# Pennguard linings in free standing brick flues
# Three projects in the United States of America

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Albert de Kreij joined Hadek Protective Systems in 1989. He has been closely involved in a number of projects with the use of Borosilicate Glass Block Linings especially in wet stack operation conditions.

## Introduction

Many existing power stations with brick chimney flues suffer from severe lining degradation when they operate in wet stack service. During wet stack operation, the flue gas stream is not reheated to above its water dewpoint, and as a result large amounts of aggressive condensates are present on the chimney flue walls. Wet stack operation is often economically attractive, but it creates the need for corrosion resistant linings or materials of construction. Any porous lining material will be completely saturated. Brickwork is porous, so acidic condensate is able to penetrate through the brickwork into the annular space, eventually attacking the structural integrity of the chimney itself.

This paper presents three cases from the recent past, where the owner had to install FGD plants and chose to re-use the existing chimney with independent brick flue. To protect the existing flue, the Pennguard Block Lining was used.

The case studies are two chimneys of Craig Station in Craig Colorado, installed in 2003 and 2004, Dallman Station in Springfield, Illinois, installed in March/April 2006 and Killen Station in Manchester, Ohio, installed in April/May 2006.

## Case 1: Craig Generating Station, Craig, Colorado

Craig Generating Station consists of 3 x 420 MW coal fired units and is owned by Tri-State Generating and Transmission Association (picture 1). Each unit is equipped with a 182 m high chimney with a free-standing brick flue. Unit 3 has a dry scrubber and baghouse combination for flue gas desulfurization. Units 1 and 2 have wet limestone scrubbers. In late 2003 and early 2004, units 1 and 2 got an environmental equipment upgrade, resulting in completely wet flue gas entering the chimney.

During the selection of a suitable lining for the existing flues of units 1 and 2, the owner had two options in mind. Option A: partial lining of the brick chimney flues with the Pennguard Block Lining System (up to 65 m) together with annulus pressurization (figure 1), and option B: lining of the brick chimney flues full height with the Pennguard Block Lining System (up to 183 m) (figure 2).

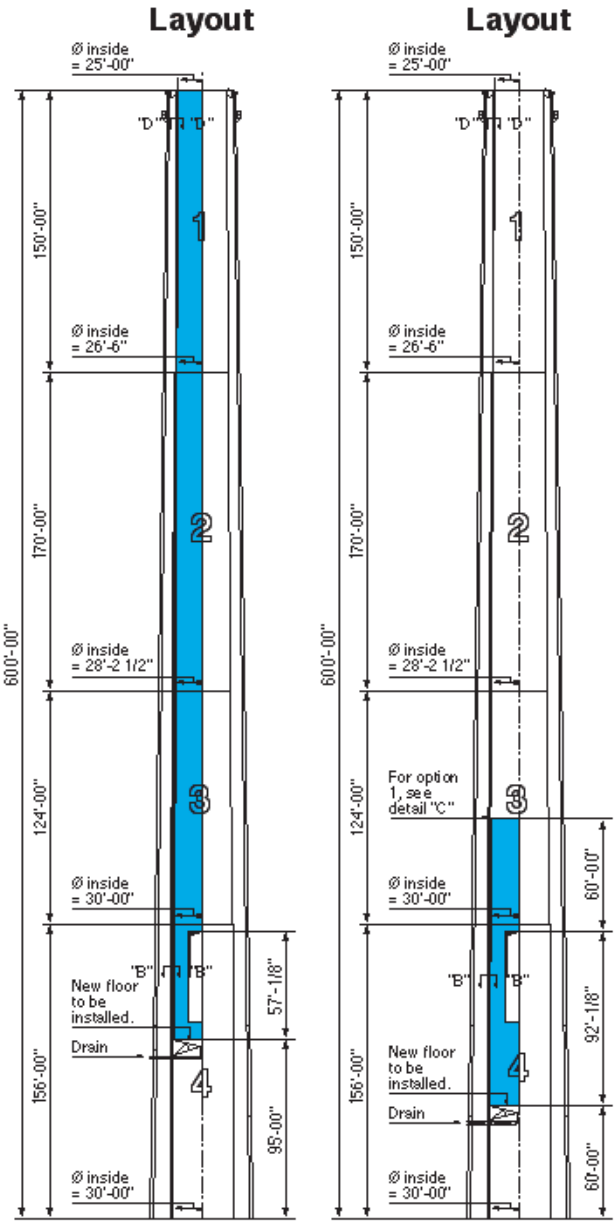
The owner selected option A, partial lining, together with annulus pressurization.

