Internal Joint Bonding of Prestressed Concrete Cylinder Pipe: The Improbable Project

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ABSTRACT

Located in North Texas, this project required navigation through over 20 miles of sloping 72-inch raw water Prestressed Concrete Cylinder Pipe to install internal bonding wires at each joint. The work required demolition and removal of the 2.5-inches of interior concrete to expose the steel cylinder and spigot ring of the pipe, installation of three bond wires across each joint via thermite welding, application of coating to the wires and welds with 100% volume solids epoxy, testing electrical resistance, and grouting the concrete cutout. The 72-inch diameter pipeline provides raw water for treatment and distribution to 1.7 million people, as well as water required at a local power generation plant, so project timelines were extremely tight. The total project consisted of approximately 4,325 joints, requiring approximately 13,000 bond wires, 26,000 thermite welds, cases of epoxy and pallets of cement and sand, and it was all completed in 44 working days.

INTRODUCTION

The North Texas Municipal Water District's (NTMWD) "Texoma 72-Inch Pipeline Improvements" project consisted of installation of new test station, dewatering of over twenty miles of 72-inch diameter pipe, installation of new butterfly valves and internal joint bonding of approximately 4,312 joints. While each of the tasks required focused planning and coordination the joint bonding was anticipated to be the most challenging with extremely short timelines for completion and a challenging environment in which the work would need to be completed.

The Texoma Water Supply System currently provides almost a third of NTMWD's raw water demand used to service potable water to more than 1.7 million people in their service area, as well as providing necessary water for a local power generation facility. The 72-inch pipeline has the capacity to move 125 million gallons per day (MGD) from Lake Texoma to the NTMWD Texoma Balancing Reservoir. Given the critical needs serviced by the pipeline, the project was setup to be completed in multiple phases that would take place during several short outages.

The pipe was originally designed and built in three segments. Section II was constructed from steel pipe with Section I and III being constructed of prestressed concrete cylinder pipe that required joint bonding. Bonding is necessary to ensure that the entire length of pipe will be electrically continuous for the application of Cathodic Protection. At just over 10 miles long the plans for Section I indicated there were 2,069 push-on joints to be bonded. Section III measured just under 11 miles in length with a planned 2,243 push-on joints to be bonded and was split into two segments, Section IIIA and Section IIIB. The work was originally scheduled in two phases; Phase 1 included bonding joints on Section IIIA and approximately 1/3 of the joints on Section IIIB between March 12, 2018 and March 30, 2018, Phase 2 included the remainder of Section

IIIB to be completed between October 1, 2019 and October 24, 2019 as well as all of Section I between October 25, 2019 and December 10, 2019. Table 1 below outlines the quantities and specified dates for completion of the joint bonding.

Phase 1			
Description of Work	**Dates for Completion of Work**	**Push-on Joints**	**Welded Joints**
Bond Joints on Section IIIA (Sta. 850+00 to Sta. 1069+85)	March 12, 2018 through March 23, 2018	895	68
Bond Joints on Section IIIB (2018) (Sta. 1069+86 to Sta. 1190+00)	March 12, 2018 through March 30, 2018	530	41
Phase 1 Totals	***19 Days***	***1,425***	***109***

Phase 2			
Description of Work	**Dates for Completion of Work**	**Push-on Joints**	**Welded Joints**
Bond Joints on Section I (Sta. 4+51 to Sta. 542+08)	October 25, 2019 through December 10, 2019	2,069	181
Bond Joints on Section IIIB (2019) (Sta. 1190+00 to Sta. 1393+74)	October 1, 2019 through October 24, 2019	818	33
Phase 2 Totals	***71 Days***	***2,887***	***214***

Table 1. Contract Scheduled Phases and Quantities

Bonding of the joints was to be completed on the interior of the 72-inch diameter pipe at each push-on joint (bell & spigot) which would require precise coordination of tasks with the Prime Contractor, other Subcontractors, the Engineer and Owner.

JOINT BONDING PROVE-OUT

With the improbable timelines for the work to be completed significant testing and planning commenced well in advance of mobilizing for Phase 1 work. There were two primary purposes for the testing; first to determine the most efficient method to safely remove the inner concrete layer of the Prestressed Concrete Cylinder Pipe (PCCP) to expose the steel cylinder, bell ring and spigot ring, and second to determine if the specified thermite weld package size would damage the cylinder. It was critical that the cylinder of the PCCP not be punctured or cut during the removal of the concrete for the installation of the bonds, so spare PCCP C301 pipe, dating to the same installation time period and geographical region, was located and numerous field tests were completed.

The concrete removal testing was critical in order to determine how to remove the concrete without damaging the cylinder, but would also be the basis for establishing production rates that would be essential to determining resource needs and production schedules that would allow all work to be completed during the short outage times.

