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OPERATION & MAINTENANCE

Water cannons make a clean sweep at RWE's lignite burning plants

Cannons hit the mark

Water cannons are proving effective for boiler cleaning at RWE's lignite-fired power plants

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The steam generators at RWE Rheinbraun's Weisweiler power station are intended for baseload operation, with fuel supplied from the Inden open-pit lignite mine. Flue gas excess pressure arising from possible hot standby operation was therefore not taken into account in the design of cleaning systems for the steam generator heating surfaces.

At Weisweiler power station there are six units, with a total of nine boilers:

	Unit C (2 boilers)	Unit D (1 boiler)	Unit E (2 boilers)	Unit F (2 boilers)	Unit G (1 boiler)	Unit H (1 boiler)
Commissioning date	1955	1965	1965	1967	1974	1975
Steam production (t/h)	300 each	480	550 each	500 each	1900	1900
Power (MWe)	150	155	348	348	625	625

Water blowers were originally installed for cleaning the furnaces of the steam generators. However for the 1900 t/h steam generators of units G and H, it was decided to add water cannons.

In 1992 a test water cannon was installed and numerous measurements were performed to determine wall temperature loading during cleaning by the cannons. In the first step four water cannons were installed in each boiler of units G and H for cleaning the evaporator helix between +64 m and +46 m.

In the second step another four water cannons were added to each boiler for cleaning the membrane walls in the burner area between +46 m and +17 m.

Water cannon design

The basic arrangement of the water cannon and the way it is attached to the membrane wall is shown in Figure 1. As the frame is permanently attached to the membrane wall, the flexible water supply connection has to compensate for relative movement between the water piping and the cannon due to boiler expansion. Using various controllable guide rails it is possible to aim the water jet as required, allowing it to follow a meander pattern on the membrane wall, see Figure 2.

As shown also in Figure 2, each water cannon cleans the opposite membrane wall. In the Weisweiler case there are four cannons at level +54 m and another four at +26 m. Various blowing figures can be run at each level. At Weisweiler, three blowing figures are successively run in meander form during each blowing process. Membrane wall offsets such as flue gas recirculation heads, burnout air nozzles and burner mouths are left out. Thus, the whole evaporator helix, elevation +17 m to +54 m, can be cleaned from the two cannon installation levels, +26 m and +54 m. The first heating surface bank delimits the area of action for the water cannons. It must not be allowed to come into contact with the water jet due to the high operating temperature of this region and the related thermal shock risk.

Operating experience at Weisweiler

Some of the key aspects of operating experience to date with water cannons at Weisweiler be summarised as follows:

● *Effectiveness of cleaning*

Fouling of the membrane walls largely consists of porous deposits. When the water from the cannons impinges on these deposits, it penetrates the pores and then is abruptly evaporated. As a result, the deposits flake off so that very effective cleaning is achieved.

● *Cleaning intervals*

Because the water cannons clean so effectively they only have to be operated once a day. In addition the fuel currently being used at the plant is such that there is further potential for reduction in cleaning intervals. Moreover, it is no longer necessary to do further manual cleaning of the membrane wall during the periodic boiler inspection outages.

● *Adjustment/deflection of the water jet*

The water jets and the blowing figures are adjusted during the boiler downtime, first by means of laser and then by doing a test run with the water jet itself. It has become evident that, relative to in-service cleaning, a deflection of the water jet of about 1 m must be taken into account in the vertical direction. In the horizontal direction a safety margin of about 0.5 m is needed, eg from the burner mouths. Boiler outages need to be used to check and adjust the actual impact of the water jet on the membrane wall so that it corresponds as closely as possible to the blowing programme originally required.

● *Setting the blowing figures*

During cleaning of the membrane wall special care must be taken to ensure that the water jet is not parallel with the evaporater tube, as this can disturb the steam flow in the tube. During cleaning the water jet should always impinge at right angles to the tube direction.

