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# WELL CASING CATHODIC PROTECTION

# UTILIZING PULSE CURRENT TECHNOLOGY

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## ABSTRACT

Pulse current technology (PRT) for well casing cathodic protection has been successfully applied in North America since the late 1960's. Pulse technology has been limited primarily due to a lack of understanding of how the advantages are achieved. As well, there have not been any strong case histories that clearly demonstrate pulse current success where conventional DC current could not adequately protect the casing. This paper will provide a short review of pulse technology, along with a brief review of case studies from earlier publications. This paper will also present a new case study that demonstrates the superiority of pulse current over DC current.

Keywords: well casing, cathodic protection, pulse current

## WELL CASING CATHODIC PROTECTION UTILIZING PRT

### Principles of Operation

In PRT, pulse rectifiers generate short electrical pulses several thousand times per second. Typical frequency range is between 2000 and 5000 hertz. The "on" time is adjustable and ranges between 10 and 50 microseconds, resulting in a total duty cycle between 2% and 25%. Further descriptions of the technology and its advantages/disadvantages can be found in previous papers/publications [1,2,3]. Some of the highlights of these publications that warrant repetition here include:

- PRT current requirements are typically significantly lower than conventional DC current requirements.
- PRT can provide current to significantly deeper levels than conventional DC current.
- PRT provides more uniform current distribution to the casing.

In the previous papers, there were strong indicators that PRT could offer significant advantages to conventional DC current for well casing cathodic protection, however, there were no absolute conclusions. The Jumping Pound 9-24-26-6W5M reference [3] did provide evidence that 4.88-pulsed amperes provided the same level of protection that 18 amperes of conventional DC current. This field has now had a total of 4 CPET logs performed on conventional current protected casings and all have confirmed the same conventional current target level. The Sorge 10-5-6-1W5M example [3], one ampere of axial current was measured at a depth of 3567 m (11,700 ft.) with only 4.2 amperes applied at surface. This data was shared with several experienced cathodic protection specialists and they all agreed that conventional current could not hope to achieve the same level of current distribution with such a minimal amount of applied current at surface.

## CASE STUDY

### Subject Field History

The first wells in the field analyzed were completed in the mid 1970's. Completion depths typically exceeded 4600m (15,000 feet). In the span between May 1988 and February 1989, four casing failures were detected. The four failures occurred between 9 and 11 years after completion. The total workover costs associated with the four failures exceeded $6MM (Canadian), not including equipment replacement, e.g., tubing, liners, etc. Downhole casing inspection logs were performed and the failures were all attributed to external corrosion at depths between 3100 and 4600m. Bottom hole temperatures were in the 140 – 150 $^{0}$C range. Despite the depths involved, in conjunction with high formation temperatures, it was recognized that cathodic protection might be able to mitigate corrosion and testing was implemented.

### E log i Testing

The principles of E log i testing are well known, if not necessarily universally accepted. Applying current in incremental amounts for a fixed time interval and plotting resulting "instantaneous off" potentials versus applied current on semi-log graph paper can indicate where the linear relationship between these two factors changes. E log i testing was performed on one well and the resultant graph was not convincing on where protection was ostensibly achieved. The cathodic protection consultant deemed that 32 amperes was the minimum required current and their recommended design called for a 50-ampere capacity.

### Casing Potential Profile®™1 Testing

Measuring structure-to-soil potentials is not practical on well casings, therefore alternate means are necessary for assessing corrosion rates. Basic corrosion theory dictates that current flow out of the structure at any given points indicates corrosion, whereas net current flow to the structure indicates protection. Casing Potential Profile®™ (CPP) is a technology employed to measure current flow in well casings. The CPP tool has two sets of contacts that measure the potential difference of the casing. Using an assumed casing resistance, axial current flow is calculated. If the current measured at each station is continually increasing, corrosion cannot be occurring, i.e., corrosion occurs at points of current discharge. The CPP technology has significant limitations, specifically, that it assumes a uniform resistance between contacts, as well as, assumes excellent contact resistance. As the assume resistances are in micro-ohms and the measured potentials are in micro-volts, slight variations in the actual resistance as compared to the perceived resistance can significantly affect calculated axial current flow. Based on this type of testing on one well casing, it was recommended that a minimum of 32 amperes be applied to the casing.

