REMOVE FOULING IN THE NATURAL DRAUGHT COOLING TOWERS

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BACKGROUND

During the 21st operating cycle of the Cofrentes nuclear power plant, the natural draught cooling towers of the N71 system were found to be less efficient. A follow-up study confirmed that the water distribution system inside the towers was, to varying degrees, encrusted with calcium carbonate scale, which was clogging up the nozzles.

The main aim of this project was to eliminate and remove all fouling and scale (mainly calcium carbonate) that had accumulated in the internal water distribution system of the two N71 system towers (N71DD104A "East Tower" / N71DD104B "West Tower").

The aim of this article is to describe the procedure to remove fouling in the N71 natural draught cooling towers during Refuelling Outage 22 at Cofrentes NPP. It outlines the tasks performed, the person-hours employed, the procedures followed and the proposals for improvement.

The project comprised two phases:

- The **first phase** consisted of developing and validating a specific procedure. The following activities were carried out in this phase:
  - Design of a technical solution for removing scale deposits inside the pipes.
  - Design and manufacture of a 1:1 scale model of the main pipes and nozzles.
  - Tests on the scale model and with the tower in operation.
  - Validation of the system and the procedure.
- The **second phase** comprised the set-up and implementation of the solution validated in the first phase. The following activities were carried out in this phase:
  - Preparatory and support activities.
    - Partial disassembly of drift eliminators.
    - Installation of protection sheets for the fill media.
    - Installation of auxiliary equipment: lifelines, lighting and electrical panels.
  - Internal and external cleaning and unblocking of nozzles.
  - Internal and external cleaning of the DN250 PVC pipes.
  - Internal cleaning of flumes.
  - Removal and management of all waste.

DEVELOPMENT AND VALIDATION PHASE

A project of this nature has to begin with the design of a technical solution that will lead to the development of an effective proposal. To this end, the staff at IBERDROLA GENERACIÓN NUCLEAR conducted a detailed study of the facilities in operation. One of the keys to the success of this project was the high-quality ad-hoc characterisation that was provided. Another factor to its success was having sufficient time for development and for designing the process prior to implementation; a project of this magnitude, in a limited timeframe such as a refuelling outage, requires a high level of preparation and control.

Figure 1. Various images from the validation phase.

With all the information supplied by IBERDROLA GENERACIÓN NUCLEAR, the GDES technical team, drawing on previous experience, drew up a list of possible technical solutions, expanding upon the technical details of each in different phases as different stages of the preliminary evaluation were completed.

A 1:1 scale model of a typical tower section was designed for the purpose of validating the agreed solution, and to determine the operating parameters and times required. This model contained the essential parts: flumes, DN250 PVC pipes and real nozzles.

As was the case during the whole project, the collaboration of the staff at IBERDROLA GENERACIÓN NUCLEAR, who are familiar with the system and its operating parameters, was essential in creating this scale model.

Figure 1 shows different images of the validation phase. The various proposed solutions were tested on the model in a process of elimination, and the most significant parameters were fine-tuned. Next, tests on the scaling and fouling to be removed were carried out on the real towers in operation.

For final validation of the selected solutions, and in order to determine the operating parameters and times required, a 1:1 scale model of a typical section of the tower was created. This scale model contained the essential parts: flumes, DN250 PVC pipes and real nozzles.

As was the case during the whole project, the collaboration of the staff at IBERDROLA GENERACIÓN NUCLEAR, who are familiar with the system and its operating parameters, was essential in creating this scale model.

Various images of the validation phase are shown in Figure 1. The various proposed solutions were tested on the model in a process of elimination, and the most significant parameters were fine-tuned. And, once the process had been fine-tuned, tests on the scaling and fouling to be removed were carried out on the real towers in operation.

For the tests on the in-operation towers, specific tools were created to isolate the pipes on which the test was to be carried out. With the help of the Inspection Department of the Cofrentes nuclear power plant, the tools were fitted to seal off the pipes and, finally, real tests were carried out on them.

