

THE CUSTOM DESIGN AND FABRICATION OF A CONDENSER AUTOMATIC TUBE CLEANING SYSTEM FOR DOMINION POWER

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ABSTRACT

The application of online Automatic Tube Cleaning System (ATCS), where sponge projectiles pass through the tubes of shell and tube heat exchangers in the mitigation of fouling is well documented in industrial applications. However, not all ATCS applications have proven functional in operation. Dominion's Mount Storm Power Station is the largest coal-fired power station managed by Dominion Resources. The 3 units can generate nearly 1,600 megawatts of electricity. Despite excellent operating processes, during the summer months Mt. Storm's turbines can lose 2-4% of output capacity (20-40 MW) due to condenser tube fouling.

The existing ball trap had demonstrated exceptionally high operating pressure drop and a propensity to pin sponge cleaning balls inside it. Dominion expressed interest in evaluating possible replacements or upgrades to existing tube cleaning systems to recover this lost power generation capacity. As an essential element of the design validation, hydraulic modeling and testing was conducted at the University of Iowa Hydraulic Laboratory (IIHR). Results are presented of the completed performance testing on a 1/6 scale model. The subsequent commissioned ATCS field results matched precisely with the hydraulic laboratory performance results, where all balls were returned without pinning and a pressure drop of well under 7kPa (1 psi) was measured across the ball traps.

INTRODUCTION

Dominion Power is one of the United States of America's largest producers and transporters of energy, with a portfolio of approximately 25,700 megawatts of generation and 6,500 miles of electric transmission lines. Dominion serves more than 5 million utility and retail energy customers in 14 states. Dominion's Mount Storm Power Station is the largest coal-fired power station managed by Dominion Resources. Its 3 units can generate nearly 1,600 megawatts of electricity.

In 2015 Dominion contracted Innovas Technologies to provide optimized performance over a competitor's existing condenser tube cleaning system on Mt Storm Unit 3B Condenser, and to expand the automatic tube cleaning system from treating one condenser to two condensers. The existing competitor's ball trap had demonstrated exceptionally high operating pressure drop and a propensity to pin sponge cleaning balls inside it. The existing system pressure drop

measured approximately 3.5 psi at a water velocity of 6 ft/s (1.8 m/s). The overall goals of the project were to:

- Reduce operating pressure drop across ball trap
- Improve sponge cleaning ball return rates
- Reduce overall physical footprint of the ball trap
- Expand the condenser tube cleaning system capability to treat two condensers rather than one
- Demonstrate reliable & effective tube cleaning system performance for further deployment

For the project, Innovas Technologies employed best-practice engineering techniques to develop custom ball trap designs and completed performance testing on a 1/6th scale model of the competitor's 36" ball trap and custom Innovas ball trap designs. This testing was conducted at the University of Iowa Hydraulic Laboratory (IIHR). The primary purpose of the laboratory tests was to develop pressure loss coefficients and measure the ball trap collection efficiency. Innovas then performed detailed design and fabrication of two 36" diameter ball traps utilizing the optimal ball trap configuration. Additionally, Innovas designed and fabricated the necessary piping and PLC digital control systems to expand the tube cleaning system to provide condenser tube fouling prevention for two surface condensers.

EXPERIMENTAL

IIHR laboratory was used for testing of an existing competitor's T-style ball trap Automatic Tube Cleaning System (ATCS) for heat exchangers. The ball trap utilizes internal perforated and solid plate material to divert the balls from the main pipe flow and into a ball return pipe while allowing the fluid to continue through the pipe system. The aim was to test the collection efficiency and develop pressure loss coefficients for the existing T-style ball trap design. In addition, design alternatives were developed and tested to improve the design. IIHR fabricated a 6-inch diameter translucent ball trap for enhanced visualization during testing.

A specific testing rig was made for the ATCS evaluation. Flow was conveyed to the ball trap using 6-inch PVC pipe. A straight section of clear acrylic pipe 8 diameters in length was installed immediately upstream of the ball trap to facilitate flow visualization.

A straight section of steel pipe extended 4 diameters downstream of the trap and terminated with a flow control valve. A manually controlled ball injection system was designed and built by IIHR and installed upstream of the clear pipe section. A 1.5-inch PVC pipe and valve were installed on the trap drain outlet to flush and recover the balls. The flowrate through the 6-in pipe was controlled with a variable frequency drive (VFD) on the pump and by adjusting the discharge butterfly valve. Flowrates were set and measured using a weigh-tank calibrated orifice flow meter, built and installed to ASME specifications.

Pressure ports were installed in the piping immediately upstream and downstream of the ball trap flanges to facilitate pressure drop measurements across each trap design. A Dwyer digital differential manometer was used to directly measure the pressure drop. A schematic of the test apparatus is shown in Figure 1. A photograph of the completed test stand is shown in Figure 2.

