Innovative Joint Designed for 84-inch Raw Water Transmission Main Tunnel Carrier Pipe

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ABSTRACT

Lake Travis is located northwest of the City of Austin, Texas. Due to the unanticipated population growth in the area, the Austin Water Plant No. 4 was designed and constructed in the "hill country" to extract water from the lake. The raw water line is located between the raw water pump station and the water treatment plant-raw water flume. This part of the project consisted of approximately 3,900 L.F. of 84-inch steel water pipe installed in a tunnel. The installation contractor had concerns that their crews would have fit-up problems with butt-welded field joints due to numerous horizontal curves so the contractor requested alternative solutions. Consequently, the pipe manufacturer and installation contractor worked in cooperation to devise an appropriate jointing system that fit the intended application. The joint was unique in that it allowed for lap welding to be utilized for deep insertion which in turn permitted greater flexibility for installation of the steel liner pipe into the tunnel.

The objectives of this paper will be three-fold: first to describe the art and engineering of jointing steel pipe (the process of welding steel pipe joints, the differences between butt-welding and lap-welding, beveled joints, etc), followed by a discussion of the design and subsequent redesign of the field joints on this project, and will end with a discussion of the installation process. The paper will discuss these items from both a manufacturer's and an installer's perspective, and will describe the background of what led up to the final design and manufacture of the field-joint supplied. Changes that took place between the design and approval process and the final installation will also be explained in detail. The contents of the paper will be useful to Owners of large diameter water transmission systems, Design Engineers, as well as the Construction community.

INTRODUCTION

The Austin Water Treatment Plant No. 4 is located northwest of Austin, Texas. This 300 MGD plant will pull water out of Lake Travis and supply it to the fast-growing area of northwest Austin.

Figure 1 illustrates the hydraulic profile where water is being moved from the lake into the intake screens, then to the raw water intake tunnel. Next is the raw water pump station. Water is then moved from the raw water pump station to the water treatment plant via the raw water transmission main. Total costs for the project is estimated to be around $359 Million, with around $15 Million estimated for the raw water transmission main, including the tunnel installation.

Manufacturer's Perspective

PROJECT DETAILS

The raw water transmission main consists of around 3,900 LF of 84" steel water pipe, with a wall thickness of ½" installed in a tunnel. The pipe was supplied in 50-foot joint lengths and grouted in-place. The ID of the pipe was left bare and the OD of the pipe was coated with 50mils of polyurethane. Each 50-foot piece weighs approximately 22,900 lbs. After the line was installed, ½" thick cement lining was applied in-place. The pipe ends were originally specified with butt welded joints, beveled ends and a backing bar.

The first part of this paper will explore from the manufacturer's perspective the process the pipe manufacturer, installer, contractor, and engineer accessed in order to come up with a more appropriate joint that matched the means-and-methods that the installer wanted to employ. The second part of this paper will explore the installation aspect from the specialty installer's perspective.

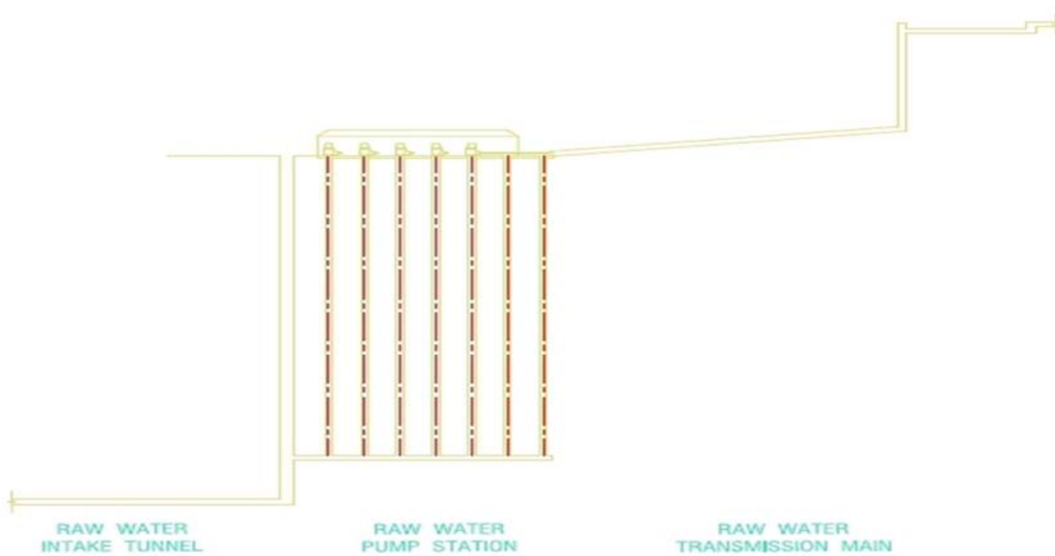


Figure 1 Hydraulic Profile for Austin Water Treatment Plant No. 4 Project

Three conditions exist for this line that made it a special installation. First, the 84" raw water transmission main is to be completely installed within a tunnel. Secondly, the plan-view layout of the line includes several horizontal curves with a radius approximately 800 feet.

