ONSHORE PORTION OF SEA WATER COOLING SYSTEM OF AL KHALIJ POWER PLANT PROJECT

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1.0 Introduction

Al-Khalij Power Plant Project is an oil fired thermal power plant project with four units each having 350 MW capacity located approximately 20 km west of town Sirte, Libya. Owner of the project is GECOL (General Electrical Company of Libya) and the project is designed and constructed under supervision of Bechtel-USA. Construction of the plant was carried out with collaboration of Hyundai for turbines, generators and electro-mechanical works, Doosan for boilers, Geocean for marine works and GAMA Industrial Plants Manufacturing and Erection Company for civil works.

Cooling water system is once through cooling system, for which water is received from and discharged to Mediterranean Sea. Marine intake and discharge lines are 3 m and 2.8 m diameter GRP pipes respectively for each four units separately. Onshore portion of this cooling water system, which is the subject of this paper, consists of Intake Structure, pumps, Intake Header, 2.5 m diameter underground GRP pipes, Surge Chamber structure, Outfall Structure and relevant intake and outfall Sluice Gates as shown on Figure 1 and Figure 2. Onshore portion of cooling water system except pumps with their drives, chlorination and screening systems are supplied and constructed by GAMA under civil scope.

There are four supply and four return cooling water pipe lines for four units of the power plant. Total length of the onshore portion of supply and return cooling water pipes is approximately 6000 m. Each line is designed for flow rate of 51,000 m^3/h in normal operating conditions; and the maximum flow rate for each line is considered as 54,000 m^3/h. Operating pressure for the cooling water lines is 4.0 barg. Design lifetime for the civil underground cooling water lines is 35 years. In the original contract, the onshore cooling water lines were specified as Prestressed Concrete Cylinder Piped (PCCP); and they were changed to GRP during the course of detail design.

Effective date of the contract was November 2008; and construction of onshore portion of cooling water system was completed in February 2014. During this construction period, whole project had to be stopped between beginning of 2011 and end of 2012 because of the Libyan Civil War.

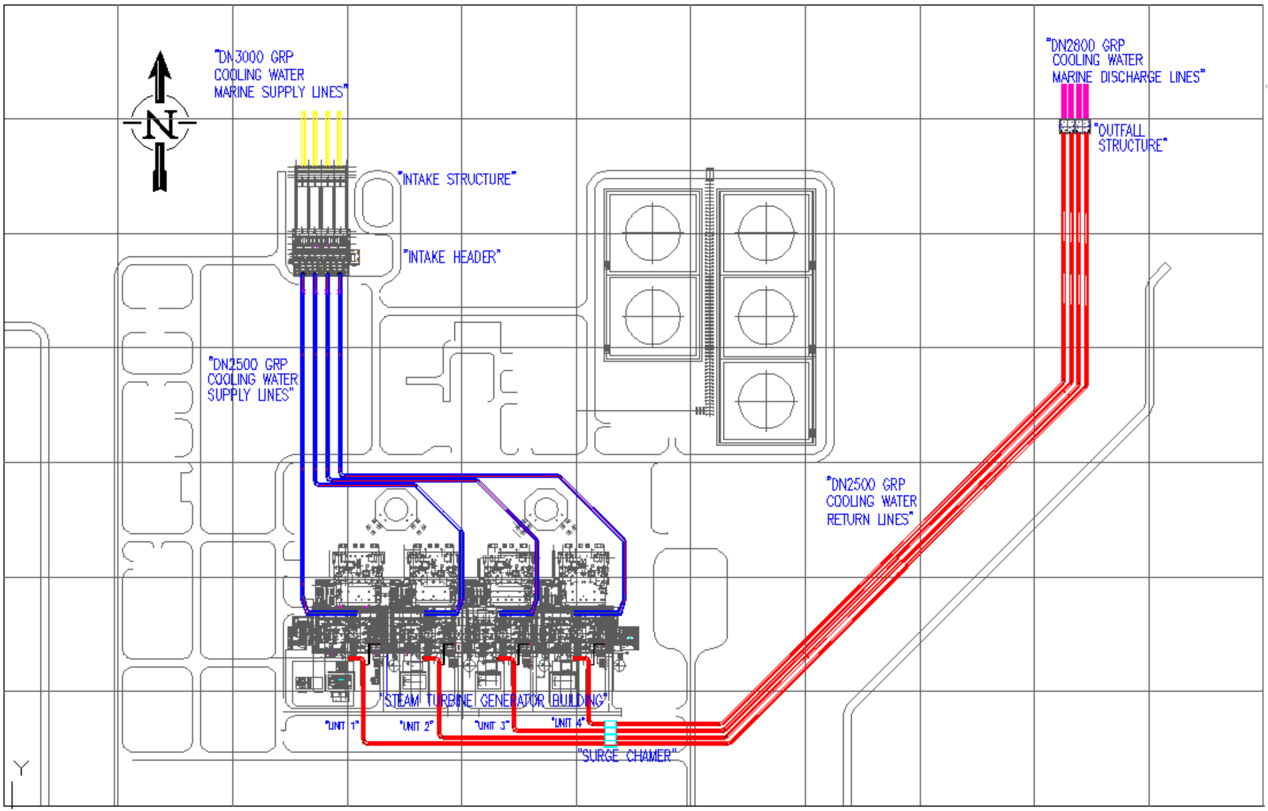

Figure 1. Al Khalij Power Plant Circulating Cooling Water Lines Layout
(Yellow lines: 3000 mm dia. marine intake lines; blue lines: 2500 mm dia. cooling water supply lines; red lines: 2500 mm dia. cooling water return lines; purple lines: 2800 mm dia. marine discharge lines)

