TIVAR® 88 High Performance Lining Solutions Engineering Case Book

Applications, Case Studies, & Technical Resources to assist your design process

QUADRANT

You inspire . . . we materialize®

Introduction to Quadrant's SystemTIVAR® Engineering Group

TIVAR® 88 HIGH PERFORMANCE LINING SOLUTIONS

For more than 30 years, Quadrant's SystemTIVAR® Engineering Group has been recognized for consistent, reliable products, highly qualified staff and innovative lining solutions in the bulk material handling industry, earning a reputation throughout the world for providing long-term, cost-effective lining solutions. Well-known by many of the world's engineering experts and consultants in the bulk material handling field, Quadrant's SystemTIVAR® Engineering Group has assumed a leadership role in the industry by developing and introducing lining products to meet individual customer needs and expectations.

Quadrant's SystemTIVAR® Engineering Group offers the bulk material handling industry a solutions-oriented approach that includes full-line processing methods for TIVAR® products, specially formulated grades of TIVAR®and engineering and technical support services. Liners manufactured from TIVAR® 88 offer companies in the bulk material handling industry a versatility and combination of properties not available in any other polymer.

As specialists in providing flow, abrasion, impact and corrosion solutions in the field of bulk solids, Quadrant's SystemTIVAR® Engineering Group uses TIVAR® 88 to line a wide array of process equipment that handles, moves or stores bulk materials – bins, hoppers, bunkers, silos, chutes, railcars, off-road haul trucks, ash conditioners/pugmills, scrapers, dozers, loader buckets and ship holds – with particular expertise in the power generation, cement manufacturing, minerals and metals mining, and chemical industries.

Arching, ratholing, erratic material flow and aggressive flow promotion devices (vibrators, sledge hammers, etc.) can be reduced or even eliminated with TIVAR® 88 linings, due to the material's low coefficient of friction. TIVAR® 88 linings are also recognized worldwide for their abrasion-, corrosion-, moisture- and chemical-resistant properties that contribute to a long wear-life, lower maintenance costs and reduced downtime. Quadrant's SystemTIVAR® Engineering Group team will design, fabricate and install TIVAR® 88 linings anywhere in the world.

Quadrant is the world's largest processor of semi-finished UHMW-PE, sold under the TIVAR® and QuickSilver® brand names. Headquartered in Reading, PA, USA, with manufacturing, fabricating and sales facilities worldwide, Quadrant began processing TIVAR® products in 1970 and started developing and manufacturing plastic materials over 60 years ago.

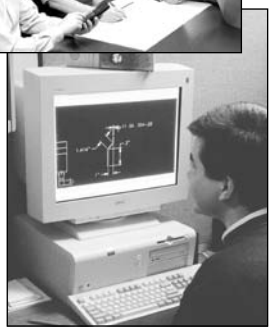
Introduction to Quadrant's SystemTIVAR® Engineering Group

TIVAR® 88 HIGH PERFORMANCE LINING SOLUTIONS

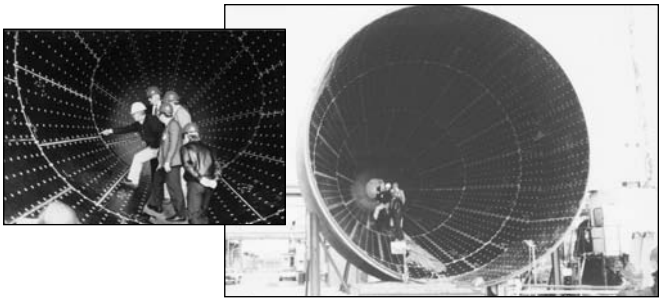
PROJECT ANALYSIS
Quadrant's SystemTIVAR® Engineering Group team will study your specific situation – your bulk materials, equipment and operating environment. Using knowledge compiled from applications throughout the world, they will assist in selecting the optimum product from the TIVAR® 88 family and the most cost effective installation method for your application.

DESIGN SERVICES
We design TIVAR® 88 lining systems and provide detailed installation drawings to ensure each system is engineered and installed correctly.

GLOBAL INSTALLATION
We offer complete turnkey installation anywhere in the world. Assistance from your nearest authorized SystemTIVAR® installer is also available.



STATE-OF-THE-ART INSTALLATION METHODS
During the last thirty years, we have developed many unique installation methods, including: fasteners for many different substrates, seam profiles, leading edge protectors, oversized panels and drop-in TIVAR® 88 lining systems.



TIVAR® 88 PRODUCT FAMILY
Featuring a very low coefficient of friction, and excellent abrasion and corrosion resistance, TIVAR® 88 is available in UV-resistant and antistatic formulations. TIVAR® 88-2 is a weldable formulation of TIVAR® 88 featuring the same high quality characteristics: excellent abrasion and corrosion resistance and a low coefficient of friction. In fact, it is possible to achieve 100% weld strength compared to the base material, allowing you and Quadrant's SystemTIVAR® Engineering Group the flexibility to consider alternative installation techniques.

Color: Blue (black if antistatic)
Gauge: 1/4″-2″ (6.4-50.8mm)
Standard sheet size: 48″ x 120″ (1220 x 3048mm)
Custom sheet size: 60″ x 120″ (1524 x 3048mm)
Operating temperature range:
-450°F to +212°F (-268°C to +100°C)
Consult with Quadrant's SystemTIVAR® Engineering Group for high temperature installations >+150°F (+65°C)

TIVAR® 88/TIVAR® 88-2 APPLICATIONS
- Belt scrapers
- Bins
- Bucket liners for reclaimers
- Bunkers
- Chain conveyor flights
- Chutes
- Conveyor skirting
- Cyclones
- Drag conveyors
- Dragline bucket liners
- Dust collectors
- Front end loader bucket liners
- Hoppers
- Off-road truck bed liners
- Railcar liners
- Self-unloading ships
- Slider beds
- Silos
- Under chain wearstrips
- Vibrating bin dischargers
- Vibratory pan feeders

SAMPLING OF BULK MATERIALS HANDLED
- ABS resin
- Animal feed
- Anthracite culm
- Bauxite
- Bituminous coal
- Bituminous gob
- Brown and black coal
- Charcoal
- Chemical powders
- Clay
- Copper concentrate
- Dust
- FGD sludge
- Flyash
- Foundry sand
- Glass batch
- Grains
- Gypsum
- Iron ore
- Kaolin clay
- Lignite coal
- Lime
- Limestone
- Nickel ore
- Peat
- Pesticides
- PET resin
- Phosphate
- Potash
- Prilled urea
- PVC resin
- Salt
- Sand
- Silica sand
- Sinter
- Soap detergent
- Sub-bituminous coal
- Synthetic gypsum
- Titanium dioxide
- Waste coals
- Wood chips
- Zinc concentrate
- Zinc oxide

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TIVAR® 88 HIGH PERFORMANCE LINING SOLUTIONS

Case Study: Sub-Bituminous Coal (PRB)

TIVAR® 88 HIGH PERFORMANCE LINING SOLUTIONS

CASE IN BRIEF
Application: Coal Bunker
Quantity: (2) 3 Outlet Bunkers
Liner: TIVAR® 88 w/BurnGuard, 5/8" Thick

Bulk Material: Sub-Bituminous Coal (PRB)
Substrate: Gunite
Problem: Flow problems, stagnation, bunker fires
Date Installed: 2003, 2005

TIVAR® 88 w/ BurnGuard Liners Eliminate Bunker Fires Associated with PRB Coal, Reduce Frequency of Bunker Fillings

• PROJECT
Lansing Board of Water & Light
Eckert Station (375 MW)
Lansing Michigan

• APPLICATION
Unit #2 & #4 Coal Bunkers

•PROBLEM
After switching to 100% PRB coal (Black Thunder Mine) in 2001 the Lansing Board of Water & Light began experiencing fires in their coal bunkers which supported the generation units at the plant. The Eckert Station was constructed in 1955. The bunkers were built of carbon steel with a pyramidal shape geometry. The interior surfaces of the bunkers were coated with 2 1/2" thick gunite for corrosion and abrasion resistance. Sloping walls of the bunkers varied between 60°, 64°, and 74° from the horizontal. Coal flow within the bunkers was acceptable while burning bituminous coal, but became problematic after switching to PRB fuel.

• SOLUTION
In an effort to eliminate bunker fires, in 2002 the plant took (1) 3 outlet bunker supporting Unit #5 and removed the gunite from the sloping wall surfaces and installed stainless steel liners to improve coal flow. The results were better than a fully gunite lined bunker, but fires still occurred when PRB coal was received with high moisture. In addition, the cost to remove the gunite and install stainless steel liners was extremely high which limited the possibility of this approach for future consideration.

In 2003 the Eckert Station installed TIVAR® 88 w/ BurnGuard liners in (1) 3 outlet coal bunker supporting Unit #2. The TIVAR® 88 w/BurnGuard liners were installed directly over the existing gunite surfaces on the sloping walls of the bunker. Since the installation of the TIVAR® 88 w/BurnGuard liners in 2003, the plant has not experienced any fires in the Unit # 2 bunker. The cost of the TIVAR® 88 liner installation was 50% less than the Unit #5 approach. An additional benefit from the lining was a reduction in the frequency of bunker filling. In the fall of 2005 the Eckert Station installed TIVAR® 88 w/BurnGuard liners in the Unit #4 coal bunker.

• UPDATE
An inspection was performed on the Unit 2 bunker liners in March, 2006. The TIVAR® 88 w/BurnGuard liners had no measurable wear and were providing continuous flow with no bunker fires and no maintenance.

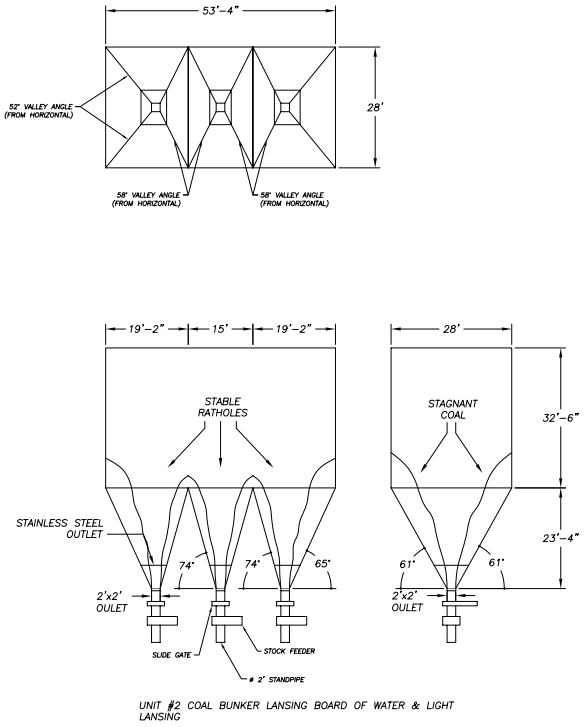

Figure 1: Unit #2 Coal Bunker Lansing Board of Water and Light Lansing

Case Study: Standpipe Liners

TIVAR® 88 HIGH PERFORMANCE LINING SOLUTIONS

CASE IN BRIEF
Application: Coal Handling System Standpipes
Quantity: 18
Liner: TIVAR® 88 w/BurnGuard
Bulk Material: Coal
Substrate: Carbon Steel
Problem: Flow problems, caking, plugging
Date Installed: 2008

TIVAR® 88 w/ BurnGuard Standpipe Liners Eliminate Flow Problems

• BACKGROUND
A South Korean coal fired power plant uses a variety of coal types, some with high volatility properties prone to self-combustion. Coal is fed into the mills through carbon steel standpipes with an inside diameter of 600mm (24") and varying lengths and geometries

• PROBLEM
The power plant was having flow problems associated with their coal handling system standpipes feeding the coal mills. Coal did not flow smoothly or reliably through the standpipes due to caking and plugging. The power plant was concerned that a flow-promoting liner would reduce the inside diameter of the standpipes and was against using a standard polymer liner because of the high volatility of the coal used.

• SOLUTION
Together with Korea Engineering Corp., our SystemTIVAR® Partner in Korea, Quadrant proposed the design and supply of a one-piece welded pipe liner fabricated from 15.88mm (5/8") thick TIVAR® 88 w/ BurnGuard material. Korea Engineering Corp. performed the simple installation on site. The one-piece pre-fabricated liner only required two rows of fasteners at the leading edge of the standpipe to allow for expansion and contraction based on the ambient temperature.

• RESULTS
The one-piece TIVAR® 88 w/BurnGuard liner was installed in one standpipe in March 2008 as a trial. Complete flow was restored with no further problems associated with plugged standpipes. The flame retardant properties of the liner material eliminated concerns with the high volatility coal. The power plant was very pleased with the liner performance. Since that time the remaining 17 standpipes have all been lined with one-piece pre-fabricated TIVAR® 88 w/BurnGuard liners with the same success.

Case Study: Bituminous Coal

TIVAR® 88 HIGH PERFORMANCE LINING SOLUTIONS

CASE IN BRIEF
Application: 3,000 Ton Coal Bunkers
Quantity: 3
Liner: TIVAR® 88-2 (1/2″ and 3/4″ thick)
Bulk Material: Bituminous Coal
Substrate: Carbon Steel
Problem: Flow problems, arching, plugging
Date Installed: 2003

TIVAR® 88-2 Eliminates Flow Problems with Bituminous Coal

• BACKGROUND
The coal handling system from the tripper car to the volumetric rotary feeders consists of (3) 3000 ton coal storage bunkers, one for each generating unit. Each coal bunker is 45 feet high from the top of the discharge hoppers to the tripper conveyor floor and is constructed of carbon steel with carbon steel interior sloping walls that transition down to (8) pyramidal discharge outlets, measuring 4′ x 4′ square. The slopes in the discharge hoppers are between 57° and 59°. Beneath each of these outlets are (8) transition hoppers that taper down to 2′ x 2′ square discharge outlet. Located beneath the 2′ x 2′ discharge outlets are (4) auxiliary hoppers that combine the coal flow from two discharge outlets into a single coal stream which feeds the volumetric rotary feeders. In the late 1990's the plant owners lined the interior surfaces of the (8) transition hoppers and (4) auxiliary hoppers, with stainless steel to reduce surface corrosion and improve coal flow within this region.

• PROBLEM
Inspection of the (8) transition hoppers and (4) auxiliary hoppers revealed a significant build-up of coal in the sloping valley angles. The coal deposits had accumulated over the years in an area not impacted by coal flow. Under the coal deposits, the stainless steel had corroded, making the coal deposits adhere more to the hopper walls. The build-up of coal in the valley angles of the hoppers was determined to be the result of higher moisture content fuel and the smaller size of coal particles. The original design fuel was to be 4.6% moisture, but coal presently supplied to the station is about 5.5% moisture. Once coal began to build-up in the valley angles, it would then continue to migrate into the primary flow stream, eventually choking off coal flow, resulting in load generation curtailments.

• SOLUTION
In an effort to reduce the generation curtailments resulting from coal flow problems in the lower portion of the coal bunkers on Units # 1, 2, & 3, the plant installed air cannons through the doors angled downward into the transition hoppers. After the installation of the air cannons coal flow was improved, but extensive usage on a daily basis was required. In a continuing effort to improve coal flow and reduce output curtailments the Mirant/Dickerson engineering team made the decision to install TIVAR® 88 liners on the sloping wall surfaces of the transition and auxiliary hoppers in Units 1, 2, & 3. The liners were prefabricated and shipped to the plant ready to install. Little or no fabrication was required in the field, therefore reducing the installation time. To complete the installation, the lower sections of the auxiliary hoppers which had been damaged by years of sledge hammer abuse to promote coal flow, were replaced with new steel hoppers pre-lined with TIVAR® 88.

• RESULTS
The TIVAR® liners and air cannons have been intact and have performed beyond expectations. Since the liners and air cannons have been installed, approximately 9 million tons of coal have been discharged through the transition and auxiliary hoppers without the assistance of plant personnel manually lancing and/or beating on the sides of the hopper to dislodge the coal. The air cannons are periodically fired to clean-out any build-up of the coal in the transition and auxiliary hoppers when the coal bunkers are emptied for unit overhauls. During normal operation, the liners are sufficient to provide coal flow without using air cannons.

An inspection of the liner was performed during an outage in early 2009 and the liner showed only minimal signs of wear. It is estimated that using the same type and blend of coal at the current discharge rate, the liner should last another 20 years. There was no issue or maintenance required with the air cannons.

The total cost for the installation of air cannons and liners was less than $150,000/unit. By eliminating curtailments due to coal pluggage each of the three Mirant/Dickerson generating Units have been able to produce an additional 25,000 MW hours of electricity per year. The savings incurred was estimated to be $2,500,000 in gross revenues per year. Payback was achieved in less than 6 months.

NOTE: The above article was extracted from the paper "Mirant uses plastic liners and air cannons to maintain coal flow". The paper was presented at the Power-Gen Show on 12/09/09.

Case Study: Synthetic Gypsum

TIVAR® 88 HIGH PERFORMANCE LINING SOLUTIONS

CASE IN BRIEF
Application: FGD Stack-Out Conveyor System
Quantity: (1) Upper Trans. Chute, (1) Lower Pipe
Liner: TIVAR® 88-2 ESD

Bulk Material: Synthetic Gypsum
Substrate: Carbon Steel
Problem: Flow problems, arching, plugging
Date Installed: 2009

TIVAR® 88-2 ESD Drop-In Liner Installs in 20 Minutes and Eliminates Flow Problems with Synthetic Gypsum

• BACKGROUND
In 2009 a Midwest power plant installed a Flue Gas Desulfurization (FGD) stack-out conveyor system to handle synthetic gypsum. The synthetic gypsum was transported by a belt conveyor through a transition chute and telescopic chute on its way to being stacked in piles on the ground.

• PROBLEM
Synthetic gypsum has the consistency of wet, sticky sand which results in serious flow problems for hoppers, chutes, conveyors, etc. In this particular application, a belt conveyor was used to transfer synthetic gypsum up to and through a transition chute; then down through a telescopic chute into piles in a storage area on the ground. The material was sticking to the walls and square corners of the chute resulting in blocking (arching) and plugging rendering the system unusable. The chutes were located several meters above the ground making installation a concern. The customer would not allow any holes to be drilled in the substrate and, because of the flow problems they had been dealing with, could not afford a long down-time for installation.