Because the pipeline included horizontal curves, joint deflections were required. Using pipeline routing geometry, the required deflection per each joint was calculated. Figure 2 shows how to determine the amount of required deflection per joint, based upon the pipe length and the curve radius.

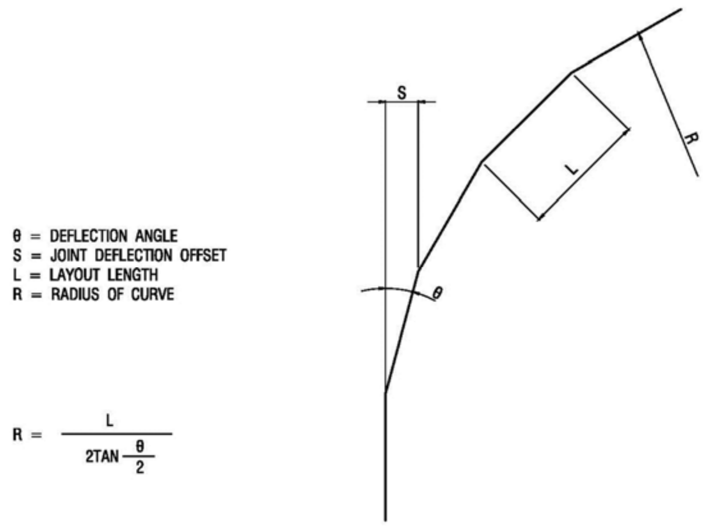


Figure 2 Route Geometry Calculation to Determine Joint Deflection

PIPE JOINT EVALUATION

The contract drawings required that the pipe butt welds have beveled ends. The contractor was then required to apply a complete joint penetration (CJP) butt weld at the joint. The pipe welding and installation contractor, National Welding Corporation had concerns about the ability to meet the root opening tolerances required for the butt welds when putting the pipe joints together in the horizontal curves. Figure 3 shows the contract drawing detail of the required field joint. 50-foot pipe joint lengths were utilized to minimize the number of field welds.

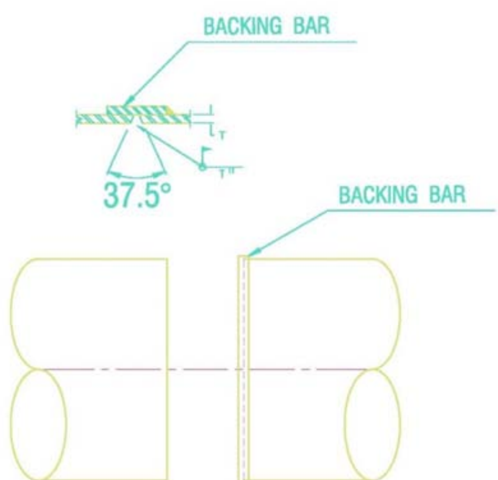


Figure 3 Beveled Joint in Contract Drawings

While laying out the line, the Northwest Pipe Company project engineer noticed how close the pipe was to the tunnel wall. Since the pipe was going to be moved through the entire length of the tunnel as it was installed, from the low-end to the high-end, the contractor asked Northwest Pipe Company to check the alignment to determine if any pipe "pinch points" existed. These are angles in the tunnel that the carrier pipe cannot pass. The contractor surveyed the tunnel to determine the actual alignment. Figure 4 shows a typical scenario for locating potential pinch points that the pipe manufacturer evaluated.