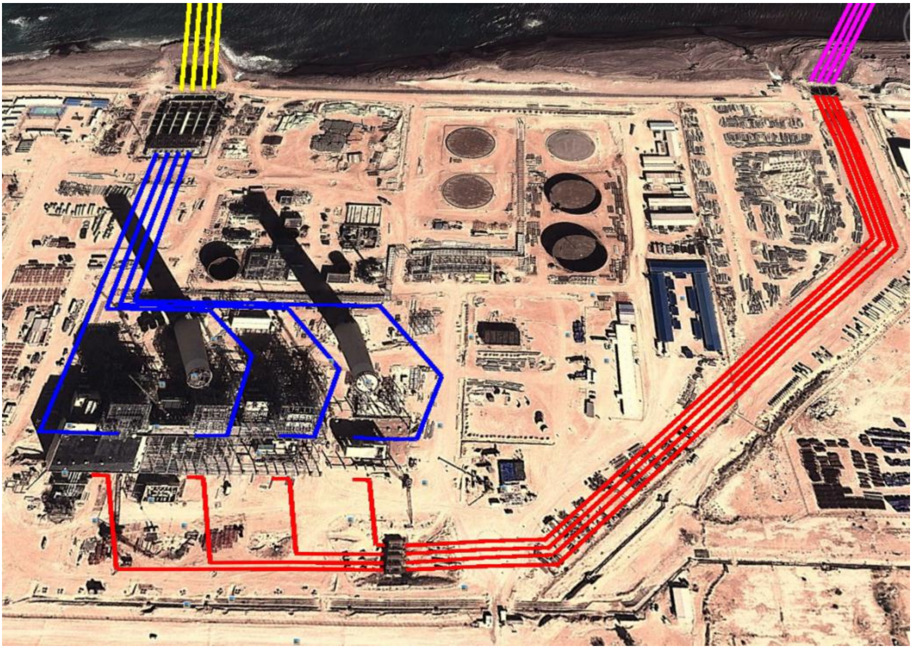

Figure 2. View of Al Khalij Power Plant in Google Earth and Marked Circulating Cooling Water Lines

2. 0 Intake Structure

Intake Structure is approximately 50 m wide and 85 m long concrete structure. Its depth is about 15.5 m with respect to the ground level (Figure 3, Figure 4 and Figure 5). It consists of four water intake channels after baffle walls in front of the each marine intake pipes. There are Sluice Gates at the end of each marine intake lines to close water entrance to the Intake Structure. Intake Structure is also equipped with fixed trash rakes and traveling band screens. In order to be able to carry out partial maintenance works, there are sets of Stop Logs suitable for dewatering the relevant sections of the Intake Structure.

Since the Intake Structure is constructed as deep foundation on the shore line, shoring system was a challenge for excavation, dewatering and construction of the Intake Structure. Secant pile system all around the Intake Structure was used for this purpose with 800 mm diameter and 17 to 21 m long piles driven to the rock layer together with steel strut members in longitudinal and transverse directions as shown on Figure 3, Figure 4, Figure 5 and Photo 1.

North part of this secant pile system was cut under the sea water after completion of the construction for connection of the marine supply pipes to the Intake Structure.

