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CORROSION CONTROL OF THE HANFORD SITE WASTE TRANSFER SYSTEM

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ABSTRACT

Corrosion control of the Hanford Site waste transfer system is necessary to assure the system is operational for planned activities leading to successful environmental restoration. Cathodic protection of the Hanford Site waste transfer system has been in existence since the 1940's with acceptable results. The original system was updated with an improved modern design. Energization surveys and a recent baseline survey demonstrate that the existing system operates as intended.

Key Words: Hanford Site, corrosion, transfer systems, tank farms, cathodic protection

INTRODUCTION

In 1943, the Hanford Site was created by the federal government for plutonium production for national defense. The Site consisted of nuclear production reactors, spent fuel processing facilities and other support facilities. Irradiated metallic fuel was chemically processed at the Hanford Site to recover plutonium for over 40 years. Processing large volumes of spent reactor fuel and other related waste management activities created radioactive wastes that have been stored in underground high-level waste storage tanks since the 1940's.

Spent fuel processing is no longer an ongoing activity at the Hanford Site. The mission is now waste reduction and minimization, and environmental restoration of the Hanford Site. Future activities at the Hanford Site will prepare the high level waste for permanent disposal in a geologic repository.

The effluent waste streams from the processing facilities were stored underground in high level waste storage tanks. The waste was transferred between storage tanks and from storage tanks to waste processing facilities in a complex network of underground piping. The underground waste transfer system consists of process piping, catch tanks, lift tanks, diversion boxes, pump pits, valves and jumpers[1]. The corrosion of the process piping from contact with the soil is a primary concern of the transfer system. The other transfer system components are made of corrosion-resistant alloys or are isolated from the underground environment and experience little degradation.

Corrosion control of the underground transfer system is necessary to assure that transfer routes will be available for future waste retrieval, processing and disposal. Today, most waste transfer lines are protected by an active impressed-current cathodic protection system.

TRANSFER SYSTEM DESIGN

The existing configuration of the underground transfer system took form over the past 40 to 50 years. The early waste transfer systems fabricated in the 1940's and early 1950's were made largely of 300 series stainless steel, single-walled, direct buried pipe. The transfer system design evolved from the early single-walled, direct-buried design to either stainless steel or carbon steel pipe encased in a concrete trough-like encasement to either carbon steel or stainless steel pipe encased in an outer pipe of either carbon steel or stainless steel. Carbon steel piping is also direct-buried with an intended short term use. The direct-burried lines are heat traced and coated or encased in an insulating foam, to reduce salt precipitation with decreasing temperature during transfer operations. Piping which enter or exit a pit; be it a valve pit, jumper pit or pump pit, are electrically interconnected to reduce the likelihood of stray current corrosion. In addition, all metallic structures are tied into a grounding grid.

Cathodic protection was first installed on the transfer systems at the Hanford Site in the 1940's due to premature failures of the early stainless steel transfer lines at an alarming rate from external soil corrosion[2]. The cathodic protection installed was reported successful with adaquate protection. This original cathodic protection design consisted of air-cooled copper oxide rectifiers tied in to a surface anode bed consisting of 33-ft.-long carbon steel rails[3]. All rectifiers were totally interconnected, with anodes staggered along the piping on opposite sides. All adjacent steel piping or other metallic structures buried in the ground were bonded to the protected piping.

The original cathodic protection system has since been replaced with one of more modern design. From a cathodic protection standpoint, the waste storage tanks are considered to be an integral part of the protected structure due to their inadvertent bonding with the transfer piping. The existing transfer system has many different configurations and is made of a variety of materials.

CATHODIC PROTECTION SYSTEM DESIGN

By 1967, many of the steel rail anodes were largely consumed, leading to installation of new duriron anodes[4]. In 1980, the original cathodic protection system was evaluated and determined to be outdated and not operating properly. The interconnected rectifiers were difficult to operate, with variations of one rectifier output affecting the entire system. Test stations were not provided during the original installation, making it difficult to monitor and/or troubleshoot the cathodic protection system. The cathodic protection system was shut down, and recommendations were made to upgrade the system.

