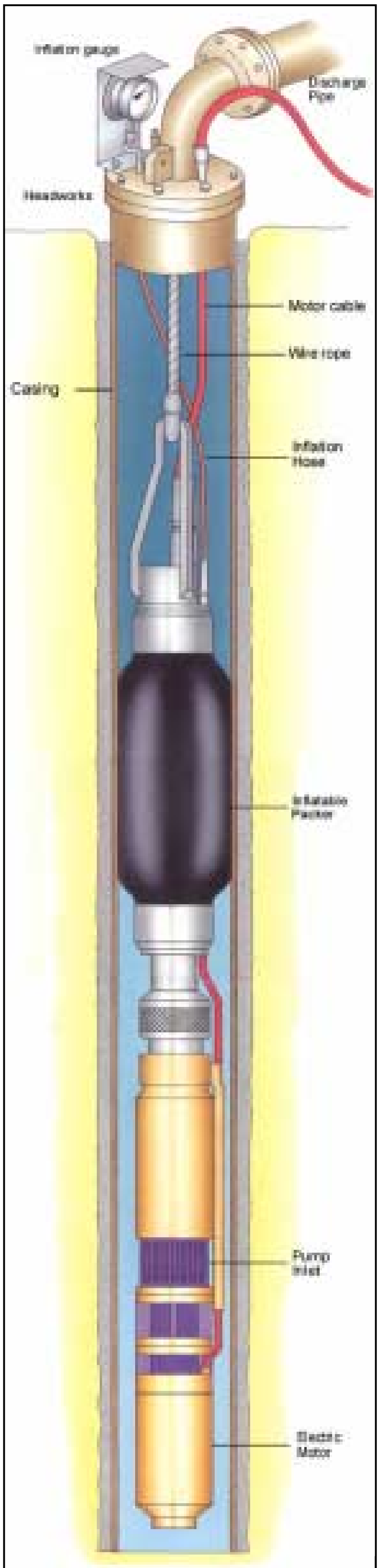

Figure 1 - Typical Riserless Pump System

This system eliminates the need for a separate riser column providing a broad range of contingent advantages such as:

- Fast, efficient installation and removal
- Removal without dismantling piping
- Low frictional head loss
- Lower power consumption due to high electrical power efficiency and low frictional head loss
- Protects pump assembly
- Prevents chaffing of casing and pump
- Less corrosion
- Reduced maintenance costs
- Improved well bore hydraulics
- Suitable for wells with severe dog-legs
- Ensures potentially polluted surface water and upper aquifers are excluded from produced water
- May allow reduced hole diameter
- May allow use of thinner wall casing

It is ideally suited to large, deep bores and offers even more advantages in new wells where the original casing and drilled hole diameter can potentially be reduced without any reduction in bore production rate.

This article investigates the methods available to sense pumping water level (and hence drawdown) in a well fitted with a Riserless Pumping system and the unique characteristics of these systems.

Level Monitoring

Common methods employed for level monitoring in wells are by using:

- An airline or “bubbler”;
- A dip-meter (either mechanical or electrical with the latter being preferred);
- An electronic pressure sensor.

An airline may be used to determine the depth of water in a well by running the line to below the water surface an then bubbling gas through the line to determine the pressure just required to displace the head of water above the outlet. This information, together with the known depth to the airline outlet, may be used to calculate the depth to water.

In the second case, the water level in the well is measured by lowering the probe of the dip-meter into the well on a marked line or tape to locate the top of the water. The depth is then, either read off the tape, or measured against known depth marks on the line.

The third method, that of using an electronic pressure sensor, is similar in principal to the airline method except that the sensor is used to determine the depth below water. Depth to top of water is then calculated as for the airline method.

The above methods have been presented in approximate order of accuracy. Fletcher G Driscoll in "*Groundwater and Wells (2nd Ed.)*" says, on page 552, that using the airline method "depth to water can usually be determined within 0.2 ft (0.06 m)" depending on "the accuracy of the pressure gauge and the care used in determining the initial pressure reading." The 2nd edition of the "*Ground Water Manual*" published by the US Department of the Interior is less confident, saying, on page 90, "An air line is accurate to only about 0.15 metres (0.5 foot) unless calibrated against a tape for various drawdowns, but is sufficiently accurate for checking well performance." We'll return to their latter point shortly.

Neither of the references mentioned appear to offer any guidance on the specific accuracy to be expected using a dip-meter though both indicate they are considered accurate for wells up to 100 ft (30 m) deep. Our personal experience is that they are commonly used for static water level measurement in wells up to 100 metres (330 ft) deep.