• SOLUTION
Quadrant's TIVAR® 88-2 ESD was selected as the correct lining material due to its very low coefficient of friction and excellent wear properties. Taking the installation issues into consideration, a decision was made to design the liner system as a one-piece drop-in liner. The upper transition hopper liner consisted of two welded TIVAR® sections. The lower pipe liner section was attached to the transition hopper liner using a custom three-sided metal connector which held the whole assembly in place without compromising the integrity of the existing chute.

• RESULTS
The unique solution enabled the installation team to drop the liner into place in one piece using a crane. The result was a 20 minute installation time, a perfect fit, minimal down time, no holes drilled in the substrate and a solution to the customer's flow problems with no blockages or loss of valuable production time.

Case Study: Sub-Bituminous Coal

TIVAR® 88 HIGH PERFORMANCE LINING SOLUTIONS

CASE IN BRIEF
Application: Wet Scrubber System Modules
Quantity: 24
Liner: TIVAR® 88-2, 1/4" Thick

Bulk Material: Sub-Bituminous Coal (PRB)
Substrate: 10 Gauge Stainless Steel
Problem: Wear, abrasion, cost
Date Installed: 1999-2000

TIVAR® 88-2 Liners Eliminate Flyash Build-up in Wet Precipitator System

• BACKGROUND
The Xcel Energy (formerly Northern States Power) Sherco Plant, located in Becker, Minn., is a coal-fired facility that burns a low-sulfur, sub-bituminous coal from Wyoming and Montana. This plant, Xcel's largest, was the site where the wet precipitator process within a scrubber system was pioneered – a process that removes more particulates and SO2 from flue gases. The stack opacity went down to 10% from the original 30% as a result of the installation of the wet precipitator. This system was possible because of the calcium content in the PRB coal; it was high enough to neutralize the sulfur dioxide when mixed with the water spray. The Sherco plant is rated at 2,425 MW.

• PROBLEM
The original scrubber module (Fig. 1) for Units 1 & 2 was retrofitted with the wet precipitator system to further reduce the emissions of particulates and SO2 (Fig. 2). However, the 10 gauge stainless steel sloping surface above the venturi rods and the crossover duct slope under the venturi rods could not withstand the abrasive conditions of the spray, so maintenance personnel were frequently called upon to patch holes. Eventually, they had to line the area, trying first a polyurethane that was successful, but expensive. When it, too, needed to be replaced, plant staff determined they would look for a material with which they were familiar and one that was not only abrasion- and wear-resistant, but also cost-effective.

• SOLUTION
Having a familiarity with Quadrant and its TIVAR® 88 material from applications at other Xcel plants, TIVAR® 88-2 liners were installed. Chosen for its key abrasion- and wear-resistant properties, TIVAR® 88-2 was lower in cost compared to other liner options. Additional benefits included no flyash build-up due to TIVAR® 88-2's low coefficient of friction and the fact that TIVAR® 88-2 was easy to fabricate.

• RESULTS
The TIVAR® 88-2 liners are performing exceptionally well according to senior system engineers at Xcel. Maintenance costs and downtime have been reduced while maintaining the 10% stack opacity.

• UPDATE
The TIVAR® 88-2 liners installed in the wet precipitator system at the Xcel Energy-Sherco Plant are still in service and being used. Since the original installation (1999-2000) the plant has replaced some panels and performed minor repairs. The TIVAR® 88-2 liners perform as expected and Xcel is satisfied with its performance.

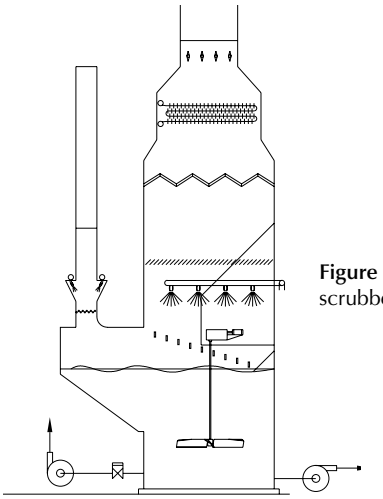

Figure 1: Original NSP Sherco scrubber module configuration.

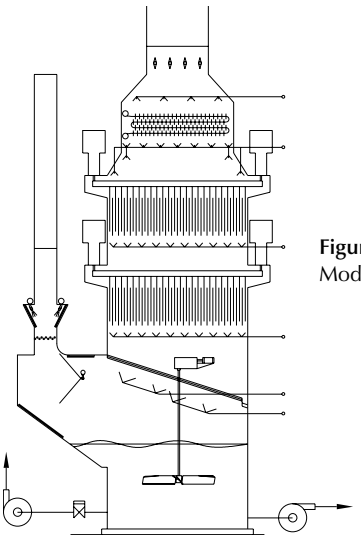

Figure 2: Retrofitted System - 101 Module West Esp Flush Water P&ID

Case Study: Sub-Bituminous Coal

TIVAR® 88 HIGH PERFORMANCE LINING SOLUTIONS

CASE IN BRIEF
Application: Coal Bunker
Quantity: 2 Bunkers
Liner: TIVAR® 88-2, 1/2" Thick

Bulk Material: Sub-Bituminous Coal (PRB
Substrate: Gunite
Problem: Flow problems, plugging and ratholing
Date Installed: 1995

TIVAR® 88-2 Linings Achieve Mass Flow, Eliminate Coal Stagnation, Bunker Fires

• BACKGROUND
A generating station located in Wisconsin, built and commissioned in the mid-60s, has six coal-fired units with a total generating capacity of 387 MW. The type of coal burned is sub-bituminous which is transported by rail from the Powder River Basin in Wyoming.

• PROBLEM
The plant was originally designed to burn bituminous coal. As part of the effort to comply with the Clean Air Act Amendment, the plant switched to low sulfur sub-bituminous coal. Unfortunately, problems soon developed with the fuel handling and storage systems because the sub-bituminous coal has a higher concentration of fines and increased moisture content, making it more cohesive.

The fuel storage bunkers for the six generating units were designed for funnel flow. This type of flow pattern was suitable for handling bituminous coal, but does not work well with sub-bituminous coal because the sub-bituminous coal builds up and adheres to the gunite surface of the bunkers, resulting in stagnant coal. If coal remains stagnant for an extended period of time, spontaneous combustion can occur, resulting in bunker fires.

In 1992, a bunker explosion occurred, the result of a bunker fire. The explosion was caused when coal dust was being back-filled into the bunker while a hot pocket of coal was present. The resulting explosion damaged the conveyor floor and roof above. Several employees were injured during the explosion.

• SOLUTION
A corrective action plan was implemented to alleviate the coal flow problems. An internationally known flow consultant was hired to do a flow analysis on the bunkers and to develop a solution for eliminating the bunker fires. The recommendation was to convert the bunkers from funnel flow to mass flow. Achieving mass flow would require adding valley angle clean-out plates and covering all of the sloping wall surfaces with TIVAR® 88-2 (Fig. 1).

In early 1995 the retrofit of two 750-ton bunkers was initiated. Steel clean-out plates were mounted to the steel bunkers after the gunite was removed from the attachment areas. Once this was completed, 1/2"-thick TIVAR® 88-2 was installed over the clean-out plates and the remaining sloping wall surfaces.

Shortly after the unit was brought back on line, it was evident that the flow pattern had been significantly changed and that mass flow had been achieved with the sub-bituminous coal.

• RESULTS
Since the installation, the bunkers have performed extremely well. Coal stagnation and the risk of bunker fires have been eliminated.

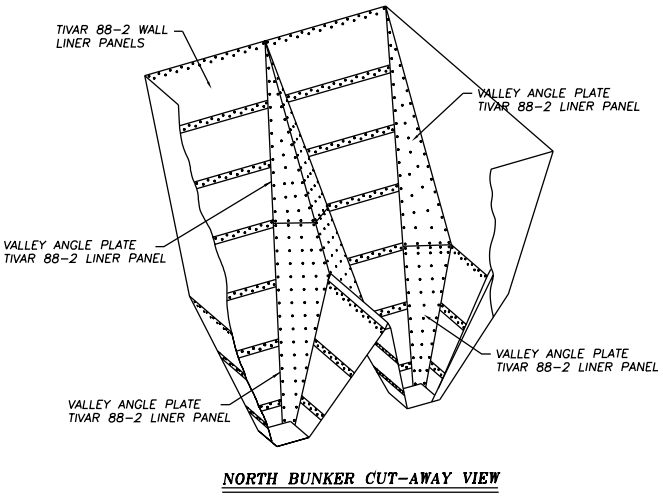

Figure 1: TIVAR® 88-2 liners were used on the valley angle clean-out as well as the sloping walls in the bunker.

Case Study: Sub-Bituminous Coal

TIVAR® 88 HIGH PERFORMANCE LINING SOLUTIONS

CASE IN BRIEF
Application: 250-ton Railcar Receiving Bunkers
Quantity: 2 Bunkers
Liner: TIVAR® 88, 3/4" Thick

Bulk Material: Sub-Bituminous Coal (PRB)
Substrate: Gunite
Problem: Coal sticking, hang-up and stagnation
Date Installed: 1986

Coal Flows Reliably After Installing TIVAR® 88 Liners in Concrete Railcar Receiving Bunkers

• BACKGROUND

The Xcel Energy (formerly Northern States Power) Black Dog Power Plant, located in Burnsville, Minn,, is a coal-fired facility that burns a low sulfur, sub-bituminous coal from Wyoming and Montana.

The coal receiving system consisted of two 250-ton hoppers that were located below ground in an outdoor railcar receiving shed. The hoppers were fed through a grizzly by bottom dump railcars and tractor scrapers that retrieved coal from an outdoor stockpile. The hoppers themselves were constructed of concrete in a wedge-shaped design with sloping wall angles of 50-52° from horizontal. Coal was discharged from each hopper through a 5′ x 5′ square outlet at a rate of 600 to 800 tons per hour onto a 60″ wide belt conveyor (Fig. 1).

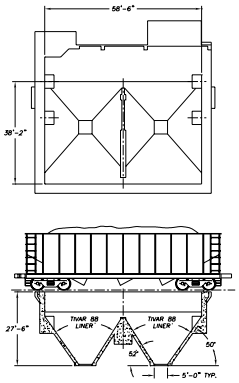

Figure 1: Plan and elevation views of Black Dog rail dump receiving bunkers. Note: Coal flow stagnation problems originated in the valley angles of the bunkers.

• PROBLEM

The two primary coal receiving hoppers did not provide consistent discharge of the 4″ x 0 sub-bituminous coal. As a result, plant personnel were forced to poke the coal with steel rods to maintain material flow – an extremely inefficient, costly and unreliable method of operation.

In early 1986, Xcel Energy contracted with Abe W. Mathews Engineering Company to develop a solution to the flow problems existing in the coal receiving hoppers. Following an evaluation of the coal receiving system, Abe Mathews Company determined the flow problems were the result of three elements working in conjunction that caused the coal to stick and cling to the hopper sidewalls and build to the no-flow point.

The first element was the shallow angle of the hopper walls – only 50°-52° from horizontal. The second element was the condition of the interior wall. The concrete surface was pitted and porous enough to serve as a deterrent to material flow. The final element was the condition of the coal. The coal being fed into the hoppers had a high percentage of moisture due to outdoor stockpiling, transportation and winter snow.

• SOLUTION

Abe Mathews Company's recommendation was to install TIVAR® 88 liners on the sloping walls of the concrete bunkers. TIVAR® 88 liners, with their low coefficient of friction and non-stick surface, would cover the pitted concrete, as well as compensate for both the shallow wall angles and the stickiness of the high-moisture coal. In 1987, 3/4″-thick TIVAR® 88 liners were installed in the receiving hoppers by a certified Quadrant contractor. All fasteners were countersunk and protected with a TIVAR® plug (Fig. 2) to provide a smooth surface for the flowing coal.

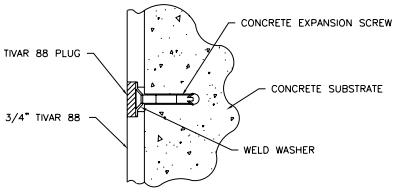

Figure 2: TIVAR® 88 attachment system detail

• RESULTS

The extremely low surface friction of TIVAR® 88 liners dramatically improved the coal flow through the receiving hoppers. The need for rodding the coal to stimulate material flow was reduced from an everyday occurrence to once or twice a year. The TIVAR® 88 liners also serve as an excellent wear surface.

The TIVAR® 88 liners showed no visible signs of wear even after 1,000,000 tons of coal had been conveyed through each hopper. Black Dog Plant personnel were so impressed by the results of the TIVAR® 88 liners in this application that they have installed TIVAR® 88 liners in other chutes and hoppers.

• UPDATE

A 3/4″ TIVAR® 88 liner system is still being used in the concrete railcar bunkers at Xcel Energy - Black Dog Plant. The original TIVAR® 88 liner system was installed in 1986 and lasted for 22 years. In 2008, the TIVAR® 88 liner 4 was replaced and installed by Xcel Energy's personnel. The TIVAR® 88 liner material has performed as expected.

Case Study: Sub-Bituminous Coal

TIVAR® 88 HIGH PERFORMANCE LINING SOLUTIONS

CASE IN BRIEF
Application: Unit 8 Bunker
Quantity: 5 Outlets
Liner: TIVAR® 88, 1/2" Thick

Bulk Material: Sub-Bituminous Coal (PRB
Substrate: Gunite and Stainless Steel
Problem: Spontaneous combustion due to stagnant coal
Date Installed: 1994

Xcel Energy Uses TIVAR® 88 to Solve Sub-Bituminous Coal Handling Problems

• ABSTRACT
This paper focuses on the storage and handling problems associated with the use of sub-bituminous coal mined in the western United States and how Xcel Energy (formerly Northern States Power) solved them at its Riverside Generating Station.

Comparative differences in the storage characteristics of sub-bituminous coal and bituminous coal, and the effect of common bunker geometries, construction and internal surface finishes on coal flow will also be discussed.

In addition, a portion of the paper addresses the issue of spontaneous combustion relative to storing sub-bituminous coal in storage bins, bunkers and silos. An analysis of the problem is presented based on actual experiences of power stations in the United States. Risk and liability of spontaneous combustion will be considered along with the financial impact.

Specifically, the different types of bunker flow patterns are described along with experiences of handling sub-bituminous coal.

We will discuss commonly used flow-correcting solutions, such as inserts and hopper liners, that minimize or eliminate flow problems within coal storage systems as well as reduce the potential for spontaneous combustion and bunker fires.

According to some theories, spontaneous combustion is most likely to occur in storage bins that contain regions of stagnant coal due to limited flow conditions. These "dead" regions are usually the result of funnel flow bin design.

In contrast, mass flow bins, in which all of the material is in motion whenever any of it is withdrawn, eliminate stagnation. At the Riverside plant, the original funnel flow bins were converted to mass flow for the purpose of eliminating the "dead" regions.

This conversion process, including the analysis leading to the implementation of the project is described in detail within the confines of this paper. In addition, we have reviewed the economic justification, operating performance and overall solution, with emphasis on transferring this knowledge to other power plants and applications.

There are many power stations that experience coal-handling problems similar to those of the Riverside plant, but are not aware that it is possible to eliminate these problems and ensure a reliable storage and discharge system. These problems have been magnified in recent years as power plants switch fuels to comply with the Clean Air Act. For example, many coal storage bunkers were not designed to handle the cohesive, poor-flowing coal characteristic of the low-sulfur sub-bituminous coal mined in the western United States.

• BACKGROUND
Xcel Energy's Riverside plant is a two-unit, 384 MW coal-fired station located in Minneapolis, Minn. The coal bunkers in Units 7 and 8 were built in 1949 and 1963, respectively. They were originally designed to handle relatively free-flowing bituminous coal.

At the time of construction, bunker design was based on storage capacity, space constraints and process requirements. The flow properties of the coal being handled were not a priority. Flow problems did occur in bunkers handling bituminous coal but were not considered unusual. Companies learned to live with the problems rather than search for methods to alleviate them.

After switching to low-sulfur sub-bituminous coal from the Powder River Basin, the coal storage bunkers at this plant experienced several fires and an explosion resulting from spontaneous combustion.

The most recent incident happened in Unit 7 when an explosion occurred in the coal storage bunker in November 1993. It was determined that coal in the bunker ignited due to spontaneous combustion at the same time that coal dust from the dust collection system was being conveyed back into the bunker. The dust exploded when it came in contact with the hot coal.

As a result of the Unit 7 bunker explosion, Xcel Energy management established a task force to investigate the situation and develop a corrective solution to eliminate fires and explosions at all of its coal-fired plants.

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Case Study: Sub-Bituminous Coal

Xcel Energy Uses TIVAR® 88 to Solve Sub-Bituminous Coal Handling Problems (cont.)

A forced outage in Unit 8 at Riverside in March 1994, was an opportunity for the task force to implement flow-correcting modifications, designed to meet Xcel Energy's goal of eliminating coal stagnation in the bunker as well as fires and explosions.

• EVALUATION OF UNIT 8 COAL BUNKER

The coal bunker was found to contain very large regions of stagnant coal due to the flow pattern in the bin. These "dead" regions started to form in the valley angles and would enlarge outwardly along the bunker walls due to the cohesive nature of the sub-bituminous coal and the rough surface of the gunite. Eventually, these regions of stagnant coal severely reduced a large portion of the bunker's "live" capacity, as shown in Fig. 1. The coal, soft with a moisture content up to 37%, easily compacts or consolidates during storage. The situation was not expected to improve as long as this flow pattern remained the same.

The funnel flow pattern was primarily due to the bunker geometry and condition of the hopper wall surfaces. The hopper walls were not smooth or steep enough to force flow along them. Funnel flow can be described as a first-in, last-out sequence, which means that coal introduced first into the bunker may remain there indefinitely.

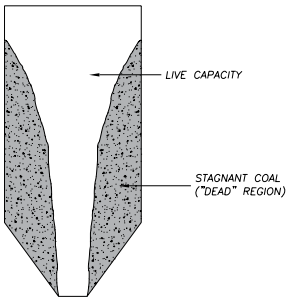

Figure 1: Stagnant coal forms in the bunker and severely reduces the bunker's live capacity.

