Fiberglass Pipe Helps Solve the World's Drinking Water Shortage

Jeffrey LeBlanc and Matthew Sternisha

With the aim of alleviating an endemic water shortage, the San Diego County Water Authority (SDCWA) initiated the Carlsbad Desalination Project, which was slated to begin delivering fresh drinking water to businesses and residents by the end of 2015. The plant was designed to convert more than 100 mil gal a day (mgd) of raw seawater into 54 mgd of desalinated drinkable water. This is the first of 12 such plants due to be constructed in California.

Designing and building the pipeline involved a number of unique challenges. The pipe had to be buried at depths up to 18 ft, sometimes 6 ft below groundwater level. This required the pipe to withstand the soil and American Association of State and Highway Transportation Officials (AASHTO) H-20 traffic loading, as well as resist buckling from the external water pressures. The highly corrosive nature of both the seawater and the chemically treated permeate water, with pH values ranging between 2.5 and 10.5, placed severe demands on pipe, joints, and fittings. As a potable water application, the pipe requirements included compliance with the American Water Works Association (AWWA) C950 and American Society for Testing and Materials (ASTM) D3517 standards, as well as National Science Foundation (NSF) certification and phthalate-free resins. The project specification called for a minimum 30-year service life.

The contractor, Kiewit Shea Desalination (KSD), outlined an aggressive construction schedule, requiring the fast-paced production of pipe and fittings to meet specifications. As the chosen supplier of Flowtite® filament wound fiberglass pipe for the project, the Thompson Pipe Group arranged to have the pipe produced in Louisiana.

The installation of the large-diameter fiberglass pipe included many different joint types and installation methods. The pipe manufacturer provided onsite field crews and technical support throughout the phases of the contract as a construction partner. With precut fiberglass lamination kits shipped from the pipe manufacturer, field butt-wraps were performed in place. In other areas on the project, the contractor took advantage of the fiberglass pressure-rated couplings, which eliminated many of the 72-in. field wraps on the project and shaved valuable time from the tight installation schedule.

In addition to the traditional direct-bury installation method, 350 lin ft of 72-in. fiberglass pipe were installed using a "jack and bore" application. The pipe manufacturer's engineers worked with the contractor to design a system to fit within the casing of the jacking tunnel. Using the pressure-rated couplings, the pipe sections could be joined together within the tunnel, simplifying the installation process and saving even more time.

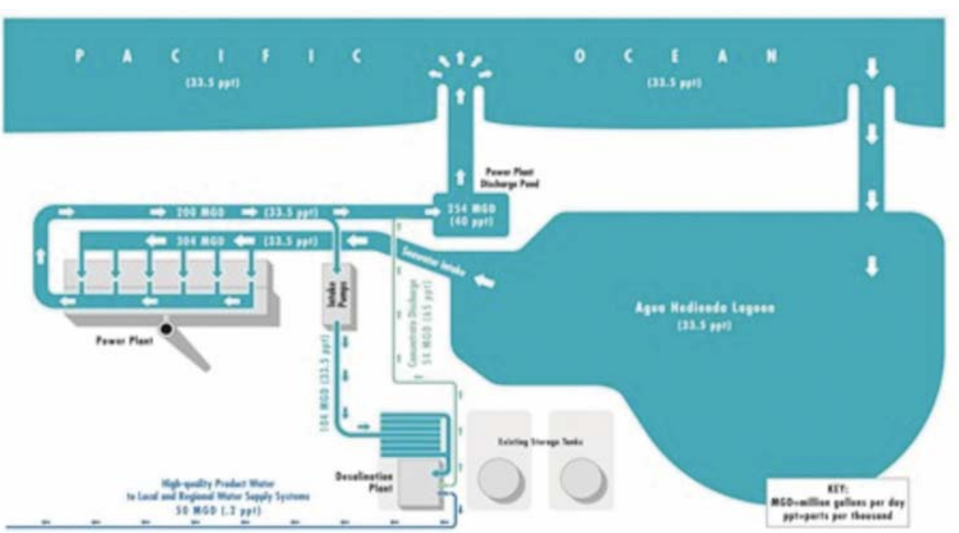

Figure 1. Carlsbad Desalination Plant Layout

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This project was difficult due to the aggressive construction schedule, as well as the field-quality control requirements. This article will review this unique project from the aspect of construction, installation, and inspection.