● *Jet impact angle*

Figure 3 shows the swivel range of the water cannons as installed at Weisweiler. If the water jet impinges on the membrane wall at too sharp an angle, the cleaning effect decreases markedly. This is why it is desirable to have four water cannons installed at each cleaning level, even though the swivel range of the cannons is such that in theory only two are needed to achieve coverage of all four membrane walls.

● *Hose connection design*

The hose connection must, on the one hand, compensate for the relative movement between boiler and water piping, and on the other, ensure free movement of the blowing

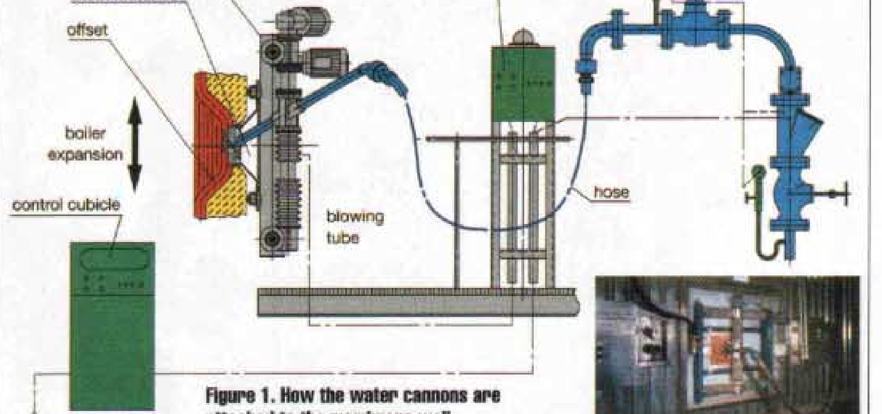

Figure 1. How the water cannons are attached to the membrane wall

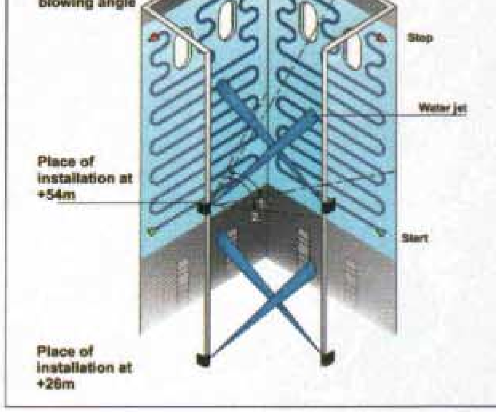

Figure 2. Typical cleaning pattern

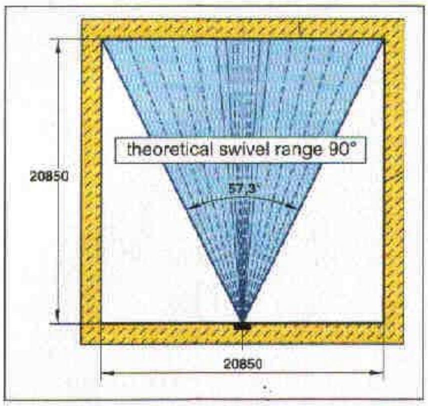

Figure 3. Swivel range of water cannons

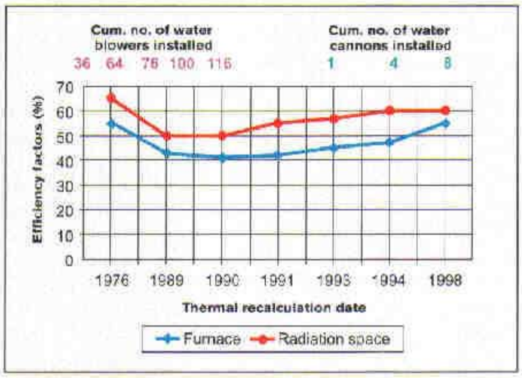

Figure 4. Efficiency factors for furnace and radiation space, showing cumulative number of water blowers and cannons installed

tube. At Weisweiler damage was found to have been caused to the hose due to the temperature loading and the local installation conditions encountered. Therefore a different hose type was selected. If possible the choice of hose should take into account such factors as bending radius, torsional strain, and strain relief.