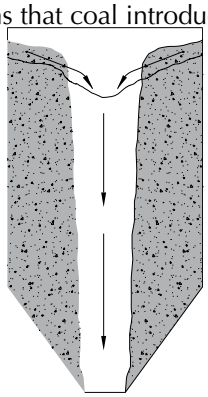

Figure 2: Material flows preferentially through a funnel-shaped channel directly above the outlet while the rest is stagnant.

Funnel flow discharge is characterized by a condition in which the hopper wall angles are too shallow or surfaces too rough for coal to slide along them. As a result, material flows preferentially through a funnel-shaped channel located directly above the outlet while mate-rial outside the flow channel is stagnant[1] (Fig. 2). Ratholes and arches (Fig. 3) form readily when non free-flowing bulk solids are handled in funnel flow bins.

Funnel flow bins are for coarse free-flowing bulk solids that do not segregate or degrade with time. However, they are not suitable for cohesive bulk solids. When coal remains stagnant long enough, it becomes highly susceptible to spontaneous combustion. Non-flowing or "dead" regions are a result of funnel flow in most situations. Theoretically, the stagnant coal may never discharge if it solidifies along the bunker walls. Mechanical means may be necessary to break it up and dislodge it.

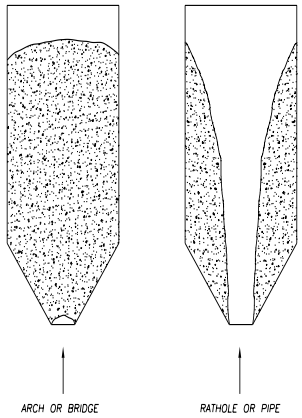

Figure 3: Ratholes and arches form readily when non free-flowing bulk solids are handled in funnel flow bins.

The task force concluded that coal stagnation caused the fires. They began their search for a solution to eliminate the "dead" regions within the bunker. At this point, the task force had only four options: do nothing, install more flow promotion devices, change the hopper wall material to one with a lower surface friction, or modify the existing bunker geometry.

The original coal bunker (Fig. 4), was equipped with twenty air cannons, two on each of the five pyramidal-shaped hoppers and ten on the vertical wall section of the bunker. The vertical and sloping wall sections of the bunker were coated with a 2"-thick gunite surface down to the top of the five discharge hoppers, which were constructed of stainless steel.

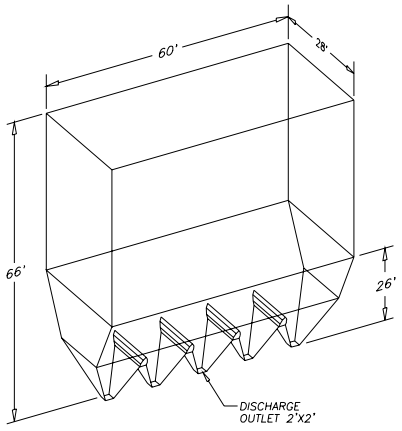

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Figure 4: Original design of the bunker in Unit 8. The vertical and sloping walls were coated with 2" - thick gunite and the hoppers were constructed of stainless steel. The 20 air cannons are not shown.

Case Study: Sub-Bituminous Coal

TIVAR® 88 HIGH PERFORMANCE LINING SOLUTIONS

Xcel Energy Uses TIVAR® 88 to Solve Sub-Bituminous Coal Handling Problems (cont.)

Close inspection of the five discharge hoppers revealed that coal flow was limited to a central core immediately above the outlets. This fact was established by excessive discoloration and corrosion on the stainless steel walls.

A highly polished area on the stainless steel existed immediately above each discharge outlet indicating that flow was confined to a relatively small central channel. Xcel Energy engineers estimated this flow pattern reduced the "live" storage capacity of the bunker by 20%.

Xcel Energy contacted Quadrant's SystemTIVAR® Engineering Group and inquired about the possibility of using TIVAR® 88 to achieve their objectives, thinking it might provide a solution to this flow problem since it (TIVAR® 88) had been used successfully at the Black Dog Power Plant (Burnsville, Minn.) in a rail dump receiving hopper. Quadrant's SystemTIVAR® Engineering Group studied the current design of the bunker along with the current coal flow problems and determined that a solution was possible, but knew it would require further analysis in order to substantiate the effectiveness of a TIVAR® 88 liner. Quadrant's SystemTIVAR® Engineering Group referred Xcel to Jenike & Johanson, Inc., consultants located in Westford, Mass, and San Luis Obispo, Calif., who are experts in the flow of solids from bins and hoppers.

• SOLUTION

As stated previously, Xcel Energy's top priorities were to prevent fires, decrease coal stagnation and increase coal flow/capacity. To do so, it would be necessary to eliminate the regions of stagnant coal. In mass flow design, all of the bulk solid in the bin is in motion whenever any of it is withdrawn. It is a first-in, first-out flow pattern (Fig. 5). This flow pattern eliminates stagnant or "dead" regions of non-free-flowing bulk solids. It provides complete and reliable uninterrupted flow from the bin.

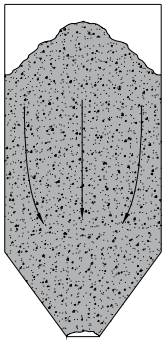

Figure 5: Mass flow is one in which all of the bulk solid in the bin is in motion whenever any of it is withdrawn.

Xcel Energy engineers knew that bunker modifications were required to change the existing funnel flow design to mass flow design. Because a change of this nature affects the pressure distribution within the hopper during discharge, and the flow properties of the coal would have a major influence on the proposed modification, Xcel Energy engineers contacted Jenike & Johanson to test a representative sample of the coal and make recommendations for modifications to the bunkers.

Samples of the coal were collected and flow property testing began using the Jenike Shear Tester[2] (see Fig. 6), which measures friction between coal and various wall materials. Coal samples are placed in a retaining ring that sits on top of the proposed wall materials. Weights are applied to the coal to simulate the normal pressure that will occur in the bin. The coal is then forced to slide along the proposed wall material and the shear force is measured. The proposed wall materials chosen for this test were 304-2B stainless steel, aged (corroded) carbon steel and TIVAR® 88. The Jenike & Johanson flow properties test report confirmed that carbon steel would be unsuitable as a wall material in the bunker because the coal adhered to the carbon steel surface. It also showed the shear force on TIVAR® 88 was lower than on 304-2B stainless steel[3].

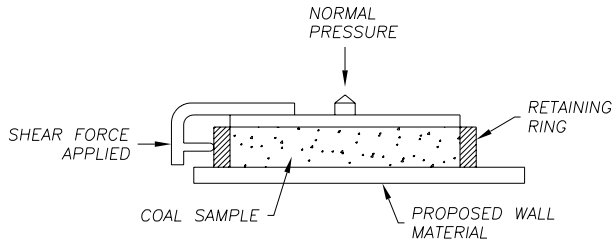

Figure 6: Jenike Shear Tester (ASTM D 6128-97) measures the shearing force required for the coal to slide along a wall material.

The flow properties test report indicated that the sub-bituminous coal at 37% moisture content has enough strength to form stable ratholes in a funnel flow hopper even under continuous flow conditions. The tests also indicated the critical arching dimension of the coal would increase from 1.5 ft. diameter during continuous flow to 6.2 ft. diameter after three days of storage at rest. This means that some sort of flow aid is required to induce flow after the storage period[4].

• JENIKE & JOHANSON, INC. RECOMMENDATION

Jenike & Johanson recommended converting the bunker to mass flow to avoid "dead" regions and the associated fires in the bunker. Structural analysis of the existing bunker confirmed it could withstand the pressures associated with mass flow. In order to accomplish mass flow, the following modifications to the existing bunker were necessary:

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Case Study: Sub-Bituminous Coal

Xcel Energy Uses TIVAR® 88 to Solve Sub-Bituminous Coal Handling Problems (cont.)

• Replace the bottom section of each pyramidal hopper with new conical extensions;
• A BINSERT®[5] (cone-in-cone design used to achieve mass flow with minimum headroom), as discussed by Carson and Dick[6,7], should be installed in the lower portion of the bunker above each hopper outlet;
• The remaining portion of each pyramidal hopper, including the valley angles, the BINSERT, the new conical extensions and the sloping bunker walls should all be lined with TIVAR® 88 1/2″-thick .

The complete modification is shown in Figs. 7 & 8. Xcel Energy was also given instructions regarding the quality of workmanship required to get the greatest benefit from the modifications. This included such items as grinding weldments, proper mating of flanges and proper layout and attachment procedures for TIVAR® 88 liners to eliminate any unnecessary obstructions in the flow channel[8].

• PERFORMING THE MODIFICATIONS

Once Xcel Energy agreed to perform the modifications recommended by Jenike & Johanson, all contractors met at the Riverside Plant to lay out the plan details. This planning meeting took place in March 1994 and included the Xcel Energy engineering staff, Quadrant's SystemTIVAR® Engineering Group engineers, a certified Quadrant's SystemTIVAR® Engineering Group installation contractor, Acrotech Services, Inc. of Bismarck, N.D. and Xcel Energy's Special Construction Unit from the Ironworkers Local Union 512.

Understanding and implementing the sequence of steps required to complete the modification was critical to the success of the project (Table 1). The team had 50 days to complete the entire modification. The ironworkers carried out the steel modification procedures and the TIVAR® 88 liner installation.

Quadrant's SystemTIVAR® Engineering Group provided engineering assistance and drawings showing the exact liner layout and attachment method. The TIVAR® 88 certified installation contractor supervised the entire liner installation and engineers from Quadrant's SystemTIVAR® Engineering Group were at the job site during different phases of the installation to monitor the procedures and progress of the work.

• CONCLUSION

Upon completion of the modification – within the scheduled time period – the bunkers were filled with sub-bituminous coal and Unit 8 went back on line.

Employees in the coal yard reported that prior to the modification, they would stop filling the Unit 8 bunker every day at 4 p.m. and by 3 a.m. (the next day) the bunker had to be charged with fuel as indicated by the level sensors in the bunker. They were able to obtain 11 hours worth of fuel from the bunker before it required refueling.

Since the modification, the coal yard stops filling the bunker at 4 p.m. and it does not require refueling until 10 a.m. (the next day) or 18 hours later. These statistics indicate a "live" capacity improvement of 64% over the original design.

According to Xcel Energy personnel, the TIVAR® 88 liner continues to perform well with no flow problems after seven-and-a-half years in operation.

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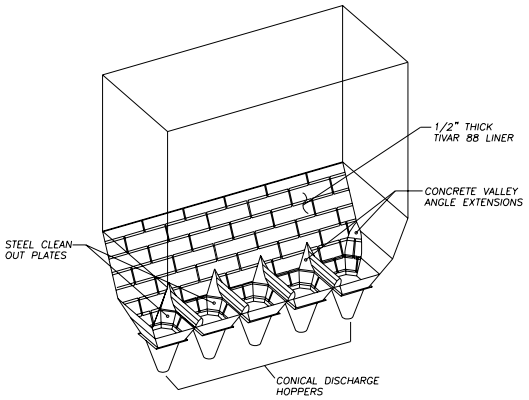

Figure 7: Partial view of the modification as recommended by Jenike & Johanson. The sheets of TIVAR® 88 are placed in a shingle (overlap) fashion to eliminate exposed horizontal seams and the vertical seams are protected by using a TIVAR® "H" profile.

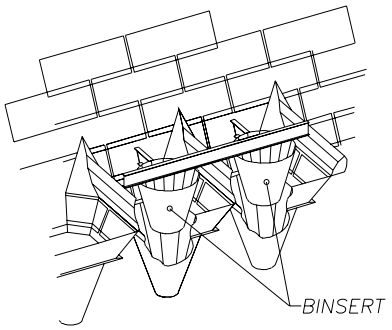

Figure 8: Exploded view of the hopper modification, showing two hoppers fitted with the BINSERT® design by Jenike & Johanson, Inc. The BINSERTs and outer hopper cones are lined with TIVAR® 88. *BINSERT® is a registered trademark of Jenike & Johanson.

Case Study: Sub-Bituminous Coal

Xcel Energy Uses TIVAR® 88 to Solve Sub-Bituminous Coal Handling Problems (cont.)

SEQUENCE	MODIFICATION PROCEDURE
1	Sandblast interior steel and gunite surfaces.
2	Frame the valley angles with wooden forms and fill with concrete.
3	Remove the existing standpipes.
4	Remove the lower 10 ft. of the five pyramidal shaped hoppers.
5	Weld four new conical shaped hoppers to the remaining portion of the pyramidal shaped hoppers.
6	Line the sloping, high friction gunite walls with TIVAR® 88, which is fastened directly to the gunite using concrete expansion bolts.
7	Raise the five new BINSERTs (lined with TIVAR® 88) into the bunker through the remaining opening in fifth hopper section.
8	Install the steel support beams and attach the BINSERTs.
9	Weld the fifth new conical shaped hopper to the last pyramidal shaped hopper.
10	Continue lining the concrete valley angles, the pyramidal shaped upper hopper sections, and the new conical shaped lower hopper sections with TIVAR® 88. (The TIVAR® 88 was fastened to the steel substrate with a weld washer attachment system.)

Table 1: Sequence of procedures to complete the bunker modification within 50 days.

• REFERENCES

[1] Marinelli, J. and Carson, J.W.: "Solve Solids Flow Problems in Bins, Hoppers, and Feeders"; Chemical Engineering Progress, May 1992, pp. 22-28.

[2] Jenike, A.W.: Storage and Flow of Solids, Bulletin 123; University of Utah, Engineering Experiment Station, Nov. 1964.

[3] McAtee, K., Bermes, S. and Goldberg, E.: "TIVAR® 88 Provides Reliable Gravity Discharge from Coal Storage Silos," bulk solids handling, Vol. 11 (1991) No. 1, pp. 79-83.

[4] Jenike & Johanson, Inc. Report 932930-1: "Modifications to Unit 8 Coal Bunker, Northern States Power Riverside Plant," April 19, 1994.

[5] Johanson, J.R.: "Blending Apparatus for Bulk Solids"; US Patent #4,286,883 Sept. 1, 1981.

[6] Carson, J.W. and Dick, D.S.: "How Bin Retrofits Can Correct Flow Problems", Presented at the AIChE Spring National Meeting, Houston, April 4, 1989.

[7] Carson, J.W.: "North American Advances in the Design of Silos, Bins and Hoppers", bulk solids handling, Vol. 11 (1991) No. 1, pp. 37-44.

[8] Steppling, K. and Hossfeld, R.J.: "Ultrahigh Molecular Weight Polyethylene Abrasion Resistant Liners Facilitate Solids Flow in Hoppers", bulk solids handling, Vol. 5 (1985) No. 5, pp. 1049-1052.

Case Study: Sub-Bituminous Coal

TIVAR® 88 HIGH PERFORMANCE LINING SOLUTIONS

CASE IN BRIEF
Application: Receiving Bunkers
Quantity: 1 Receiving Bunker
Liner: TIVAR® 88, 1/2" Thick

Bulk Material: Sub-Bituminous Coal
Substrate: Concrete
Problem: Ratholing, no flow condition
Date Installed: 1993

TIVAR® 88 Liners Eliminate Flow Restriction in Concrete Receiving Bunkers

• BACKGROUND
Comision Federal De Electricidad (C.F.E.) is Mexico's state run electric utility. The Carbon II 1,400 MW coal-fired power station in Piedras Negras, Coahuila, Mexico consists of four units that generate 350 MW each.

Two of the concrete receiving bunkers are located outside to accept sub-bituminous coal retrieved from an outdoor stockpile. The hoppers themselves were constructed of concrete in a wedge-shaped design (Fig. 1) with sloping wall angles of 56-60° from horizontal. The hopper was designed to discharge the coal through a 980mm x 980mm (38 1/2" x 38 1/2") square outlet at a rate of 800 to 1,000 tons per hour onto a vibrating feeder.

• PROBLEM
The sub-bituminous coal would adhere to the sloping concrete walls in the bunkers almost to the point of complete blockage. It also adhered to the vibrating feeders directly beneath the hoppers. This severe adhesion resulted in a discharge flow rate of only 200 to 300 tons per hour, although the designed capacity was 800 to 1,000 tons per hour. In an effort to improve the flow rate, plant personnel rodded the coal on a continuous basis whenever the coal was wet, a problem exacerbated during the rainy season.

• SOLUTION
In order to eliminate coal adhesion on the bunker's sloping walls, they were lined with 1/2"-thick TIVAR® 88. This material has a very low coefficient of friction that works well on shallow wall angles, allowing cohesive sub-bituminous coal to slide along its surface. The vibrating feeders were also lined with 1/2"-thick TIVAR® 88.

The TIVAR® 88 was fastened directly to the concrete using concrete expansion bolts which were capped with a TIVAR® plug (Fig. 2) to protect the fastener and to provide a smooth liner surface. This installation took place in early 1993.

The outdoor bunkers are in direct sunlight. Therefore, the TIVAR® 88 was supplied with a UV package (black color) for protection from ultraviolet radiation.

• RESULTS
The extremely low surface friction of the TIVAR® 88 liners immediately and dramatically improved coal flow through the receiving hoppers. The need for rodding the coal to stimulate material flow has been eliminated. In addition to providing a low coefficient of friction, the TIVAR® 88 liners also serve as an excellent wear surface.