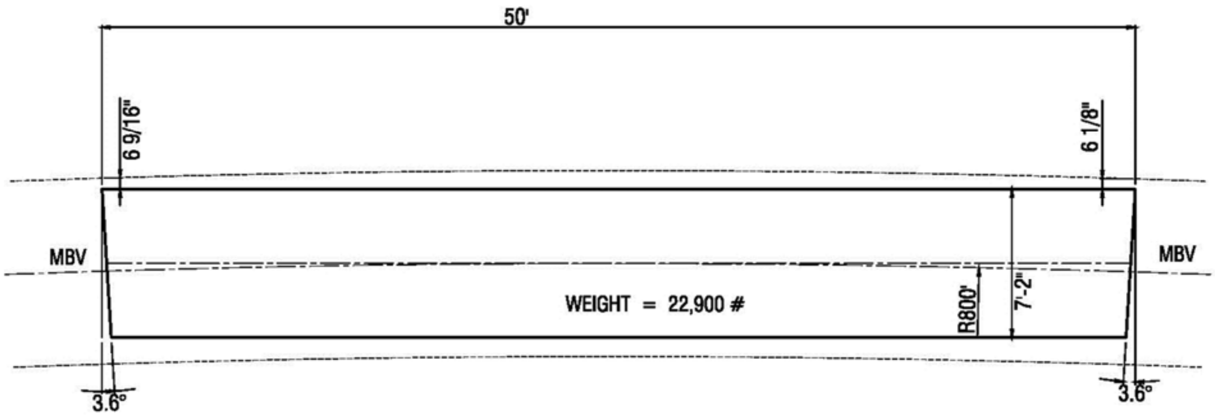


Figure 4 Potential Pinch Point Dimensions

Based upon the information provided to the contractor, a discussion about the pipe installation, assembly and joint welding was held with the consulting engineer, AECOM. The engineer came back to the contractor and requested a proposal for the design change to the joint that all parties could agree upon. In turn, the contractor requested a proposal from Northwest Pipe for a field-welded joint that would meet the following conditions:

- Allow for bell-over-spigot installation;
- Allow for a mitered bell to be constructed with varying angles up to 3.60°;
- Allow the joint stab depth to vary between a length of 2-1/2" to 4-1/2";
- Provide the installation subcontractor the greatest amount of flexibility.

Northwest Pipe Company went back to the drawing board, and pulled from their experience with field joints to develop a new joint meeting the criteria. It had to be formed on the same process as bell expansion, and not add another manufacturing step. AWWA C206-11 (AWWA 2011), Field Welding for Steel Water Pipe Standard gives specific requirement for the insertion and fit up of lap-welded joints that had to be met. Several questions arose. When the pipe was expanded using the proprietary end ring, would the rise cause too much of a joint gap beyond those allowed by standard? Would the rise in the bell be enough to allow the joint to be pushed "home" successfully? Would the rise in the bell affect the joint lap?

It was suggested to use a hybrid lap-welded joint that would have a slight rise in the bell end and would meet all of the previous-stated criteria. After many test runs, a proprietary end ring was developed for the bell expansion that would meet the conditions laid out in the engineer's requirements.

HYBRID LAP-WELDED JOINT MANUFACTURING

As described earlier, this hybrid lap-welded joint, shown in figure 5, is manufactured using a hydraulic expander. In order to manufacture the bell, a proprietary end ring was built into the expander to create a slight rise in the bell end of pipe when expanded. Finally, no additional steps were required as all necessary bell-forming was completed in one step.

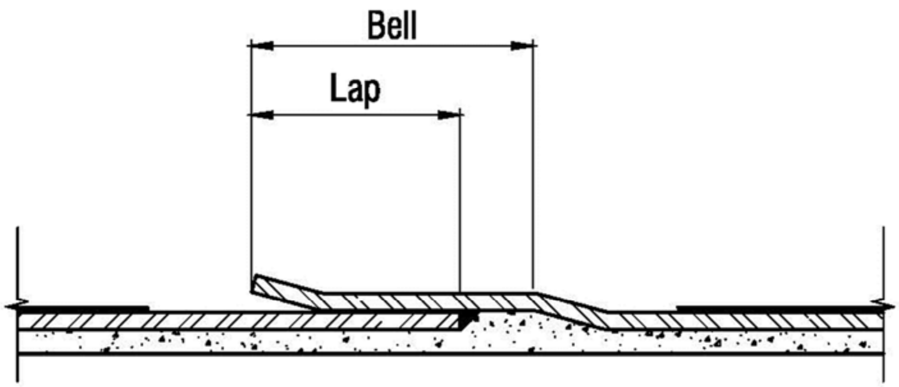


Figure 5 Hybrid Lap-Welded Joint for Steel Water Pipe

CONCLUSION OF MANUFACTURER'S SECTION

After the transmission main was installed, Northwest Pipe Company received complements from both the installer and the contractor as to the ease of installation and fit-up. It was reported none of the assembled joints required extra fit-up time after insertion into the bell. The hybrid lap-welded joint proved to meet all the criteria the engineer had laid out in his specification for approval. Also, from the manufacturing perspective, no additional steps were required as all required bell-forming was completed on the expander machine.