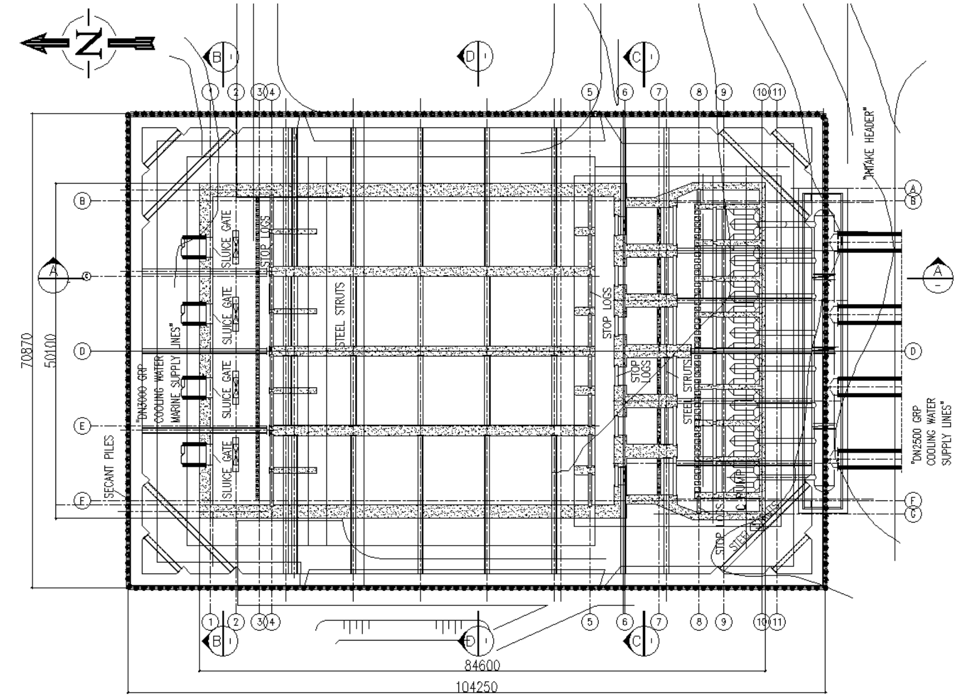

Figure 3. Intake Structure Plan View

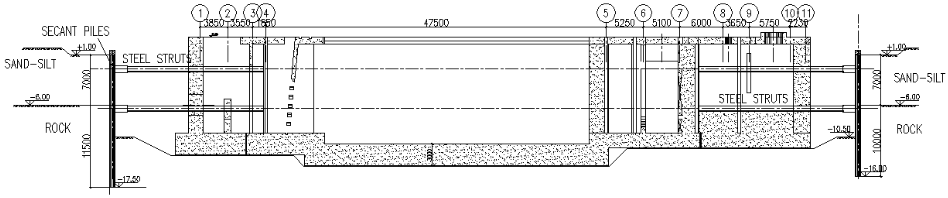

Figure 4. Section A-A of Intake Structure

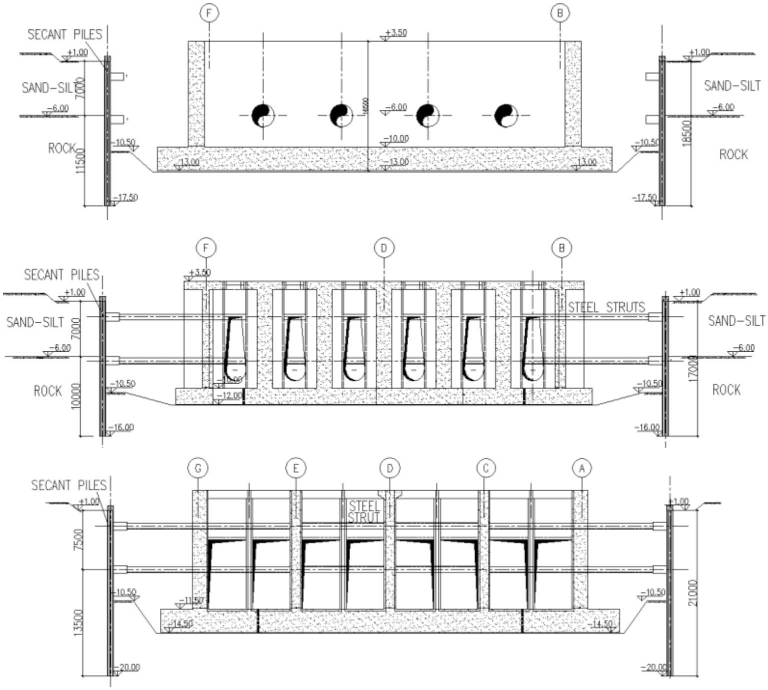

Figure 5. Sections B-B, C-C and D-D of Intake Structure.

Sluice gates, trash rakes, travelling screens, pumps and other relevant equipment and Cooling Water Pump House were installed afterwards.

Photo 1. Construction of Intake Structure (November 2010)

After completion of the construction of Intake Structure, sea water is taken to the structure by opening the Sluice Gates as indicated on Photo 2.

Photo 2. Intake Gate Sluice Gates and the First Sea Water in Intake Structure (October 2013)

3.0 Intake Header

Water is pumped from Intake Structure with eight pumps each having 25,500 m^3/h capacity in nominal operational conditions and 27,000 m3/h maximum capacity to Intake Header which is located just downstream of the Intake Structure.

Diameter of Intake Header is 2800 mm and it is welded carbon steel construction with epoxy coating. It is protected with impressed current cathodic protection system against corrosion. There are eight DN1800 inlet nozzles for supply pumps connections; and there are four DN2500 outlet nozzles for connection of cooling water supply pipes to turbines. The Intake Header is fabricated in four segments, which are connected to each other by using sectionalizing DN2800 butterfly valves. Connection of these butterfly valves with the Intake Header segments is made by using dismantling joints. Figure 6, Figure 7 and Figure 8 are for details and Photo 3 is for fabrication of the Intake Header.

