

Important Design Considerations for the Use of PVC to Construct Large-Diameter Water Wells

Introduction

Only a very small percentage of high-yielding water wells are constructed of blank and perforated casing manufactured from materials other than steel. Nevertheless, it is common for well designers to consider alternative casing and screen materials, most often PVC, in an effort to reduce the construction cost of a new well. For some applications, PVC is a viable choice. However, one should understand and be willing to accept the inherent limitations of PVC, particularly if it is being considered to construct a large-diameter water well. This memorandum discusses PVC casing in terms of its strength and durability, and the low efficiency and clogging potential of slotted PVC when used as screen.

Large-Diameter Wells

A large-diameter well, as defined in this memorandum, is one that has an inside diameter (ID) of 10 inches. The American Water Works Association (AWWA) indicates that 10-inch ID pipe will accept a 6-inch diameter pump capable of yielding 150 to 400 gallons per minute (gpm). Given that PVC pipes are available in 10-inch ID sizes, one might naturally assume that PVC is an acceptable choice. However, well diameter is only one well design parameter; others have greater importance.

Well Depth

Well depth is a variable of well construction which is site-dependent because each new well must be drilled down to the depth(s) of the source-water aquifer(s). Well depth is important because casing and screen (steel and PVC) must be able to withstand various forces that are directly related to depth. For example, assume that a new municipal well is to be 150 feet deep. Its design might consist of 100 feet of blank casing connected to 50 feet of perforated casing that is installed within the depth interval of the aquifer(s). Surface protection would typically consist of a cement grout seal around the blank casing and extending to a minimum depth of 50 feet. Finally, a filter pack (i.e., select gravel) would envelope the well screen. This seemingly simple PVC casing and screen well could fail structurally unless it has sufficient tensile strength and collapse strength to withstand depth-related forces such as: 1) the hanging weight of the string of casing and screen; and 2) the collapse forces generated from the weight of cement grout used for the sanitary seal.

Tensile Strength

Tensile strength is needed most during construction when the string of casing and screen is assembled at ground level and lowered into the well. As the drilling contractor adds each length of casing or screen the hanging weight of the string increases until all segments of casing and screen are connected. The full weight of the entire string is eventually supported by the uppermost length of casing that is suspended at the floor level of the drilling rig. Catastrophic failure is possible if the tensile strength of the casing is insufficient to bear the weight of the entire length of casing and screen.

Collapse Strength

Collapse strength is important during construction, well development, and pumping.

- A common method of perforating PVC pipe is to simply cut longitudinal slots into it. The numbers of slots per linear foot of pipe can be selected to increase the open area within the “screen”. However, whenever slots are cut into any pipe (PVC or steel) the collapse strength of the pipe is unavoidably reduced.
- While filter pack is placed into the annulus around the perforated casing, the column of gravel can bridge and thereby creates a void around the casing. When the well is subsequently developed the gravel can quickly consolidate in the annulus as it fills the void. The sudden subsidence of the gravel column has the potential to exert very large tensile forces (e.g., up to tens of tons depending on the depth) on the casing that can easily exceed its tensile strength and cause it to fail.
- Well development with a tight-fitting swab is a highly effective method but it also has the potential to collapse casing and screen.
- Rapid drawdown on pump startup can quickly evacuate water from the interior of the casing. If pressure from the column of water around the casing is too great, the casing can collapse. Table 1 shows the extreme difference in collapse strengths of steel and Schedule-40 PVC.

Table 1 – Hydraulic Collapse Pressures

Nominal Outside Diameter (in)	Material Type	Wall Thickness (in)	Hydraulic Collapse Pressure (psi)	Hydraulic Collapse Pressure (ft. water)
10	PVC	0.365	40*	92
10	Steel	0.312	760	1756

Note: *PVC 12454

Cement Grouting

Large collapse forces are exerted on casing when cement grout is pumped into the annulus to form the sanitary seal. Probably no other single task has lead to more well collapses than grouting. Placing a cement grout sanitary seal is problematic for PVC because thermoplastic casing has a low heat tolerance. When a cement sanitary seal is placed, the process begins by mixing dry cement and water which creates slurry that can be pumped into the annulus. Once the slurry is in place around the casing the cement begins to cure and it releases heat. The temperature in the annulus around the casing increases dramatically and can transfer directly to the pipe which affects the physical properties of the pipe. Temperature increases in thick cement grout are typically considerably higher. For example, field measurements in a 1½-inch thick annulus showed that the temperature of the cement grout increased 26°F (above ambient temperature), whereas temperatures rose up to 67 °F in 4-inch thick cement grout seals.

Thermoplastic pipe retains 100 percent of its working strength (i.e., collapse strength and tensile strength) at 73.4°F. However, at 100°F, it has only 62% of its working strength. At 140°F, thermoplastic pipe has only 22 percent of its working strength. This marked loss of working strength in PVC clearly shows its sensitivity to heat.

Clogging of Perforated PVC Pipe

For low yield wells and/or monitoring wells, longitudinal slots might be acceptable to some. However, longitudinal slots are highly prone to clogging which is a major limitation with respect to efficiency and productivity. Clogging in longitudinal slots comes about because the parallel sides of the slot tend to trap and retain sediment particles. This problem becomes more pronounced in thicker walled pipe.

Summary

PVC pipe is a low-cost alternative well casing and screen material that is appropriate in some instances/applications under specific conditions. However, for large-diameter water wells any cost savings offered by PVC are clearly offset by its limitations in tensile strength, collapse strength, and heat tolerance. These factors are troublesome for these wells and have the potential to be serious structural deficiencies.

References

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