### Corrosion Protection Evaluation Tool®™2 Testing

Two Corrosion Protection Evaluation Tool (CPET) logs were performed on another well within the field. The CPET is a proprietary downhole tool developed by Schlumberger that provides far more accurate data than the CPP technology. In short, the CPET not only measures actual casing resistance between the contacts, it also measure contact resistance. The measurements can now accurately calculate axial current flow within the casing

®™1 Baker Hughes Canada Company
®™2 Schlumberger Canada Ltd.

once the potential is measured. The two logs were performed two weeks apart on the same casing. The applied current was 49 amperes in both cases.

The conclusions reached by the cathodic protection consultant was that while complete protection was not being achieved, additional polarization time may eliminate remaining anodic areas. The recommended design called for a 60-ampere cathodic protection system that was hoped to be adequate.

A third CPET was performed on a different well, again with an applied current of 48 amperes. The results were similar to the initial logs, in that the applied current was insufficient to eliminate all anodic zones, but, with time, could possible achieve protection.

**Cathodic Protection Design**

At this point, the owner felt uncomfortable with the recommendations provided to date. Two experienced consultants were both stating that 40 – 50 amperes might protect the casing, but there were doubts. Upon hearing about the work being done with PRT technology, the owner investigated further. Feedback provided to the owner clearly stated that PRT had not been applied to circumstances as severe as were being encountered in this field. While PRT had demonstrated being able to reach significant depths [3], the corrosiveness of the aquifers was not as pronounced as in this field. Furthermore, work with PRT at that time was targeting casing current levels at 5.0 amperes or less. It was recommended that if PRT was a serious option, the minimum target applied current should be 12 amperes, with the flexibility to increase to as high as 20 amperes. Combining all the facts and suppositions in front of the owner, a decision was made to implement PRT with a target current of 17 amperes per casing. Groundbeds were to consist of 20 cast iron type “D” anodes installed vertically in a single deep well configuration, placed no closer than 400 meters from the casing. This design was applied to all wells within the field in 1991. Identical PRT designs have been applied to all new wells completed since then.

**Results**

The immediate impact of energizing the PRT cathodic protection systems was that the casing leak frequency decreased dramatically. Between 1988 and 1991, the leak frequency was one casing annually. Between 1991 and 2003, there have been a total of two casing failures, both of which occurred on wells that were in excess of ten years old when cathodic protection was applied. The obvious implication is that these two casings had suffered significant corrosion prior to the application of cathodic protection and were in a state where failure was imminent, regardless of any mitigation measures taken.

A CPET log was performed on the same well that the third CPET was performed described earlier, at 48 conventional DC amperes. The PRT applied current was 18 amperes at the time of the log. The total logged depth was 4315 m (14,150 ft.). While the previous log on this casing indicated anodic areas in the bottom portion of the casing, the PRT log found the casing to be completely protected, with no evidence of any anodic areas along the entire length of the loggable casing.

In all three conventional DC cathodic protection applications, current losses to surface/intermediate casings were significant, ranging between 30 and 60% of the applied current. The PRT loss to those areas was less than 2 amperes or only 11% of the applied current. This further demonstrates the ability of PRT to distribute current in a more uniform manner than conventional current and provide current to those areas where the actual requirements exist.

## SUMMARY

- The subject field suffered severe external casing corrosion, resulting in failures within 11 years of completion.
- Conventional DC current cathodic protection was tested and positive results were measured, however complete protection was not achieved within the time frame of the testing.

- Conventional DC current cathodic protection was deemed as possibly achieving success if a minimum of 32 amperes was applied, but there were reservations as to the ultimate success.
- PRT, applied at an average current of 18 amperes effectively eliminated further casing failures.
- CPET logging of a casing with an applied PRT current of 18 amperes, that was originally analyzed with DC applied current, found complete protection along the entire length of the casing.

## CONCLUSIONS

- Comparatively high levels of conventional DC current achieved a high degree of success, but no guarantees were provided to assure the desired result.
- PRT, applied at less than 40% of the prescribed conventional DC current levels, provided complete protection of the casing.

## REFERENCES

1. T. M. Doniguian, "The Pulse Rectifier", American Gas Association Operating Section Proceedings, 1982, Arlington, VA, p. T44-49
2. N. N. Bich, J. Bauman, "Protection of Well Casings by Pulsed Cathodic Currents", presented at the 1991 NACE Canadian Region Western Conference, Saskatoon, Saskatchewan, February 1991.
3. N. N. Bich, J. Bauman, "Pulsed Current Protection of Well Casings", presented at NACE Corrosion – 94, Paper no. 566, Baltimore, Maryland.