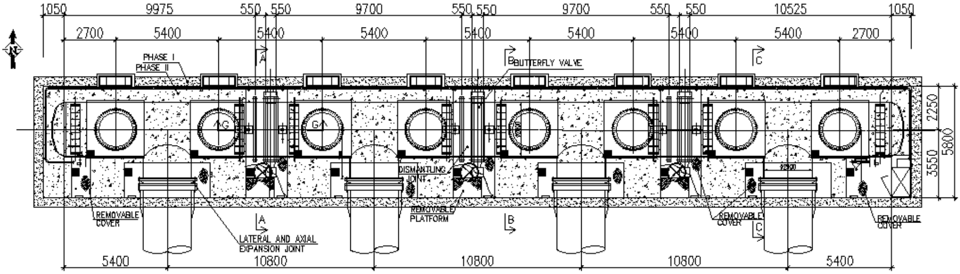

Figure 6. Plan View of the Intake Header

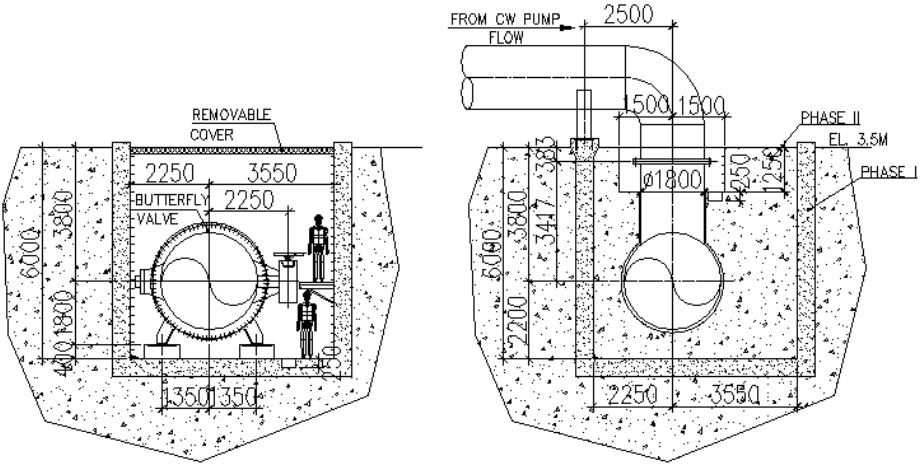

Figure 7. Section A-A and Section B-B of Intake Header

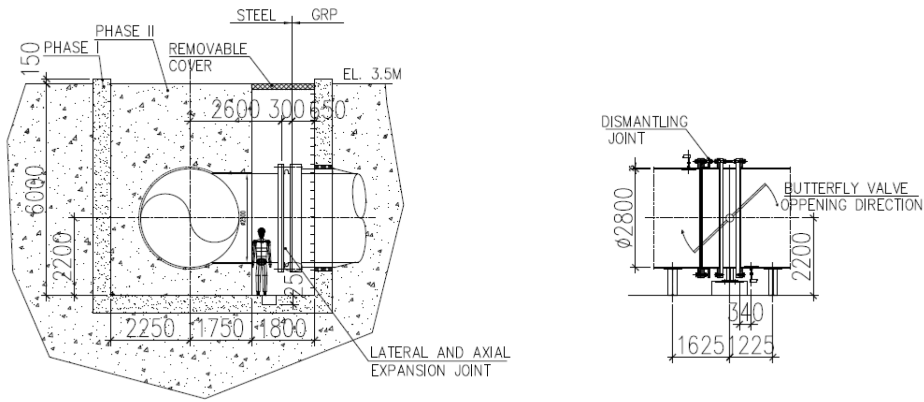

Figure 8. Section C-C and Section G-G of Intake Header

Photo 3. Fabrication of Intake Header (February 2011)

Intake Header is placed inside the concrete vault which is also filled with lean concrete after completion of Intake Header installation by leaving required rooms for connections, operation and maintenance of butterfly valves and cathodic protection system. Connection of Intake Header with sea water supply pipes from pumps is made with flanged connections (Photo 4 and Photo 5); whereas connection to GRP supply cooling water pipes is made through expansion joints to compensate probable lateral axial relative movements between the fixed Header and buried GRP pipes as shown on Figure 6, Figure 8 and Photo 4.

Photo 4. Connection of DN1800 Supply Water Pipe from Pump and DN2500 GRP Cooling Water Supply Line through Expansion Joint with One of the Intake Header Segment (November 2013)

Photo 5. Connection of Eight DN1800 Supply Water Pipes from Intake Sea Water Pumps inside the Cooling Water Pump House to Intake Header

4.0 GRP Cooling Water Pipes

Onshore underground cooling water pipes are designed against 5.8 barg internal design pressure, which is also the site test pressure, for full vacuum and against earth cover and additional surcharge loads within heavy haul routes as stated in the relevant contract specification[[1]], by using GRP uniaxial and biaxial pipes without any trust blocks based on the stress calculations that were carried out by using Caesar II software.

GRP pipes are fabricated with thermosetting isophthalic polyester resin and closely spaced E type random chopped strand mat glass fiber stiffened with silica sand as structural layer. Internal liner has resin rich interior layer with a minimum thickness of 0.2 mm and ECR glass surface tissue. The minimum thickness that the barrier layer shall have is 0.8 mm, which is made of E glass hoop, isophthalic polyester resin and polyester yarn. The exterior resin rich layer of the pipes have a minimum thickness of 0.2 mm reinforced with polyester veil or ECR glass veil impregnated with isophthalic polyester resin.

