Neckartal Dam,
The design & supply of the hydro mechanical equipment

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Introduction

Neckartal Dam is located on the Fish River, a tributary of the Orange River. The construction of Neckartal Dam started in September 2013. It will be the largest dam in Namibia and the eighth largest dam in Southern Africa by storage volume. Neckartal Dam is primarily for irrigation. Water is released from the dam and abstracted some 13km downstream from a weir. From there it is pumped to a balancing dam above the irrigation area. There is a mini hydropower station at the dam to generate electricity from the irrigation releases. Although the civil works make up the largest proportion of the capital cost of the project, the hydro mechanical equipment is vitally important to the success of the project. This paper gives a description of the hydro mechanical equipment for the project, the contractual arrangements to procure and install it, some of the important specifications used for the design and manufacture of the equipment and the quality assurance methods used to ensure that the equipment meets the long-term project requirements. Figure 1 shows the downstream view of the dam and outlet works taken from a drone.

Fig. 1. Neckartal Dam view from downstream.

1. Dam outlet works

Water will be released into the river from the dam to be abstracted from the river some 13km downstream. The outlet works for Neckartal Dam serve the purpose of releasing the active storage in accordance with the irrigation and environmental release requirements. The Neckartal Dam outlet works are located on the left bank. All isolation and control valves will be accessible from either the intake control room or the downstream outlet control house. The maintenance bulkhead gate will be stored on the dam non-overspill crest and operated using a permanent gantry crane in the control room. Because of the infrequent movement and mixing of the live storage, stratification of the stored water is anticipated. In order to deal with this phenomenon and to enable water of an environmentally desirable temperature and quality to be released, provision has been made for selective withdrawal from the reservoir. A multilevel intake has been constructed for the low capacity outlets at Neckartal Dam, while a single, bottom level intake is provided for the high capacity release system. Figure 2 is the three-dimensional CAD model of the dam outlet works.

The **high capacity outlet** takes the form of two 3000mm diameter pipes, with bell mouth intakes, in a trash rack structure, which can be isolated using bulkhead gates lowered down slots from the crest and sealed against steel sealing frames cast into the concrete around the bell mouth intakes. The pipes run parallel, cast into the body of the dam and emerging at the sleeve valve house at the toe of the dam structure. From here, flow will be released through 3000mm diameter butterfly valves. Discharges will be controlled using 1800mm diameter hooded sleeve valves immediately downstream of the butterfly valves. The sleeve valves will discharge into a stilling basin.

The **normal release system** consists of two 1600mm pipe stacks. The intakes to the pipe stacks are staggered at 6.0m intervals to allow for flexibility in selecting the most appropriate abstraction level. There are precast concrete trash racks and stainless-steel screens in front of the inlets to prevent debris from entering the outlet. The screens can be removed to be cleaned using the overhead crane. The pipe stacks can be isolated upstream with a bulkhead closure gate and butterfly valves. Discharges are controlled downstream by means of 800mm and 400mm sleeve valves. The low flow release system also branches off to the turbines.

