Armor™

PROJECT PROFILE

# PENNGUARD™ Block Lining System Applied to 5 Small Diameter Flues

**INDUSTRY**
Pulp & Paper

**LOCATION**
Jeddah, Saudi Arabia

**COMPLETION**
2023

**OPERATION**
Power Generation

**PRODUCTS**
PENNGUARD™ 55 BLOCK
PENNGUARD™ Adhesive/Membrane
PENNGUARD™ HP Epoxy Primer

**Challenge: Replace small diameter flues in aggressive service with minimum downtime**

**Solution: Prefabricate new, modular flue with custom-designed PENNGUARD Block Lining System in a nearby laydown area then, over about 2 weeks, shut down and replace existing flues**

**PROJECT BRIEF:**
- 1 flue for each of 5 units completed in 15 calendar days
- Small 1.7 m (5' 7") diameter flues, 62 m (203' 5") tall
- 1,656 $m^2$ (17,825 $ft^2$) of internal linings required
- Heavy Fuel Oil (HFO) boilers with high sulfur trioxide ($SO_3$)
- Gas temperature 70°C with flue gas desulfurization (FGD), 265°C during bypass

**PROJECT OVERVIEW:**
Heavy oil with high $SO_3$ content fuels the paper mill's boiler. Under normal operation, a wet flue gas desulfurization (WFGD) scrubber with no reheat drops the gas temperature down to 70°C before it enters the flues at a velocity of 15 m/sec. When the WFGD unexpectedly goes off-line, the gas temperature can spike to 265°C before it is quenched to 130°C. The mill needed to minimize downtime while upgrading the flues to handle the wide temperature variability and corrosive gas condensate.

***1. Project Laydown Area -*** *PENNGUARD Block was applied to each section of a flue while laying horizontal on a ground level*

In the fall of 2022, an industrial paper mill in the Kingdom of Saudi Arabia required upgrades to its environmental control system's three metal chimney flues. The flues would operate under a wide range of conditions—from hot, dry, high $SO_3$ content bypass gas to cooler, wet, scrubbed gas. During each flue replacement, the other two flues would remain in operation to minimize downtime. Three factors made this a challenging project.

- Few linings can handle the wide flue operating conditions.
- Workers had to install the lining inside flues of only 1.7 m ID.
- Each flue had to be replaced near 2 other operating flues.

The project's success hinged upon an adaptable lining system and collaborative implementation planning. The mill chose Armor's 51 mm thick PENNGUARD™ 55 Block Lining System, a closed-cell, foamed borosilicate glass block lining with a global reputation for long-term corrosion protection in fossil fuel combustion plants. The lining supplier, Armor, and installer, Dominion Arabia, developed an execution plan to deliver the project quickly, safely and with minimal downtime.

***2. All day (24-Hour) Shifts -*** *A flue being worked on at night using proper safety precautions*

Only one off-line flue was being replaced at any given time, allowing the power plant to remain in operation throughout the project. Extra planning kept workers safe while standing up each new flue, right beside 2 hot flues. Working shifts 24 hours a day, 7 days a week, Dominion Arabia replaced each newly lined flue in just 15 calendar days.

Dominion lined each new flue in a nearby laydown area, mobilizing a total of 3 times, once for each flue, to complete the project. First, a new flue was fabricated, laid on the ground horizontally and lined. Next, Dominion removed an existing flue and replaced it with a new one.

Each stage of the project—from material selection, to construction planning, to execution—played a critical role in its success.


***3. Small Diameter Flues -*** *PENNGUARD Block Lining System being applied in a 1.7 m (5'7") diameter flue*

## 3 STEPPING STONES TO SUCCESS
## STEP 1: LINER SYSTEM SELECTION

The mill required that the corrosion resistant flue liner possess the following benefits:

- Manufacturing Quality
- Durability in Service
- Performance Track Record
- Fire Resistance
- Suitability for Confined Space Installation

**Manufacturing Quality.** The presence of crystalline silica in a borosilicate lining composition negatively impacts safety, durability and retention of insulating properties. Tight controls over PENNGUARD 55 Block's chemical composition, foaming procedure, kiln firing rate and temperature effectively prevent the formation of crystalline silica in this US-manufactured closed-cell block. X-ray fluorescence (XRF), titration, x-ray diffraction (XRD) and combustion analysis tests confirm PENNGUARD 55 Block is free of crystalline silica.