Background

The Claude "Bud" Lewis Carlsbad Desalination Plant is a 54-mgd and 56,000 acre-ft-per-year seawater desalination plant located adjacent to the Encina Power Station (EPS) in Carlsbad, Calif. Desalination has evolved into a desirable water supply alternative by tapping the largest reservoir in the world: the Pacific Ocean. The technology is at work in many arid areas of the world, including the Middle East, the Mediterranean, and the Caribbean. A 30-year water purchase agreement is in place between SDCWA and Poseidon Water for the entire output of the plant.

For over 50 years, the operators of the EPS have regularly maintained the lagoon and dredged an opening to the ocean to sustain a source of seawater to cool the power plant's generators. As a result, the 388-acre Agua Hedionda Lagoon is a man-made and shallow coastal embayment teeming with marine life, as well as an array of recreational and educational activities and environmental research. The lagoon supports a thriving marine ecosystem and is home to the Hubbs-SeaWorld fish hatchery, the Carlsbad Aquafarm, a YMCA camp, and the Lagoon Foundation's Discovery Center.

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The seawater-cooled power plant is expected to be decommissioned in the coming years, leaving the lagoon without an entity responsible for its long-term maintenance. Locating the new seawater desalination plant next to the EPS solves this problem. The operators of the desalination plant are assuming responsibility as steward for the Agua Hedionda Lagoon and the surrounding watershed, providing long-term maintenance and dredging, once the power plant is decommissioned. This will guarantee for many years to come that the citizens of Carlsbad will be able to enjoy the benefits of this clean lagoon and its surrounding beaches.

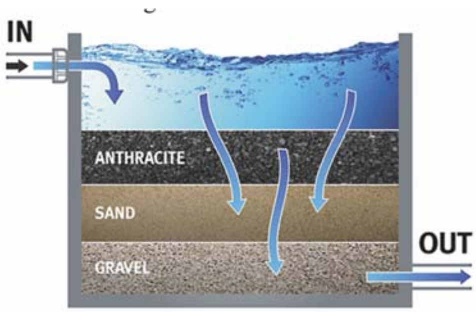

Figure 2. Pretreatment Process

This lagoon is wholly owned by Cabrillo Power LLC, and since 1952, it has been kept open to the Pacific Ocean by routine maintenance dredging. The original location of the EPS site was determined to be desirable due to its close proximity to the ocean, compatible land use, and the availability of the existing intake and outfall. The choice to place the desalination facility within the EPS was made so as not to conflict with Carlsbad's redevelopment plan goals related to facilitating the conversion and relocation of the existing power plant and enhancement of commercial and recreational opportunities. The site of the desalination plant is a 6-acre parcel in a portion of the power plant that leaves the majority of the property open for potential recreational or redevelopment activity at some future date.

The desalination facility will conform to the 35-ft height limit in the local coastal plan, and the building design has been enhanced to ensure compatibility with future land use in the area. Onsite improvements include an intake pump station and pipeline, concentrate return pipeline, sewer connection, electrical transmission lines, road improvements, and a product water pump station and pipeline.

The desalination facility is connected to the discharge channel of the EPS at two locations. The intake pump station is connected to the upstream portion of the discharge channel and delivers 100 mgd of seawater to the desalination facility. Half of the seawater processed by the desalination facility is converted to high-quality drinking water, which is delivered to Carlsbad and the surrounding communities. The remaining water (50 mgd of seawater with an elevated salt content) is returned to the discharge channel where it's diluted with additional seawater prior to being discharged to the ocean. This ensures that the increased salinity will not impact the marine organisms in the vicinity of the discharge channel.