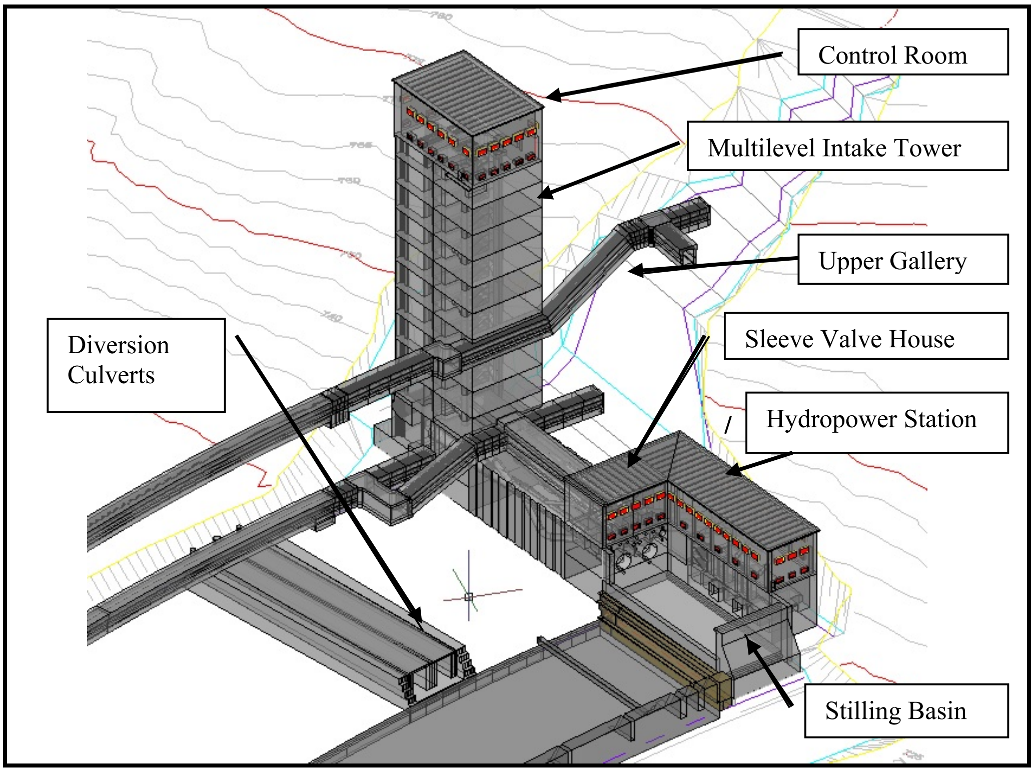

Figure 2: Neckartal Dam Outlet Works (isometric view)

The **hydropower station** will be operated to utilise the irrigation releases for power generation. The hydropower station comprises two turbines. The turbines and generators are housed in a turbine room adjacent to the sleeve valve house. The gross head is 60m and the combined rated flow is 6m^3/s. Francis turbines have been installed. The turbine-generator sets have a horizontal-axis configuration. The two 1600mm penstock bifurcates from each of the multi-level outlets to the turbines. There are two isolating valves. The penstock then joins to a single 1600mm penstock before bifurcating to each turbine. There are two 1000mm butterfly valve MIV's to isolate the turbines. These valves may be closed without power using a counter weight. The installed capacity of the plant is 3MW and consists of two 1.5MW units. Energy production will depend on the dam water level and the irrigation scheme's water requirements. The turbines were supplied by Camuna Idroelettrica S.p.A., the generators by Marelli S.p.A. and the electrical BOP by ABB. Figure 3 shows the intake structure with the precast trash rack structure. Figure 4 shows the layout of the mini hydropower station.

Fig. 3. Neckartal Dam: Intake Tower. *Fig. 4. Neckartal Dam: Power Station.*

2. Abstraction weir, sediment trap, pumping station and delivery pipeline

Raw water will be abstracted for the irrigation scheme some 13km downstream of the dam. The abstraction weir has a scour channel with an automatic scour gate, intake screens, a sediment trap and suction pipeline to the pumping station. From the pumping station there is a 9km delivery pipeline to a balancing dam. The pipeline is an 1100mm steel pipeline with a 10mm wall thickness. Two different grades of steel were used for the pipeline: X52 for the higher-pressure section and X42 for the lower pressure section. The raw water pumps were manufactured by KSB and are single stage, double entry impeller, horizontal split casing, centrifugal pumps. Figure 5 shows the abstraction weir from downstream taken from a drone.

Fig. 5. Neckartal Abstraction Weir spilling in February 2018

Figure 6 shows the scour channel, sediment trap and pumping station in the background. Figure 7 shows the internal layout of the pumping station.