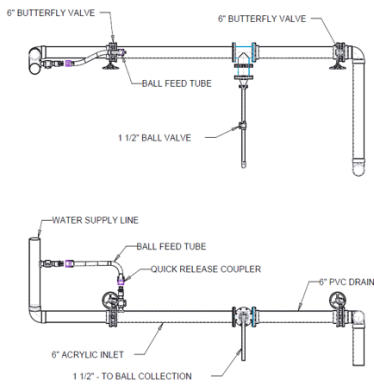


Fig. 1 Ball trap test stand



Fig. 2 Photograph of completed test stand

The existing as-built ball trap design is shown in Figure 3. The existing as-built ball trap design consisted of a two-piece perforated assembly, with a conical perforated inlet and a cylindrical perforated outlet in the branch tee connection. A solid plate was located at the heel of the 90 degree turn, and a solid plate also covered approximately 30% of the conical perforated inlet.



Fig. 3 Existing as-built ball trap

Two alternative ball trap designs were developed by Innovas Technologies. Option 1 is shown in Figure 4 and consisted of a two-piece perforated assembly, with a conical perforated inlet mated to a solid small-bore elbow, and a cylindrical perforated outlet in the branch tee connection. The second design option consisted of a two-piece perforated assembly, with a conical perforated inlet and a cylindrical perforated outlet in the branch tee connection. The entirety of the 90-degree turn was fabricated from perforated steel plate. This is shown in Figure 5.

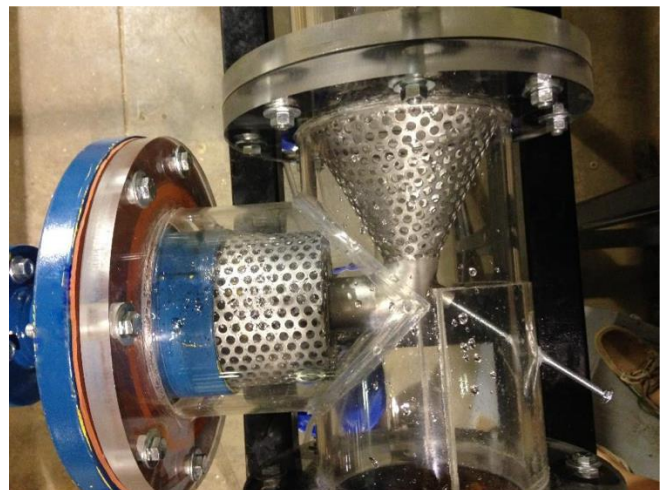


Fig. 4 Option 1 ball trap (Innovas Technologies)

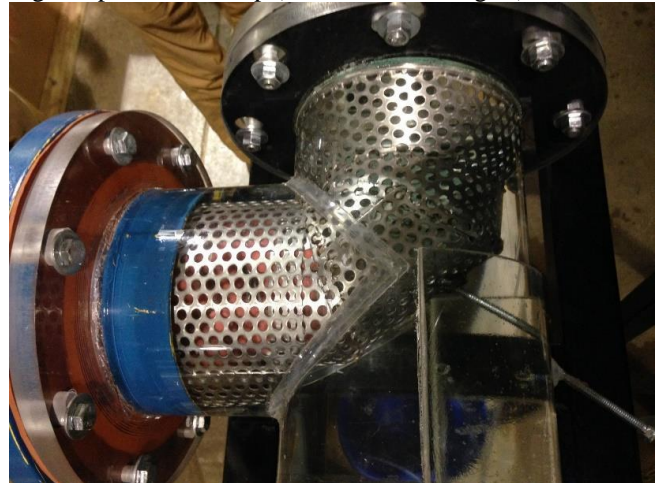


Fig. 5 Option 2 ball (Innovas Technologies)

RESULTS

Ball trap designs were tested at three average flow velocities of 1.2 m/s, 2.1 m/s and 3.05 m/s. For each design, the clean ball trap pressure drop was measured and recorded. Several injections of 100 balls were made for each trap design at each flow velocity. The number of balls that were pinned in the trap prior to collection and the number of balls returned on collection were noted. Figure 6 summarizes the clean trap pressure drops for each design across the range of velocities tested. Figure 7 summarizes the number of cleaning balls returned on collection for each design across the range of velocities tested.