● *Slagging of flue gas recirc shaft heads*
The excellent cleaning effect of the water cannons results in a level of furnace heat absorption which is almost optimal. This leads to a reduction in the furnace end temperature, which in turn reduces the tendency for slagging at the flue gas recirculation shaft heads.

● *Removal of old water blowers*
In view of the good operating experience with water cannons at Weisweiler, the old water blowers were removed. In addition, the membrane wall offsets of the old water blowers in the area of maximum membrane wall stresses were closed off, leading to a reduction in the number of boiler damage events.

Thermal recalculation

From 1987 to 1990 fouling of the membrane wall was found to steadily increase at Weisweiler. This change in fouling behaviour can be attributed to a changeover to a low-NO_x operating mode and/or to a change in fuel. To counter the phenomenon, the number of water blowers in the furnace was progressively increased from 64 to 116 units. Furthermore, complete cleaning of the evaporator helix became necessary during inspections. However, with the installation of the water cannons it became possible to progressively remove the SK58 water blowers.

Figure 4 shows the efficiency factors for the furnace and the radiation space resulting from the thermal recalculation. It can be seen that 116 type SK58 blowers were unable to keep the combustion chamber completely clean. Optimal cleaning is only achieved with installation of all eight water cannons. This outcome is attributable, on the one hand, to the more effective cleaning action of the water cannon technology and, on the other hand, to the fact that the water cannons clean the entire area of the membrane wall.

At Weisweiler, in addition to the eight water cannons, 16 of the old SK 58 water blowers were kept for cleaning the membrane wall in the region of the first superheater heating surface.

Temperature loading of wall

Before taking into service the first test water cannon RWE had already contracted for investigations to be carried out on thermal shock loading issues. The purpose of these investigations was to forecast the service life of the evaporator helix of a 1900 t/h steam generator when using water cannon technology for the membrane wall cleaning.

These investigations highlighted the importance of the residence time of the water jet on the rate of life consumption of the evaporator wall. For a water jet residence time on the membrane wall of about 1 s and a water cannon useage frequency of once per shift a life consumption of 50 per cent is reached after about 14 years of operation. For a residence time of around 1.5 s this value is reduced to 10 years of operation.

At Weisweiler the water cannons are therefore operated with a water jet residence time on the membrane wall of about 0.5 s.

To investigate these results further, a test cannon was installed in boiler G of Weisweiler in 1992 with the aim of comparing the temperature loading of the membrane wall during operation with the conventional SK58 water blowers with that recorded for the water cannon.

As Figure 5 shows, thermocouples were fitted in the web of the membrane wall for temperature measuring, both protruding from, and flush-mounted with, the web. The locations of the thermocouples were selected so that they were within the effective radius of