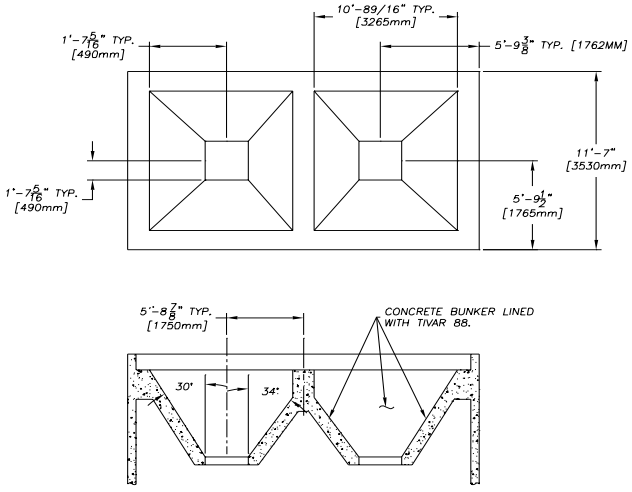

Figure 1: Coal receiving bunker

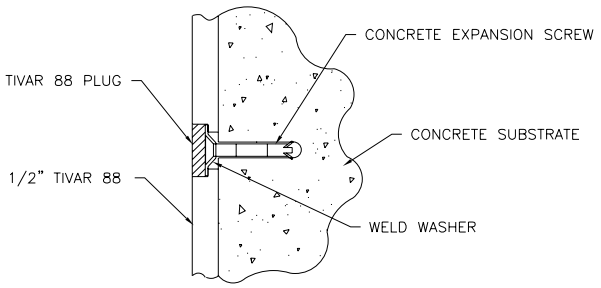

Figure 2: Detail of TIVAR® 88 attachment system

Case Study: Sub-Bituminous Coal

TIVAR® 88 HIGH PERFORMANCE LINING SOLUTIONS

CASE IN BRIEF
Application: Fuel Silos
Quantity: 5 Silos
Liner: TIVAR® 88, 1/2" Thick

Bulk Material: Sub-Bituminous Coal
Substrate: 316 Stainless Steel
Problem: Ratholing, no flow condition
Date Installed: 1993

TIVAR® 88 Liners Eliminate Ratholing, Create Mass Flow

• BACKGROUND

Comision Federal De Electricidad (C.F.E.) is Mexico's state run electric utility. The Carbon II 1,400 MW coal-fired power station in Piedras Negras, Coahuila, Mexico consists of four units that generate 350 MW apiece. The facility burns approximately 260,000 tons of sub-bituminous coal annually, using coal mined at Mexico's Mincare Mine. Each unit at the power station has five, 1,000-ton-capacity storage silos designed with a carbon steel cylinder section and a 316 stainless steel eccentric hopper section (Fig. 1).

Photo A: Plant personnel would regularly beat on the hoppers when the coal stopped flowing.

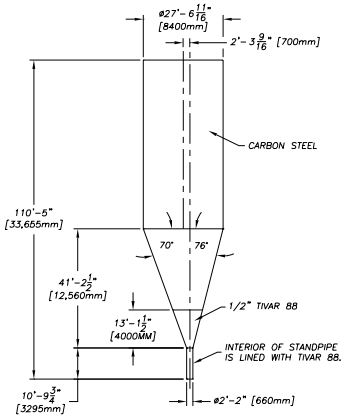

Figure 1: Original eccentric hopper at Carbon II

• PROBLEM

During the rainy season in the fall and winter, the 3/4"x 0 sub-bituminous coal (45-60% fines) adhered to the interior vertical walls of the standpipes and to the stainless steel hopper walls (Photo A). The funnel flow pattern in the silos resulted in the formation of stable ratholes that extended from the outlet to nearly the top of the cylinder. The storage capacity of these silos was significantly reduced.

• SOLUTION

To create mass flow with the silos, it was necessary to eliminate ratholing. To do this, the standpipes and lower part of the hopper cones were lined with 1/2"-thick TIVAR® 88 (Fig. 3), recognized worldwide for its low coefficient of friction. The project took place during regularly scheduled shutdowns in 1993.

The liner was placed directly on top of the stainless steel in the hopper sections of the silos using a weldable fastener, which was then covered with a TIVAR® plug to maintain surface continuity along the hopper wall (Fig. 4). For the standpipes, which lead to the gravimetric feeders, 1/2"-thick TIVAR® 88 sheet was easily formed to proper size and shape by the installer.

• RESULTS

TIVAR® 88's key performance property – low coefficient of friction – allowed the power station to achieve the desired mass flow within the hoppers by eliminating the ratholing that occurred due to the funnel flow pattern. The storage capacity of the silos in the original design is now fully realized.

• COMMENTS

In addition to loss of capacity, stable ratholes have collapsed in large silos resulting in severe structural damage to the silo. This event can be life-threatening to plant personnel. In less severe situations, collapsing ratholes may form an arch over the hopper outlet, creating a no-flow condition.

The use of partial TIVAR® 88 hopper linings within a silo may not be sufficient to create mass flow in all circumstances. Coal flowability characteristics are different for coal mined in different locations. Often, it is necessary to line the entire hopper section with TIVAR® 88 to promote mass flow. Flowability tests can be run on the coal using the Jenike Shear Tester (ASTM D 6128-97) to evaluate the performance of a hopper liner in specific applications.

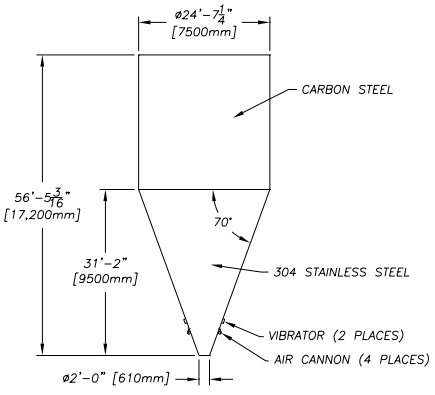

Figure 3: Eccentric hoppers and standpipes at Carbon II are lined with 1/2" -thick TIVAR® 88.

In new construction, it is economically sound to consider a TIVAR® 88 liner with a carbon steel substrate for hoppers handling non-free-flowing, cohesive bulk solids such as sub-bituminous and lignite coal, lime, limestone, FGD sludge (synthetic gypsum) and flyash.

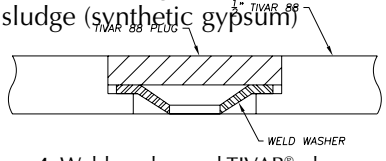

Figure 4: Weld washer and TIVAR® plug assembly

Case Study: Sub-Bituminous Coal

TIVAR® 88 HIGH PERFORMANCE LINING SOLUTIONS

CASE IN BRIEF
Application: Coal Silos
Quantity: Five 500-Ton Silos
Liner: TIVAR® 88, 1/2" Thick

Bulk Material: Sub-Bituminous Coal
Substrate: 304-2B Stainless Steel
Problem: Complete blockage/bridging in lower portion of cone
Date Installed: 1992

TIVAR® 88 Liners Reduce Coal Silo Blockage Occurrences at Power Plant from 200 to 1

• BACKGROUND
Perusahaan Umum Listrik Negara (PLN) is Indonesia's national electric utility – the primary electricity supplier for the country. The coal-fired steam boilers supply approximately 40% of the electricity on Java Island.

The Suralaya Power Station is an existing PLN facility with four units of 400 MW (megawatts) each. This coal-fired plant burns sub-bituminous coal that is mined at Sumatra in Indonesia. Unit 1 has been in operation since 1984, Unit 2 since 1985, Unit 3 since 1987 and Unit 4 since 1988.

• PROBLEM
Unit 2 coal silos were originally constructed with a carbon steel cylinder section and a 70° (from horizontal) hopper section of carbon steel clad with a 304 stainless steel with a 2B finish (Fig. 1).

The plant experienced complete blockage or bridging in the lower hopper cone section of the silos an average of 200 times each year. The vibrators, originally installed on the hopper sections, provided no contribution to the flow improvement so plant personnel resorted to using sledgehammers to beat on the hoppers and downspouts (standpipes) to maintain coal flow.

The station was derated by 25% (maximum of 100 MW) of its designed electrical output capacity due to the blockages that lasted an average of 15 minutes each time.

• SOLUTION
In 1991, TIVAR® 88 linings were introduced to the Suralaya Power Station as a flow improvement solution for these 500-ton cylindrical coal silos. In July 1992, the hopper portion of the five silos at Suralaya in Unit 2 were lined with 1/2"-thick TIVAR® 88. The TIVAR® 88 was installed directly over the 304 stainless steel (Fig. 2).

• RESULTS
During the next year, the power plant experienced only one blockage in the TIVAR® 88 lined hoppers – a reduction in the number of occurrences of nearly 100 percent.

Due to the extremely satisfactory performance of the TIVAR® 88 hopper liners in Unit 2, plant personnel have expressed great satisfaction and an intent to line silos in three additional units. All liners continue to perform successfully.

• COMMENTS
Coal-fired power plants often experience a variety of flow problems in coal silos even when hopper sections are designed with 70° cones that are lined with 304 stainless steel with a 2B finish. These coal-handling problems are particularly apparent when handling sub-bituminous and lignite coals due to the combination of finer particle sizes and high moisture levels.

During these occurrences, plant personnel often resort to "active" methods to achieve bulk flow, i.e., using mechanical means such as vibrators or sledgehammers. There is a theory in this industry that the problem will be alleviated as the flowing coal polishes the stainless steel surface. Unfortunately, this does not always happen.

In order to ensure smooth uninterrupted flow and eliminate the problems within the hopper, a passive method, such as the installation of a TIVAR® 88 liner over the stainless steel, is the most effective, cost-efficient long-term solution. TIVAR® 88's extremely low coefficient of friction allows the coal to flow smoothly down the 70° hopper wall.

In new construction, it is economically sound to consider a TIVAR® 88 liner with a carbon steel substrate for hoppers handling non-free-flowing, cohesive bulk solids such as, sub-bituminous and lignite coal, lime, limestone, FGD sludge (synthetic gypsum) and flyash.

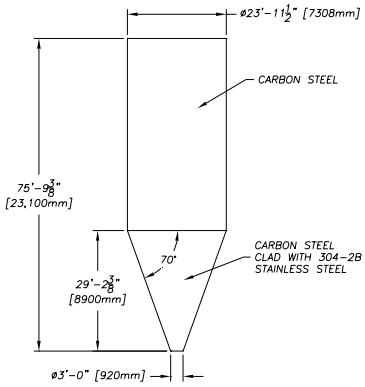

Figure 1 (right): Original hopper designed with a 304-2B stainless steel liner

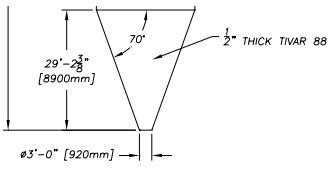

Figure 2 (below): Detail of TIVAR® 88 lined hopper provides, reliable, uninterrupted coal flow

Case Study: Sub-Bituminous Coal

TIVAR® 88 HIGH PERFORMANCE LINING SOLUTIONS

CASE IN BRIEF
Application: 500- to 700-ton Silos
Quantity: 28 Silos
Liner: TIVAR® 88, 1/2" Thick

Bulk Material: Sub-Bituminous Coal
Substrate: Stainless Steel
Problem: Flow problems, bridging, ratholing
Date Installed: 1984

Mass Flow Achieved in Gravity Discharge Coal Storage Silos

• BACKGROUND

American Electric Power (AEP) is a public utility holding company that owns several electric utilities. The AEP Indiana-Michigan Rockport Plant is one of the newer power plants in the AEP system, with an annual output capacity exceeding 9,000,000 KWH. The plant burns approximately 10,000,000 tons of sub-bituminous coal annually, mined in the Powder River Basin of Wyoming. Sub-bituminous coal mined from this area has a low sulfur content and a moisture content between 30% and 40%.

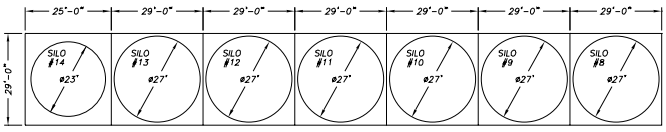

Figure 1: Plan view of Unit 1 coal silos; Unit 2 is identical

Twenty-eight storage silos provide indoor coal storage for Units 1 & 2 at the Rockport plant. Within the individual battery of 14 silos (Fig.1) for each unit, 12 of the silos have a storage capacity of 778 tons each. The other two silos have a storage capacity of 553 tons each. All 28 silos are constructed of 3/8" high-strength, low alloy steel with a 16 gauge 304 stainless steel 2B finish liner in the hopper cone (Fig. 2).

• PROBLEM

Ratholing and bridging problems developed in the storage silos of Unit 1 during its initial start-up. These plugging problems caused disruption in the coal flow and lowered the electric power output of the generating unit. Conservative estimates indicated that this plugging problem could result in a loss of up to 100 MW of electric power per silo during the 3 to 4 hours required to restore coal flow. Plant personnel unsuccessfully attempted to alleviate coal-plugging problems using sledgehammers and portable unit heaters.

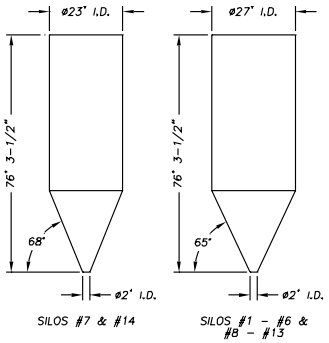

Figure 2: Silo geometry - elevation view of the two hopper configurations

• SOLUTION

In an effort to evaluate and compare performance properties of various materials before committing to one lining material over another, the lower 10 ft. sections of only four silos were lined, each with a different material. In the two silos lined with TIVAR®, there was an immediate reduction in the coal bridging and ratholing problems.

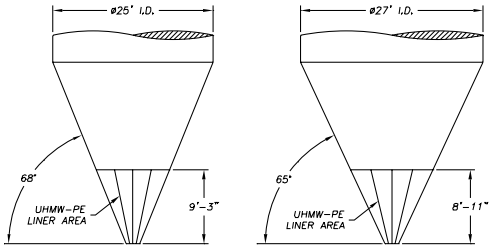

Figure 3: Drawing showing the liner location

To substantiate these results and determine the long-term suitability of this solution, (prior to making a final decision on a solution to achieve mass flow in these gravity discharge silos), AEP contracted with a consulting firm specializing in the field of bulk solids flow to determine the parameters necessary to produce a mass flow condition within the storage silos. With supportive findings from the consulting firm, AEP proceeded with the installation of TIVAR® 88 liners in the remaining unlined silos of Unit 1. Using a stainless steel weld washer fastening system, 3/8" TIVAR® 88 was installed in the lower 10 ft. sections of the cones and a stainless steel leading edge protector (Figs. 3, 4, 5) was attached to prevent migration of the coal between the liner and the hopper wall.

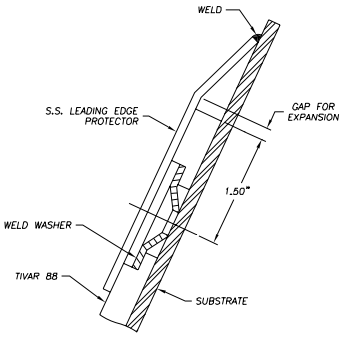

Figure 4: Typical stainless steel leading edge protector detail

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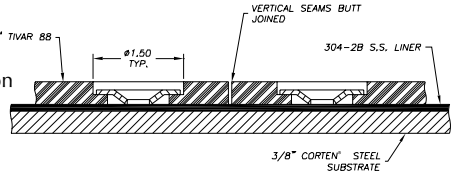

Figure 5: Cross-section of the weld washer and vertical seams

Case Study: Sub-Bituminous Coal

TIVAR® 88 HIGH PERFORMANCE LINING SOLUTIONS

Mass Flow Achieved in Gravity Discharge Coal Storage Silos (cont.)

• RESULTS

With the installation of the TIVAR® 88 liners, plugging problems have been reduced by 30-50% while the time required to restore coal flow has been reduced to less than 30 minutes, compared to the 3-4 hours of time spent previously.

Silo plugging problems that remain typically occur in the fall and winter due to high precipitation levels. According to plant personnel, the elimination of only one silo plugging occurrence has provided enough cost justification for the TIVAR® 88 lining system. Consequently, silos in Unit 2 were lined with 1/2" TIVAR® 88 using a stainless steel stud and spanner nut combination with a TIVAR® H-profile seam protector (Figs. 6, 7) (H-profile was used to provide vertical seam protection and prevent potential coal fine migration behind the liners.)

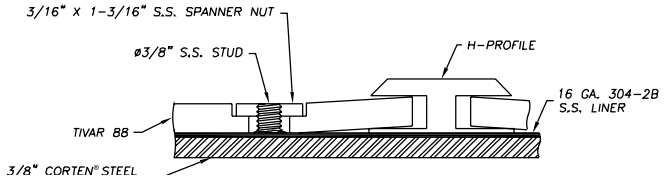

Figure 6: Cross-section of the weld stud, the spanner nut and the H-profile

• COMMENTS

Two key aspects of this case study are the performance benefits of TIVAR® 88 and the projected service life of TIVAR® 88 in gravity discharge applications. The consultant's test data supported field testing that TIVAR® 88 provided the lowest wall friction angle. However, in order to provide quantitative values of TIVAR® 88's superior slide abrasion wear resistance in gravity discharge silo applications, Jenike & Johanson, industry experts in the flow of solids industry, were hired to conduct a wear-life study for TIVAR® 88 and 304 stainless steel with a 2B finish using both western and eastern mined-coal. Results of the study projected a wear-life of 17+ years for TIVAR® 88 (Figs. 8, 9) with little or no decline in key properties, i.e. low coefficient of friction and slide abrasion wear resistance.

Based on this positive test data and the performance evaluation from AEP, it can be concluded that TIVAR® 88 liners provide economically justified, workable solutions to flow problems in gravity discharge silos.

CORTEN® is a registered trademark of USX Corporation

• UPDATE

AEO Rockport Plant was named the PRB Coal User's Group "2009 Plant of the Year." Quadrant's SystemTIVAR Engineering Group and their TIVAR® products were recognized as instrumental in allowing them to accomplish that goal. Over the 25 years since the original liners were installed, Rockport has performed only minimal maintenance on the liners. AEP continues to use TIVAR® 88 throughout Rockport and other plants to solve flow problems with a variety of bulk materials.

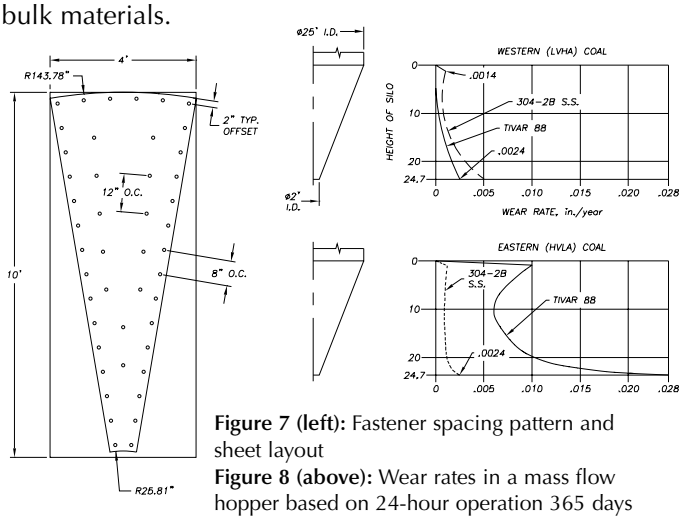

Figure 7 (left): Fastener spacing pattern and sheet layout

Figure 8 (above): Wear rates in a mass flow hopper based on 24-hour operation 365 days per year, assuming the coal has a bulk density of 50 lb/ft³ being withdrawn at 50 t/h

• REFERENCES

This case history is a condensed version of the article published by *bulk solids handling*, Vol. 11, No. 1, March 1991, and written by K. McAtee, S. Bermes and E. Goldberg.