For the complete onshore portion of supply and return cooling water lines, 381 straight pipe pieces and 151 fittings were fabricated between the end of 2009 and end of 2010 (Photo 6).

[1] 25458-000-V11-C00Z-00143, Technical Specification for Design, Fabrication, Supply, Installation and Testing of GRP Piping for Onshore Circulating Water System.

Photo 6. Fabrication of 2500 mm Diameter GRP Pipes (December 2009)

All these pipes were fabricated and shop tested as per the contract specification under supervision of the Third Party and random participation of the Owner and Owner's Engineer Bechtel (Photo 7).

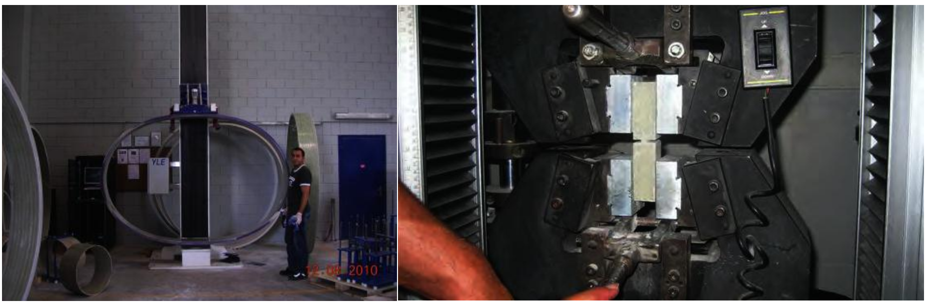

Photo 7. Mechanical Shop Testing of GRP Pipes Fabrication

Installation of cooling water pipes was started in March 2010 (Photo 8). All installation works are also supervised by the Third Party. Except flanged connections to Intake Header (Photo 4) and to DN1800 Turbine condensers (Photo 9); and special non-rigid connections to the concrete structures (Surge Chamber and Outfall Structure), all site connections are butt and wrap type connections (Photo 10).

Photo 8. Installation of DN2500 GRP Cooling Water Pipes

Photo 9. Flanged Connection of Return Lines GRP Headers to DN1800 Turbine Condensers

Photo 10. Butt and Wrap Connection of Pipe Pieces and Post Curing of these Connections

All rigid cooling water supply and return lines were site hydrotested after completion of installation as per the routing indicated in Figure 1 by use of the specifically fabricated test covers as per the approved method statement (Photo 11 and Photo 12) for specified site test pressure of 5.8 barg (Photo 13).

Photo 11. Hydrostatic Site Test of Unit 4 Cooling Water Return Line between Turbine and Surge Chamber with DN2500 Test Cover on Surge Chamber Side (January 2014)

Photo 12. Hydrostatic Site Test of Unit 4 Cooling Water Return Line between Turbine and Surge Chamber with DN1800 Test Covers on Turbine Side (January 2014)

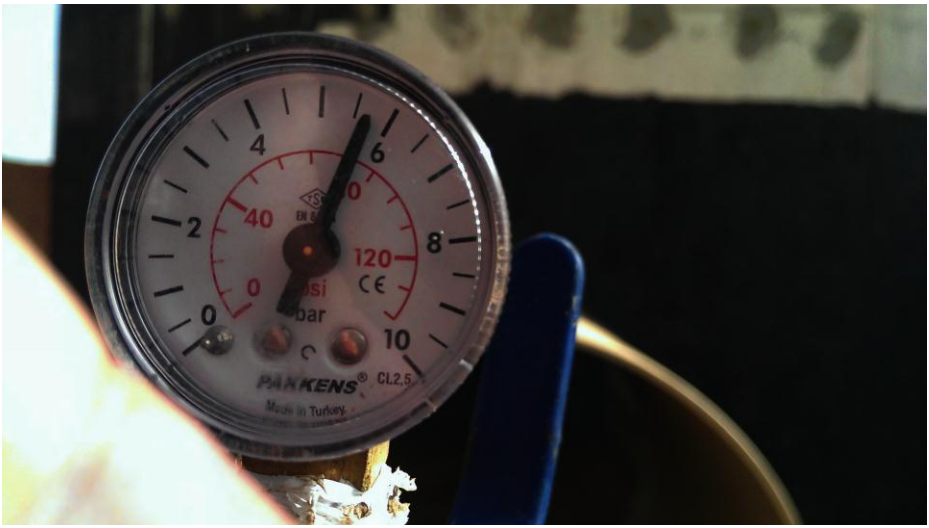

Photo 13. Monitoring of 5.8 barg Site Test Pressure During Hydrostatic Site Test of Unit 4 Cooling Water Return Line between Turbine and Surge Chamber (January 2014)

REKA couplings for non-rigid connections were tested against leaks internally by using specifically fabricated “joint tester” (Photo 14).