Crystalline silica is a weakness in the armor of protection that a borosilicate lining could provide, a flaw that potentially exposes lining installation crews, and perhaps the public, to a cancer-causing respiratory hazard. Additionally, its presence in cellulated borosilicate glass block products is associated with higher long-term water absorption by diffusion, which translates to a mechanically weaker and less durable lining. The absence of this defect in PENNGUARD 55 Block may account for its unmatched longevity.

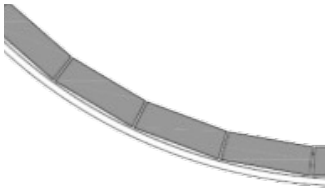
Long-Term Water Absorption by Diffusion is tested by EN 12088 at 90°C, which simulates a wet stack environment. When tested in accordance with this standard, PENNGUARD 55 Block exhibits maximum 15% absorption and nominal 7% absorption. Higher rates of long-term water absorption by diffusion will result in:

- Reduced thermal insulating capacity that risks adhesive/membrane damage
- Moisture absorption into the block that adds weight load to the structure
- Increased thermal shock sensitivity during bypass or cool ambient conditions

**Durability in Service.** The mill chose Armor's PENNGUARD 55 Block for its durability. Manufactured in the USA, PENNGUARD 55 Block features an industry-leading high percentage of closed cells, delivering consistent insulation to the soft, flexible PENNGUARD Adhesive/Membrane that protects the flue interior from corrosive condensate. Made of borosilicate glass, the block is resistant to cracking under the anticipated thermal stress.

**Performance Track Record.** PENNGUARD Block has protected over 1.5 million square meters of industrial chimney flues since it was introduced in the USA almost 50 years ago. Many of those installations have operated successfully for over 10 years, several over 20 years.

**Fire Resistance.** The PENNGUARD 55 Block Lining System bears the exclusive distinction of Factory Mutual Group Approval (FM Approval) for fire resistance. FM Approval requires rigorous lab testing including fire simulation. To its unique credit, PENNGUARD 55 Block Lining System has proven effective in protecting steel flues and concrete chimneys in both FM testing and real fire events.



***4. ~5° bevel of PENNGUARD Block***

***5. Premeasured Closure of Flue Sections***

**Suitability for Confined Space Installation.** With only 1.7 m diameter, the flues did not offer a lot of room for personnel access and lining installation. The PENNGUARD Block Lining System consists of a primer, blocks, and adhesive/membrane. The primer could be applied with a roller, and the adhesive/membrane could be applied with a flat trowel. The absence of spray-applied components favored successful installation in a confined space.

## STEP 2: CONSTRUCTION PLANNING

The tight radius of the small diameter flues and short shutdown to replace each demanded thoughtful advance planning to ensure the quality of the installed lining and adherence to the schedule. Armor specified trimming the long sides of each block to about a 5-degree angle. This reshaping, which was efficiently performed in the field using a custom cutting jig, minimized variation in the bedding membrane thickness and prevented the interior surface of the lining from exhibiting excessive "scalloping." As a bonus, the use of shaped blocks made efficient use of the adhesive/membrane, the ultimate corrosion barrier.

Armor and Dominion Arabia collaborated on the lining installation process to optimize constructability, quality and efficiency. Dominion sandblasted, primed, and lined the majority of the interior flue surfaces in the laydown area, leaving precisely measured, unlined leading edges at the ends of each flue section. After erecting the new flue, their crew applied the final rows of block over the seams. This careful attention to detail prevented excessively wide and potentially under-insulated side joints around these last rows of block and minimized how much of the lining was installed in situ after each new flue was erected.