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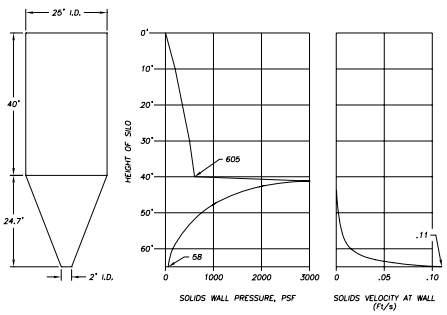


Figure 9: Solids pressure and velocity in a mass flow bin

Case Study: Bituminous Coal

TIVAR® 88 HIGH PERFORMANCE LINING SOLUTIONS

CASE IN BRIEF
Application: Coal Storage Bunkers and Feed
Quantity: 12 Bunkers and 20 Feeders
Liner: TIVAR® 88, 1/2" Thick

Bulk Material: Bituminous Coal
Problem: Existing basalt tiles fell out, restricted flow
Date Installed: 1984-1994

TIVAR® 88 Liners Improve Mass Flow in Discharge Feeders, Hoppers, Bunkers

• BACKGROUND
China Light & Power Co., Ltd. operates Castle Peak Power Station A and Power Station B. The two stations are located at Tap Shek Kok in Tuen Mun, N.T., Hong Kong and supply electricity to Kowloon, New Territories and most of the outlying island, including Lantau Island, the site of the new Hong Kong International Airport. Together, the stations have an electrical capacity of 4,110 MW and consumed over nine million tons of coal in a record-breaking year between October 1992 and September 1993. Both stations burn bituminous coal from China and Australia.

China Light & Power

• PROBLEM
Both units were built during a seven-year span from 1982 to 1989, and almost immediately experienced two-fold flow problems. Coal would begin to build up on the feeder sidewalls – restricting flow – and sliding abrasion wear was occurring on the bottom of the feeder pans.

Other flow problems were becoming apparent in Castle Peak B. The coal bunkers were initially lined with Basalt tiles. However, the tiles began falling out as a result of the impact loading. The large pockets or areas along the hopper wall where the tiles had fallen out trapped the coal and prevented it from flowing. The problem became worse as the coal continued to build on itself, forming large, stagnant regions in the bunkers. This restricted flow – sometimes "no-flow" – limited the capacity of the plant.

• SOLUTION
TIVAR® 88 was chosen for the first test in the feeders at Castle Peak A in 1984, eliminating hang-up and abrasion problems. Eventually, all 20 coal feeders were lined with 1/2"-thick TIVAR® 88 – covering approximately 11,400 sq. ft. of surface area between 1984 and 1994.

TIVAR® 88 was also chosen for the first trial hopper lining in Castle Peak B in 1988. The 1/2"-thick TIVA®® 88 was installed using a weld washer and TIVAR® plug for the fastening method. After receiving proper training from Quadrant's SystemTIVAR® Engineering and a Hong Kong-based SystemTIVAR® partner, the liners were installed by plant personnel from China Light. After the initial successful installation, an additional 12 coal bunkers at this station were lined with 1/2"-thick TIVAR® 88, covering a surface area of approximately 103,000 sq. ft.

• RESULTS
The coal now flows reliably on demand. China Light & Power is very happy with the overall results of the TIVAR® 88 liner installations.

• UPDATE
China Light & Power continues to be very satisfied with the success they have with Quadrant EPP's TIVAR® materials. CL&P is now using TIVAR® 88 with BurnGuard for many of their flow problems.

Case Study: Lignite Coal

TIVAR® 88 HIGH PERFORMANCE LINING SOLUTIONS

CASE IN BRIEF
Application: Steel Storage Bunkers
Quantity: : 8 Bunkers – Approx. 4,000 m²
Liner: TIVAR® 12 mm

Bulk Material: Lignite Coal
Substrate: Carbon Steel
Problem: Sticking, Bridging
Date Installed: 2006 – 2010

TIVAR® Solves Lignite Flow Problems

• BACKGROUND
The Rhineland, Germany is one of the largest lignite coal mining areas in Europe. Due to the high moisture content of the lignite coal mined here it is very adhesive and difficult to handle. Numerous lignite fired power plants are located throughout the Rhineland. The referenced power station has eight (8) large storage bunkers constructed of carbon steel.

• PROBLEM
This large power station continually had interruptions with the flow of coal through their storage bunkers due to the lignite coal sticking and bridging. The geometry and substrate of the bunkers caused the coal to build up in the valley angles and adhere to the sloped sections. The interruptions had serious effects on the operation and efficiency of the plant as well as creating many safety concerns.

• SOLUTION
A German Flow Consultant was employed to analyze the flow problems. Tests resulted in the specification of a 12 mm thick TIVAR® liner system to cover the storage bunkers. The corners were lined with pre-formed corner profiles with a radius of approx. 300 mm. The TIVAR® lining system was fastened in place using stainless steel weld studs and spanner nuts. All vertical and critical seams were extrusion welded to prevent the fine grained lignite from getting behind the liner. The complete lining project was designed, fabricated and installed by the Quadrant PHS Deutschland lining group.

• RESULTS
The low coefficient of friction and high wear properties of the TIVAR® lining system enabled the sticky lignite coal to freely flow through the storage bunkers. The pre-formed corners enhanced material flow and eliminated build up in the valley angles. As a result of the success with this project, numerous other chutes, hoppers and bunkers in the Rhineland area have been lined with TIVAR®. Over 20,000 m² of TIVAR® liners have been installed in lignite power stations in Germany.

Case Study: Lignite Coal

TIVAR® 88 HIGH PERFORMANCE LINING SOLUTIONS

CASE IN BRIEF
Application: Lignite Coal Storage
Quantity: 9 bunkers (4,000 m^2)
Liner: TIVAR® 88 12.5mm Thick

Bulk Material: Lignite Coal
Substrate: Mild Steel
Problem: Caking, Bridging
Date Installed: 1997-1999

TIVAR® 88 Liners Achieve Mass Flow of Lignite in Bunkers

• BACKGROUND
Turow Power Station is Poland's third largest lignite-fueled power station, with a capacity of 2,000 megawatts of electricity. The goals for the modernization of the plant were to update technology to improve production efficiency and to meet tough, new emissions requirements, which would enable the station to sell clean competitive power into national and European Union grids. In addition, the plant reconfiguration has been tagged as a model for the renovation of other old, inefficient, high-emission power plants.

• PROBLEM
Turow uses Polish lignite from open cast mining nearby in Bogatynia. Lignite, or brown coal, is a soft, brownish coal with a low carbon content and very high moisture content (approximately 44%). With a particle size of between 0 and 30mm – in addition to the high moisture content – the coal became very sticky, reducing flow consistency and power plant efficiency. The bunker geometry of this power plant, like others of its generation, made it very susceptible to caking, bridging and ratholing, resulting in unacceptably high periods of downtime and high maintenance costs.

• SOLUTION
Foster Wheeler Pyropower, in cooperation with ABB Poland was tapped to renovate the power station. Working closely with Quadrant's SystemTIVAR® Engineering Group in both Germany and the United States, Foster Wheeler hired Jenike & Johanson to conduct material flow tests. The result of those tests indicated that the wall angles of the plant were too shallow to allow mass flow to occur. Jenike & Johanson recommended the installation of TIVAR® 88 linings in order to achieve mass flow at these low valley angles. Nine bunkers, each with two outlets, were lined with 12.5mm thick TIVAR® 88. Corners were lined with shells to eliminate any areas in the outlets that would inhibit mass flow. In addition, proprietary welding techniques were used on all joints and corners to prevent material migration behind the liner.

• RESULTS
Due to the consistent, even flow of lignite through the bunkers, Turow Power Station now has the ability to efficiently produce electricity at capacity. With the modernization of the entire plant complete, SO2 emissions have been lowered by 92%, NOx by 19% and dust by 91%.

Case Study: Lead, Zinc Concentrate

TIVAR® 88 HIGH PERFORMANCE LINING SOLUTIONS

CASE IN BRIEF
Application: Bottom Dump Hopper Railcars
Quantity: 45 Hopper Railcars
Liner: TIVAR® 88-2, 3/8″ and 1/2″ Thick

Bulk Material: Lead, Zinc Concentrate
Substrate: Mild Steel
Problem: Poor discharge of concentrates
Date Installed: 1996

TIVAR® 88-2 Lining Incorporated into Hopper Railcar Design Improves Discharge Rate

• BACKGROUND
In the mid-1990s, plant personnel at a Canadian rail company received a mandate to develop and implement a plan to reduce unloading times at the dock and thereby reduce expenses by finding an economical way to modify the 45 existing hopper railcars that transported zinc and lead concentrate. The existing 100-ton railcars were built in 1966 with 45-degree interior sloping walls.

• PROBLEM
The zinc concentrate that was transported had a bulk density of 120 lbs. cu. ft. and moisture content of 6%. Due to the 1966 design, only 50% of the material discharged when the doors on the hopper rail car were opened. After bumping the car with a trackmobile three to four times another 35% discharged. Cleaning out the remaining 15% of the ore was a costly and time-consuming process, particularly in light of the time spent using the trackmobile and not receiving complete discharge of material.

• SOLUTION
Due to the age and design of the railcars, the company recognized that the cars needed a structural redesign and state-of-the-industry liners in order to achieve acceptable mass flow levels. Working in conjunction with the Quadrant's SystemTIVAR® Engineering Group team, one car was modified and lined as a test to determine if and how the material would flow. The interior of the car was modified by increasing the sloping walls from 45° to 70°. All wall surfaces of the railcars were lined with 3/8″-thick TIVAR® 88-2, but the discharge doors were covered with stainless steel.

• RESULTS
The test car, modified and lined with TIVAR® 88-2, completely discharged dry concentrates in 4 seconds and wet concentrates in 14 seconds, surpassing customer expectations. Test results for the stainless steel lining on the discharge doors were not as successful.

TIVAR® 88-2 liner panels and TIVAR® "H" profile as a seam protector provide a "super slick" interior surface on which the coal will flow reliably.

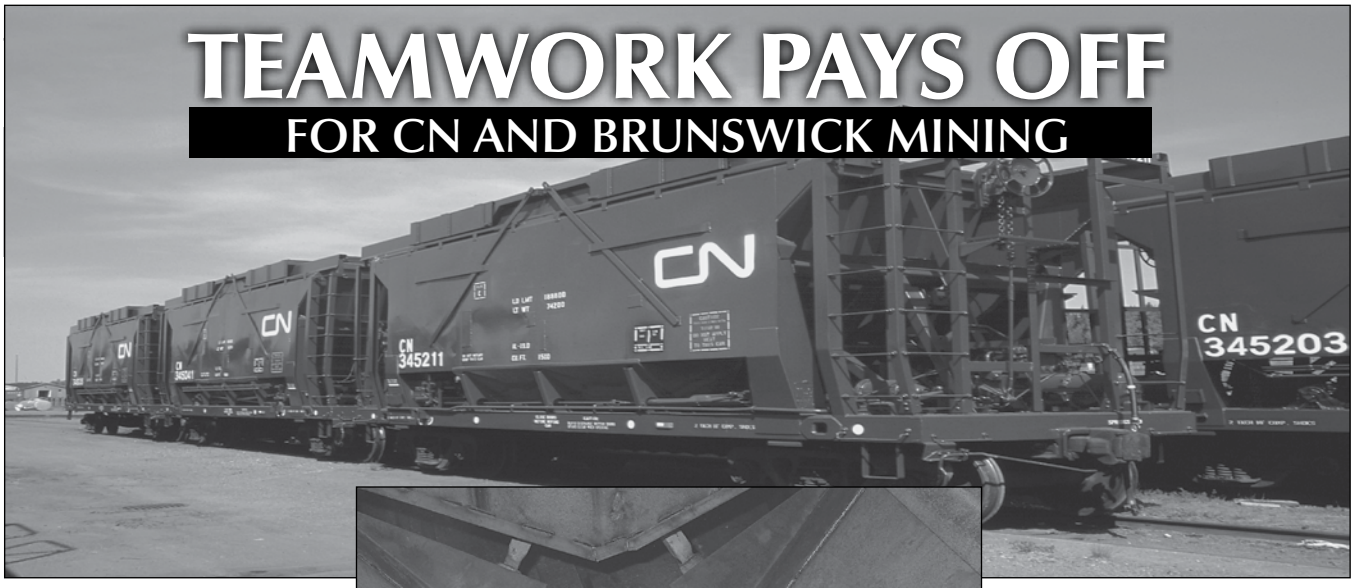
Excessive sticking on the stainless steel-lined surface caused plant personnel to deem the stainless steel unacceptable for unloading concentrates. The doors were then lined with 1/2″-thick TIVAR® 88-2 (1/2″-thick was used here because more bulk material flows across these areas than elsewhere in the car), eliminating sticking and reliably discharging the concentrates.

Based on the results of the test car, the interior sloping walls of the remaining 44 cars were modified and all were completely lined with TIVAR® 88-2. According to plant personnel, the TIVAR® 88-2 liners continue to perform well over five years later, successfully discharging all material and reducing unloading times and costs.

• UPDATE
The railcar liners are still in place and functioning well. "This liner just doesn't wear" states CN mechanical supervisor.

TEAMWORK PAYS OFF

FOR CN AND BRUNSWICK MINING



These modified hopper cars, due to enter service in September, will result in a faster, more cost-effective way of unloading concentrates.

WHEN BRUNSWICK MINING, A DIVISION OF NORANDA MINING AND EXPLORATION INC., DECIDED TO RELOCATE ITS UNLOADING SITE FROM DALHOUSIE TO BELLEDUNE, NEW BRUNSWICK, THE SHIFT GAVE CN AND ITS CUSTOMER AN OPPORTUNITY TO DEVELOP A FASTER, MORE COST-EFFECTIVE WAY OF UNLOADING CONCENTRATES. THEY PUT THEIR HEADS TOGETHER AND CAME UP WITH A RADICALLY MODIFIED HOPPER CAR, JUST RIGHT FOR THE JOB.

Mary Taylor, account manager in CN's Industrial Products business unit, attributes the innovation to teamwork: "Our people worked very closely with Brunswick's people, and the synergy between us unleashed a lot of creative thinking. Thanks to their knowledge of the product and our knowledge of railroading, we solved the problem in a way that satisfied both companies."

Team members included from Brunswick Mining—engineer Gerry Bisaillon, superintendent of Information and Purchasing Services Denis Babin, and concentrator superintendent Larry Urbanoski and from CN—technician Manning Jay and engineer Pierre Dubé.

• BREAKTHROUGH IN EQUIPMENT DESIGN

Unloading a train made up of 25 gondola cars can take up to eight hours. With CN personnel on site, the process can tie up two locomotives and a full crew for an entire day—a costly proposition. The Brunswick/CN team went looking for a solution that would cut unloading time in half. That way, a train could make the return journey between mine and unloading site in a single day.

They challenged the conventional view that concentrates do not flow. They discovered that given the power of gravity, concentrates will indeed flow, if loaded in a rail car with a large bottom dump shape and lined to minimize friction. The team then developed a prototype car with angles suited to the particular product and a large, streamlined "hole" and all surfaces coated with the non-stick product TIVAR® 88-2.

The prototype performed beautifully. Dry concentrates discharged in four seconds, wet concentrates in fourteen. CN's Moncton shops then set to work on modifying 44 hoppers, due to enter service in September.

"The project was extremely gratifying," says Brunswick's Gerry Bisaillon. "It showed that anything is possible when you combine expertise and determination." CN

* Reprinted courtesy of Canac MOVIN – cn Summer 1996

Case Study: Lignite Coal

TIVAR® 88 HIGH PERFORMANCE LINING SOLUTIONS

CASE IN BRIEF
Application: Ortner Rapid Discharge Railcars
Quantity: 50 Railcars
Liner: TIVAR® 88-2, 3/8" Thick
Bulk Material: Lignite Coal
Substrate: Corten®
Problem: Flow problems, sticking and freezing
Date Installed: 1997 & 1999

TIVAR® 88-2 Liners Improve Bottom Dump Railcar Operating Efficiency

• BACKGROUND
Basin Electric, a lignite coal-fired power plant in the upper Midwest, utilizes carbon steel Ortner rapid discharge railcars to transport coal to storage bunkers. Plant personnel were charged with finding a way to haul greater volumes of coal with the same number of cars and take advantage of the cars' full storage capacity.

• PROBLEM
Carryback was a major problem, particularly during the winter months. At one point, each car was accumulating 50 tons of carryback. Turnaround times at the raildump receiving bunkers had reached an unacceptable level. In addition, the power company was forced to use car shakers to discharge loads, damaging the railcars in the process.

• SOLUTION
The plant first opted to try TIVAR® 88-2 linings on the sloping end walls of 50 hopper cars. Although coal dis-charge improved notably, during the winter months, 2-3 tons of material would accumulate on the cross beams each trip, and with a standard two-trips-per-day schedule, build-up remained costly. Next, the utility designated two bottom dump railcars to test complete lining systems. Quadrant's SystemTIVAR® Engineering Group team designed linings for the discharge doors and structural sup-port components, including cross beams and center sills. Using thermoforming and proprietary welding techniques, the Quadrant's SystemTIVAR® Engineering Group team pre-fabricated linings using 3/8" TIVAR® 88-2 UV-resistant material. A certified SystemTIVAR® installation contractor installed one railcar lining each day.

• RESULTS
Tested in year-round weather conditions, the 100-ton capacity cars showed less than 1/16-ton carryback – an insignificant amount as deemed by the utility. Turnaround times at the raildump receiving bunkers have been cut by as much as 50% and loads are effectively discharged without the frequent use of car shakers, thawing sheds or other techniques that fatigue railcar structures.

