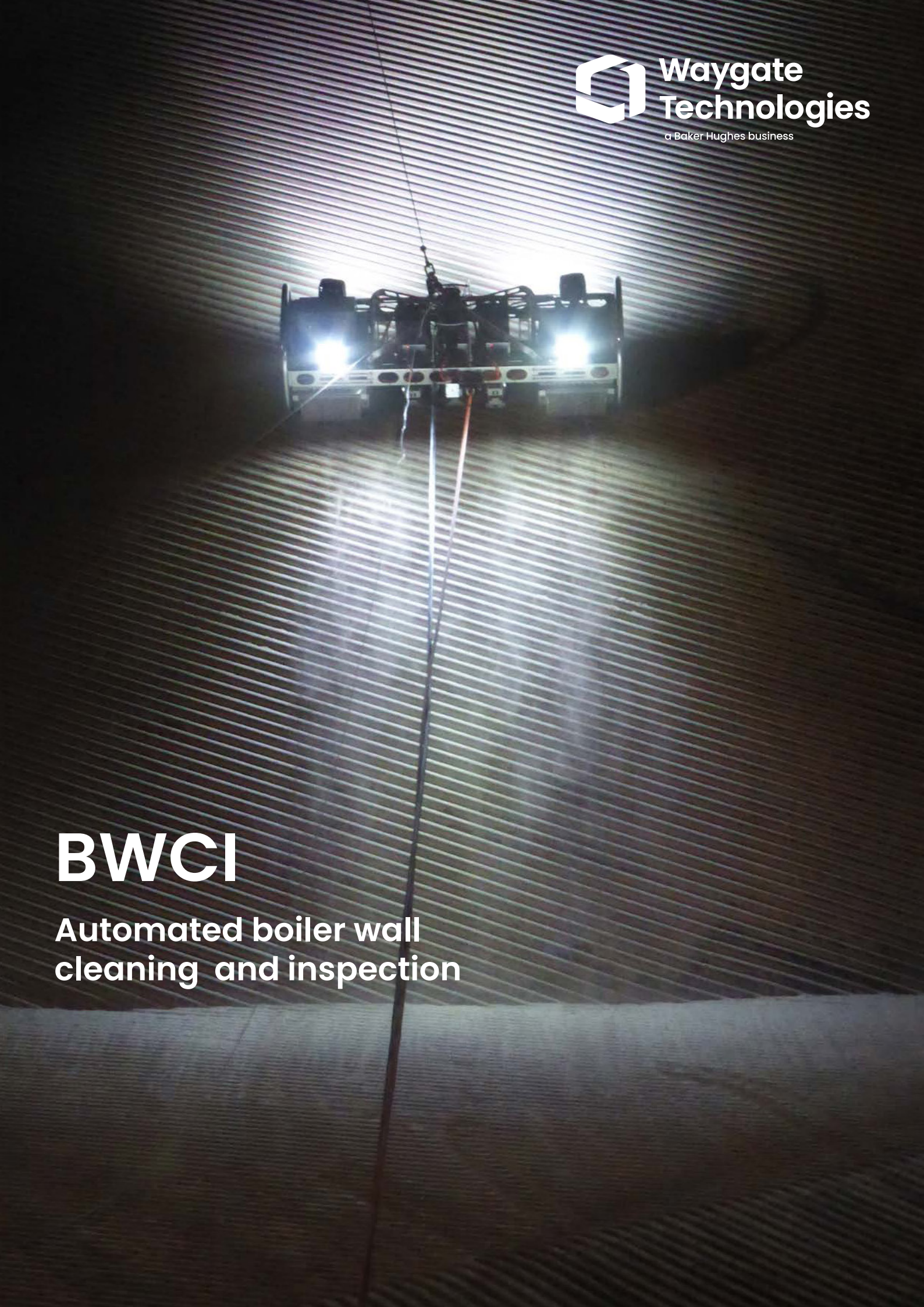


Waygate Technologies
a Baker Hughes business

BWCI

Automated boiler wall cleaning and inspection

Boiler wall maintenance today

In the steam boiler the evaporation phase, where water is converted to steam, occurs in water wall tubes. Boiler water walls are membrane walls that are made of tubes welded together. These tubes form the enclosure of the coal combustion chamber, they are submitted to a temperature gradient ranging from 300 °C to 500 °C between the bottom and the top section of the boiler. So-called fin tube water walls are the standard design today because of high efficiency and heat transfer rate.

Corrosion, scaling and sludge deposits are the main causes of reduced reliability and performance of steam boilers. Especially on the hot areas of the boiler water wall this frequently leads to unscheduled downtime or even forced outages.

To avoid steam boiler failures the maintenance recommendations today comprise of cleaning and inspection by means of Non Destructive Testing.

Cleaning is usually done using conventional sand-blasting systems. To get access to the concerned sections a scaffold is built inside the boiler and cleaning specialists perform the job.