***6. Primer Application -*** *PENNGUARD™ HP Epoxy Primer being applied inside flue via paint roller*

The PENNGUARD Lining was largely installed at night, with the brightly lit flue modules situated on the ground level in a nearby laydown yard. Oriented horizontally, the sections were accessible from both ends, so installers and inspectors had two points of egress and could easily bring materials inside. When the daytime temperatures were very high, working at night was easier on the workers.Once it was time to install the replacement flues, efficiency enhanced safety. Since the other two flues remained operational while the one flue was replaced, the project team sought to minimize the amount of time workers needed to be in the new flue. The PENNGUARD Blocks designated for installation over the flue seams were precut to ensure they could be installed with maximum efficiency. This advance planning and prefabrication limited the time both the Dominion installer's and Armor QA technicians were in the hot, close quarters.

To prevent lag time between each stage of the project—can lining, demo, and erection—the construction crews filed daily progress reports. As the lined modules neared completion, the mill could prepare to shut down the existing flue and seamlessly move to the next stage. Without skipping a beat, the old flue was removed, and the new one was erected in its place.

## STEP 3: EXECUTION

Before Dominion started installing the PENNGUARD Block Lining System, Armor's quality assurance (QA) representative performed 3 checks:

- Inspect condition of material packaging
- Verify delivered quantities match bill of materials
- Confirm each material lot number had a corresponding certificate of analysis (C of A)

Under Armor's QA representative's oversight, Dominion constructed a jig to consistently trim the sides of the blocks to the angle Armor recommended. While the blocks were trimmed and inspected, the interior surfaces of the metal cans were sandblasted to meet SA 2.0 surface preparation standards. Once Armor's QA representative approved the surface preparation, he submitted an inspection report with written approval for Dominion to proceed with the lining installation.

***7. Flue Sections Craned Into Place -*** *The gaps between the flues were then covered with PENNGUARD™ Adhesive Membrane and PENNGUARD™ Block prior to final inspection*

***8. Job Site Perspective -*** *The flue sections being coated in the laydown area were disassembled from the tower structure in the forefront*

Dominion applied the PENNGUARD HP Epoxy Primer over the prepared substrate with a roller. Using a roller to apply the primer allowed the installer to control the film thickness, avoid wasting material, and protect the fresh coating from marring. Applying the primer with spray equipment inside the small, tubular cans would have introduced avoidable challenges to a quality installation.

After the cans were primed, Dominion staged a mixing area for the PENNGUARD Adhesive/Membrane. This is a two-component mastic consisting of a pail of heavy base resin and a small bottle of thin hardener. Using a simple timer and handheld mixing tool, Armor's QA representative demonstrated the mixing time, hardener addition and mixing action required to achieve complete dispersion of the hardener into the base resin.

The membrane is the primary barrier to protect the flue interiors from corrosion. Proper cure of the PENNGUARD Adhesive/Membrane is key to the performance of the PENNGUARD Block Lining System, and proper mixing is key to proper cure. To ensure proper cure of each kit of membrane consumed, a small wet sample was collected and applied to a cure verification card. The QA representative reports the results from the cure verification cards in Armor's final project QA report.

To make the most efficient use of materials, installation labor and QA representation, multiple flues were staged in the laydown area and lined simultaneously. The PENNGUARD Block was laid up to a precise distance shy of the ends of each can. Once the cans were lifted into place and assembled, the PENNGUARD Block Lining System was applied over the recessed areas, bridging the seams between cans.

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## LEARNINGS

When timeliness is essential to success, and work conditions present unique safety hazards, careful advance planning is a worthy investment. This project's small flue diameter, short outage window and hot ambient temperature presented schedule and safety risks that required thoughtful mitigation.

Small diameter flues are common in many industrial applications. Though the PENNGUARD Block Lining System has a global reputation as an effective, long-term corrosion barrier in large diameter WFGD flues, it can easily be adapted to protect small diameter flues. Using wood saws and a simple jig, the blocks can be trimmed consistently, quickly, and easily.

When downtime is costly and disruptive, it's wise to invest in quality materials that have stood the test of time. A comprehensive lifecycle analysis and risk assessment will typically favor low-maintenance, long-term solutions for facilities designed to operate for decades.

Close collaboration between the constructor and material supplier can yield a comprehensive project plan that achieves the owner's objectives. Surfacing solutions to potential problems before crews are mobilized to the project site reduces schedule risk. Together, the installer and material supplier can develop a very robust project schedule, quality control plan, assessment of equipment needs, and crew sizing to deliver a successful project.