Basin Electric railcars with TIVAR® 88-2 liners installed.

Due to the success of the test cars and savings through maximizing hauling capacity and shortened turnaround times, the power plant has fully lined all 50 railcars. According to power plant personnel estimates, the cost of the TIVAR® 88-2 liners was recovered in less than two years with a projected 8- to 10-year wearlife for the lining systems.

• UPDATE
The TIVAR® 88-2 ESD liners installed in the bottom dump railcars for Basin Electric are still in service and being used. Since the original installations of the liners took place (1997 & 1999), minor repairs and liner panel replacements have occurred over the years. These repairs and liner panel replacements are attributed to the normal wear & tear conditions of use, and are concentrated in and around the door areas. The end-wall liner panels have held up longer as the abuse and wear from the coal is less significant in those areas. Even with the maintenance and repair of TIVAR liners, Basin Electric is satisfied and is very happy with the performance of the TIVAR® 88-2 ESD railcar liners.

Case Study: Ship Lining

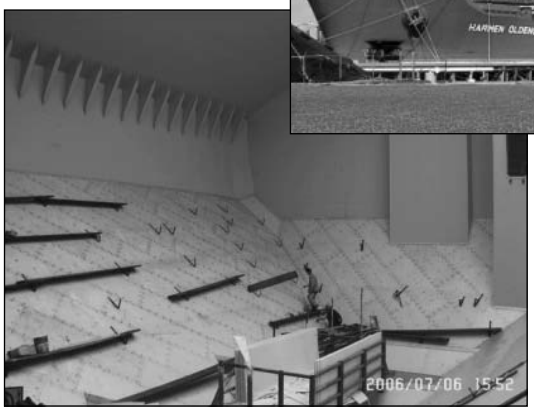
TIVAR® 88 HIGH PERFORMANCE LINING SOLUTIONS

CASE IN BRIEF
Application: Self-Unloading Ship
Quantity: 6,600 m^2
Liner: TIVAR® Marine Grade

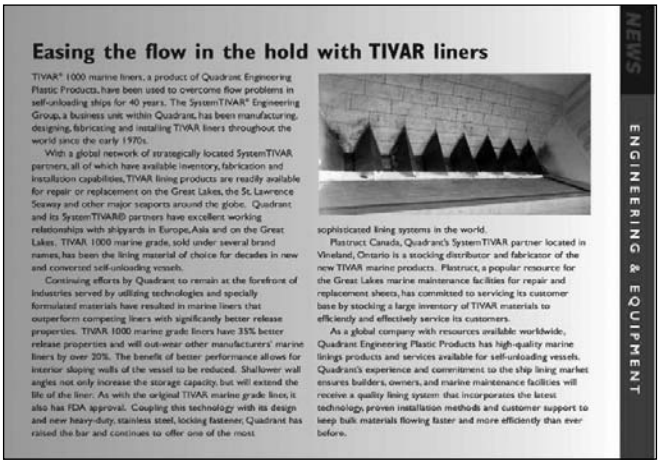
Bulk Material: Coal, Gypsum, Bauxite, Grain, Limestone
Substrate: Carbon Steel
Problem: Flow problems, plugging
Date Installed: 2006

TIVAR® Marine Grade Eliminates Flow Problems for Self-unloading Steamships

• BACKGROUND
Self-unloading steamships carry a variety of bulk materials across the oceans of the world, on the Great Lakes and other major waterways. These ships are often built in Chinese shipyards but spend most of their time out to sea. The major steamship companies have found the importance of lining the holds of these large vessels to promote flow, reduce wear and resist the effects of chemicals. Quadrant's TIVAR® liners have been used for over 40 years in these applications



• PROBLEM
Self-unloading steamships carry many hard to discharge materials such as coal, grain, gypsum, bauxite, iron ore, limestone and other types of aggregates. Due to the low angles of the interior sloping walls these bulk materials have many flow problems making it difficult and time consuming to unload the vessel. Also cross contamination of materials can be a major issue when changing from one type of bulk material to another. Some materials require an FDA approved liner.



NEWS ENGINEERING & EQUIPMENT

Easing the flow in the hold with TIVAR liners

TIVAR® 1000 marine liners, a product of Quadrant Engineering Plastic Products, have been used to overcome flow problems in self-unloading ships for 40 years. The SystemTIVAR® Engineering Group, a business unit within Quadrant, has been manufacturing, designing, fabricating and installing TIVAR liners throughout the world since the early 1970s.

With a global network of strategically located SystemTIVAR partners, all of which have available inventory, fabrication and installation capabilities, TIVAR lining products are readily available for repair or replacement on the Great Lakes, the St. Lawrence Seaway and other major seaports around the globe. Quadrant and its SystemTIVAR® partners have excellent working relationships with shipyards in Europe, Asia and on the Great Lakes. TIVAR 1000 marine grade, sold under several brand names, has been the lining material of choice for decades in new and converted self-unloading vessels.

Continuing efforts by Quadrant to remain at the forefront of industries served by utilizing technologies and specially formulated materials have resulted in marine liners that outperform competing liners with significantly better release properties. TIVAR 1000 marine grade liners have 35% better release properties and will out-wear other manufacturers' marine liners by over 20%. The benefit of better performance allows for interior sloping walls of the vessel to be reduced. Shallower wall angles not only increase the storage capacity, but will extend the life of the liner. As with the original TIVAR marine grade liner, it also has FDA approval. Coupling this technology with its design and new heavy-duty, stainless steel, locking fastener, Quadrant has raised the bar and continues to offer one of the most sophisticated lining systems in the world.

Plastruct Canada, Quadrant's SystemTIVAR partner located in Vineland, Ontario is a stocking distributor and fabricator of the new TIVAR marine products. Plastruct, a popular resource for the Great Lakes marine maintenance facilities for repair and replacement sheets, has committed to servicing its customer base by stocking a large inventory of TIVAR materials to efficiently and effectively service its customers.

As a global company with resources available worldwide, Quadrant Engineering Plastic Products has high-quality marine linings products and services available for self-unloading vessels. Quadrant's experience and commitment to the ship lining market ensures builders, owners, and marine maintenance facilities will receive a quality lining system that incorporates the latest technology, proven installation methods and customer support to keep bulk materials flowing faster and more efficiently than ever before.

• SOLUTION
A TIVAR® Marine Grade liner system, designed specifically for the geometry of the ship hold, was installed. The horizontal edges were beveled at 45°. The top horizontal seams of the liner were capped with stainless steel leading edge protectors. The liner is FDA approved, has a low coefficient of friction and will out wear stainless steel. It is resistant to a majority of chemicals and is easy to clean.

• RESULTS
The TIVAR® liner system has been effective at releasing the different bulk materials increasing the speed and efficiency of unloading the vessel. Quick, easy cleanout eliminates concerns of cross contamination. Wear has not been an issue. Since Quadrant maintains a global network of strategically located SystemTIVAR® partners, all of which have available inventory, fabrication and installation capabilities, Quadrant Marine Grade liner material is available for maintenance regardless of where in the world the ship is.

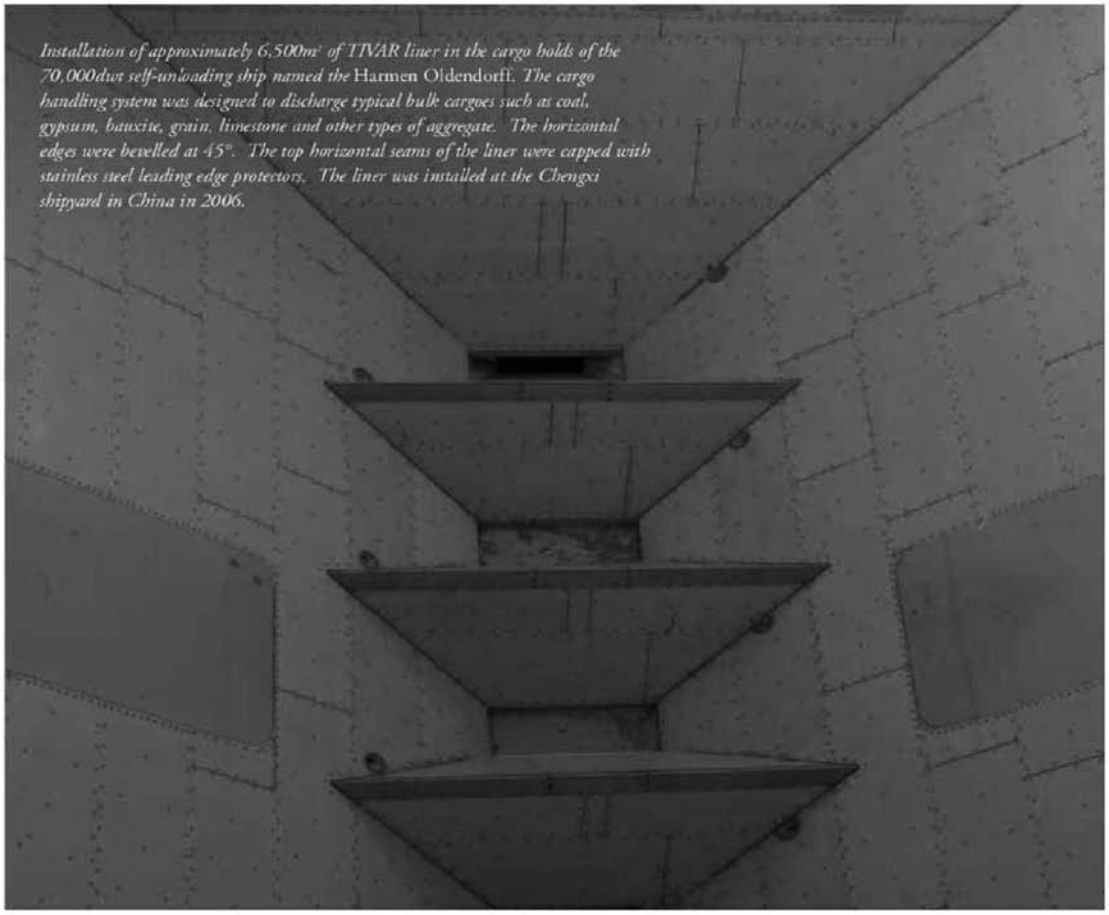
Case Study: Ship Lining

TIVAR® 88 HIGH PERFORMANCE LINING SOLUTIONS

SHIP LININGS

REGIONAL REPORT

Quadrant Engineering's TIVAR liners improve flow in self-unloading vessels



Installation of approximately 6,500m² of TIVAR liner in the cargo holds of the 70,000dwt self-unloading ship named the Harmen Oldendorff. *The cargo handling system was designed to discharge typical bulk cargoes such as coal, gypsum, bauxite, grain, limestone and other types of aggregate. The horizontal edges were bevelled at 45°. The top horizontal seams of the liner were capped with stainless steel leading edge protectors. The liner was installed at the Chengxi shipyard in China in 2006.*

Quadrant Engineering Plastic Products, a major manufacturer of machinable plastics provides various grades of polymer materials to service many market segments such as power, cement, mining, chemical and transportation industries. The Quadrant linings group specializes in providing products and services designed to replace or protect metallic and non-metallic substrates to drive fluid and bulk handling process efficiency.

TIVAR liners have been used over the past 40 years to help reduce flow problems in self-unloading ships. TIVAR products boast a low coefficient of friction and abrasion and chemical resistance which enhance the flow of various hard to discharge materials such as coal, grain, gypsum, bauxite, and iron ore in self-unloading vessels worldwide and on the Great Lakes and St. Lawrence Seaway.

Quadrant recognizes the need to have its materials readily available. For this reason it has strategically selected, set up and trained a specialty group of companies throughout the world that it refers to as its SystemTIVAR Partners. They stock Quadrant's lining materials and have machining capabilities and installation expertise to mobilize very quickly in the event of an emergency situation. Providing the link in the chain from the manufacturer to the partner to the end user has improved Quadrant's efficiency in installing lining materials in self-unloading vessels. TIVAR liners can be found servicing various ship owners within the Great Lakes. Some of the vessels that Quadrant has recently been involved with are the *Lake, Cresswell, Weigh, Atlantic Erie* and *the Paul Martin.* Quadrant continues to investigate new ideas, installation methods and products that reduce installation costs and enable bulk materials to discharge faster on self-unloading ships. Through the joint co-operation of all parties involved and experience from other lining projects, many exciting and mutually beneficial products have been developed for the ship-lining industry.

Quadrant addresses the international market directly. Many ship owners have ships manufactured throughout the world. The company works with the owners to obtain necessary data to design and deliver fabricated liner kits. Its international partners become involved at this point to provide installation support at the appropriate shipyards. A recent international complete ship lining project is a ship named the *Harmen Oldendorff.* The liner was installed at the Chengxi shipyard and Quadrant's German affiliates manufactured and fabricated the liner. Another ship, the *Splitnes*, was lined in 2006 in Germany.

Quadrant's experience and commitment to the ship lining market ensures builders and owners will receive a lining system that involves the latest technology, proven installation methods and customer support to keep bulk material flowing quicker and more efficiently then ever.

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Case Study: Blended Coal

TIVAR® 88 HIGH PERFORMANCE LINING SOLUTIONS

CASE IN BRIEF
Application: Coal Bunkers
Quantity: 56 Discharge Hoppers
Liner: TIVAR® 88-2, 1/4" Thick Drop-in Liners

Bulk Material: Bituminous Coal, Sub-bituminous Coal Blend
Substrate: Stainless Steel
Problem: Flow problems, sticking and bridging
Date Installed: 1995

Drop-in TIVAR® 88-2 Liners Solve Coal Bunker Flow Problems at Coke Plant

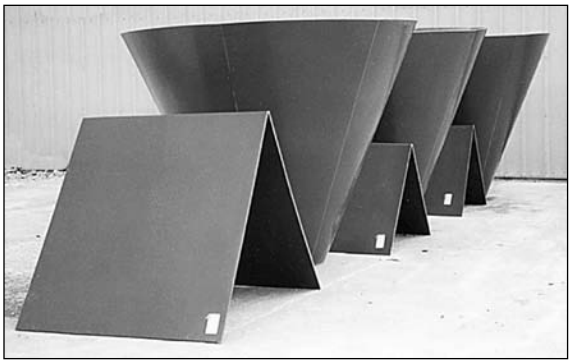
• BACKGROUND
The coal bunkers at a U.S. steel coke plant were originally designed to have an expanded flow pattern, with mass flow occurring in the discharge hoppers and funnel flow occurring in the upper portion of the bin. (An expanded flow pattern results when the mass flow at the top of the discharge hoppers is significant enough to prevent a stable rathole from occurring in the funnel flow portion of the bin.)

However, instead of handling bituminous coal – for which the original bunkers were designed – the plant switched to a blended coal comprised of bituminous coal, sub-bituminous coal and petroleum additives. The flow characteristics of this blended coal were different from those of the pure bituminous coal, therefore changing the overall flow pattern in the bunker.

• PROBLEM
When the flow characteristics changed, flow did not occur along the walls in the stainless steel hoppers, resulting in severe flow problems within the bunkers that supplied the coke ovens. Stable ratholes developed over the discharge outlets within the bunker, resulting in a reduction in live storage capacity of 50-60%.

• SOLUTION
Plant engineers at the coke plant contracted the services of a bulk materials flow consultant, who proposed two options. The first option was to modify the design of the coal bunkers by changing the sloping wall angle of the discharge hoppers from 67° to 70°. To do this, however, would have meant complete replacement of, or significant structural modifications to, the discharge hoppers.

The second option involved lining the existing hoppers with a low coefficient of friction liner and installing air cannons. Based on a cost comparison of the two options and the downtime required to make structural modifications, the decision was made to pursue the low-friction lining option. Quadrant's SystemTIVAR® Engineering Group was contracted to design a liner installation solution.



SystemTIVAR'S® Engineering team recommended fabricating seamless drop-in hopper liners and diverter plate covers manufactured from TIVAR® 88-2.

• RESULTS
Using this solution expedited the lining process and the one-piece, seamless design – eliminating fasteners in the flow stream – significantly increased the overall performance of the lining system by maximizing the surface integrity of the TIVAR® 88-2 material. Of the 56 TIVAR® 88-2 drop-in liners installed in 1995, none are showing any signs of wear. Approximately 40,000 tons of coal pass through each lined hopper every year and according to the plant project engineering manager, discharge of the coal is 100% and full bin capacity is now being realized. Although air cannons were purchased, they were never installed and have never been needed. The successful use of these liners has enabled the plant to delete one operating turn per day, saving several hundred thousand dollars each year.

• UPDATE
"The best project we've done in the past 50 years. All liners are working great. We check them every 5 years and have found very little wear and experienced no problems."

Case Study: Cement

TIVAR® 88 HIGH PERFORMANCE LINING SOLUTIONS

CASE IN BRIEF
Application: Chutes
Quantity: 16
Liner: TIVAR® 88-2
Bulk Material: Stone
Substrate: Carbon Steel
Problem: Flow problems, sticking and plugging
Date Installed: 2009

TIVAR® 88-2 Liners Eliminate Plugging in Cement Chutes

• BACKGROUND
A large cement company was experiencing major plugging issues in their chutes. The new stone crusher that was purchased was expected to help increase plant production as well as improve reliability. The new crusher produced more fines than the previous model. The belief was that a finer product would improve overall handling and production and also require less energy to pulverize the stone. This theory proved to be only partially true. After the stone is crushed it is stored in a 60,000 ton A-frame storage building. The stone is separated into piles according to the chemistry of the stone. The crushed stone is dropped below onto one of fifteen vibratory feeders. The combined stone from all fifteen feeders is transferred by conveyor belt to a vertical roller mill that pulverizes the stone prior to the preheater tower and eventually the kiln. Stone quality and constant feed supply is critical to making superior cement. Any piece of equipment operating below optimal performance can result in an inferior product as well as cause severe damage to the kiln and other pieces of equipment.

• PROBLEM
During the conveying of the stone the finer stone became a major issue. Due to the high moisture content the fines created a stickier feed resulting in caking and sticking onto the surface of the chutes. The result caused poor flow and plugging of the chutes. Most of the flow issues surfaced during the winter months when the stone conveyed is at higher moisture content due to the ice and snow. Concern began to grow when stone handling issues continued into the spring and early summer. The feeders were old and damaged due to the abuse from using sledge hammers and jack hammers to free the plugged fines.