Fig. 6. Neckartal Dam: Sediment trap. *Fig. 7. Neckartal Dam: Pumping station.*

3. Description of the hydro mechanical equipment

The main hydro mechanical equipment for the project included the following items;

- River diversion culvert closure gates,
- Maintenance, scour and sluice gates,
- Stainless steel intake screens
- Butterfly and sleeve valves (Butterfly valves up to 3000mm in diameter and sleeve valves up to 1800mm)
- A twin set of multilevel outlets housed in the intake structure each with a diameter of 1600mm,
- Two high capacity low level outlets with a diameter of 3000mm,
- A mini-hydropower station with two 1.5MW horizontal Francis turbines,
- A pumping station with four horizontal split casing centrifugal pumps, &
- Overhead travelling cranes

4. Contractual arrangements

Neckartal Dam has been constructed using the FIDIC Red Book (First Edition 1999) Conditions of Contract for Construction. This implies that the works are designed by the Employer. However, some amendments were made to the contract document for the Contractor to procure specialist suppliers for the design and supply of the hydro mechanical equipment for the project. Design requirements and material specifications were provided by the Employer in the contract for the hydro mechanical equipment. The detailed design of hydro mechanical equipment was undertaken by specialist suppliers and sub-contractors in Southern Africa and in Europe. A wide range of specialist suppliers and manufacturers was used for the supply of the hydro mechanical equipment.

The project specifications for the supply of the hydro mechanical equipment were divided into seven sections. The first section dealt with general mechanical and then each of the others dealt with specific equipment or procedures. The seven sections were:

- General mechanical
- Hydro mechanical equipment, including maintenance, scour and sluice gates, built in parts and screens
- Pumps
- Pipes and specials excluding the delivery pipeline
- Valves
- Power generating equipment
- Painting and corrosion protection

The project specifications required that the hydro mechanical suppliers have established dealerships and/or agencies in Namibia or the Republic of South Africa to make future maintenance easier. For logistical reasons not all the equipment was supplied from Namibia or South Africa.

5. Hydro mechanical specifications

The hydro-mechanical specifications for the project were contained in seven sections comprising hundreds of pages. However, the following paragraphs aim to highlight just some of the important hydro mechanical requirements detailed in the project specifications.

5.1 General philosophy

The project specification provided the performance requirement for each of the hydro mechanical components, the load cases to be used for the design and the relevant industry standard specifications which must be followed for the design and manufacture. The specification also provided the material requirements for each of the components and the corrosion protection requirements for each individual item. The material specification for the pipework cast into dam that was greater than 600mm was specified as 3CR12. Pipework with a diameter 600mm or less was specified as stainless steel SS316. Minimum pipe wall thickness for each pipe diameter was also specified.

The Engineer's drawings outlined the location and requirements of the gates, screens, pipework, valves and cranes. The specification required that the Contractor develops the detailed design of the hydro mechanical equipment, within the space and layout constraints indicated by the Engineer's civil drawings for the project.

5.2 Specified loads

For the transfer of loads to the civil structures, restrictions were specified: the hydro mechanical equipment shall be designed such that no part of the Works under any loading condition shall impose any stress greater than those set out below on or in any concrete work:

- For compressive bearing stress: 7.0 MPa;
- For shearing stress: 1.7 MPa; and
- No tensile stress shall be allowed in concrete.

The load cases and loading for each of the hydro mechanical items were specified. For the gates, stoplogs and valves, the stresses including transient and earthquake forces should not exceed 80 % of the yield stress of the material used.

5.3 Site Conditions

The specifications also provided information on operating conditions of each component and the local climatic conditions. Neckartal Dam is located in a hot dry climate with temperatures of over 40°C regularly recorded on site. The specification required that the equipment supplied must be designed for;

- ambient temperatures ranging between -5°C and 55°C.
- water temperatures ranging between 10°C and 28°C, and
- pH ranging from 4.0 to 9.0

5.3 Welding and materials

All welding procedures had to be approved by the Engineer in writing and no alterations were allowed without prior approval of the Engineer. All welders had to be qualified in accordance with BS EN 1993. All welds were identified to enable each weld to be traced to the welder by whom it was made. All welds were physically examined and non-destructively tested by radiographic means.

