

Storage Well Cathodic Protection Comparative Assessment

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ABSTRACT

The long-term service life outcomes were compared for similar natural gas storage wells operated with either no cathodic protection or partial cathodic protection. Cathodic protection for storage wells is not mandated by regulation and industry practice varies so the outcomes for more than 350 wells were assessed based on casing inspection logs, historical failure rates and service lives. Casing inspection logs indicated a higher prevalence of external corrosion on the wells without cathodic protection. Furthermore, of the wells that had been remediated/abandoned, those operated with partial cathodic protection were found to have increased service lives when compared with the wells operated without cathodic protection. A higher percentage of the wells operated without cathodic protection also required remediation/abandonment. Overall, the data supported a conclusion that partial cathodic protection lead to improved service life outcomes and reduced external corrosion.

Key words: Corrosion control, Cathodic protection, Underground corrosion

INTRODUCTION

When two long-time operators of natural gas storage wells in southwestern Ontario merged, it was an opportune time for the combined company to evaluate the effectiveness and impact of cathodic protection (CP). Staff from both legacy operators expressed general satisfaction with the longevity of their storage wells, typically 30+ years, but they had relied on two different approaches to corrosion control: one had isolated wells from flowlines and operated without CP, while the second had resistively bonded wells to cathodically protected flowlines. For the second operator, typical well currents were in the range of ~3 A.

Lending weight to the 'no CP' approach were internal studies from the 1990's shared by other storage well operators in the vicinity that had concluded that CP was not beneficial and could even be detrimental. This detrimental effect was attributed either to interference between clustered wells or to current

discharge on a single well from one well casing to another, such as from the production casing to the intermediate casing (see Figure 1 for terminology). Based on these interference concerns and well lives exceeding 20 years without CP – which was attributed to conditions not being aggressively corrosive – these other storage well operators had subsequently removed CP from their wells. It was noted at the time that the cost of CP was relatively low and was not a factor in the decision.

Therefore, to determine the optimal approach to CP, the combined company commissioned a comparative assessment on the corrosion outcomes of each of the legacy operators. This comparative assessment was intended to answer two questions: first, whether CP was effective at reducing external corrosion rates; and second, whether the application of CP would be economically beneficial. This paper includes the findings of this comparative assessment.

LITERATURE REVIEW AND INDUSTRY PRACTICE

Well Casing Background

A typical well consists of a well head, a conductor casing, a surface casing, one or more intermediate casings, and a production casing, as shown in Figure 1 (note that the maximum depths of the production and intermediate casings is significantly different). Wells are designed so that the casings are not subjected to a pressure exceeding 100% of their respective minimum yield strength, which depend on the grade and weight of the casings, e.g. per CSA Standard Z341.2-18 *Storage of Hydrocarbons in Underground Formations* Section 7.3.2.e.