• SOLUTION
New chutes lined with AR plate were purchased and put into operation. The original design of the chutes was intended to move 250 TPH of material. The new chutes were permitting only 100 TPH of material flow – nearly a 90% reduction in feed rate. A new lining material with a lower C.O.F. was required to meet the demands. Quadrant EPP was contacted by the cement company to determine if they had any materials and/or ideas that would help meet the criteria that the plant required. The STE Group designed a drop-in liner that was held in place by two TIVAR® 88-2 strips which were extrusion welded to the main chute body and sandwiched between the existing angle iron and the side steel plate of the chute. This design eliminated any fasteners in the flow area of the chute. The liner was also score-cut and rolled to transform the existing square corners of the steel chute into a radius shaped configuration. Incorporating radiused corners permitted the bulk material to discharge freely without sticking to the corners of the chute

• RESULTS
The liners paid for themselves within a few days of operation. Savings of over $100,000 on labor cost alone were expected during the first year. More importantly, the properly operating stone feeders now provide a more consistent stone mix resulting in improved kiln reliability as well as improved refractory life. A side benefit is that more time is allowed for routine maintenance in other areas of the plant resulting in fewer unexpected failures and improved run times.

NOTE: The above article was extracted from the article “Stone Feeder Improvements”. The article was published in the World Cement / March 10 issue.

Case Study: Clay

TIVAR® 88 HIGH PERFORMANCE LINING SOLUTIONS

CASE IN BRIEF
Application: Hopper Liners
Quantity: 1 Clay Hopper
Liner: TIVAR® 88, 1/2" Thick

Bulk Material: Clay, Gypsum
Substrate: Mild Steel
Problem: Flow problems, sticking and bridging
Date Installed: 2000

TIVAR® 88 Liners Help Cement Plant Achieve Mass Flow in Clay Hoppers

• BACKGROUND
The Krupp Polysius 320-ton clay hopper (Fig.1) for clinker Line #2 at the Kedah Cement Plant in Langkawi, Malaysia, was designed for mass flow using mild steel as the hopper wall material. This hopper was expected to have a discharge rate of 250 TPH.

• PROBLEM
The welded seams on the hopper walls had worn off and there appeared to be some trace of polishing at least on the upper portion of the hopper section. It was suspected the hopper achieved some sort of mass flow when the clay was dry; however, surface corrosion was also visible and this suggested that wetter clay did not flow or move well along the walls. There were almost daily incidences with up to 75% blockage and lost capacity. Three large air cannons with 100-litre tanks– fitted to the upper conical section of the hopper– failed to solve the flow and blockage problems. The air cannons loosened the clay in the immediate vicinity of the air cannon outlets, but the vast majority of the clay continued to bridge and gain strength sufficient to support the rest of the clay sitting on top of it and the result was no flow or restricted flow.

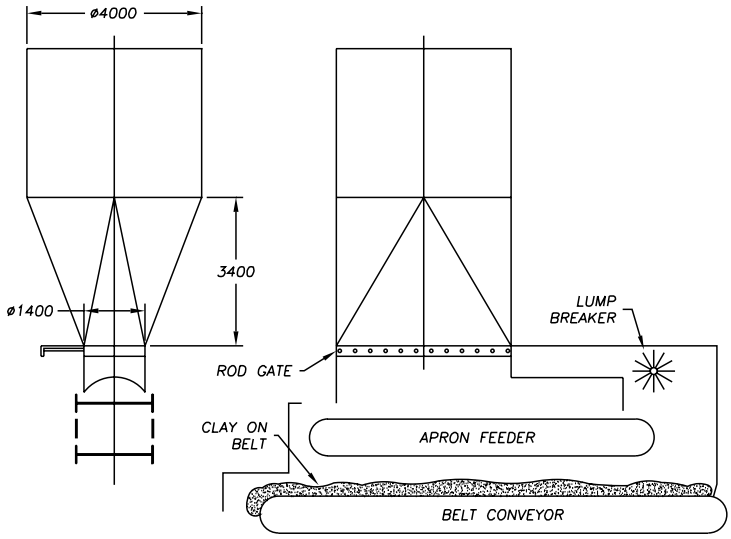


Figure 1: 320-ton clay hopper was originally constructed with mild steel.

• SOLUTION
Prior to installing the TIVAR® 88 lining system, extensive cleaning in the conical section was necessary, with removal of hardened clay chunks, some weighing up to 100 kg each. TIVAR® 88 liners, 1/2"-thick, were installed in the sloping hopper wall section from the outlet up to the transition point where the vertical section begins. The liner was attached with stainless steel welded studs and spanner nuts. Individually cut liner panels were formed to follow the contour of the steel hopper ensuring that it would sit flush against the wall.

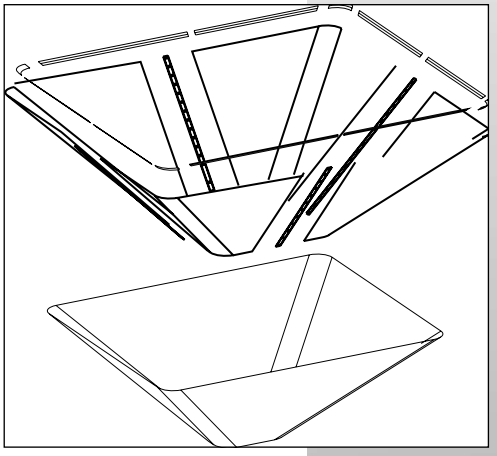
The final stage of this lining project was the installation of the stainless steel leading edge protectors welded on the wall above the top row of TIVAR® 88 liner panels to prevent clay migration behind the liner. The installation was completed on schedule and was promptly accepted by the customer. As recommended by the SystemTIVAR® installer, the apron feeder's skirting and the upstream and downstream transfer hoppers were also lined with 1/2"-thick TIVAR® 88 during the same period.

• RESULTS
The plant has since operated the TIVAR® 88-lined clay hopper and ancillary equipment smoothly throughout the rainy season.

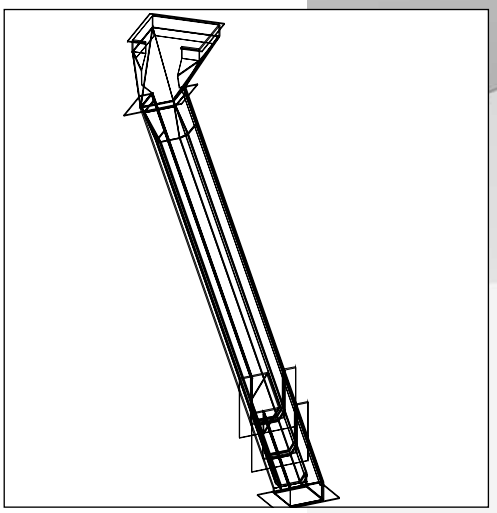
The plant engineers' delight with the success of, and confidence in, the TIVAR® 88 lining system was evident by their immediate decision to line the gypsum hopper and other ancillary equipment. These have been completed and are operating successfully. To date, more than 360 m^2 of TIVAR® 88 have been installed at this plant. The clay hopper for clinker Line #1 was also lined with 1/2"-thick TIVAR® 88 after the great success with Line #2.

Power Plant Applications

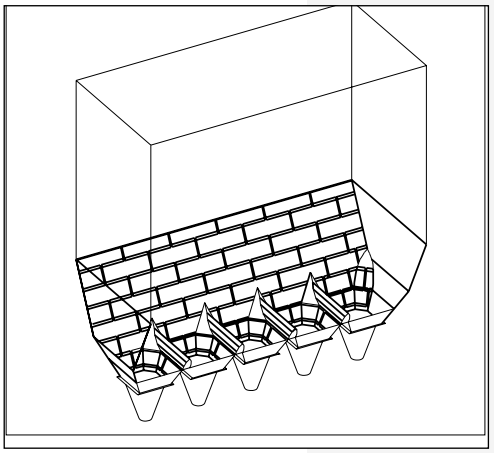
TIVAR® 88 HIGH PERFORMANCE LINING SOLUTIONS



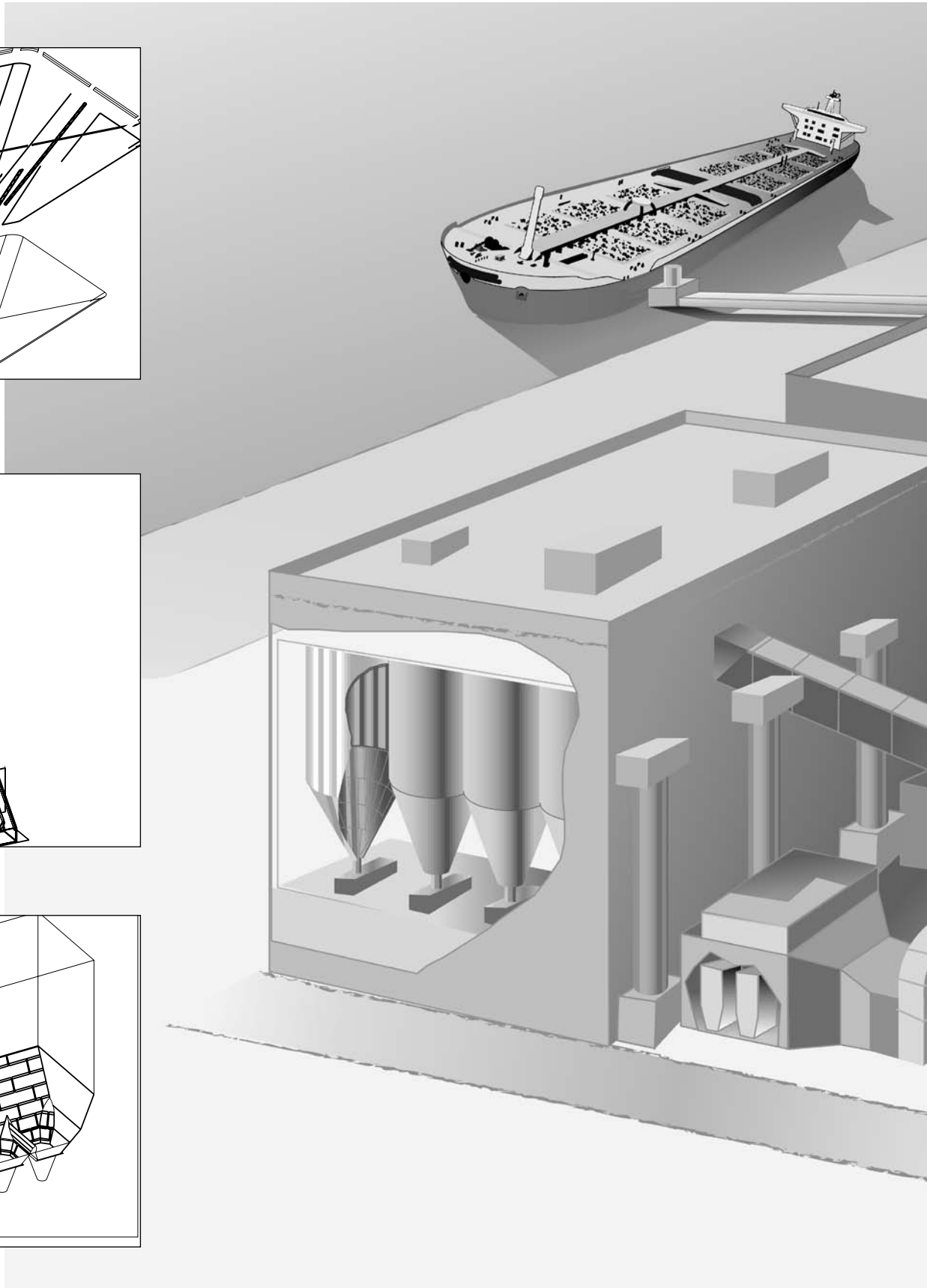
Hopper Lining System: Coal, Flyash, Gypsum, Limestone



Chute Lining System

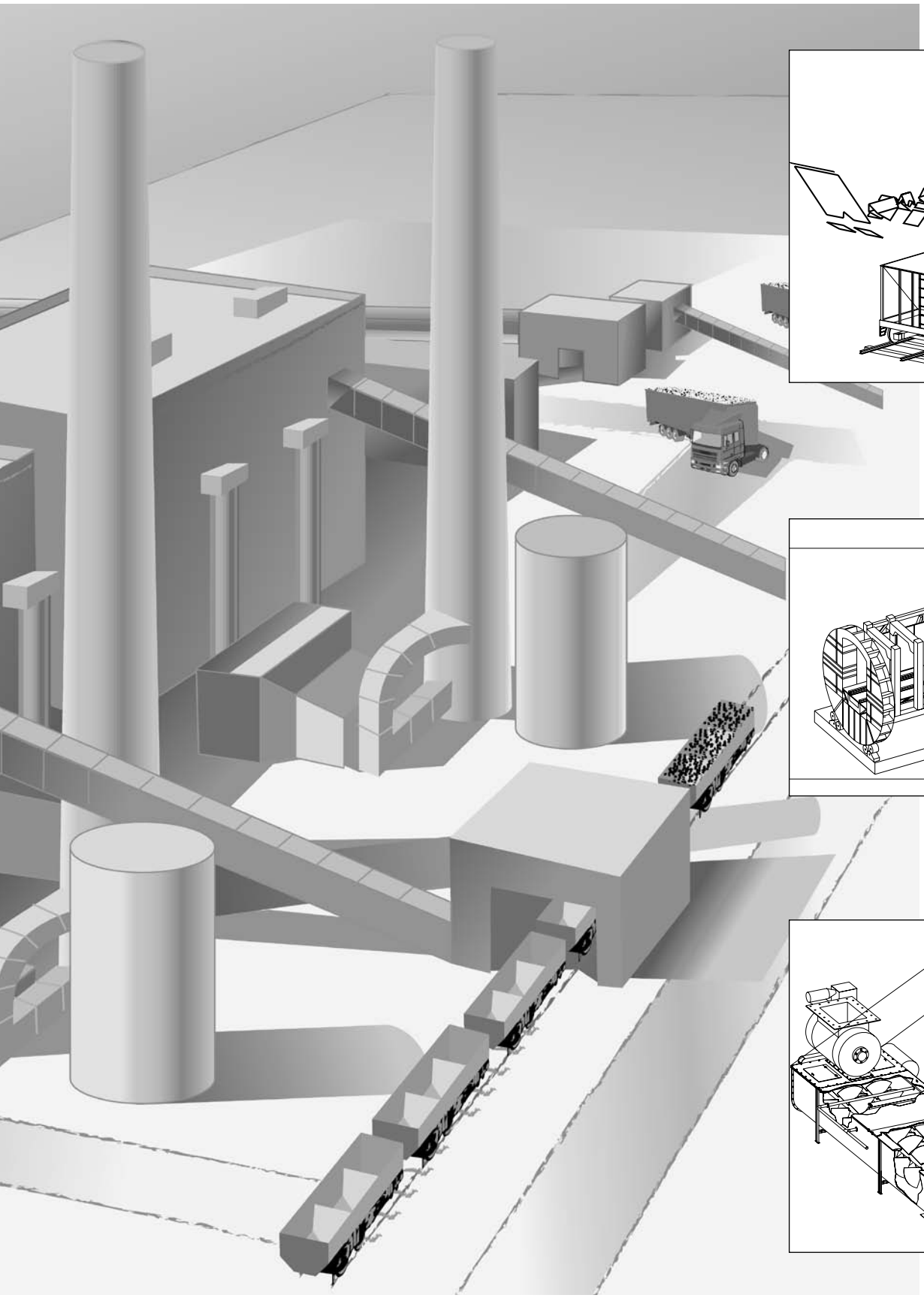


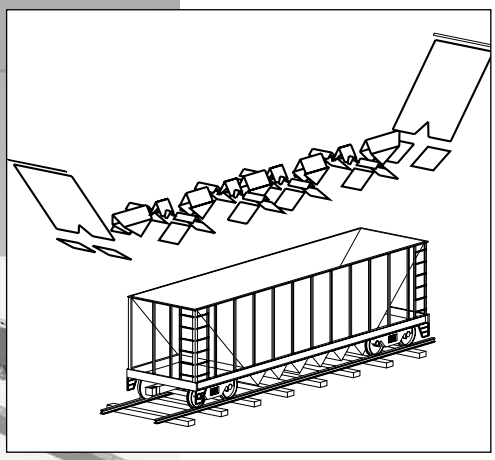
Bunker Lining System



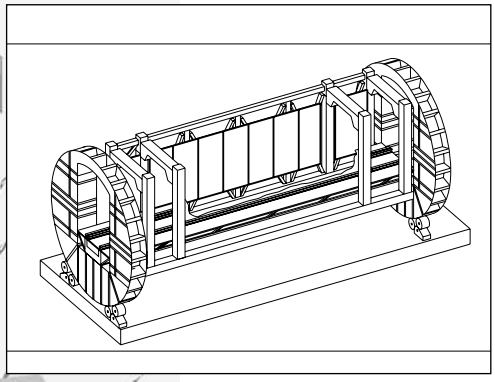
Power Plant Applications

TIVAR® 88 HIGH PERFORMANCE LINING SOLUTIONS

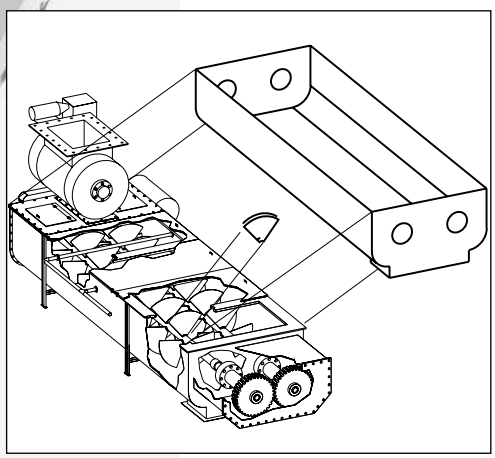




Railcar Lining System



Rotary Dump Lining System



Flyash Conditioner
Lining System

Case Study: Fertilizer

TIVAR® 88 HIGH PERFORMANCE LINING SOLUTIONS

CASE IN BRIEF
Application: Hoppers and Chutes
Quantity: 300 m²
Liner: TIVAR® H.O.T.

