Design Considerations for Selecting Casing for ASR Wells: Use of Epoxy-Coated Steel or High Strength, Low Alloy Steel

BACKGROUND

Many new aquifer storage and recovery (ASR) wells have been installed in recent years as part of a concerted effort to better manage ground-water resources. The majority of ASR wells have been constructed with stainless steel (casing and screen); the attributes of stainless steel for these applications are well known. As an alternative to stainless steel, some ASR well designers have selected high-strength low alloy steel (HSLA) for its strength, durability, utility, useful life, and cost. Another alternative for casing material is epoxy-coated mild steel pipe, which has been installed in recently constructed ASR wells. This memorandum presents a brief comparison between epoxy-coated steel pipe and HSLA steel for ASR well construction.

EPOXY-COATED PIPE

Applicable ANSI/AWWA Standard

The American National Standards Institute (ANSI)/American Water Works Association (AWWA) Standard C210-03, entitled *Liquid-Epoxy Coating Systems for the Interior and Exterior of Steel Water Pipelines* is the applicable standard that provides guidance to the water industry in selecting and evaluating liquid-epoxy coatings for use in potable water service. The standard provides options for the epoxy coating and lining systems such as a) a two part primer and topcoat; b) two or more coats of the same two-part coating; or c) a single coat of two-part coating. The minimum thickness of the coating is to be at least 16 mils (406 µm).

The standard also includes guidance on the field procedures for the use of liquid-epoxy coated pipe for pipeline construction. It does not make specific reference to water well construction. However, it does indicate that precautions should be taken to minimize damage to the protective coating. It recommends against the use of metal tools or heavy objects to contact the finished coating. In the event that the coating is damaged, the standard indicates that the pipe should be reprocessed and recoated. In reference to the use of coated pipe for an ASR well, removal of the pipe for reprocessing and recoating is not a viable option. It would have to remain in place.

Use of Epoxy-Coated Pipe for Water Well Casing

Epoxy-coated pipe is known for its use in water transmission pipe; however, its use as water well casing is relatively new. Proponents of epoxy-coated pipe refer to its reduction or elimination of the steel surface area that is subject to rusting (Pyne, 1995). The production of rust from steel casing is, of course, undesirable for ASR wells because the particulate matter might clog the aquifer. However, the application of a liner material to mild steel pipe to achieve non-rust producing conditions comes with some considerations. The first is the epoxy itself. It is widely recognized that a coating material can fail if not properly applied. It is also known that it is almost impossible to avoid some pinholes or holidays when applying a coating or lining. When this occurs, the steel will suffer corrosion attack at these points (Schweitzer, 1983). This localized corrosion will be more severe than the general corrosion that would occur had the lining not been present (Roscoe Moss Company, 1990).

HIGH-STRENGTH, LOW ALLOY STEEL

Applicable ASTM Standard

American Society for Testing and Materials (ASTM) Specification A 606, entitled *Standard Specification for Steel, Sheet and Strip, High-Strength, Low-Alloy, Hot-Rolled and Cold-Rolled, with Improved Atmospheric Corrosion Resistance* covers both cut lengths or coils intended for use in structural and miscellaneous purposes. These steels have enhanced resistance to atmospheric corrosion and are supplied in two types. Type 2 contains 0.20 minimum copper. Type 4 provides corrosion resistance that is substantially better than carbon steels with or without copper addition.

Use of HSLA Steel for Water Well Casing

HSLA (ASTM 606 Type 4) is particularly well suited for use as water well casing. It offers both high yield strength (minimum 50,000 psi) and high tensile strength (minimum 60,000 psi) with the added benefit of corrosion resistance that is four to six times greater than carbon steel. The results of extensive testing of HSLA steel have shown that the corrosion rate for HSLA steel essentially levels off after 2 years of service. The test results further show that:

1. The addition of 0.05% to 0.2% copper concentration reduces the corrosion rate by 50%; and
2. The addition of low concentrations of other alloys (e.g., chromium, molybdenum, manganese, phosphorous, and nickel) reduces the corrosion rate by another 50 % (Roscoe Moss Company, 1990).

The combination of high yield strength, high tensile strength, and enhanced corrosion resistance are positive attributes that enhance the applicability of ASTM 606 Type 4 steel for use in water well construction.