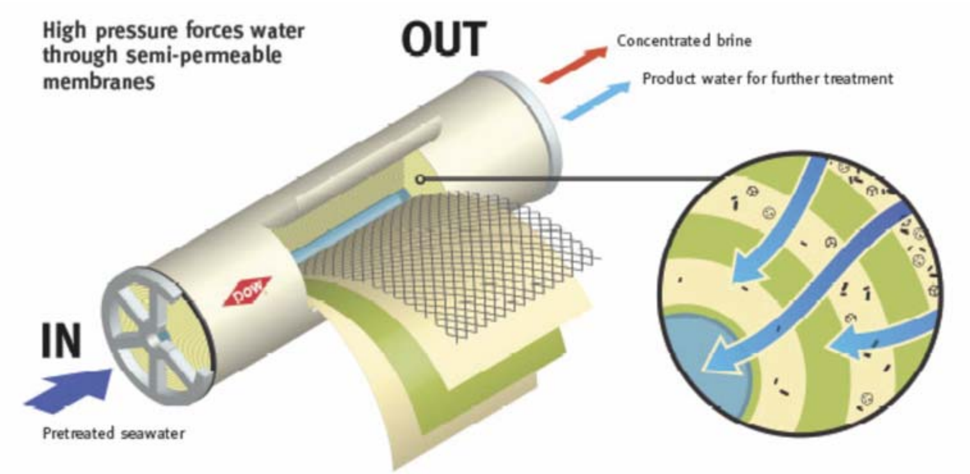

Figure 3. Reverse Osmosis Process

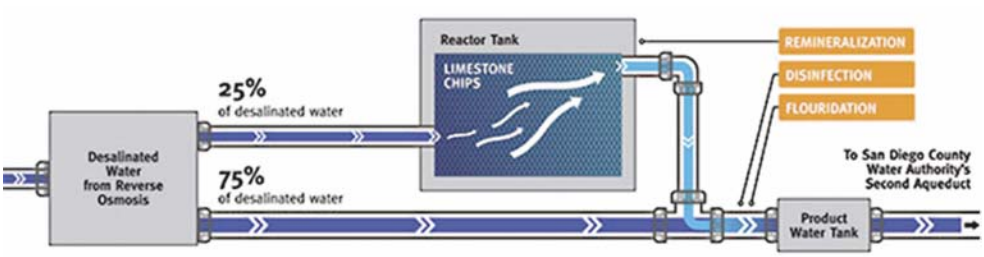

Figure 4. Post-Treatment Process

The Process

Pretreatment

Pretreatment is the first stage of the desalination process. When seawater arrives at the plant, it goes through a pretreatment process to remove algae, organic materials, and other particles. Seawater is pumped into multimedia filter tanks, which include layers of anthracite and sand atop a bed of gravel. Once filtered, the water moves into the next stage of desalination.

Secondary Pretreatment

Before seawater enters the reverse osmosis (RO) filters to remove the salt particles, it must go through a second stage of pretreatment called microfiltration to remove smaller and even microscopic impurities. At this point, virtually all impurities other than dissolved salts and minerals have been removed from the water, but it still needs to go through one more step to remove the dissolved salts and minerals to be ready for drinking.

Reverse Osmosis Building

The RO building is the center of the desalination process and the desalination plant. During this process, dissolved salt and other minerals are separated from the water, making it fit for consumption. The building contains more than 2,000 pressure vessels housing more than 16,000 RO membranes.

The RO works by pushing water, under intense pressure, though semipermeable membranes to remove dissolved salts and

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Table 1. Fiberglass Pipe Scope for Underground Sections

Nominal Diameter (inch)	Nominal Pressure (PSI)	Pipe Stiffness (PSI)	Pipe OD (Inch)	Pipe Wall Thickness (Inch)	Pipe Quantity (Feet)
24	150	46	25.79	0.41	160
36	50	36	38.31	0.59	40
42	50	36	44.49	0.67	120
48	50	36	50.79	0.76	210
60	50	36	61.61	0.91	30
72	100	36	72.44	1.06	1440

Table 2a. Fiberglass Pipe Section Conditions

PIPE PROJECT SECTION Section – Material - Diameter	100-GRP-72	200-GRP-72	700-GRP-36	700-GRP-24
LINE DESCRIPTION	IPS Suction Line	IPS Discharge Line	Neutralization Tank To Post Treatment	SBT to Clean/Flush Pump
Cl (ppm)	18,000	18,000	180 - 1,252	42 - 87
Hardness (ppm as CaCO3)	5,500 - 12,500	5,500 - 12,500	3 - 30	3.55
CO2 (ppm)	1.00	1.00	0	1.91
TDS (ppm)	28,000 – 34,500	28,000 – 34,500	400 – 3,500	73
Conductivity (µS)	~54,000	~54,000	700 - 6,500	155 - 450
pH	7.8 - 8.3	7.8 - 8.3	10.5 - 11.7	5.62
Temperature (°F)	57 - 86	57 – 86	57 - 88	86
Design Pressure (psig)	22	87	44	118
Design Vacuum (psig)	7.25	0	7.25	7.25
Fluid	Seawater	Seawater	4th Pass Brine	Front Permeate
FRP Resin Type	Polyester Resin	Polyester Resin	Vinyl Resin	Polyester Resin