The weld package size was tested based on several questions that came up during the initial submittal process. First, the specification called for solid No. 4 AWG Copper wire to be welded using a 25gm thermite weld package, while the thermite weld manufacturer recommended a 15gm package be utilized with No. 4 AWG Wire. Due to prior testing indicating that a 25gm charge would provide lower electrical weld resistance, testing of both package sizes was requested. Additionally, when exposing the joint internally the spigot ring of the joint was accessible, but the bell ring was not, meaning the bond would have to be welded to the thinner steel cylinder. The second question was if the thermite weld might damage the cylinder, specifically if the larger 25gm charge was utilized. In order to determine if the weld might damage the cylinder, a section of the cylinder was removed from the spare PCCP C301 pipe during testing to view the effects of the weld on the backside of the cylinder. Given that the lose piece of cylinder was removed from the PCCP pipe and would not have the benefit of the heat sink provided by the concrete, this was a worst-case scenario.

The prove-out clarified several questions from the specification and Engineer and provided critical insights into what would be needed to complete the work on schedule. The means and methods for the most efficient execution of the work were determined. 25gm thermite weld packages were determined to be safe to use on the cylinder and provided lower electrical weld resistance. The length of bond wires was increased from the specified six inches to eight inches in order to reach from the spigot ring to the cylinder while allowing room for the thermite welding mold, which also changed the acceptance criteria for allowable resistance at each joint for the new wire length.

PRESCOPE PLANNING

Following the completion of the prove-out, preliminary production rates were determined based on the methods that had been identified during the testing. Using the estimated production rates along with the pipeline shutdown timelines, the first preliminary schedules were built, and resource loaded. Equipment needs were considered to meet the timelines and it was determined the project would require approximately $60,000.00 in new battery powered tools, batteries, chargers and generators alone, to complete the work on schedule. With an estimated 1,425 joints to bond, Phase 1 would require 4,275 8-inch No. 4 AWG copper wires, 8,550 25gm thermite weld packages, 80 graphite molds and 14 control units for firing the weld packages.

The lead times on the tools and materials was such that all orders would have to be placed well in advance of mobilizing to the project site. The initial mobilization to the site included: a 53-foot tractor trailer, two 16-foot enclosed gooseneck trailers, two flatbed trailers, a camper trailer, six pickups, a 4x4 mule, a tracked crawler, an 18-passenger 4x4 van, and a 27-man crew.

SAFETY – CONFINED SPACE ENTRY

Crew safety was a major concern during the design and construction phases of the project. Before crews entered the pipe, the Lake Texoma pump station (source of water) was locked and tagged out keeping any pumping operations from taking place. After the water was pumped down, crews were able to enter the pipe. With up to 24 people (from the joint bonding contractor) occupying the line at one time, spread out over more than 10 miles, establishing and maintaining safe work practices was crucial. Teams of up to eight were staged in three different sections of the line which allowed work to be completed in stages throughout multiple sections of the pipe but increased the logistical difficulty in maintaining a safe confined space. Multiple 30,000 cubic feet-per minute blowers were utilized along multiple locations to ensure adequate air flow was provided in all locations as work was occurring. The pipeline was treated as a Permit Required Confined Space per 29 CFR 1926 Subpart AA and each point of entry and egress had a Confined Space Attendant staged at the specific locations. Identification cards were also created and utilized for anyone that was going to enter the confined space. As personnel entered the pipe, their specific identification card was secured to a confined space entry board. As entrants exited the confined space the individuals were given their individual identification card back. This allowed the team to manage who was in the confined space, the durations that they were there, and allowed for quick identification of staff inside the space should an emergency arise. With a safe space established work could progress, and it would bring with it additional challenges in maintaining a safe working space.

It was determined that the most effective and efficient approach to remove the concrete was to pre-cut the concrete to a specific depth prior to chipping the concrete out. This approach allowed for little chance in damaging the cylinder while allowing for the power hammering to more easily break away the concrete at each joint of pipe, but it created a significant amount of dust. The hammering, grinding and welding all produced additional dust and fumes that had to be adequately evacuated from the pipe with the forced air ventilation system. Exposure monitoring was completed to determine employee exposures and to assure appropriate controls were in place and appropriate PPE was available and utilized at all times.

CONTRACTED SCOPE OF WORK:

The scope was simple in nature. The crews would enter the pipe, cut out a 12-inch by 10-inch section of the interior concrete pipe to expose the spigot ring and cylinder (see Figure 1), clean the steel surface with grinders to remove all corrosion and debris, thermite weld three 8-inch No. 4 AWG Copper wires at each joint, epoxy coat the welds and wires, measure for resistance, and fill in the cut out with new grout. However, there were still quite a few unknowns or potential challenges not experienced during above ground testing.