**Picture 1: Graig Generating Station**

In-stead of two breechings, only one breech-ing was con-structed above the ex-ist-ing breech-ing openings. A false floor was in-stalled at ele-va-tion 29 m above da-tum and a liq-uid collection gut-ter installed at ele-va-tion 65 m. Be-tween the floor and the gut-ter, the brick sub-strate was lined with the Penn-guard Block Lin-ing Sys-tem.

Two new pres-suri-za-tion fans were in-stalled to pres-sur-ize the an-nu-lar space to limit con-den-sate per-mea-tion through the brick flues at ele-va-tions above 65 m. The brick flues it-self is con-structed of acid bricks and an in-or-ganic po-tas-sium sili-cate mor-tar.

The installation of the Pennguard lining took place in Octo-ber 2003 in unit 1 and in March 2004 in unit 2 (see pictures 2 - 5).




**Figures 1 & 2: Option A and B: Partial lining vs Full height lining (Blue color indicates Pennguard lining)**

**Picture 2: 2003, Brick flue before Pennguard lining**

**Picture 3: Pennguard lining application onto irregular brick surface.**

**Picture 4: Pennguard lining installation**

## March 2006, Inspection of the Pennguard lining in unit 1 flue

Af-ter more than two years of op-era-tion, an out-age pre-sented an op-por-tu-nity to in-spect the chim-ney flue on the out-side and in-side. The in-spec-tion proved that the Penn-guard Block Lin-ing Sys-tem com-pletely closes off the sub-strate from the flue gas and con-den-sates that is run-ning down the in-side of the flue con-tinu-ously.

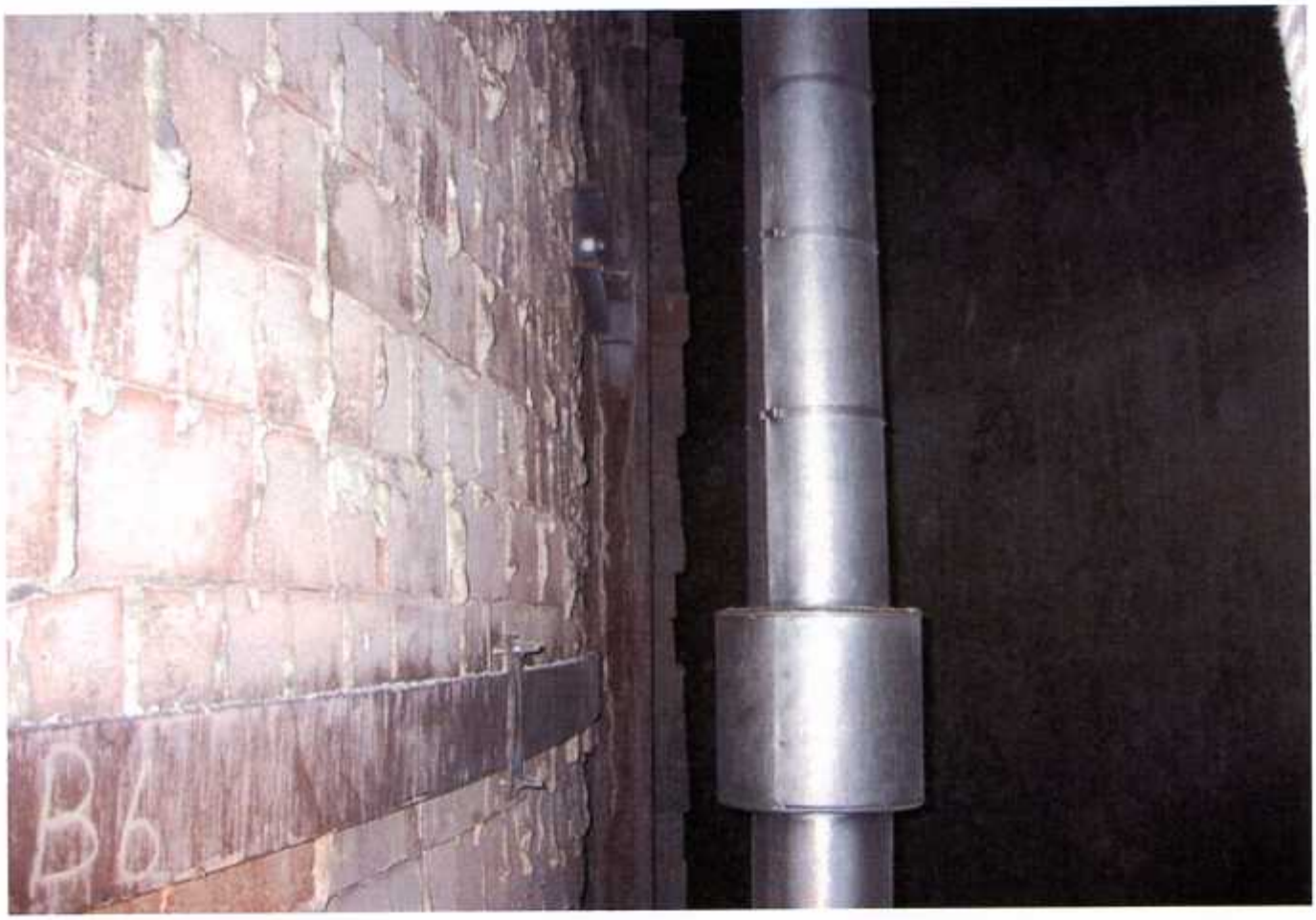
The following pictures were made during this inspection:

**Picture 6: Height 65 m, in-side flue at liq-uid col-lec-tion gut-ter level.**

**Ter-mi-na-tion of Penn-guard Block Lin-ing Sys-tem**

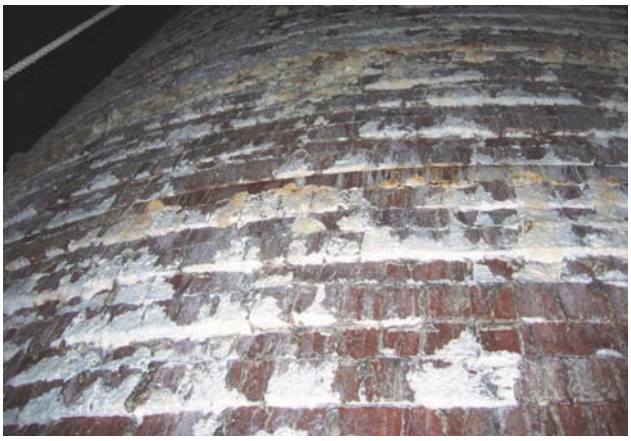
**Picture 7: Height 29 m, outside of flue, an-nu-lar space at floor level.**

**Shown bolts are false floor sup-port-ing bolts**




**Picture 8: Height 46 m, outside flue, annular space, mid Pennguard lining level**

**Picture 9: Height 65 m, outside flue, an-nu-lar space at top of liq-uid col-lec-tion drain**



**Picture 10: Height 65 m, outside flue, annular space, beyond top of Pennguard lining level, look-ing up from 65 m**

## Case 2: Dallman Power Station, Springfield, Illinois

The city of Springfield's Utility, City Water Light and Power (CWLP), owns the Dallman Power Station (picture 11). It consists of one 152 m high chimney and three coal fired units; units 1 and 2 with 80 MW capacity each and unit 3 with 192 MW capacity. Unit 3 was built in 1978 and an FGD was added in 1980. Originally by-pass reheat of the flue gas was achieved with 5% - 10% unscrubbed flue gas. However, to increase efficiency bypass reheat was abandoned and completely wet flue gas 54oC would have to pass through the existing free standing brick flue. A pressurization system was installed shortly after switching to wet flue gas service, to prevent the positive pressure flue, leaking flue gas and condensate.