Since the original system was shut down in 1980, a new cathodic protection system was installed, in a piece-meal fashion based on safety prioritization, as funding became available. The installed rectifiers were three phase 480-volt input with silicon diode circuitry. The NEMA 4 constructed rectifiers are oil immersed and cooled with all-weather fire-proof boxes. Lightening arrestors are installed. The Durichlor Type D anodes are installed both vertically and horizontally. The anodes are high silicon cast iron packaged in coke breeze. The anodes are 8 inches in diameter and 96 inches in length.

The new design eliminates the original interconnected rectifier design and provides numerous monitoring stations for improved operation. Special design considerations were employed to minimize stray currents. Since 1985, all new waste transfer lines installed at the Hanford Site are required to have cathodic protection. In 1986, the first portion of the upgraded cathodic protection system was energized. Table 1 shows the current rectifiers and protected areas. There are currently 26 rectifiers operational and one rectifier system (Rectifier 36) to be installed.

Stray currents generated from the cathodic protection system are minimized by distributed groundbeds with evenly spaced anodes along the header cable. The anodes are located parallel and adjacent to the transfer lines. Both ends of the header cable terminate at the rectifiers, providing assurance that the anode groundbed will continue to operate should the header cable break. Existing grounding grids located throughout the individual tank farms pick up any stray currents that develop. The new rectifiers are grounded to the piping and to the grounding grid. All non-welded joints (flanges) are electrically bonded with cables to reduce the possibility of isolation. By design, the cathodic protection system does not protect water lines, steam lines, and other unidentified process lines. Those nonprotected structures tied into the cathodic protection systems will be protected or partially protected. Test leads were installed on all surrounding piping for the purpose of evaluating stray currents during energization and operation. Most nonprotected piping surrounding the protected piping were redundantly bonded to the protected piping, with provisions to tie in other nonbonded piping if stray currents are identified after energization. In addition, reference electrodes are installed in the proximity of the waste storage tanks at the 10-ft. and 25-ft. levels for identifying existing stray currents[5].

The current cathodic protection system was designed to protect critical transfer piping associated with the existing double shell tanks. The rectifiers are sized and the anodes placed only to protect this piping. However, the proximity of the tanks, conduit, non-essential piping, and even fencing to protected piping requires all metallic structures be electrically bonded into the cathodic protection circuit to avoid accelerated corrosion by stray currents. All metallic structures in the double shell tank farms, including the waste storage tanks' carbon steel walls and concrete reinforcing bar, receive nominal protection from the rectifiers.

Anode distribution boxes were provided in the cathodic protection system design to allow for disconnecting anodes from the circuit if tests indicate that a particular anode is creating unwanted stray currents. The cathodic protection system was not designed with the intent of protecting the waste storage tanks, and futhermore, the waste storage tanks were not intentionally isolated from the transfer system, such as by installing isolation gaskets.

INITIAL ENERGIZATION SURVEY RESULTS

Following installation of the cathodic protection system, initial energization surveys were performed as the systems were installed.[5,6,7,8] The criteria for evaluating the cathodic protection operation was -0.850V versus a $Cu/CuSO_4$ reference electrode. This potential indicates complete protection on buried steel structures. All readings were taken in accordance with the National Association of Corrosion Engineers (NACE) recommended practice RP0169-83, "Control of External Corrosion on Underground or Submerged Metallic Piping Systems." In addition to monitoring the operation of the rectifiers, potential measurements were made on all protected and nonprotected piping in the vicinity of the cathodic protection system. Surveys were also performed to evaluate the existence of stray currents impacting the waste storage tanks.

The surveys demonstrated that stray currents from the operation of the cathodic protection system did not impact the underground storage tanks. Stray currents were located on several nonprotected piping, and eliminated by permanently bonding affected lines to the protected structures. This was achieved by permanently connecting the test lead of the affected pipe to a test lead of one of the protected pipes in the test station. This effectively allowed the stray current to safely return from the affected pipe to the rectifier via a metallic path. Reduced currents were observed on several underground structures due to insufficient anodes. To alleviate the reduced current, additional anodes were installed. Other observations made during the initial energization surveys are reported below.