Different scenarios were considered in the light of all the data obtained, including the possibility of using the sealing tools to carry out the cleaning operations while the towers were in operation. It was decided that the best way to clean the nozzles was to dismantle them, thereby facilitating the task of cleaning the pipes. For all these reasons and given the magnitude of the project and the imminent refuelling outage, it was decided (for reasons of performance, safety and effectiveness) to carry out the scaling and fouling removal operations during tower shutdown.

Finally, and in order to optimise the procedure that yielded the best results in the tests, it was concluded that the most efficient solution was a rotating nozzle made-to-measure for the dimensions and properties of the task. The requisite materials were procured, and the method and performance parameters were validated, enabling the operation to be scheduled for completion within the planned refuelling outage time.

EXECUTION PHASE

The main aim was to eliminate and remove all fouling and scale (mainly calcium carbonate) that had accumulated in the internal water distribution system of the two N71 system towers (N71DD104A "East Tower" / N71DD104B "West Tower").

A diagram of the tower, together with the internal segmentation used to ensure that the tasks were performed correctly, is shown in Figure 2.

The following tasks were performed:

- Preparatory and support activities.
  - Partial disassembly of drift eliminators.
  - Installation of lifelines.
  - Installation of lighting and electrical panels.
  - Installation of protection sheets for the fill media.

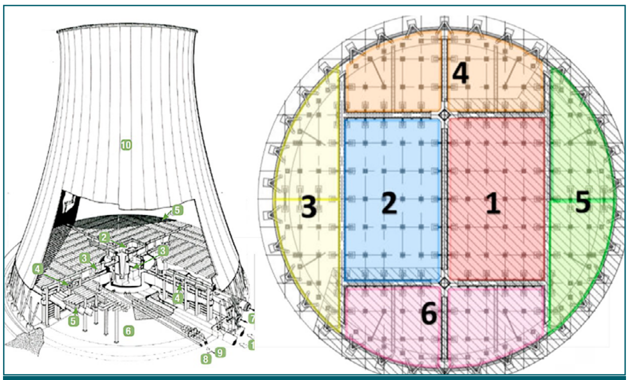

Figure 2. Internal segmentation of the tower.

- Internal and external cleaning and unblocking of nozzles (a total of 12,500 units).
- Internal cleaning of a total of 9,859 m of DN250 PVC pipes.
- External cleaning of a total of 9,859 m of DN250 PVC pipes.
- Internal cleaning of a total of 822 m of flumes.
- Removal and management of all waste deposited at the bottom of the flumes.
- Cleaning of the drift eliminators in all sectors of the towers.
- Cleaning of the fill media under all tower sectors.
- Cleaning of walkways.
- Repair of handrails and toeboards of the walkways.
- Repair of the rubber seals of the DN250 PVC pipes in the towers.
- Repair of the nozzle pipes embedded in the flumes.
- Removal of obsolete fill media from inside the basins.

To describe these tasks adequately, they can be grouped into the different phases of execution.

EXTERNAL SET UP

Figures 3 and 4 show different moments in the setting up of the equipment on the outside of the towers.

The following equipment was assembled outside the tower.

- Lifting and handling equipment:
  – 70 t crane.
  – 2 x 15 m scissor lifts.
  – Forklift truck.
  – Boom truck.
  – Small loader: Gehl®.
  – Large loader: Manitou®.
- Cleaning units:
  – 3 combination jetting and vacuum tanker units.
- Auxiliary units:
  – 17 m³ water tanker.
  – 200 m³ flexible tank.
  – 2 water transfer pumps.
  – Water supply hoses.
  – Waste containers.
  – Lighting

One of the challenges of this project was how to **optimise water consumption during the defouling and descaling process and the need for a continuous supply of water**. In anticipation of possible supply disruptions due to system maintenance during shutdown, the flexible tank and tanker were positioned close to the West Tower.

As shown in Figures 3 and 4, two skips were located near the West Tower and one near the East Tower (in places easily accessible to vehicles for loading and unloading).

A lifting platform was placed alongside the tower being serviced to bring materials in and out, and another lifting platform was placed under this same tower as an emergency measure in the event of an accident. These platforms were moved from one tower to another as work was performed on one or the other.