Photo 14. Site Hydrotesting of REKA Couplings with “Joint Tester”

5.0 Surge Chamber

Surge Chamber is an open top concrete structure on cooling water return lines in order to compensate effects of surges on the return lines (Figure 9, Figure 10 and Photo 15).

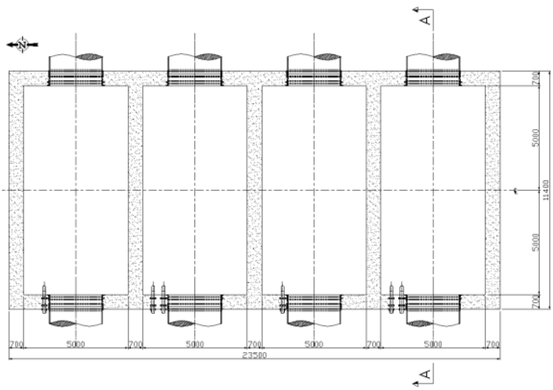

Figure 9. Plan View of Surge Chamber

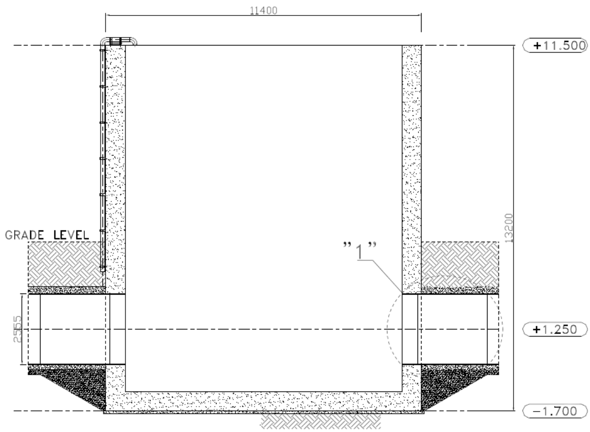

Figure 10. Section A-A of Surge Chamber

Photo 15. Surge Chamber after Construction is Completed (May 2014)

Connection of the GRP return lines to the concrete Surge Chamber structure is also a challenging problem, where sealing and differential settlements between pipes and massive concrete Surge Chamber are the main issues to be considered during design and construction. For this connection two REKA type couplings with “short pipe” pieces (2500 mm long) are used to compensate differential settlements with the rocking action of “short pipe” within the allowable limits of the two REKA couplings at both ends of the “short pipe” (Figure 11 and Photo 16).

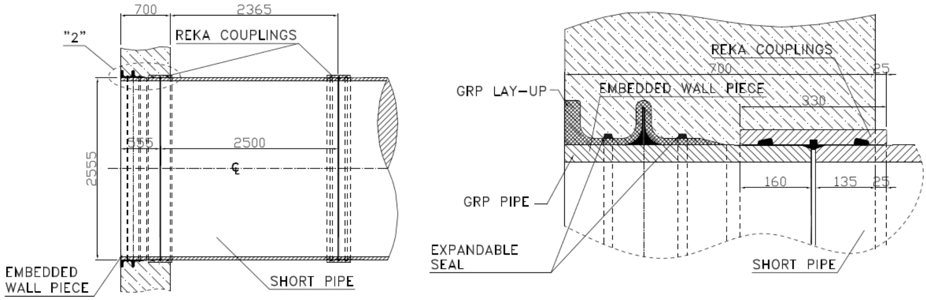

Figure 11. Detail 1 and Detail 2 of Surge Chamber

In order to obtain better adhesion and sealing between concrete structure and "embedded wall piece" outer surface of the "embedded wall piece" is roughened with sand (silica) particles connected with polyester resin (Photo 16). Seal elements, which are expandable with the contact of water are also used for leak free connection as indicated on Detail 2 of Figure 11.

Photo 16. "Short Pipe" together with "Embedded Wall Piece" and REKA Coupling

Non-rigid connection of GRP pipes to Surge Chamber with "short pipes" and REKA couplings is indicated on Photo 17.

Photo 17. Connection of GRP Pipes to Surge Chamber with "Short Pipes" and REKA Couplings

6.0 Outfall Structure

Outfall Structure is also an open top approximately 27 m wide and 14 m long concrete structure at the end of cooling water return lines for dissipation of energy with flow of water over the weir to the lower chamber before discharge of water to Mediterranean Sea through DN2800 GRP marine discharge pipes. Its depth is about 14 m with respect to the ground level (Figure 12 and Figure 13).