If butt welded beveled ends would have been used, stab adjustment would have been nearly impossible as the pipe would have been required to meet the tight-fit tolerances prior to welding. The hybrid-lap welded joint was welded from the inside prior to the cement lining being applied. All pipe laid in the horizontal curves had the necessary miter angles cut into the bell-end which eliminated the requirement to cut miters on both ends of the pipe for butt welded beveled ends. The hybrid lap-welded joint provided a winning solution for all parties concerned.

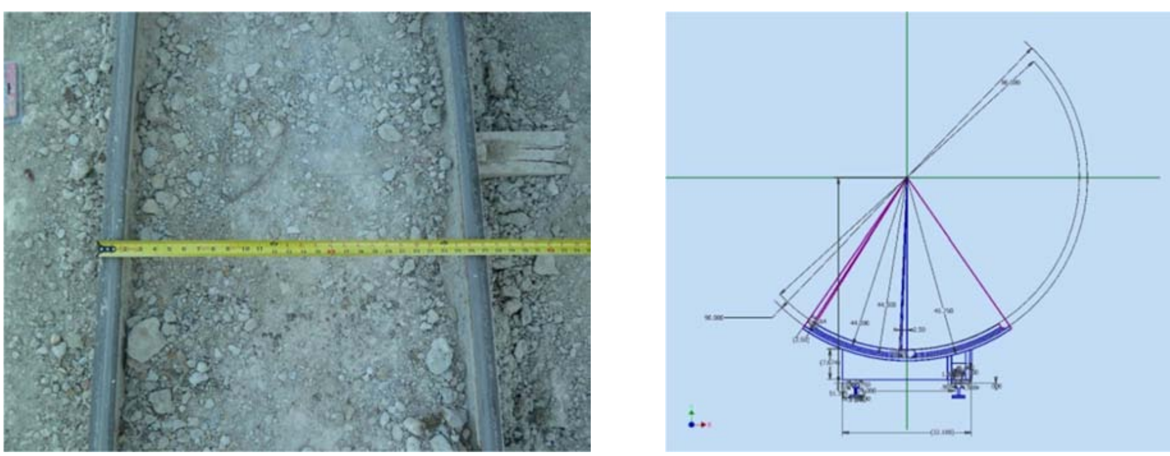
Specialty Installation Subcontractor's Perspective

THE CONSTRUCTION TEAM

National Welding Corporation was responsible to transport the pipe segments inside the tunnel, fit and weld the tunnel liner as a subcontractor to Obayashi Corporation. Obayashi Corporation was the General Contractor of the overall project and self-performed most other key project elements including tunnel excavation, material handling and oversight of all other activities. Northwest Pipe Company prepared the shop drawings, performed all the shop fabrication and shipping to site.

PRE-INSTALLATION PLANNING

The team decided that the rail used for the road header would be re-installed after pouring the tunnel invert thus creating a level surface that could be utilized for the pipe installation. This created an initial task of determining the pipe elevation relative to tunnel rail, this dimension needed to be agreed upon before pipe carrier design could begin. The team decided the 84" diameter pipe would be installed at a minimum of 12" above the tunnel rail allowing for sufficient room for a "cradle" style pipe carrier and limiting excessive over excavation for Obayashi Corporation, Figure 6a and b. At this time it was also determined that Northwest Pipe hybrid lap welded joints would be used to accelerate installation.



Figures 6a, 6b: Rail Gauge and preliminary pipe elevation drawings

The design of the pipe carrier needed to accommodate transportation of the pipe, allow for clocking or rotation of the pipe segments before engagement at the installation location, lifting the pipe segments to a maximum height of 9" above the carrier, the ability to make minor adjustments side to side to keep the liner centered inside the tunnel and be able to engage the hybrid lap welded joints at the determined tunnel elevation.

Polyurethane coated wheels were used on the final design to allow for clocking the pipe segments as well as Kevlar reinforced rubber coated high-pressure lifting airbags for pipe engagement and location adjustments, Figure 7a and b. The polyurethane coated wheels and rubber coated bags would protect the pipe epoxy coating during installation and allow for use of the existing high pressure air connections inside the tunnel for lifting power.