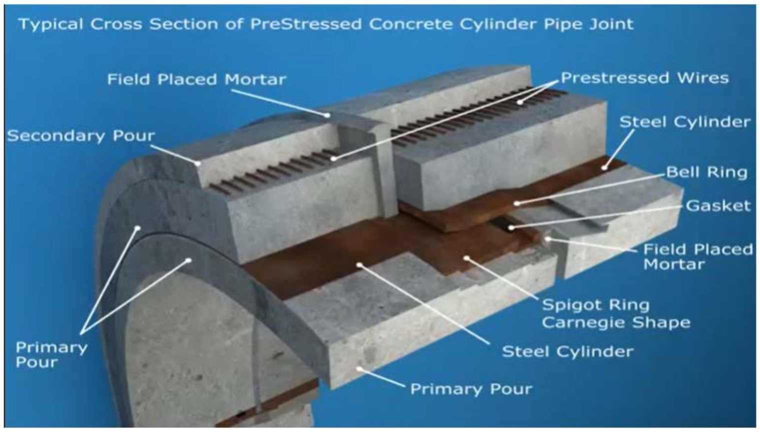

Figure 1. PCCP Typical Cross Section
Pure Technologies, Oct 24, 2017

The pipe had not been inspected properly in years and the overall condition was unknown. It was expected that there would be many locations with low spots (bellies) in the pipe that would hold water after initial draining which would prevent work from being completed, but the exact locations would not be known until entry was made. The bonds have to be placed near the bottom of the pipe (between the 5 o'clock and 7 o'clock location) as the thermite weld uses gravity to feed the weld material onto the surface so water in the pipe would prevent that work from being completed. Water in the pipe would also significantly reduce the ability to maneuver quickly and easily through the pipe. It was critical that the dewatering crews, and bonding crews were coordinating schedules and plans to keep the appropriate sections of pipe dry for maneuverability and bonding work to be completed. Without the ability to cut or create mockups on the existing pipe prior to the initial outage, the nominal thickness of the concrete lining was still not certain. Careful attention had to be paid to the removal of the concrete, so the steel cylinder component of the pipe was not damaged in the process.

During the initial phase of work the prime contractor needed to enter the pipe to move water from low areas to pumps that could evacuate the water. They were also responsible for identifying the welded joints and marking them as they did not require bonding. This turned out to be challenging and many of the welded joints were still exposed to ensure bonding was not required, and then later re-grouted with the rest of the bonded joints.

INTERNAL JOINT BONDING

Once the pipe was dry and ventilated, the bonding crew was split into three entry teams ranging from 5 - 8 technicians, with an additional team handling logistical support outside the pipe. The teams worked in an assembly line fashion, first cutting 12-inch by 10-inch 'windows' over each joint at the 5 o'clock to 7 o'clock position, using saws with depth guides set to 1/8-inch shy of the determined thickness of the concrete. Then the concrete would have to be chiseled out using power chipping tools, and the debris had to be cleaned up to ensure efficient travel through the pipe. Once the concrete had been removed down to the bare metal cylinder (see Figure 2), the steel was cleaned with power tools to remove all mill scale, corrosion and debris. Next three 8-inch No. 4 American Wire Gauge (AWG) wires were installed across each joint of pipe with a thermite weld attaching each end of the copper wire to the cylinder and spigot ring (see Figure 3). After each end of the three wires had been secured across each joint of pipe, quality control testing was complete using a low resistance ohmmeter, to measure the electrical continuity of each joint following bonding (see Figure 4). After verification of the required continuity was made a moisture-resistant fast cure epoxy was applied over all exposed copper wire and thermite welds to protect against any future corrosion. After the epoxy had been applied and allowed time to cure, the concrete cutout was replaced by a cement and sand grout mixture. To ensure continuity across the pipeline, testing was completed from each of the test stations that had been installed, and a lineal pipe resistance (LPR) continuity calculation was completed by the corrosion engineer verifying an electrically continuous pipeline.

Figure 2. Exposed & Cleaned Joint

Figure 3. No.4 AWG Wires Thermite Welded

Figure 4. Resistance Measurement

CONCLUSION

The internal joint bonding and addition of the above ground test stations will provide operational flexibility to facilitate future assessment and repair of the pipeline and will add electrical continuity and corrosion monitoring to the system for the future implementation of a full cathodic protection system, if required. Giving the owner the ability to extend the life of the asset for many years to come.

As with almost every construction project, whether it is new construction or rehabilitation, the ‘unknowns’ are an expected piece of the puzzle. For this project extensive planning and coordination was completed prior to mobilization to ensure backup plans were in place for every conceivable challenge or issue that might be faced. The project timelines were based on outage schedules that had little to no room for error and the single most pertinent question prior to work was if the bonding could be completed in the allotted amount of time. The bonding crew arrived onsite ready to prove that they could accomplish what many believed was an improbable amount of work for the time given. The crews worked long hours without any days off and they faced considerable challenges along the way, but as they worked, they found efficiencies and they maintained a relentless effort.

There were approximately 4,564 internal pipe connections in total that needed to be addressed, including welded joints that couldn't be clearly identified without cutting. In the end the work was completed in phases that exceeded the planned timelines. Section IIIA and all of Section IIIB (2018 & 2019) were completed with a 25-man crew during Phase 1, equating to 55,373 linear feet of pipe with 2,306 joints, 6,750 wires, and 13,500 welds, all in just 19 days. The completion of Section IIIB (2019) in March of 2018 during Phase 1 saved on the dewatering work that would've been completed in 2019. For Phase 2 a crew of 15 was able to complete 54,208 linear feet of pipe with 2,258 joints, 6,210 wires, and 12,420 welds, in just 25 working days, proving that internal joint bonding is a feasible cathodic protection system solution even when working within very short pipeline outages.