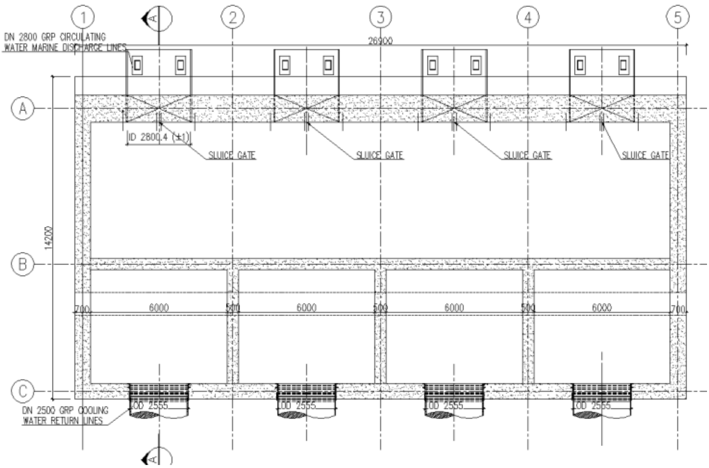

Figure 12. Plan View of Outfall Structure

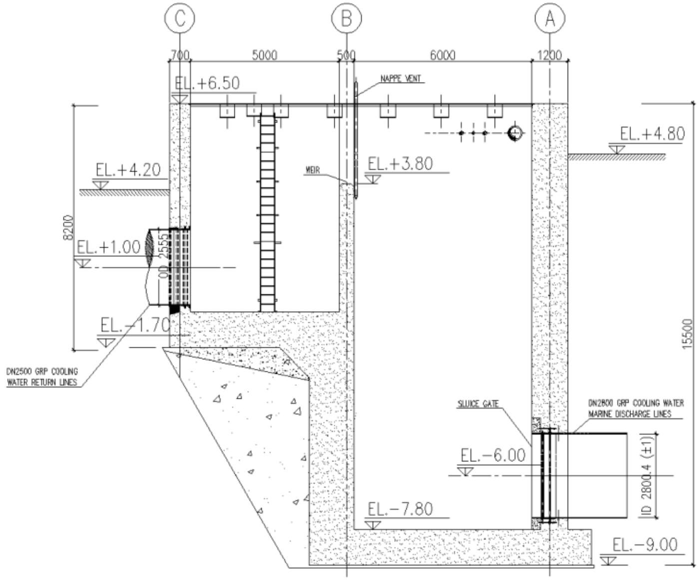

Figure 13. Section A-A of Outfall Structure

Since the Outfall Structure is also constructed as deep foundation on the shore line, secant pile type shoring system was used all around the Outfall Structure similar to Intake Structure for excavation, dewatering and construction of the Outfall Structure. North part of this secant pile system was cut under the sea water after completion of the construction for connection of the marine discharge pipes to the Outfall Structure.

In order to eliminate problems due to differential settlement between concrete Outfall Structure and GRP cooling water return pipes, connection with short pipe and REKA couplings similar to the one in Surge Chamber shown on Figure 11 was used for Outfall Structure as well.

There are sluice gates made up of Ni resist cast iron installed at the beginning of marine discharge pipes to close water passage for maintenance of discharge pipes and for closing discharge pipes corresponding non-operating power plant units to keep water flow through these discharge pipes constant (Figure 14).

Due to the geometry of the Outfall Structure, water falling over the weir crates significant hydrodynamic forces and turbulence in the lower chamber where Sluice Gates are installed; and these forces and turbulence should be considered for design and fixation of the Sluice Gate components to the concrete Outfall Structure. Computational Fluid Dynamic (CFD) analysis has been carried out to determine these effects and connection forces.

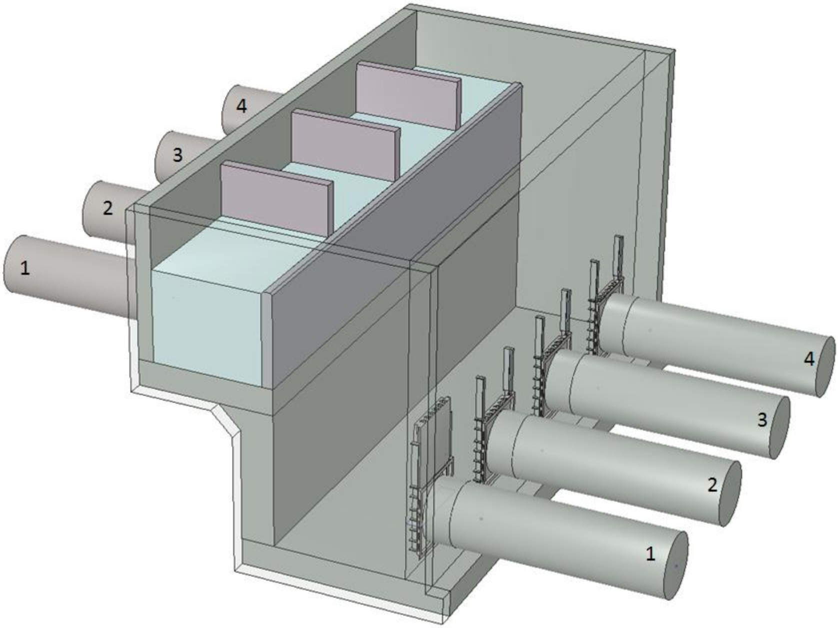

Figure 14. Outfall Structure and Sluice Gates (Hoists of the Sluice Gates are not Shown)

Since the plant operates in different operating schemes, there are various operation scenarios for the Outfall Structure and Sluice Gates that need to be considered for safe connection of the Sluice Gate members to the Outfall Structure, which are listed as follows:

- Only one of the side units (Unit 1 or Unit 4) is in operation,
- Two unit close to side (Unit 1 + Unit 2 or Unit 3 and Unit 4) are in operation,
- Two middle units (Unit 2 + Unit 3) are in operation,
- Two outer units (Unit 1 + Unit 4) are in operation,
- Three consecutive units (Unit 1 + Unit 2 + Unit 3 or Unit 2 + Unit 3 + Unit 4) are in operation,
- Other three units (Unit 1 + Unit 2 + Unit 4 or Unit 1 + Unit 3 + Unit 4) are in operation,
- All four units (Unit 1 + Unit 2 + Unit 3 + Unit 4) are in operation.