<u>Figures 7a and 7b:</u> Carrier fabrication and Components

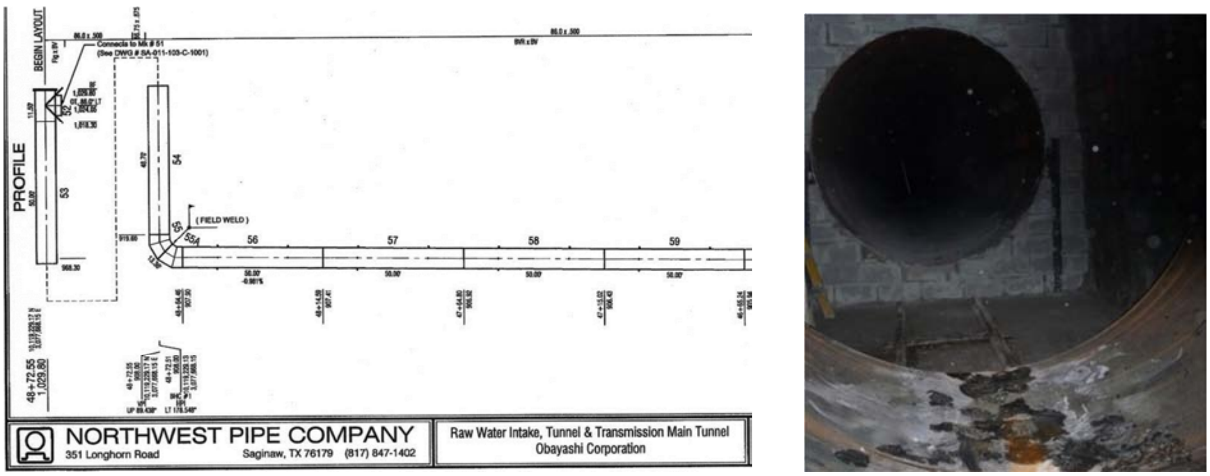
The pipe carrier and pipe segments were transported to the tunnel installation location using a Tele-handler off road forklift utilizing a trailer ball hitch as an attachment point. A custom designed man basket was attached to the front of the unit and allowed crews to access the top of the pipe for bracing installation as well as a safe flagging area during transportation of pipe segments. A diesel power welding generator was mounted on the back to supply 110 volt power and welding capabilities for the installation crew, Figure 8a, b and c.



<u>Figures 8a, 8b and 8c:</u> Transportation Method

COMMENCEMENT OF INSTALLATION

During the initial walk through of the tunnel it was discovered that the tunnel invert was poured 6” too high relative to Mk-55A, Figure 9a and b. This was the initial connection for the tunnel liner to the elbow at the bottom of the shaft which had been grouted in place.