Table 2b. Fiberglass Pipe Section Conditions

PIPE PROJECT SECTION Section – Material - Diameter	800-GRP-48	800-GRP-42	900-GRP-24	900-GRP-48
LINE DESCRIPTION	SBT to PWT Mixing Vault	Post to Buffer Tank	Buffer Tank Overflow/Drain	PWT Overflow/Drain
Cl (ppm)	400 – 1000	125.5	125.5	103.2
Hardness (ppm as CaCO3)	3 – 10	15.6	15.6	59.1
CO2 (ppm)	0 – 10	119.7	119.7	0.07
TDS (ppm)	50 – 200	212	212	265
Conductivity (µS)	90 – 400	600	600	870
pH	6 – 8.2	4.5	4.5	8.4
Temperature (°F)	95	NA	NA	95
Design Pressure (psig)	44	29	29	29
Design Vacuum (psig)	0	0	0	0
Fluid	Front & Cascade Permeate	Post Treated Water	Post Treated Water	Product Water
FRP Resin Type	Polyester Resin	Vinyl Resin	Vinyl Resin	Vinyl Resin

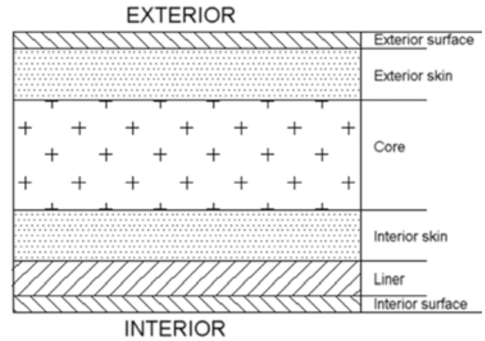

Figure 5. Typical Glass Reinforced Polymer Mortar Pipe Wall Section

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other impurities. These membranes act like microscopic strainers that allow only water molecules to pass through, leaving behind the salt, minerals, and other impurities, such as bacteria and viruses.

In addition to the RO membranes and pressure vessels, this building houses 144 state-of-the-art energy recovery devices. These devices work by capturing the hydraulic energy created by the high-pressure reject stream of seawater produced during the RO processes and transfers it into incoming seawater, without consuming any electrical power themselves. These devices save the plant an estimated 146 mil kilowatt-hours of energy per year, reducing carbon emissions by 42,000 metric tons annually, which is roughly equivalent to the annual greenhouse gas emissions from 9,000 passenger vehicles.

Post-Treatment

After RO filtration, the fresh water is nearly ready for consumption, but before making its way to the customer's faucet, the water must undergo post-treatment, which includes adding some minerals back into the water and disinfection with chlorine.

Product Water Storage

Once the desalination process is complete, the water moves to the product water tanks, where it is then pumped 10 mi to the SDCWA's second aqueduct in San Marcos. Here, the water is blended with the regional supply and transported to the surrounding communities.

Design Considerations

The plant and pipeline were taken on as an engineering, procurement, and construction design/build project by KSD, a joint venture of Kiewit Infrastructure West

Co. and J.F. Shea Construction Co. The plant's main process design (water pretreatment, RO filtration, post-treatment, and instrumentation and control systems) was integrated by subcontractor, IDE Americas.

As part of this project, the contractor had to install roughly 2,100 lin ft of underground filament wound fiberglass reinforced polymer (FRP) process to carry raw seawater and permeate product for the desalination plant. With a flow capacity up to 108 mgd of raw seawater and 54 mgd of desalinated permeate product through various processes, the diameters of the FRP pipes ranges from 24 to 72 in. The full scope of the FRP pipe installed for the underground sections is included in Table 1.

The fiberglass pipe proposed for these sections for the project was a glass reinforced polymer mortar pipe. Polymer mortar fiberglass pipes include a sand fortifier in the core of the wall construction of the pipe to provide pipe stiffness for buried pipe applications. There are two very distinct layers of structural glass reinforcements that are found in the exterior and interior skin sections of the pipe wall. Figure 5 shows the cross section of the fiberglass wall structure.