Especially in case of brick flues, thermal shocks can be detrimental to the structure of the brickwork. Due to the high mass of brick flues, they do not quickly adjust to temperature changes in the flue gas. Resulting stresses in the brick can easily exceed the tensile stress of the brickwork and even the

**Picture 11: Dallman Power Station**

**Picture 12: Acid condensate attacked all steel reinforcement bands as well as the concrete foundation**

**Picture 13: Pennguard linings can easily adapt to offsets**

bricks themselves. In positive pressure flues, flue gas will then be able to leak through these cracks into the annular space with equipment susceptible to corrosion.

Although pressurization of 76,2 mm water column will help to counteract leaking of flue gases through these wide cracks, it will only slightly reduce the capillary permeation of acid condensate through a brick chimney flue since capillary pressure may be up to 762 mm water column.

In case of the Dallman chimney, this permeation had become a continuous maintenance issue, since the acidic condensate in the annular space corroded ladders and platforms including the steel bands that hold the independent brick flue together (picture 12). On the concrete foundation, residual sulfuric salts were building up, attacking the concrete underneath. A permanent solution to this problem was found in closing the brick flue off from the flue gas and its condensates by applying the Pennguard Block Lining System on the inside of the brick flue. The Pennguard lining was installed in 5 weeks (pictures 13 – 15). After one year of operation, an inspection showed that the outside of the brick flue is now completely dry (pictures 16 – 17).

**Picture 14: Pennguard lining application**

**Picture 15: Platform**

the plant, resulting in wet flue gas entering the chimney. To be able to reuse the chimney and prevent damage to it, the owner decided to line the chimney with the Pennguard Block Lining System.

Since a longer outage was expected in 2006, it was decided to line the chimney in this outage, so that it would be ready for wet flue gas in 2007. The first year, the Pennguard Block Lining System would be exposed to unscrubbed flue gas of 140°C and the owner required to keep flexibility to operate without a scrubber. The chimney was therefore lined with 79 mm, 67 mm and 54 mm thick Pennguard linings, while in the first 24 meters from the breeching a steel flue with reduced diameter was inserted for liquid collection purposes. Installation of the insert was planned to be done during the scrubber tie-in outage in 2007. The total surface area of the lining installation is 8.990 $m^2$. Two platforms were used for a short period of time during the outage to increase production of the block installation.

## Case 3: Killen Power Station, Manchester, Ohio

Killen Power Station is a 600 MW coal firing power station and is owned by Dayton Power & Light Company (picture 18). The chimney is 274 m high with one free-standing brick flue. Originally designed for two 600 MW units, the chimney is oversized for the amount of flue gas. The internal flue diameter in the bottom is 16 meters while in the top it still is more than 10 meters. In 2007 a wet FGD were to be added to

In 2006, only 60 % of the Pennguard Blocks were applied in a 37-day outage because the outage was shortened from its original 45 days to resume power production.

The remaining 40% of the Pennguard lining project will now be completed in 2008.

Following pictures (19 – 22) are showing the Pennguard lining application.

**Pictures 16, 17: Outside of the flue after one year of operation without Pennguard lining (left) and with an internal barrier (right)**

**Picture 18: Killen Power Station**

**Picture 19: 15 bricklayers per shift applying the lining system**


**Picture 20: Hadek QA supervisor inspecting the work**

## Conclusions

(1) Free standing brick flues will be permeated by condensate as a result of wet stack operation;

(2) Pressurization of the annular space is not a long term solution;

(3) Pennuard lined brick flues are effectively protected and remain dry;

(4) Pennguard linings can be installed quickly, provided that manpower and logistics are well organized;

(5) Pennguard linings can be installed in multiple outages.

**Picture 21: Lower platform (max chimney flue ID is 16 m)**

**Picture 22: Five Pennguard Adhesive Membrane mixing machines were used for the job**