Table 1. RWE lignite-fuelled power stations with water cannons

	Frimmersdorf	Neurath	Niederaußem	Weisweiler	RB
Unit	Q	E	F	G and H	K11 and K12
Water cannons in furnace	8	12	4	8	8
Type WLB 30	0	2	2	4	8
Type WLB 90	8	10	2	4	0
Angles (horizontal/vertical)	55/60	54/54	54/70	54/60	90/85
Water cannons in hopper	2 x option	2 x option	2 x WLB 30	none	2 x WLB 30
Arrangement relative to hopper slot	longitudinal	longitudinal	longitudinal	—	longitudinal
Water cannons in flue gas recirculation head	none	1 x WLB 90	none	none	none
Furnace cross-section (m x m)	14 x 14	20 x 20	15.3 x 15.3	21 x 21	6.6 x 7.25, 4.2 x 7.25
Blowing pressure (by level) bar	16	20	12 and 14	16	6 - 7
Throughput per cannon (kg/s)	8.33	12.22	7.22 and 7.78	10.92	1.64 - 1.78
Nozzle diameter (mm)	14	16	14	16	8
Travelling speed (m/s)	1.0	1.04	1	1.04	0.75
Cell distance (m)	0.5	0.77	0.5	0.5	0.4
Cell misalignment (cell)	1/2	1/2	1/2	1/2	1
Main cleaning/blowing areas (no. per cannon)	0/max. 3	7-10/4-5	0/2	0/3	0/max. 5
Boiler wall / tube routing	membrane / vertical	membrane / inclined	brickwork / meander type	membrane / inclined	brickwork / meander type
Jet route (rel. to tube / to wall)	cross / horizontal	cross /vertical	cross / horiz. and vertical	cross / vertical	cross / vertical
Control	Siemens	ABB	Siemens	Siemens	Siemens
Commissioning date, WLB 30	—	June 95	Oct. 96	Sept 92	93/94
Commissioning date, WLB 90	Feb 99	Jan 99	Oct. 96	Sept. 97	—

Table 2. Factors in economic feasibility study

	Cannon (WLB90)	Blower (SK58)
Investment costs, eight water cannons, including I&C, piping, offset, pumps	Total =100	
Sale / utilisation of spare parts for 100 SK 58 water blowers		Total - 10 = 90
Upkeep / maintenance per year	16	100
Water consumption per year	16	100
Power consumption per year	16	100

the SK58 blowers and in the area affected by the water cannon. As a result of this temperature comparison, irrespective of the absolute temperatures measured, it can be concluded that the water cannon cleaning technology subjects the membrane wall to lower temperature loading than operation of the SK48 water blowers does (Figure 6).

The loading on the membrane wall is further reduced by the water cannons because the cannons are only operated once a day, not once per shift, as with the SK 58 water blowers. On the strength of these results it was decided to gradually increase the amount of furnace cleaning done by water cannon. Over the next few years additional water cannons were progressively installed in the furnaces of units G and H.

To further assess any possible thermal damage caused at the membrane wall by water cannon cleaning, the membrane wall was inspected for surface cracks during the subsequent inspection outages. The inspection was initially done over a large area, but then confined to just the corner sections. These inspections did not reveal any degradation attributable to the water cannon cleaning.

Experience elsewhere

As well as at Weisweiler, water cannons have also been used for steam generator cleaning at Frimmersdorf, Niederaußem and Neurath, three Rhenish lignite-fired power stations.

Due to the different fuel used at these locations the fouling behaviour observed in the boilers is also different from that encountered at Weisweiler. Indeed, the fouling rates found were sometimes so high that the steam generators had to be shut down because of consequential damage.

In these cases water cannons were deployed to minimise the furnace end temperature in order that caking at the platen heating surfaces could be reduced.

In addition water cannon technology has been tested at these plants for special applications such as cleaning of the furnace hoppers and cleaning of the flue gas recirculation shaft heads.

Table 1 summarises water cannon installations at RWE plants, comparing boiler geometry and blower data. It can be seen that the different furnace cross-sections result in differing jet lengths, which in turn determine the nozzle diameter, the blowing pressures and the water throughputs.

The water cannons used in these installations generally clean effectively. However, cleaning is less good in the case of densely sintered deposits.

All boilers which are cleaned with water cannons exhibit operational disturbances during the cleaning process. These include fluctuations in line temperatures, LS and RH temperature changes and LS pressure variations. The disturbances are attributable to the additional energy required for evaporation of the water input which in turn has an influence on fuel control and, as a result, on the spray water flow.

To minimise these disturbances, the water cannons must be operated only successively in sequence.

Moreover, with the exception of the Niederaußem power station, pressure surges occur in the water piping when the blowing valves are actuated. These pressure surges are attributable, on the one hand, to the required short closing/opening times of the blowing valve (for switching on the cleaning figure) and, on the other hand, to the flow velocity in the feed piping. To reduce these pressure surges, hydraulic accumulators have been installed upstream of the shut off valves.