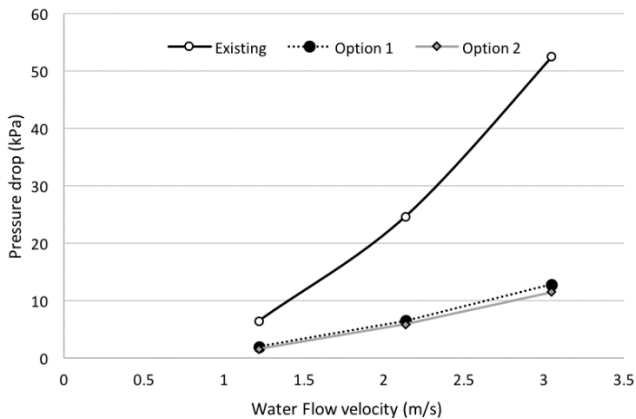


Fig. 6 Pressure drop versus water velocity for the 3 ball traps

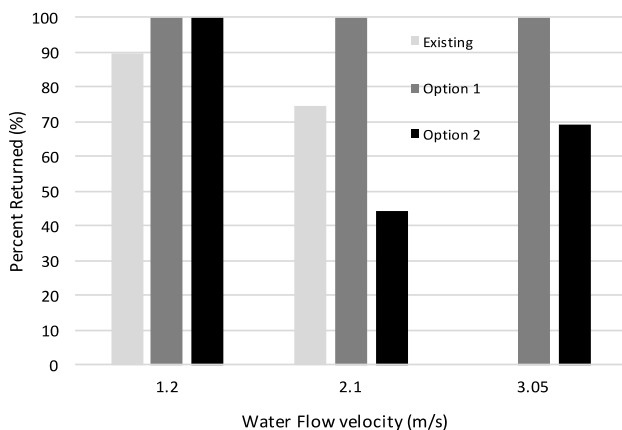


Fig. 7 Percentages of balls returned on collection

The results presented above clearly demonstrate that the existing as-built ball trap exhibited the highest clean ball trap pressure drop at all three fluid velocities. This closely correlates to the lowest percentages of balls returned on collection of all three designs. At the highest fluid velocity (~3m/s) in the range tested, the clean ball trap pressure drop became excessive (>52 kPa) and would negatively impact cooling water pumping system performance. The existing as-built design also pinned significant numbers of cleaning balls in several areas, which caused the pressure drop across the ball trap to further increase. This is demonstrated in Figure 8.

The Option 1 ball trap design exhibited acceptable clean ball trap pressure drop across the full range of fluid velocities with pressure losses lower than published pressure drops for typical industrial y-strainers. The Option 1 design also returned all cleaning balls on collection, with no pinning

across the fluid velocity range. Figure 9 shows balls approaching the trap for a 2.1 m/s run.



Fig. 8 Pinned balls in existing design

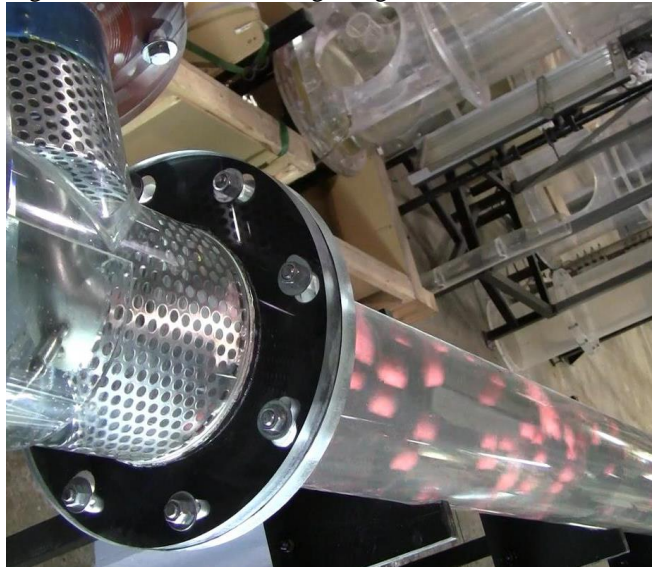


Fig. 9 Balls approaching Option 1 ball trap at 7fps

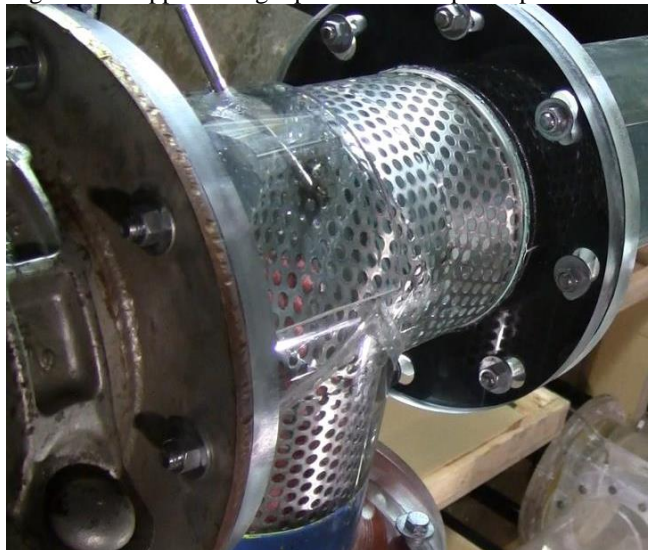


Fig. 10 Pinned balls at 3m/s in the Option 2 design

The Option 2 ball trap design exhibited the lowest clean ball trap pressure drop at all three fluid velocities. However, the Option 2 unsuccessfully demonstrated 100% ball return like Option 1. Cleaning balls were found to be pinned at both the 2.1 m/s and 3.05 m/s fluid velocities.