Electronic pressure sensors clearly offer the best available accuracy and moreover, the fastest response and measurement time. When linked to real time logging and recording data a complete record of well water levels may be made. When downloaded to a computer, either in real time or periodically, such data can be manipulated directly to provide measurements of transmissivity, storativity and provide input to complete groundwater flow models. All of this makes electronic measurement and gathering of data the preferred option where it is warranted by considerations of cost versus the value of the data.

Why are we Testing?

As in the quote above from the "*Ground Water Manual*", different methods may be appropriate to different applications. So, it is very important when selecting monitoring equipment and comparing various systems, to know why the data is to be gathered.

In water well testing there are two principal test regimes, well performance tests and aquifer characterization tests. According to page 295 of the "*Ground Water Manual*", the former are generally conducted for the following reasons:

1) to determine general adequacy of development prior to completion;
2) upon completion to determine general capacity, establish a baseline for later tests and to determine correct pump capacity and setting; and
3) to determine deterioration of the well following a period of use.

From the same source, we also learn that, aquifer characterization tests "are intended primarily to determine … transmissivity, storativity and boundary characteristics."

Performance tests require using a stepped drawdown pumping test on a single well whereas the aquifer tests usually require a constant production test and use of observation wells although one of the constant rate steps of a step test may be used instead. Each of these has different requirements with regard to measurement accuracy and frequency. For example, an aquifer characterization test is normally conducted to a tight schedule with many accurate measurements required in the early stages owing to the log time relationship with drawdown. Such a test greatly benefits from logged electronic pressure measurement but the benefit is less obvious for a step test where only measurements sufficient to indicate discharge/drawdown stability are required. Even less demanding is long term level monitoring as part of an overall well field management program.

Where are the level measurements taken?

In a standard completion, level measurements are taken in the annulus formed between the riser (or drop pipe) and the well casing. The three common level measurement techniques discussed above are all applicable though not necessarily appropriate depending on the frequency of measurements and the accuracy required. The end of the airline and the electronic pressure sensor must both be positioned below the lowest expected water level in the well. Depending on the clearance between the riser and the casing, the depth of the well, the frequency of measurements and flow conditions (such as cascading flow) it may be necessary to install a small diameter pipe in the annulus and run level measurement equipment inside that pipe.

For a Riserless system the method of level measurement influences the manner in which the system is arranged. For a dip-meter measuring system, the level is either measured inside the small diameter pipe that is used as the “hanger” pipe for the packer/pump assembly or, when a wire rope is used as the hanger, via a separate small bore synthetic tube run alongside the wire rope. In both cases a small bore pipe connects the measuring pipe to the underside of the inflated packer ensuring the true aquifer static head is indicated. As the water/air interface is entirely contained within a small bore pipe, remote from the pump inlet, there are no pumping turbulence effects.

For an airline measuring system, the airline would be connected directly to the small bore pipe that runs through the packer and a second similar pipe would be provided as a vent to the surface either via the “hanger pipe” or a separate small bore synthetic line.

When an electronic pressure sensor is used, either the sensor itself may be located below the packer, with its cable sealed through the packer or the sensor can be connected to a small bore tube passing through the packer. The latter is obviously simpler mechanically and allows for easier replacement of the sensor if such should be required. Another requirement with this system is to have a separate vent line to the surface as for the airline system. (This is in fact a standard fixture on all water well Riserless systems since operating a Riserless system without a vent to surface would allow the pump to draw the well down to less than atmospheric pressure and most pumps require a net positive head to ensure adequate cooling.)

As can be seen from the above, all common level measurement methods are easily incorporated into a Riserless Pump system.

What are we measuring?

For a standard completion, it’s pretty clear that measuring the level of water in the riser/casing annulus should provide a good estimate of the static pressure level in the aquifer. The key word here is “should” since, as is well known, casing storage effects may lead to level readings that do not accurately mirror aquifer pressures. Several conditions contribute to casing storage effects:

(1) the tightness of the formation, whether natural or induced, for example by clogging or consolidation while drilling;
(2) the degree of well and aquifer development which prevents water from freely entering the well; and
(3) the relationship between casing diameter, pump column diameter and pumping rate for example low pumping rates from large diameter casings.