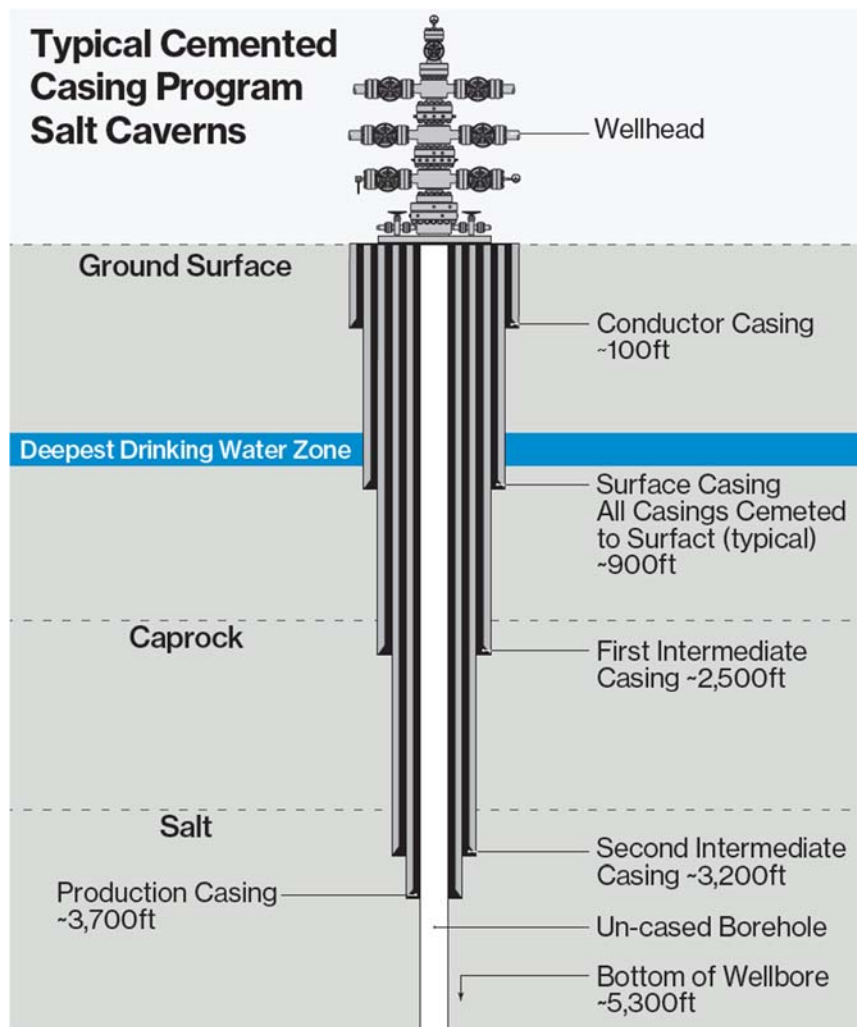


Figure 1: Typical Well Profile (not to scale)¹

Corrosion reduces the wall thickness of a casing, which results in a lower yield strength. As such, operators are required to mitigate and control corrosion.

Corrosion can occur on the internal and external metallic surfaces of the production casing. However, a CP system can mitigate the growth only of external corrosion. Furthermore, CP can only have a direct impact on the exposed portion of the casing, i.e., the portion of the production casing extending past the intermediate casing, since the shallower portion is electrically shielded by the surrounding casings. Secondary effects on the enclosed portions of the production casing are possible and were evaluated as part of this assessment.

Regulatory Requirements

The *Oil, Gas and Salt Resources of Ontario, Provincial Operating Standards* require compliance with CSA Z341.² Notwithstanding an explicit reference to the 1998 version of Z341, in the latest version Z341-18, cathodic protection is not a requirement. If cathodic protection is used, the user is directed to NACE SP0186.^{3,4}

Regulations in other Canadian provinces are generally also based on CSA Z341, although Nova Scotia requires the use of cathodic protection in its *Code of Practice Respecting the Underground Storage of Hydrocarbons*. Z341-98 is specifically acknowledged as the primary source material for the Code, but the preface states that, “Certain requirements are prescribed in this Code that differ from the requirements provided in Z341-98. These requirements are considered to be best management practices within the industry that warrant adoption when underground storage is first developed in the province.”⁵

Underground storage facilities in the US are federally regulated under 49 CFR 192.12, which includes by reference API RP 1170 (for salt cavern storage) and API RP 1171 (for depleted hydrocarbon and aquifer reservoir storage).⁶ RP 1170 does not address cathodic protection and provides very little guidance on corrosion monitoring.⁷ The guidance on integrity monitoring does not include any measurements related to cathodic protection. RP 1171 includes only a recommendation to monitor the “corrosion potential of current flows associated with cathodic protection systems,”⁸ which is likely a reference to casing potential logs whereby the net casing current is measured at different depths to assess CP effectiveness.