- One particular pipe was found to have relatively low pipe-to-soil potential. A review of the construction documentation showed that the pipe was installed in a sleeve and that the test wires were installed on the sleeve rather than on the affected pipe. The pipe was electrically insulated from the sleeve; hence, providing no cathodic protection to the transfer piping. The measured potential (of the sleeve) will be ignored in future surveys.

- Low native potentials (-0.100 to -0.300V) were observed during preliminary surveys because of the piping being in direct contact with grout used to seal the annular space of the valve pit penetrations.

- Potentials near several storage tanks did not meet the -0.850V potential criteria as a result of insufficient anode coverage. In several cases, the low potential was determined to be acceptable because the structure would be partially protected and not in jeopardy of rapid deterioration. In other situations, additional anodes were installed to boost the cathodic protection current. Generally, low power output rectifiers were installed near storage tanks for the purpose of reducing the possibility of excess current output causing stray current corrosion.

- Potential measurements on a 30-inch corrugated metal casing demonstrated accelerated corrosion from stray currents. As the metal casing is solely used for expansion and not secondary leak containment, it was decided to not excavate the line to bond the casing to the cathodic protection system, but to allow the casing to corrode.

- Low potentials were identified at several test stations near waste storage tanks. An attempt was made to increase the low potentials by disconnecting several remote anodes and maximizing the rectifier outputs to boost the potentials near the waste storage tanks. No affect was observed because of the tanks' large structures. The low potentials were acceptable with the low output rectifiers, because the rectifier systems were designed to limit potential stray currents on the waste tanks.

1994 BASELINE CATHODIC PROTECTION SURVEY

Installation of the existing cathodic protection system at the Hanford Site was performed in a piece-meal fashion. A comprehensive survey of the entire system had not been performed since installation. Operation of the cathodic protection system with overlapping systems was never characterized.

Between April and June 1994, the entire cathodic protection system was surveyed, which included every test wire in each test station.[9] Pulse generators were installed in series with all rectifiers that may potentially overlap existing structures to be measured. The pulse generators provided a synchronized interruption of all near by anode currents simultaneously.

The infrastructure at the Hanford Site, being rather complex, consists of a variety of materials with different requirements and polarization rates. The transfer system is not a homogeneous structure, but consists of different materials, environments, coatings and temperatures. The acceptance criteria for the cathodic protection system are complex due to the nature of the entire transfer line system. Hence, the conservative approach is to protect the most anodic structure and to adjust the system such that an ideal current level is achieved to polarize the cathode to the open circuit potential anode. Since carbon steel has the most anodic potential, the -0.850V criteria is acceptable for Hanford Site structures.

Potential measurements were made using a high-impedance wave form analyzer capable of capturing the maximum and minimum voltages during the pulsed rectifier cycles. Potential readings were made at each test station. In addition to all existing test stations, potential measurements were made on any metallic structure such as tank vents, electrical conduits, water piping, and fencing. In addition, continuity tests were performed on selected structures by the fixed cell movable ground method.

Results of the baseline survey demonstrated that the cathodic protection system is operating as intended. Rectifier adjustments were required to elevate several rectifier output currents. Stray currents were impacting several lines, which require bonding with protected piping. Stray currents were not indentified impacting any of the underground storage tanks. Those storage tanks evaluated by continuity tests were found to be continuous with the transfer systems.

CONCLUSION

Cathodic protection has existed on the Hanford Site since the 1940's. The early cathodic protection system was replaced with a modern design to improve operation and to assure continued transfer line protection.

Recent surveys of the updated cathodic protection system demonstrated that the cathodic protection system is operating as intended. In addition to the required periodic and annual surveys, an engineering study will be performed to evaluate system upgrade options to improve the operation of the system. The engineering studies to be performed in the future will also evaluate the likelihood of stray currents adversely impacting the waste storage tanks.

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