Thus, based on the excellent test results in hand Innovas fabricated a design of the Option 1 ball trap at the full-scale 36" diameter version required for the Mt. Storm power station. The installation configuration of the existing condensers required that the two 36" ball traps be installed into a very tight location, with a concrete mezzanine overhead and butterfly valve for isolation immediately downstream of the traps. This required the fabrication of the ball trap with high quality precision control and tight tolerances. Innovas equipment was commissioned on May 19, 2015.

The successfully commissioned tube cleaning systems yielded field results that precisely matched with the hydraulic laboratory performance results—100% of all cleaning balls returned without pinning, and a field pressure drop of 0.75 psi at equal water velocity of 6ft/s. This was well under the 1 psi target and more then met Dominion's requested in-service rate greater than 90% during the warranty period and a greater than 90% ball return rate. The completed 36" ball trap assembly is shown in Figure 11.



Fig. 11. 36" Option 1 design installed at Mt. Storm

The competitor's old 36" ball trap was inspected in the site's equipment graveyard after removal. A simple visual inspection of the trap highlights the advantages of the newer ball trap design. The existing ball trap has extensive areas of the main pipeline blocked off with solid plates to facilitate routing the clean balls to the ball exit as shown in Figure 12. The significantly improved Innovas design achieves perfect ball return rates without occluding the open area for flow in the main pipeline. This is highlighted in Figure 13. The new ball trap strainer designed by Innovas has a US patent application in progress.



Fig. 12. Existing ball trap entrance

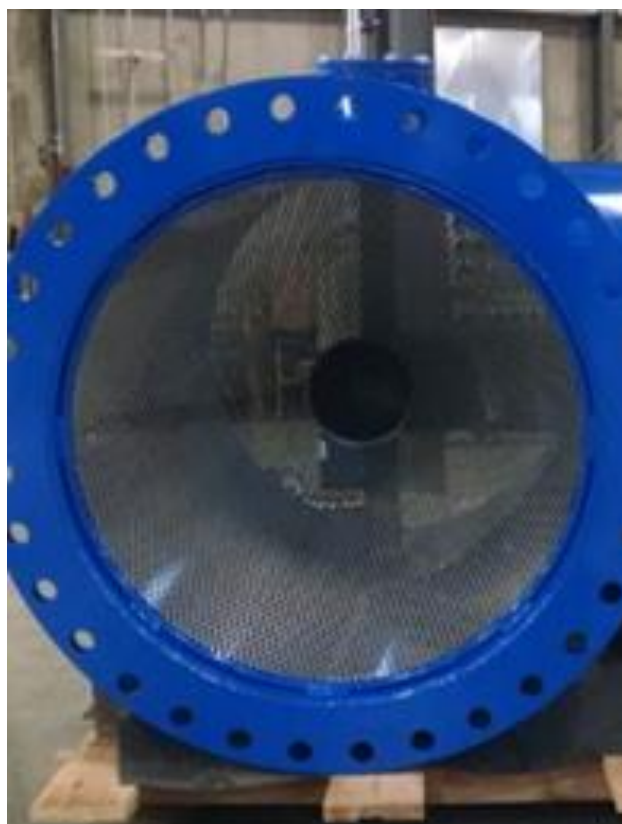


Fig. 13 Innovas ball trap entrance

CONCLUSIONS

An optimized ball trap has been successfully installed at the Dominion Power Mt. Storm Power Station's Unit 3B Condenser automatic tube cleaning system, with excellent reliability and system performance. The existing 36" ball trap had demonstrated exceptionally high operating pressure drop and a propensity to pin sponge cleaning balls inside it. Laboratory testing on 1/6th scale simulation successfully reproduced the problem which was linked to the poor design configuration. The pinned balls caused the high pressure drops. Two different design were subsequently designed by Innovas and tested at three average flow velocities. The first option was found to be the best solution with 100% of the ball returning.

REFERENCES

- Craig, A. and T Lyons, Laboratory testing of a T-Style ball trap for Innovas Technologies, Hydrosience & Engineering, 2016 Hydraulics Laboratory Iowa City, Iowa 52242-1585 USA.
- Crocker, Michael A. and Charles B. Dirks. "Strainer For Collection of Heat Exchanger Cleaning Projectiles in Continuous Tube Cleaning Systems." US Patent Application No. 15/351,594. 2016.