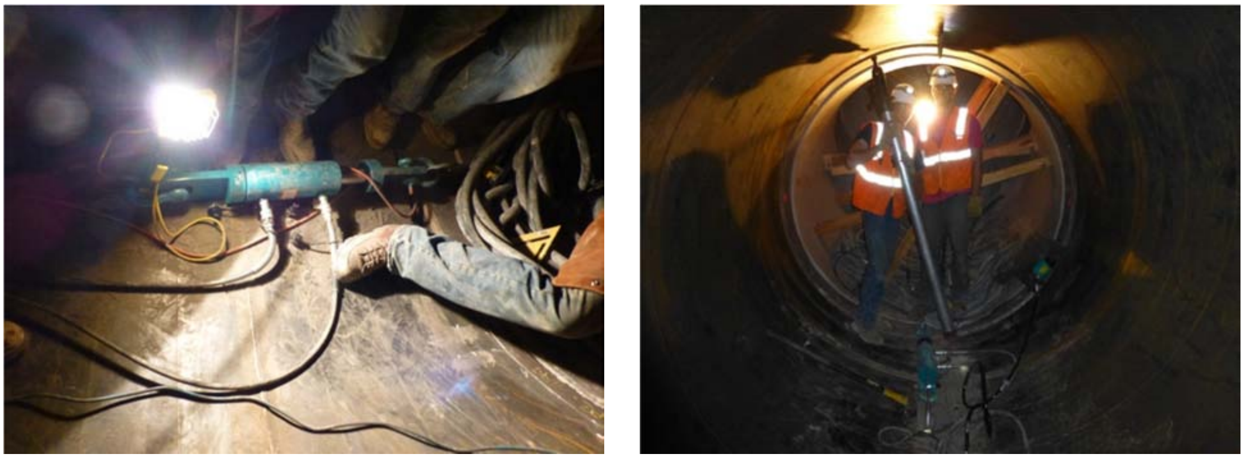


<u>Figures 9a and 9b:</u> Initial tunnel connection Mk-55A

Due to the elevation change the pipe carrier sat too high on the rail and precluded placing the pipe lower due to the interference. It was decided that the best option was to alter the installation elevation on the fly and gradually bring the liner up to the correct tunnel elevation over the next 3 joints. In addition, a low clearance pipe positioner was devised which slid on UHMW channels along the rail and allowed installation of the 3 pipe sections used to correct the elevation. An additional set of airbags was used to lift the liner segments of off the pipe carrier allowing it to be withdrawn correcting the interference condition. Once initial engagement had been achieved the pipe positioner could be withdrawn as well and used to attain correct elevation and tunnel alignment at the bracing location, Figure 10a, b and c.

<u>Figures 10a, 10b and 10c:</u> Pipe positioner fabrication

A combination of fitting tools were required to achieve initial engagement of MK-55A to MK-56 including hydraulic cylinders, pry bars, plate dogs and pipe jacks as this was a spigot to bell joint Figure 11a and b. The hybrid lap welded joint was not feasible at this location due to the tight radius of the elbow and weld-on bell configuration. The elbow was also not plumb relative to the design of the initial tunnel joint requiring a field miter to be performed at the installation location. Following completion of the field miter, a 30 ton hydraulic pull cylinder was used to achieve the required stab depth and the adjacent end of the pipe segment was then braced against the tunnel wall. Subsequent joints supplied with the hybrid lap welded joints were installed in the conventional bell over spigot configuration significantly reducing the time and effort required to initiate joint engagement. The remainder of the tunnel pipe was installed using nothing more than pry bars and in some cases required no tools at all at the engagement location to initiate or complete the stab.



Figures 11a and 11b: Fitting tools

The liner segments were braced using a combination of ½" plate "ears" that were field welded to the pipe at spring line which were welded to 3" x 3" angle irons extending to the tunnel floor. The angle iron members were manufactured longer than required to allow for variations in tunnel elevation, the angle iron members were attached to the floor via a steel base plate and concrete anchors, Figure 12a, b and c. The steel plates were laser cut with a pick point attachment that were used to attach a come-along for pipe clocking on the carrier. This bracing method provided sufficient support to the pipe for installation purposes. Additional 2" x 2" x ¼" square tubing was installed laterally at the spring line location as well as at the flow line and field top locations at Obayashi Corporations request to resist buoyancy forces during annulus grouting. The square tubing needed to be cut to length at location to allow for tunnel width and height variations prior to installation. The liner location, elevation, stab depth were documented and tunnel wall clearance tolerance of 6" was verified.

Figure 12a, 12b and 12c: Pipe Bracing

FITTING AND WELDING OPPERATIONS

Inverter style electric welding power sources were mounted to a custom built pipe cart with radialy mounted wheels allowing for a safe and organized welding system which is easily transported through the tunnel liner. The system was capable of powering 4 welders at one time and was pulled forward through the liner with a diesel powered tractor equipped with an exhaust scrubber. FCAW (Flux Cored Arc Welding) high production welding procedures were utilized for welding of the circumferential seams to quickly and efficiently complete weld out of the tunnel within days of completing liner installation.

CONCLUSION

The Raw Water Transmission Main tunnel installation was exceptionally difficult to construct due to the constantly changing tunnel geometry and unusually long pipe sections. The key elements to the success of this project were the team approach and careful planning developed prior to and during all construction activities. The engineer, contractor, installer and pipe manufacturer all contributed to the overall success of this installation that was completed ahead of schedule. The team members and their contributions all had equal importance in the timely resolution of design and construction issues. The importance of a partnering/team approach with competent members was crucial and cannot be overstated. The proactive cooperation and communications between all parties involved, including the owner, City of Austin, Texas; Design Engineers, AECOM, Carollo Engineers, and CDM Smith; General Contractor, Obayashi Corporation; Pipe Supplier, Northwest Pipe Company; and the Specialty Installation Sub-Contractor, National Welding Corporation, all contributed significantly to the resolution of challenging problems and made the project a success.

REFERENCES

AWWA C206 (2011), *Field Welding of Steel Water Pipe*, Denver, CO