Figures 3 and 4. Various images of the external set up.

Another of the challenges of the project involved working with **high-pressure water (200 bar) 24 hours a day for 20 days without interruption**. To meet this challenge, 3 teams were stationed close to the work area and worked in rotating shifts. The operation was designed in such a way that there would be as little backflow as possible, thus keeping the heating of the water to a minimum. In addition, at least one person on each shift was exclusively assigned to maintenance and monitoring system parameters such as temperatures and levels.

For 24-hour operations, adequate lighting is required. For this reason, fixed lighting was installed to provide general and spot lighting at the access points. In addition, submersible, portable, rechargeable and lightweight LED spotlights were used to provide extra lighting at the work points, helping to make the work teams more mobile.

INTERNAL SET UP

Figure 5 shows different images of the set up inside the towers.

Before work began to remove the scaling and fouling, the internal set up was prepared so as to ensure the best possible conditions for the work to be carried out. In this phase, sufficient equipment was installed to work simultaneously in the two towers so that certain activities that could not be carried out simultaneously in one sector (such as, for example, work with high-pressure water) could be carried out simultaneously in different towers.

The following activities may be highlighted:

- **Removal of the drift eliminators**. As these form the upper part of the entire spray, water and fill system, certain sections had to be removed to gain access to the system.

Figure 5. Various images of the internal set up.

- **Installation of ladders to access the space between the fill and the drift eliminators**, where the nozzles to be removed are located.
- **Installation of lifelines and weight distribution platforms**. In order to be able to walk across the fill packs and access the nozzles, it is first necessary to install lifelines and then to install weight-distributing boards to distribute the weight when walking.
- **Installation of nets on the fill media** to protect against falling nozzles and waste.
- **Installation of nets to catch algae** in Sectors 1 and 2 of the towers. When the towers are shut down, the algae that have grown on the inner walls of the towers during the operating cycle die and fall on the operators working below. It is therefore essential to install nets in the main sectors.
- **Protection of inlet connections from the flumes**. It is essential to close the inlets through which water enters the distribution system of the towers to prevent anyone from falling through them.

CLEANING AND REPLACEMENT OF NOZZLES

Under normal conditions, the nozzles are removed by hand, but limescale build-up on the threads prevented this method (Figure 6). The solution was to use pipe wrenches.

The nozzles were cleaned either manually, in dry conditions, to remove the calcium carbonate, or by flushing with water when they were additionally clogged with mud and/or Taprogge® balls.

Once the nozzles were removed and cleaned, they were inspected and the defective ones were replaced.

Some nozzles had to be repaired at the base as part of the DN250 PVC pipe that they were screwed into had broken. In some cases, the nozzles with an intact length of PVC pipe were used, and in other cases, a new coupling was used.

To facilitate the subsequent assembly, the nozzles were left close to the pipes at the end of the process.

Figure 6. Preliminary condition of nozzles.

CLEANING THE INSIDE OF DN250 PVC PIPES

The incrustations were removed from the inside of the pipes using a specific tool for cleaning pipes with high-pressure water, working with a GHD Truck at 200 bar (Figure 7). To do this, access was gained from the water distribution flume, one by one, to the intake of each of the pipes.

The rest of the work was coordinated with this activity to ensure that there were no people passing through the area where high-pressure water was being used or the lower part of the tower.

100% of the inside of the pipes were cleaned. A key factor in this was the determination of flow rate, spray times and nozzle rotation speed in the preliminary tests. As a result, cleaning was optimised, resulting in a high percentage of work performed in a single pass, and the process could be repeated in pipes with larger accumulations of scale and fouling that could not be removed with a single pass, without affecting the planned execution times.

OTHER ACTIVITIES CARRIED OUT

Other activities carried out to ensure successful completion of the service provided are described below (Figures 8 and 9):

The exterior of the DN250 PVC pipes was cleaned with a pressure washer. At the same time, scale and fouling were removed from the underside of the drift eliminators.

Fouling was removed from the flumes through which the water is distributed to the DN250 PVC pipes, firstly by removing the accumulated mud, and then with a pressure washer.