Inspection of the boiler water wall is done by NDT specialists. It consists of visual inspection, for general condition or fouling, and Ultrasonic wall thickness measurement for corrosion and erosion. The inspectors either use the scaffold, during a major outage or rope access for individual spot checks on suspected areas.

Both, cleaning and inspection are very time and cost consuming processes. The complete scope of work is taking place in confined space, exposing the specialists to danger.

Robotic cleaning and inspection

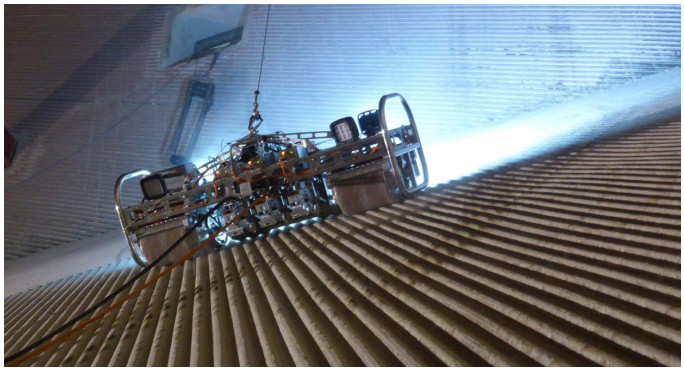
Waygate Technologies has developed an automated robotic solution to clean and inspect boiler waterwalls. The system is able to reach the point of interest inside the boiler from its launching point (typically the manway). It is fully remote controlled allowing the operator to stay in the safe zone outside confined space. The core element of the inspection system is a patented robotic crawler with 4 magnetic rollers. The roller allow for cross wall transition up to 90°. The crawler carries 1 water jet nozzle fed by a water pump outside the boiler. A dedicated deployment tool allows the operator team to safely deploy the 80kg crawler into the boiler.

Several cameras on the crawler as well as an overview camera at the opposing manway opening provide the feedback needed for navigation. A dedicated pan-tiltzoom inspection camera can be mounted at the crawler front to allow for flexible and even distant visual inspection, e.g. of coal nozzles. For inspection of remaining wall thickness an array of 7 Ultrasonic probes can be lowered onto the tube and provide exact measurements. The crawler automatically detects the tubes alignment, recognizes deviation on the driving path and corrects it automatically. For the operator this means he can purely concentrate on his cleaning/inspection task.

Looking at the big picture the time and cost saving using a robotic cleaning and inspection solution is tremendous.

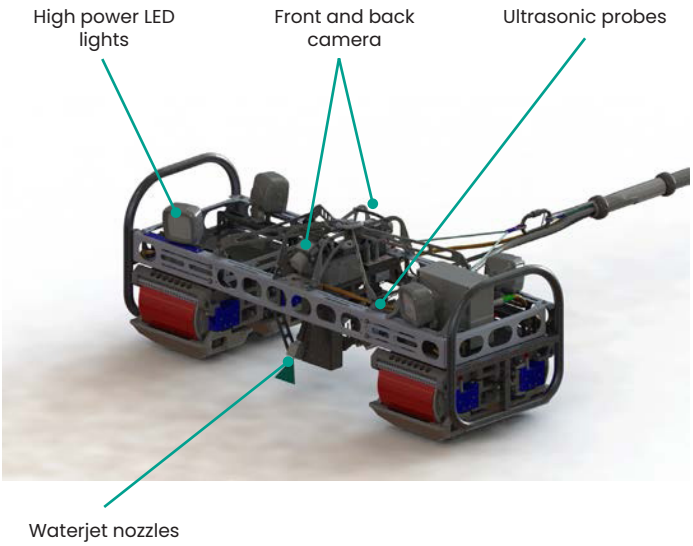
At a glance

- Eliminates human entry in confined spaces and perform the cleaning and inspection from a safe & remote location. This minimizes the risk for the operators.
- Confined space work permits, rescue plans and watchmen are not required. Preparation & logistics efforts are reduced to a minimum.
- Very efficient for short outage periods to perform partial inspections and upfront preparation for major overhaul.
- Cleaning and inspection can be performed by just 2 operators.
- Up to 70% cost reduction.