For all of the above studies, it is considered that Sluice Gates corresponding to the operating plant unit are open and the others are closed. Figure 15 indicates traces of water flow obtained with CFD analysis when only Unit 1 is in operation and Sluice Gates corresponding to Unit 2, Unit 3 and Unit 4 are closed.

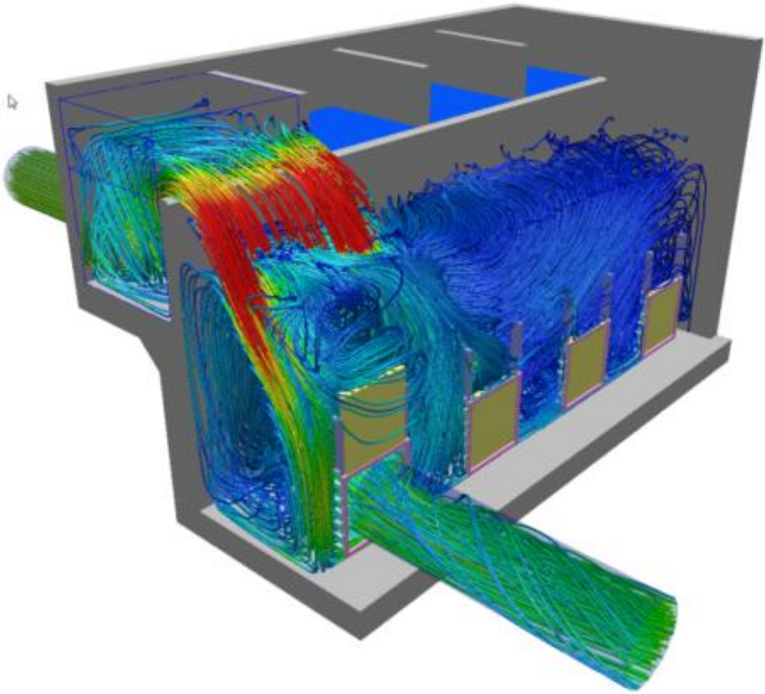

Figure 15. Traces of Water Flow Obtained with CFD Analysis when Only Unit 1 is in Operation and Sluice Gates Corresponding to Unit 2, Unit 3 and Unit 4 are Closed.

Pressure, velocity and moving fluid volumes were calculated for all above listed scenarios in this study to obtain the force magnitude and directions on the gates and connection members to check them against these forces (Figure 16).

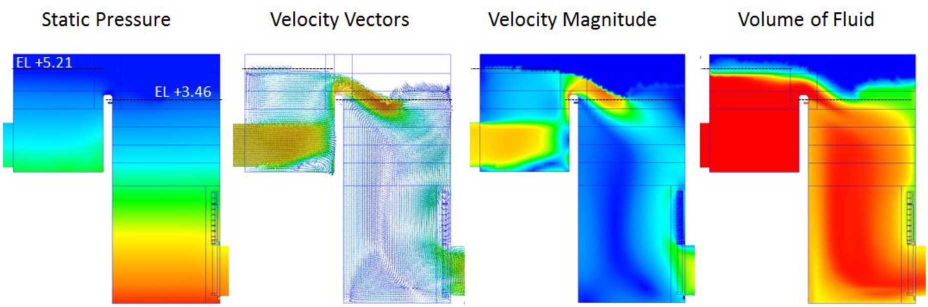

Figure 16. Static Pressure, Velocity Vectors, Velocity Magnitude and Volume of Fluid Calculated with CFD Analysis in Outfall Structure Cross Section when Only One Unit is in Operation.

7.0 Conclusion

With successful cooperation between Engineering, Site Construction Team and relevant Vendors and Third Parties and also with successful coordination with Owner GECOL, Owner's Engineer Bechtel and with the all relevant contractors participated in the sea water cooling system of Al Khalij Power Plant Project (Geocean and Hyundai), construction of Intake Structure, construction and installation of Intake Header, fabrication and installation of onshore GRP cooling water pipes, construction of Surge Chamber, construction of Outfall Structure and fabrication and installation of intake and outfall Sluice Gates were completed in compliance with the contract quality requirements and within the contract schedule that was revised due to the Libyan Civil War in 2011 and 2012.

Power generation from the first unit of Al Khalij Power Plant has already been started in May 2014 by use of the onshore cooling water piping system.

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