The FRP pipe was used in various sections throughout the facility. Each section within the facility had different requirements for the pipe material, as shown in Table 2a and 2b. The material used for the seawater intake pipe is exposed raw seawater, which is highly corrosive and has a salinity of approximately 4 percent. The FRP pipe materials utilized for the permeate water with chemical addition are exposed to various pH levels ranging from as low as 4.5 to as high as 11.7. Because of the various conditions within the system, the resin manufacturer provided both polyester and vinyl ester resin to accommodate the pipe section requirements.

As part of the physical material requirements for the appropriate FRP pipe design, specific loading conditions had to be considered for the underground pipelines. These pipes needed to be strong enough to handle the soil load from burial depths of up to 32 ft of cover, as well as AASHTO H-20 traffic loading. In addition, the pipe needed to be able to withstand the internal pressures of 118 pounds per sq in. gage (psig) and at the same time be able to handle negative pressure of 7.25 psi vacuum with the addition of 6 ft of groundwater pressure at the top of the pipe. In order to achieve the physical requirements for the underground piping, two different pipe stiffness classes were utilized (pipe stiffness of 36 and 46 psi), as shown in Table 3. The typical trench conditions for the underground pipe material included a crush stone pipe zone embedment material 6 in. under the pipe and 12 in. over the pipe. Figure 6 provides the typical trench installation conditions.

As a design/build project, the FRP pipe specifications were adapted specifically to the project to address these unique conditions. Three primary requirements within the specifications were that the pipe materials have to provide a minimum design and performance life of 30 years, the product needs to be NSF 61-certified for this potable water application, and the product has to be made with phthalate-free resins. In addition, the AWWA C950 and ASTM D3517 standards for fiberglass pressure pipe for use in water applications were utilized to provide the backbone for the manufacturing quality control.

The contractor was able to source a single manufacturer (Thompson Pipe Group – Flowtite), to supply the filament wound FRP pipe materials to cover these sections of

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Table 3. Fiberglass Pipe Installation Conditions

PIPE PROJECT SECTION Section – Material - Diameter	Pressure Rating (psi)	Pipe Stiffness Class (psi)	Min. Burial Depth (ft)	Max. Burial Depth (ft)	Trench Width (inch)
100-GRP-72-SW	100	36	6	32	102
200-GRP-72-SW	100	36	6	15	102
700-GRP-24-CIP	150	46	10	12	42
700-GRP-36-BBW	50	36	6	8	60
800-GRP-42-PR	50	36	3	8	67
800-GRP-48-PR	50	36	8	10	72
900-GRP-24-PR	150	46	17	18	42
900-GRP-48-PR	50	36	17	18	72