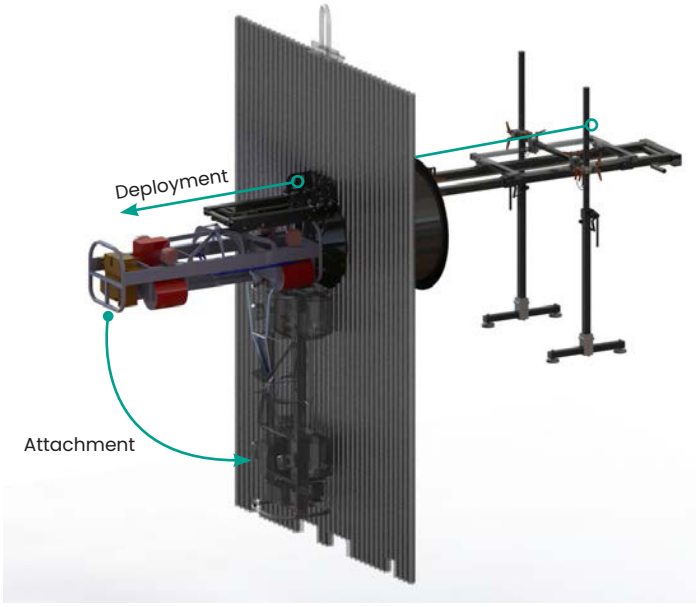


System overview

Components



Deployment through 600mm entryway



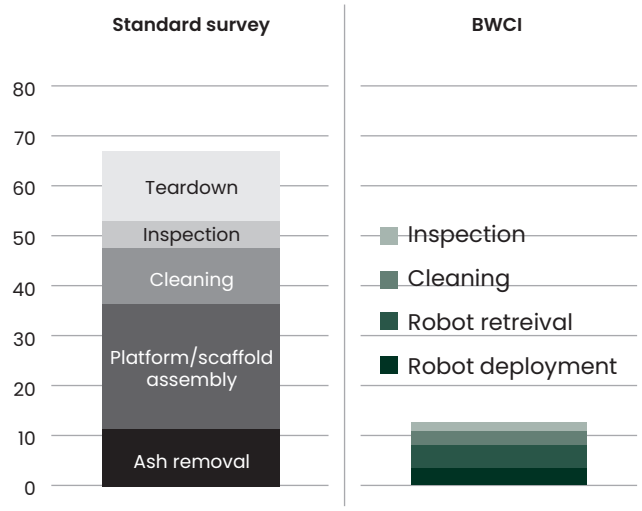
Business case

To compare the standard cleaning and inspection today with an automated robotic system the operator has to look at the full picture. Especially preparation, sourcing, logistics and EHS requirements are typically a very big - but hidden - portion of the cost for maintenance. Various parties (safety specialists, scaffolders, cleaners, NDT) are involved and need to be coordinated. For a reliable business case calculation all these parameters need to be taken into account. As every power plant and boiler is different and operating conditions vary by region the business case needs to be calculated individually for one specific site. In average a time saving of 70% compared to traditional maintenance/inspection is realistic.

Example

- 500MW boiler
- Boiler height = 40m, depth = 17m, width = 17m
- Tube diameter = 35mm
- On-center tube spacing = 50mm
- Tubes per wall ≈ 340
- Scan interval = 0.5 meter between scan path = 34 tubes

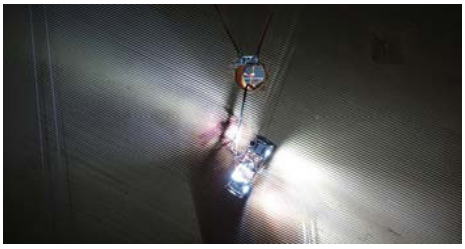
Typical figures, provided by site operator after assessing both methods.

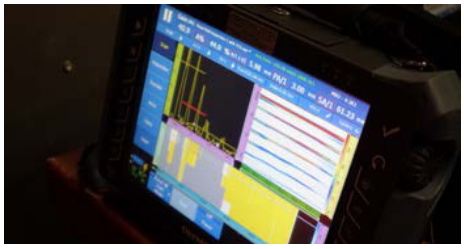


Technical specifications

Boiler and tube dimensions		
Entryway	Minimum diameter	**500mm (20")**
Water wall tubes	Tube OD	**28mm (1.1") - 89mm (3.5")**
	Wall thickness	**2.6mm (0.1") - 13mm (0.5")**
	Separation tube to tube	**0mm (0") - 10mm (0.4")**
System operation		
System setup	Installation and deployment	**<4h**
	De-installation	**<4h**
	Operators required	**2**
Cleaning	Water and abrasive suspension at up to 150bars	
	Cleaning speed up to 100mm/s (4")	
Defect detection	Wall thinning, 20% thickness loss or inservice	
	Damage such as H2 damage or caustic gouging or O2 pitting	
	Measurement accuracy 0.25mm (0.01")	
	Initiating cracks axial - 50% of wall thickness in depth 12mm (0.5") in length	

Crawler specifications		
Dimensions	Length	**800mm (31.5")**
	Width	**450mm (17.8")**
	Height	**450mm (18.8")**
Weight		**80kg (20.5lb)**
Speed	Fully adjustable	**-100mm/s - 100mm/s (-4"/s - 4"/s)**
Payload	For additional on-board devices	**20kg (44lbs)**
Temperature	In operation storage	**10°C (50°F) - 45°C (113°F)**
		-15°C (5°F) - 70°C (158°F)
Power Supply	3x 300V AC (50Hz)/3x200V AC (60Hz)	
Protection class	Cables plugged	**IP67**
Motor Controller	Integrated Inspection Robotics motor controller	
Communication	Gigabit Ethernet with power over Ethernet	
Cable length	Supply station to robot	**20m (66ft) (loger on request)**





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