ASR DESIGN AND CONSTRUCTION

The typical ASR well is constructed with uncoated blank steel such as stainless steel (Types 304 and 316L) or HSLA that extends from ground level down to the depth of the storage zone, i.e., aquifer(s), where the recharge water will be injected. In some instances mild steel with epoxy-coating has been substituted for stainless or HSLA steel. Most designs provide for the blank casing to be encased in cement grout that seals off the annular space between the borehole wall and the exterior of the blank casing. This makes it possible to maintain injection pressure and precludes the up-flow and down-flow of recharge and/native water through the annulus. The blank casing from ground level is connected to a section (or sections) of well screen through which the recharge water is injected into the storage zone. The screened section(s) of the well consist(s) of either wire-wrapped stainless steel screen or stainless steel louvered screen. Connections between the individual lengths of well casing and screen are most often made by welding; however, some small diameter wells (i.e., 4 inch or less) are designed with threaded and coupled end connections.

During the construction phase, after the well casing and well screen are installed, and the annular gravel pack and cement grout are in place, the well is ready to be developed. Development begins by removing remnant sediment from the interior of the well screen with a heavy, steel bailer. The bailer is repeatedly lowered into the well to collect sediment and then raised to the surface where it is emptied. When bailing is completed, the development continues by swabbing and airlift pumping the well. This task is conducted with a close-fitting single or dual swab which is raised and lowered to agitate the water in the annulus and aquifer(s) and force water in and out through the well screen. When swabbing is completed the well is airlifted to pump out the turbid water and sediment that were drawn into the well.

Following many hours of development, the production capacity and injection capacity of the ASR well are determined by injection and pumping tests. Production testing is usually conducted with a line-shaft turbine pump that is lowered into the blank casing to a predetermined depth. After the testing is completed the test pump is removed from the well.

It is important to note that during the construction, development and testing phases each time a tool or pumping equipment is raised and lowered inside the well there is the possibility for contact to be made with the interior of the casing. This possibility becomes even more likely if the well is not plumb or if there is a deviation in the well's alignment. In either case, if contact is made with the epoxy-coated casing, it will almost certainly damage the coating and expose the underlying steel. More importantly, any such damage to the epoxy coating cannot be repaired once the casing has been installed.

CASE STUDY

In the mid-1990's, a major Southern California water utility undertook an ambitious ASR program to develop up to 300,000 acre-feet of storage in the Los Posas Ground-water Basin. Using dual-purpose, injection/extraction wells and source water from the Metropolitan Water District of Southern California, CMWD would be able to store water and subsequently pump out the stored water on an as-needed basis.

The project included the construction of 16 ASR wells that were constructed with 16-inch outside diameter (OD), mild steel with 0.375" wall thickness. The initially well design specified that each segment of pipe would be joined by threaded and coupled connections. The design was proposed to avoid heat damage to the interior protective coating caused by welding. However, prior to construction and due to the anticipated concerns expressed by the contractor who forecasted major handling problems with the large diameter of the pipe. The design was changed such that the blank well casing, supplied by Roscoe Moss Company, was manufactured with ½-inch thick, double-weld, beveled collars to protect the epoxy-coated steel pipe. This made it possible to weld the connections between casing segments.

Following the completion of the well construction, mechanical well development, and development with the test pump, a side-scanning video-camera was lowered into each well to inspect its down-hole condition. The videos showed that the epoxy coating on the interior of the mild steel, blank casing had been severely scratched by the well development equipment (possibly including the pump bowls). As a result, there were significant bare spots, or holidays where bare, mile steel was exposed. Unfortunately, it was impossible to repair the damage to the epoxy lining to remediate the problem. The long-term impact(s) of the damage will probably accelerate corrosion of the mild steel casing. This has the potential to cause or contribute to future operational problems for the wells.

SUMMARY

HSLA steel and epoxy-coated pipe have several unique properties that relate to their utility and durability for use in ASR wells. Perhaps most important of these is the ability of the steel to resist corrosion. Since ASR wells undergo frequent wetting and drying cycles, the potential for accelerated attack on the steel is particularly pronounced. Added to this is the fact that these facilities will be expected to operate in such conditions for scores of years. Therefore, any damage to an epoxy-coated liner is serious and must be avoided.

As described in the above case study, despite concerted efforts to carefully handle materials and equipment during construction and development of ASR wells, the potential for damage to occur to an epoxy-coated liner is unavoidable. Unfortunately, if such damage takes place the long-term durability and useful lifetime of the completed well are in jeopardy. Only time will tell how significant the consequences will be.

REFERENCES

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