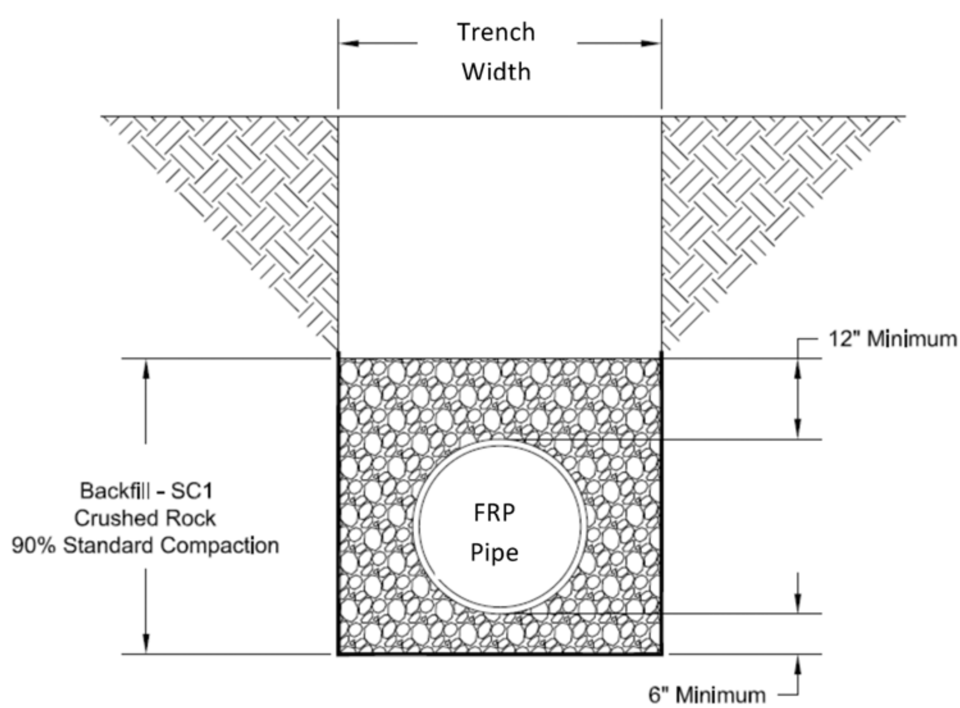

Figure 6. Fiberglass Pipe Trench Conditions

Image 1. Fiberglass Pipe Installation

Image 2. Fiberglass Field Laminations

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the project. As a team, the contractor and the pipe manufacturer worked together to optimize construction by adjusting the plans to eliminate any potential challenges that the contractor might face during the installation process. Because this was a design/build project, the construction schedule was extremely compressed, which meant that many of the design challenges were being addressed concurrently with the construction of the project.

The team worked well together to efficiently come up with solutions that benefited the project. One of the solutions, to help with reducing the installation time of the 72-in.-diameter pipe, was to utilized FRP couplings in lieu of laminated fiberglass joints. The manufacturer was already capable of producing joint lengths of 40 ft, which had already eliminated many joints through the project, but the utilization of these couplings eliminated 19 additional field laminated fiberglass joints.

This collaborative effort reduced the upfront design/submittal phase to allow for production of the pipe to begin more quickly, as well as provide for a more efficient installation process and meet the aggressive construction schedule of the contractor.

Construction

The contractor originally broke ground on the construction of this facility in December 2012, but the installation of the underground pipe section did not begin until December 2013. With the fast-paced construction schedule, it was critical that all FRP components shipped to the project were coordinated between the contractor and the manufacturer, but more importantly, the products needed to be of the highest quality.

As part of the quality assurance/quality control (QA/QC) program at the pipe manufacturing facility, a transparent quality program was created that allowed for the contractor QC representatives to visit the pipe manufacturing facility in Louisiana and perform audits with the in-house QC staff.

Once the products were delivered to the project site, the pipe manufacturer's field representatives worked together with the contractor's field staff to provide in-field solutions during the installation. To help with the speed of the pipe installation, precut glass kits were provided and labeled from the pipe manufacturing facility to the jobsite so that field crews did not have to cut glass in the field, which saved time on the fiberglass field-laminated joints.

On other solution that saved time and facilitated the ease of installation was utilizing the FRP couplings to push the pipe sections together within the tunneled portion on the project. This section included 340 lin ft of the 72 filament wound FRP pipe and couplings. In order to achieve this, the team worked together to design a system to fit within the casing of the jacked tunnel to push the joints together.

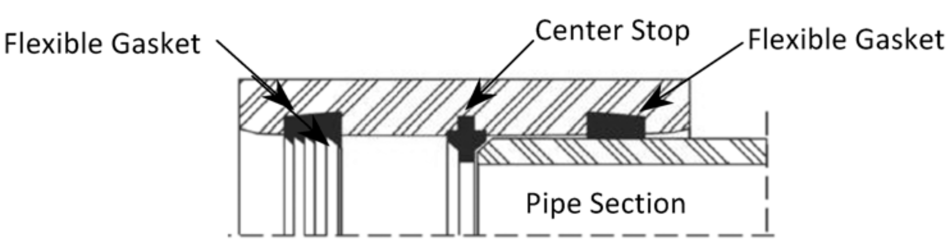

Figure 7. Fiberglass Flexible Coupling Joint System

Conclusion

The project was successfully completed on time in December 2015 and has been delivering water to the businesses and residents of San Diego County. The compressed construction schedule and the joint effort between the contractor and the FRP pipe manufacturer were some of the many reasons this project was able to be completed on time. The lessons learned that can be taken away from this project include:

- Many construction challenges can be avoided during the design phase of a project.
- The ability of the construction group and the manufacturer to adapt and overcome challenges together as a team is important on every project, but on a project with a compressed construction schedule, this collaborative effort is increasingly more critical.
- It is valuable to have the right manufacturing partner that can adapt to the construction needs on a project in order to assist with various items, which can more easily be done in the manufacturing facility than at the jobsite.

References

1. "Desalination Plant. "http://carlsbaddesal.com/desalination-planthtml.