The dirt that had built up on the interior walkways of the towers was cleaned with high-pressure water and then swept away.

Handrails, toeboards, edge protectors and walkways were repaired where necessary.

Descaling and defouling of the drift eliminators was carried out from below (fill packs) and from above (walkways). Cleaning of the fill media was carried out with localised vacuum cleaning.

Figure 7. Initial state of pipes, cleaning process and final state.

Figure 8. Images of other maintenance activities.

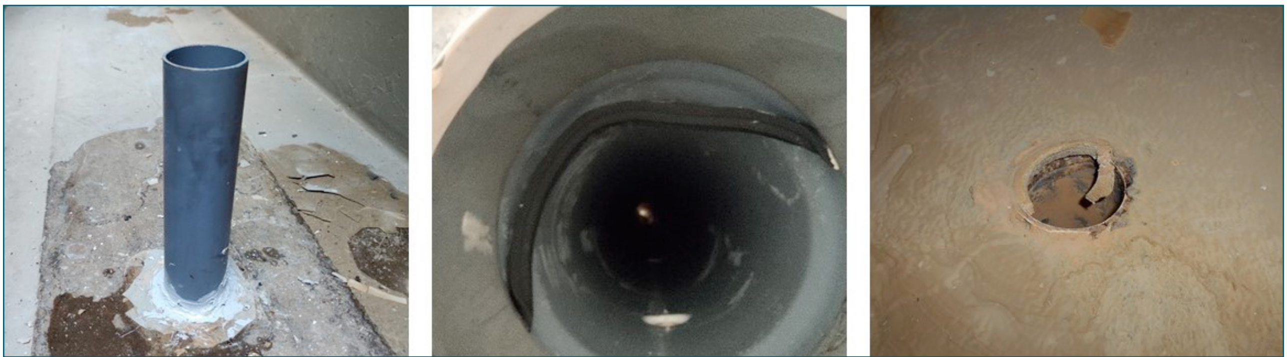

Figure 9. Images of other maintenance activities.

The rubber seals of the DN250 PVC pipes (only where necessary) were repaired by cutting off the protruding part of the seals and applying a sealant (Figure 9).

All the nozzle tubes embedded in the flumes were repositioned and sealed.

To remove the discarded fill from the inside of the tower basins (Figure 10), one small loader (Gehl®) and two large loaders (Manitou®) were used.

Figure 10. Removal of the fill packs.

SAFETY

For the removal of scale and fouling from the inside of the natural draught towers during Refuelling Outage 22 at Cofrentes NPP, the company GDES drew up specific risk assessments for each task, as well as a specific Occupational Health and Safety Plan setting out this service.

From 3 November to 5 December 2019, the period during which the on-site work was carried out, GDES worked a total of 10,000 hours on this project, with an average number of 32 workers. Neither GDES nor its subcontractors reported any accidents during the execution of this project.

For the cleaning work with high-pressure water, the usual PPE for this type of service was used, although due to the highly humid conditions in the towers, a couple of significant improvements were made:

- The use of sealed safety eyewear (mandatory to enter the tower) in combination with an anti-fog product.
- The use of neoprene suits to carry out the work of removing scale and fouling on the outside of the pipes.

CONCLUSION

By way of conclusion, and to give an idea of the scale of the service, a breakdown of the work carried out and the targets achieved is shown below:

- All scale and fouling was removed from the inside of the 250 mm diameter pipes and flushed into the flumes.
- All nozzles were cleaned, replaced or repaired.
- The total number of items cleaned in the two cooling towers were:
  - 12,500 nozzle units.
  - 10,000 m of PVC DN250 piping (internally and externally).
  - 1,000 m of connecting conduits/flumes.
- The works required a total of 10,000 person-hours and employed an average of 32 people.
- The works were completed within the scheduled timetable.
- The procedure for removing deposits from inside the pipes was successful, meeting the objectives stipulated by the Cofrentes nuclear power plant.

Finally, the two cooling towers were treated successfully on schedule and were fit for use during normal operation of the plant, thus meeting the main workplace safety objective: zero accidents. ■