Where new water piping is installed this should be dimensioned so that flow velocities are maintained at less than 2 m/s.

Overall, it can be concluded that in these other applications of water cannon cleaning, the cannons provide the required coverage and clean effectively. But at these other units the existing water blowers have not yet been taken out of service.

At present, experience is being acquired with the use of water cannons for platen cleaning programmes and for cleaning of flue gas recirculation shaft heads. Initial indications are that the water cannons look promising in these applications.

Assessing the economics

Table 2 summarises the main factors taken into account in assessing the economics of furnace cleaning with the new water cannons in Weisweiler G and H (eight cannons per boiler), compared with conventional cleaning technology using 116 water blowers of the SK58 type. The factors were indexed to the costs of the water cannon installation. Taking into account these input parameters, the feasibility study suggested a payback period of about seven years.

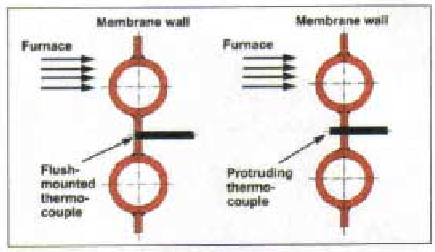

Figure 5. Thermocouple arrangement

It should be noted that, as a result of the latest operational experience, the 16 remaining water blowers could also be removed, the water cannons being able to clean the first superheater heating surface as well. This means it is not 100 water blowers that can be saved but actually 116.

Also, the additional benefits of improved heat absorption in the furnace and the related increase in boiler efficiency have not been considered in this calculation. Neither have the savings due to the fact that it is no longer necessary to carry out an additional furnace cleaning operation whenever an inspection is to be done.

Future developments

While experience with water cannon furnace cleaning has generally been positive, there is still scope for optimisation of the cleaning frequency. Up to now the cleaning operation has simply been done at predetermined fixed time intervals. Much better would be to operate the water cannons in accordance with the fouling rate actually being experienced by the furnace.

As a first step towards this kind of optimisation, in 2000 a diagnostic system called FACOS was installed at RWE's Niederaußem plant. This system automatically activates the water cannons when required, based on direct measurement of the fouling rate by heat flux sensors placed inside the furnace. The results of this project are eagerly anticipated.

Meanwhile, as well as lignite-fired boilers, water cannon technology is also under consideration for other areas of application. For example, water cannons have been installed in the Weisweiler waste incineration plant for cleaning the empty passes, six on each of the three lines.

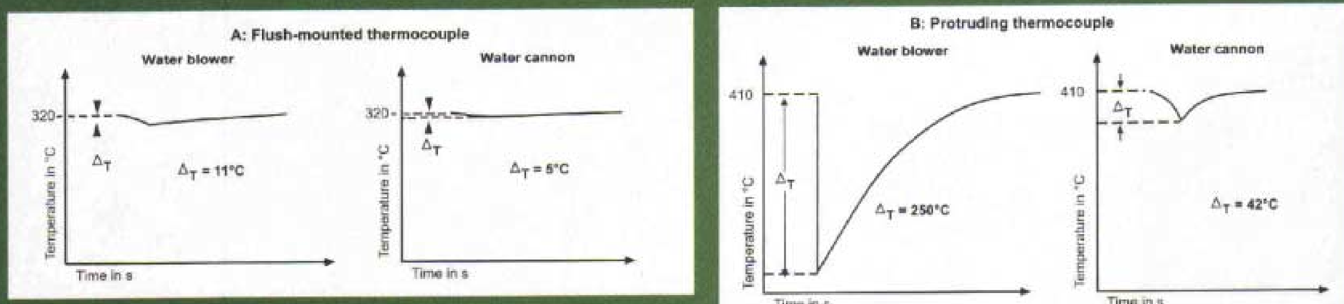

Figure 6. Temperature loading of membrane wall