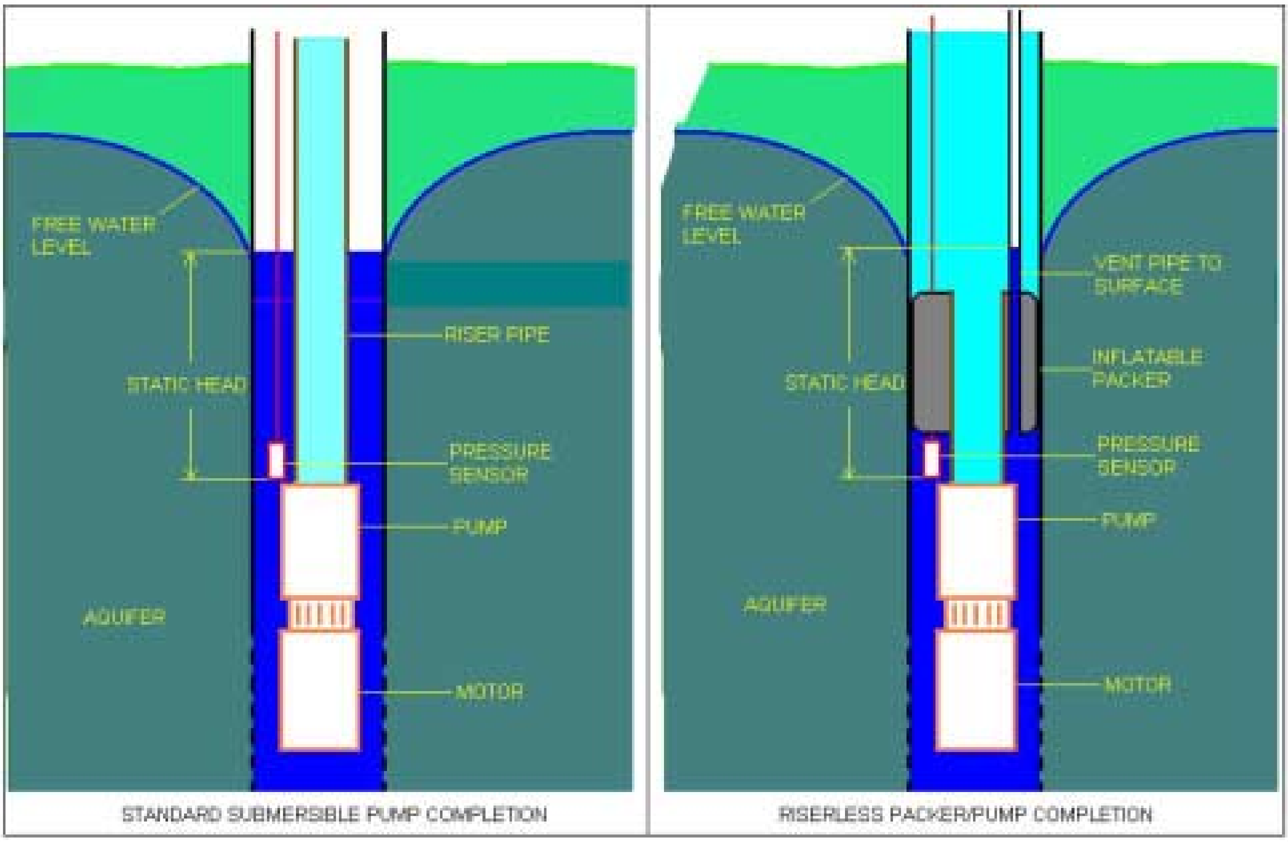

Figure 2 - Comparison of well hyrdraulics between Riserless & Standard Completions

Clearly, the most serious cases of casing storage effect would result from a combination of all three of these. Such a case is illustrated in Figure 16.22 and accompanying text of the publication “*Groundwater and Wells*” where an aquifer characterization test result seems to indicate a recharge boundary but is in fact the result of casing storage effects that effect the drawdown figures out to 260 minutes after commencement of pumping.

It is equally clear that the third contributing influence listed above for casing storage effect is completely absent when considering a Riserless system since the water above the packer/pump assembly is isolated from the pump intake.

It is also clear that, hydraulically, the levels measured from a vented region below an inflated packer are identical to the levels which would be recorded in the riser/casing annulus of an equivalent standard completion. This equivalence is illustrated in Figure 2 where it can be seen that the water level in the vent pipe is the same as that in the riser/casing annulus and thus indicates the same static head on the electronic pressure sensor. (Only the case for an electronic pressure sensor is illustrated since, it’s obvious from this that all other sensor methods would work equally as well.)