The material requirements for each individual item were specified. Generally, items that could not be easily removed and replaced were specified to be either 3CR12 or stainless steel (SS316). Items that could be removed and serviced or replaced were generally manufactured from mild steel.

All materials used required a manufacturer's material test data certificate.

5.4 Surface preparation and corrosion coatings

Surface preparation was required for all steel surfaces before the application of coatings. For surfaces that were only exposed to dry conditions, a Sa21/2 surface preparation was required. For surfaces that were wet or submerged a Sa 3 surface preparation was required before coating. Two blasts were required; a rough blast followed by final surface blast. All surfaces had to be coated within four hours of the final blast when humidity was below 70% or within two hours when humidity was between 70% and 85%. Final blasting was not carried out if the steel temperature was less than 3°C above dew point. For each individual item the corrosion coating type and thickness were specified. The most common coating for both mild steel and 3CR12 was a two-pack epoxy coating. The thickness of the coating varied depending on the application.

5.5 Contractor's submissions

The specification required the Contractor to make the following submissions for approval by the Engineer before the manufacture of the hydro mechanical plant:

- Design calculations
- Manufacturing drawings
- Materials tests reports
- Product data sheets
- Quality control plans
- Manufacturing programmes

6. Quality assurance

An independent third-party mechanical inspectorate was appointed to do the inspections of the mechanical equipment both during manufacture and installation. Both the quality control plans (QCPs) and the manufacturing programmes became the basis for organizing the inspections and monitoring the quality of the hydro mechanical equipment. Most of the equipment was manufactured in the Gauteng region of South Africa. However, some components came from other countries. The third-party inspectorate made regular visits to the manufacturing plants to check the hold points during the manufacturing process and to release items for transport to site. The third-party inspectorate also had two people on site to witness the installation of the equipment and do radiographic testing of the site welds.

Each manufacturer produced a QCP in collaboration with the third-party mechanical inspectorate. The QCP carefully listed all the main steps in the manufacturing process including reference to the relevant specification related to that activity. The QCP then had an action item for each of the manufacturing steps. These were hold, witness, verification, surveillance or approval. The QCPs were agreed and signed by all the role players, including the manufacturer, the specialized sub-contractor/mechanical designer, the main contractor, the independent hydro mechanical inspectorate and the Engineer. Each of the role players was assigned an action per manufacture and installation activity.

No equipment was transported to site without the completion of the QCP and the approval of the Engineer or the independent hydro-mechanical inspectorate. The QCPs were then kept as a record of the manufacturing process and formed part of the data pack for each item manufactured.

7. Conclusions

An innovative approach was adopted for the design and supply of the hydro mechanical equipment at Neckartal Dam. This approach has been used on several large dams in Southern Africa in recent years and proven to be effective. The approach places the design responsibility of the hydro mechanical equipment onto the specialized suppliers.

The quality and durability the hydro mechanical equipment supplied is crucial to the long-term performance of the scheme. It was therefore important that appropriate designs were adopted and that strict quality assurance procedures were implemented during construction. Hydro mechanical equipment was sourced from many different countries and from multiple manufacturers. It was a difficult task to integrate all the different equipment into a cohesive working system.

References

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The Authors

Edwin Lillie is registered as a Professional Engineer in South Africa. He has over twenty-five years of working experience as a consulting engineer specialising in dam design and hydrological studies. He has worked on several major projects including the Lesotho Highlands Water Project, the Thukela Water Project, the Ingula Pumped Storage Scheme and the Neckartal Dam Project. He is also registered as an Approved Professional Person for dam safety inspections for category III dams in terms of the South African Dam Safety Regulations.

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