The Interstate Oil & Gas Compact Commission in cooperation with the Groundwater Protection Council published the *Underground Gas Storage Regulatory Considerations: A Guide for State and Federal Regulatory Agencies* in May 2017. This informational document states that the use of cathodic protection is a site-specific issue that depends on, “Factors such as the corrosivity of soil and strata above the gas storage zone, the presence or absence of fully cemented casing strings, and the risk of damaging stray current”.⁹

Overall, neither the governing jurisdiction nor most Canadian or American regulations require CP for storage wells.

Industry Practice

The application of CP for external surfaces of well casings has been established in the industry for many years, with NACE International’s standard practice SP0186 first published in 1986. The classic *Handbook of Cathodic Corrosion Protection* by von Baekmann, Schwenk and Prinz dedicates a chapter to the subject and the references range from 1957 through 1985. This is a helpful overview and includes a discussion of the interference phenomenon for isolated or resistively-coupled casings, with the recommendation that groundbeds be located at least 100 m away from the casings they protect and unprotected casings be even further away to avoid detrimental interference¹⁰.

Regarding the possibility of corrosion due to current discharge from the innermost casing to the intermediate casing on a cathodically-protected well, the statement is made that, “Electrolytic corrosion does not occur in the annular region because of the current flow through electrical connections.”¹¹ This

reasoning does not appear to be correct since although incidental metallic electrical connections often do exist between the casings, the resistance between pairs of cemented casings via the electrolytic path is much lower than casing string resistance. This means that the current will substantially equalize between different casings, and this can generally be observed in casing potential logs. Nevertheless, although the reason given may not be entirely accurate, it is likely that the statement is accurate based on long-standing experience.

Oliphant provides a helpful summary of the state of well casing CP in Alberta in the 1980's and updated design guidance¹². Recent research on the subject of CP for well casings is limited but has focused primarily on enhancing the CP current distribution and reducing groundbed costs through modelling.^{13,14,15} The involvement of industry in these papers confirms that CP of well casings continues to be practiced in some parts of the world. Didas provides a case history demonstrating the dangers of inserting resistive bonds of differing values between the rectifier negative and several well casings.¹⁶ This is a variation on the electrical isolation interference problem described by the internal studies from nearby operators

Summary

The literature indicates that the broader industry continues to rely on CP for well casings in at least some cases, but a thorough analysis of the effectiveness of CP on well casings was not identified. The literature review indicated anecdotally that detrimental corrosion would not occur between casings on a single well, but confirmed the general concern of interference between wells, should the CP system be designed improperly. However, the overall experience of other operators and the continued widespread use of CP indicates the affect is likely beneficial.

WELL CONFIGURATION AND METHOD

Well Environment

The majority of the subject storage pool facilities are located in a 1400 km² area in southwestern Ontario. Although borehole data is not available for each well, the geological composition of the bedrock is relatively uniform in this region.¹⁷ A simplified overview of the geological strata is provided in Table 1.¹⁸

Table 1: Simplified overview of geological strata

Formation	Description	Thickness (m)	Minimum Depth* (m)	Maximum Depth* (m)	Comments
Glacial Till	clay – particles are finer than 3 millionths of a metre	20-50	0	50	-
Sedimentary Rock	limestone – mainly calcium carbonate, dolomite	300-400	20	450	-The aquifer is located at the top of this strata. -Typical strata for oil and gas production wells.
Sedimentary Salt	e.g. sodium chloride	300-400	320	850	-Typical strata for the storage caverns.
Sedimentary Rock	layers of calcium and magnesium carbonates	500-700	620	1550	-
Metamorphic Rock	e.g. granite	Unknown	1120	N/A	-

*This depth is approximate and may vary at the location of each well.

The depths of the wells are generally between 400 m and 700 m for the first legacy operator (designated “Operator U”) and between 500 m and 700 m plus a cluster around 200 m for the second legacy operator (designated “Operator D”).

Based on the proximity of Operator U's and Operator D's storage pool facilities and the uniform geology in the area, the wells are expected to have been exposed to an environment of comparable corrosiveness and the same corrosive layers (if any). As such, geology is not expected to have caused significant differences in the corrosion history of both systems.