Bulk Material: Ammon. Nit.; Calc.; Magn. Carb.; Ammon. Sulf.
Substrate: Carbon Steel
Problem: Sticking, bridging and corrosion
Date Installed: 2008/2009/2010

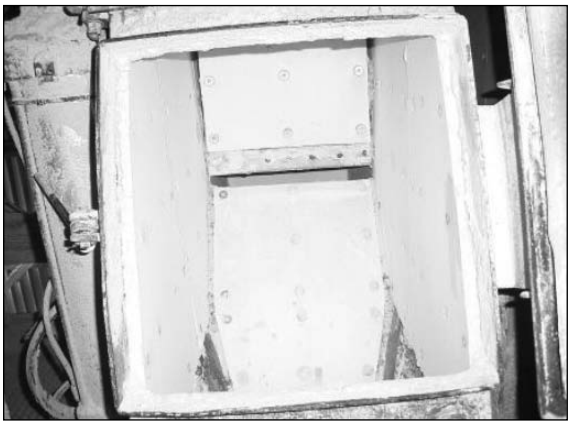
TIVAR® H.O.T. Solves Flow and Corrosion Problems

• BACKGROUND
Numerous fertilizer plants are located throughout the country of Belgium. The fertilizer produced consists of mostly Ammonium Nitrate, Calcium, Magnesium Carbonate and Ammonium Sulfate. Production temperatures range between ambient and 120° C. The atmosphere is typically very corrosive.

• PROBLEM
One of these fertilizer plants was experiencing significant problems with the raw materials sticking to the chutes and hoppers as well as causing corrosion which reduced the life of the steel equipment. The corroded substrates further encouraged sticking and bridging of the raw materials. Much time and labor was spent cleaning the chutes and hoppers several times a day to remove the material built up in the hoppers. The steel substrate had a very short life due to corrosion and had to be repaired and replaced often.

• SOLUTION
The fertilizer plant has now lined their hoppers and chutes with Quadrant's TIVAR® H.O.T. material. Thicknesses of 10 – 15 mm were used depending on the application. The liners were fabricated, pre-formed and fusion welded at Quadrant's plant in Vreden, Germany. TIVAR® H.O.T. was specified due to the high temperatures involved. The liners were fastened at the top of the hoppers to prevent buckling due to expansion issues caused by the constant change in temperature.

• RESULTS
After lining their chutes and hoppers with TIVAR® H.O.T. this fertilizer plant now has excellent flow through their bulk material handling system. The lining also protects the steel substrate from corrosion and significantly reduces cleaning, maintenance and replacement expenses.



Case Study: Phosphate Ore

TIVAR® 88 HIGH PERFORMANCE LINING SOLUTIONS

CASE IN BRIEF
Application: Hydro-cyclonic Launderer
Quantity: 2 Drop-in Liners
Liner: TIVAR® 88-2, 3/4″ Thick

Bulk Material: Phosphate Fines
Substrate: Abrasion Resistant Steel
Problem: Corrosion
Date Installed: 2000

Seamless Lining System Alleviates Flow Problems at Ore Processing Facility

Photo A: 24 hydro-cyclone "overs" discharge lines empty into a 96′ long launderer

• BACKGROUND
A major manufacturer of phosphate chemicals operates an ore processing facility in central Florida. After the phosphate-containing ore is obtained by removal from pits with drag buckets, it undergoes several refining processes to produce a product with a predefined content.

As part of the process, 40 hydro-cyclones, in two separate units, are used for separation of clays and other undesirable minerals. Large quantities of water, containing fine sand, clay, etc., are discharged from the upper portion of the cyclones into a launderer and are carried away for further processing. (Photo A)

• PROBLEM
Two launderers measuring 6′ wide x 3.5′ deep x 96′ long are used to handle the hydro-cyclone discharge. While constructed of wear resistant steel plate, the combination of fine particle abrasion and corrosion was taking its toll on the units. In addition, the extremely rough surface of the launderers limited allowable flow, thereby restricting the system. (Photo B) The launderers are located outside and are exposed to Florida environmental conditions year round.

• SOLUTION
Initially, the customer's engineers wanted to line the bottom and 18″ up the sides of the two launderers with 1″- thick TIVAR® sheet using conventional multi-fastener installation techniques. After reviewing the plan with Quadrant's SystemTIVAR® Engineering Group, it was determined that this approach had many pitfalls. For instance, the total number of fasteners required was almost 4,000, and since the launderers were constructed from hard wear plates, installation with weld washers was not a viable option. Using capped elevator bolts as fasteners was also discarded as an option due to drilling and leakage problems.

Photo B: The combination of abrasion and corrosion caused by deterioration of the 400 BHN steel used for the launderer

Photo C: A prefabricated TIVAR® 88-2 launderer liner is readied for installation. The section is 6′ W x 24′ L with 2′ H side walls

Thermal expansion problems on down days and multiple seams between butting sheets of TIVAR® were additional considerations.

Quadrant's SystemTIVAR® Engineering Group proposed a solution to completely line each launderer with a seamless one-piece TIVAR® 88-2 liner, using approx. 30 fasteners each. Four sections, 6′ wide, 2′ deep and 24′ long, were shipped directly to the job site. These sections were prefabricated using proprietary welding and fabrication techniques. Although the sections could have been fabricated in longer pieces, i.e., 28′, 32′, 36′, etc., (Photo C) the 24′ length was chosen for ease of handling since each unit had to be hoisted 40′ into the air.

After the initial section was placed into the existing launderer and secured, the next 24′ section was brought into position and field welded to the first. This was repeated twice more to completely line the launderer. The last step was the installation of leading edge protectors running the total length of each launderer to prevent material from getting behind the liner.

• RESULTS
Upon completion of the project, the liner in each launderer exhibited the characteristics of a one-piece, seamless TIVAR® 88-2 liner. The only fasteners are at the far ends of each unit (Photo D), so the liner is free to expand and contract without buckling or distortion. Due to its seamless nature, the bulk material cannot migrate between the liner and substrate.

In service for well over one year, the liner system is performing flawlessly. As a result of the extremely low friction factor, the flow rate through the launderers has been dramatically increased (Photo E). There are no signs of wear, indicating that a very long wear-life is expected.

Photo D: After each 24′ section was put in place they were field welded into a single 96′ long seamless unit. Minimal fasteners (only 24 in the first section) and leading edge protectors complete the installation.

Photo E: TIVAR® 88-2 launderer running full. To date, no signs of wear or corrosion are visible.

Case Study: Titanium Dioxide Pigments

TIVAR® 88 HIGH PERFORMANCE LINING SOLUTIONS

CASE IN BRIEF
Application: Titanium Dioxide and Titanium Ore Handling
Quantity: 15 silos (700 m2); 10 bunkers (400 m2)
Liner: TIVAR® 88 w/Antistatic package, 10mm Thick; TIVAR® special formulation, 10mm Thick
Bulk Material: titanium ore (ilmenite); titanium dioxide; titanium dioxide pigments
Substrate: ST 37 Steel
Problem: Caking, bridging
Date Installed: ore bunkers – 1985-87; dioxide silos – 2000-03

TIVAR® 88 Special Formulation and TIVAR® 88 Antistatic Improve TiO2 Handling, Quality

• BACKGROUND
A leading producer of titanium dioxide pigments in Leverkusen-Nordenham/Germany, making approximately 450,000 metric tons each year. Titanium dioxide (TiO2) pigments are produced by converting ilmenite ore, ilmenite soaps, rutile beach sand or anatase slag. Conversion occurs using a sulfate or chloride process.

• PROBLEM
During the early 1980s, this company began experiencing severe caking and bridging in the bunkers during the transport and storage of titanium ore due to extremely small particle size in the case of the ore and pigments of only µm size. In addition, the silos used to store the titanium dioxide and titanium dioxide pigments were subject to caking and bridging. Material flow was often interrupted and resulted in converted products that were non-uniform. Active flow devices such as air cannons and vibrators were used on a regular basis, an additional operating expense in terms of man-hours to run the equipment and repairs to damaged bunkers and silos.

• SOLUTION
The company made the decision to address the caking/bridging issues in the bunkers first and then focus on eliminating problems in the silos. In 1985, they began working with Quadrant's SystemTIVAR® Engineering Group to analyze the physical properties of the titanium ore as well as the wall angles in the bunkers. Results from the practical testing indicated that the caking and bridging could be eliminated by installing 10mm-thick proprietary formulation TIVAR® linings. Between 1985 and 1987, these specially formulated TIVAR® linings were successfully installed in all 10 bunkers.

With the bunker material flow issues addressed, the team turned its focus to the silos. Several different lining materials were examined and field-tested to determine performance levels and economic feasibility. The success of the bunker linings and the results of material flow/silo geometry tests indicated that the silos should be lined with TIVAR® 88 w/an antistatic package in order to achieve mass flow. All 15 silos were lined by 2003.

In both applications, vertical butt joints were welded and smoothed, the corners of the storage bunkers were lined with preformed shells and leading edge protectors were installed to ensure mass flow.

• RESULTS
After nearly 15 years in service, the bunker linings are performing as well as when they were first installed. According to staff, there is some visible wear, but not enough to negatively impact the liners' ability to keep the Titanium ore from caking and bridging. Routine inspection has been the only maintenance performed on the liners since installation. The TIVAR® 88 linings in the silos are also performing very well according to Kronos Titan staff. The use of air cannons and vibrators for both the silos and bunkers has been eliminated and maintenance expenses have been significantly reduced.

Case Study: Chemical Products

TIVAR® 88 HIGH PERFORMANCE LINING SOLUTIONS

CASE IN BRIEF
Application: Sulphuric Acid Storage Bunkers
Quantity: 6 bunkers
Liner: TIVAR® 88, 20mm Thick

Bulk Material: Sulphuric gravel and pyrite, both moistened with sulphuric acid
Substrate: ST 50 Steel
Problem: Caking, bridging, chemical wear
Date Installed: 2000

TIVAR® 88 Liners Eliminate Chemical Wear in Bunkers

• BACKGROUND
Sachtleben Chemie is a leading manufacturer of chemical products with a unique range of white pigments and extenders, such as titanium dioxide, as well as functional additives and water chemicals. The company uses a sulphate process to manufacture titanium dioxide and produces its own sulphuric acid to be used in the process. It operates one of the largest sulphuric acid production plants in Europe.

• PROBLEM
Sulphuric acid is extracted from either sulphuric gravel or pyrite. Both the gravel and the pyrite are abrasive materials that can cause equipment damage as they move through the process. However, an even greater challenge existed because prior to storage in the bunkers, these raw materials are slightly moistened with sulphuric acid. The addition of the sulphuric acid turns the raw materials into sticky, non free-flowing particulates that would cake and bridge as the materials were transferred into the bunkers. In addition, maintenance expenses were unacceptably high due to ongoing bunker wall repair and replacement from the chemical corrosion caused by the sulphuric acid.

• SOLUTION
Staff at Sachtleben was challenged to find an economical solution that would address the wear problems experienced in the bunkers. Working with Quadrant's SystemTIVAR® Engineering Group, the company initiated a thorough material analysis and bunker geometry assessment. Based on the results of that testing, 20 mm-thick TIVAR® 88 liners were installed in all six bunkers. To prevent bulk material migration behind the liner, corners were lined by preformed shells, and proprietary welding techniques were used on all vertical butt joints, corners and fastening holes.

• RESULTS
With the liners in place for nearly four years now, the company is still very satisfied with the results. Material flow problems are a thing of the past and there are no interruptions to the production process. In addition, the bunker walls no longer show any sign of chemical wear.

Case Study: Glass

TIVAR® 88 HIGH PERFORMANCE LINING SOLUTIONS

CASE IN BRIEF
Application: Chutes/Hoppers
Quantity: 200 m²
Liner: TIVAR® 88
Bulk Material: Sand, Calcium Carbonate, Dolomite, Ash
Substrate: Carbon Steel
Problem: Sticking and Bridging
Date Installed: 2006/2008

TIVAR® 88 Solves Flow Problems for Glass Manufacturer

• BACKGROUND
A large glass manufacturer in Germany was having problems with the storage and transportation of the raw materials for glass production. The particle size was 0 – 5 mm; moisture content 4 %; and the temperature was a maximum of 40° C. The raw materials were Quartz Sand (73 %), Calcium Carbonate (18 %), Dolomite (5%) and Ash (4%).

• PROBLEM
Due to sticking and bridging problems the material built up in the hoppers and chutes, especially in the corners. This caused interrupted material flow and a very poor mixture of raw material due to the separation of the bulk materials. This resulted in significant scrap and constant problems with product quality.

• SOLUTION
All hoppers and chutes were lined with 15mm thick TIVAR® 88. The corners were lined with pre-formed rounded corner profiles which was critical for a good material flow. The lining systems were fastened in place using stainless steel weld studs with spanner nuts. All vertical and critical seams were extrusion welded and steel leading edge protectors were installed to prevent the sand from migrating behind the liner. The lining job was done by the Quadrant PHS Deutschland lining group.

• RESULTS
As a result of lining their chutes and hoppers with TIVAR® 88 the glass manufacturer now has excellent material flow throughout their material handling system. The mixture quality of the raw materials is now consistent resulting in higher quality glass and a very satisfied customer.

Case Study: Copper Concentrate

TIVAR® 88 HIGH PERFORMANCE LINING SOLUTIONS

CASE IN BRIEF
Application: Sample Collector
Quantity: 1
Liner: TIVAR® 88-2, 1″ Thick

Bulk Material: Copper Concentrate
Substrate: Stainless Steel
Problem: Abrasion resulting in contamination and variations in moisture
Date Installed: 2000

TIVAR® 88-2 Welded Hopper Improves Sample Collector Quality Measurements

• BACKGROUND
Chile, the world's largest copper mining country, exports vast quantities of copper concentrate. Copper concentrate is an extremely cohesive bulk material that is very difficult to handle. On-line sample collectors are utilized to ensure consistency in the quality of the material being shipped.

• PROBLEM
At one of Chile's largest export terminals on the Pacific Ocean, significant flow problems were encountered during the ship loading process, specifically in the mild steel sample collector.

Two problems were obvious: 1) mild steel particles contaminated the mix due to abrasion as the flowing concentrate passed through the collector; and 2) it was difficult to maintain the moisture content within acceptable limits due to material hangup. As the concentrate would build up and adhere to the mild steel surface, it would begin to lose some of the moisture. This created a quality control problem as the drier material mixed in with the flowing concentrate. The build-up occurred due to the rough surface condition of the mild steel. Acceptable moisture levels were to be in the 6-8% range.

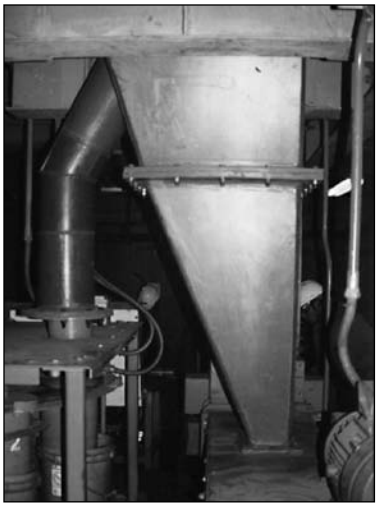
Plant maintenance personnel were required to be present at all times to prevent blockage in the sample collector and the quality control department was unable to apply useful values to the quality of the material being shipped.

• SOLUTION
In order to solve this problem, the steel sample collector chute was completely replaced with an identical part manufactured completely from 1″-thick TIVAR® 88-2. At 1/8 the weight of steel, equipment manufactured from TIVAR® 88-2 is lightweight and easy to handle. The TIVAR® 88-2 was quickly formed and welded to the correct shape. Flanges were then welded to the structure so the new TIVAR® 88-2 part could be bolted to the existing equipment.

Because TIVAR® 88-2 is not affected by the corrosion attack in this application, and it has a non-stick surface, making it the ideal material for the application.

• RESULTS
The sample collector portion of the ship loading process no longer experiences material build-up or contamination. The quality control department is now in a position to trust the values they are recording through the sample collector. This small, simple modification was relatively inexpensive compared to the costs associated with flow and contamination problems.

Before



After
Sample collector manufactured completely with TIVAR® 88-2 eliminates build-up and quality control problems.

Case Study: Ore Processing

TIVAR® 88 HIGH PERFORMANCE LINING SOLUTIONS

CASE IN BRIEF
Application: 3,000 sq. meters Iron Ore Storage Hopper
Quantity: 1 Concrete Hopper/ 28 Rectangular Outlets
Liner: TIVAR® 88, 15mm Thick

Bulk Material: Iron Ore Fines
Substrate: Reinforced Concrete
Problem: Sticking, caking, bridging, arching, freezing
Date Installed: 2001

TIVAR® 88-lined Hopper Achieves Mass Flow of Iron Ore Fines, Eliminates Flow Promotion Devices

• BACKGROUND
LKAB is an international high-tech ore processing company, exporting iron ore primarily to European steel mills. The company mines the ore from two underground iron ore mines, then processes the crude iron ore to fines, pellets and special products. The ore is transported by rail to shipping harbors for customer distribution. LKAB decided to erect a new 17,000-ton capacity storage hopper – one without the flow problems previous storage hoppers experienced.

• PROBLEM
Arching and bridging of both iron ore fines and pressed pellets was a serious problem for LKAB, resulting in an unacceptable amount of time, effort and money spent trying to achieve and then maintain mass flow. The company encountered additional problems during cold weather when the fines would freeze on the surface of the unlined equipment. In fact, the entire manufacturing process had to be shut down on a frequent basis in order to reactivate the material flow in the chutes, hoppers, silos and railcars. The two production lines alternated operation rather than both operating at the same time because LKAB was forced to constantly perform maintenance to restore acceptable material flow on one line or the other.

• SOLUTION
LKAB contacted flow consultant Schluze & Schwedes, Braunschweig, Germany, for assistance in analyzing the situation. The consultants recommended slight modifications of the hopper design in combination with a lining made from TIVAR® 88, a polymeric material recognized and used worldwide for its combination of an exceptionally slick surface, high abrasion resistance and long wear life. Stainless steel (A2-grade) was considered as a possible lining material, but the idea was quickly dismissed because the chemical properties of the iron ore would cause corrosion of the stainless steel and the lining would have been destroyed in a relatively short period of time.

The concrete hopper was lined using TIVAR® 88. Using SystemTIVAR'S® Engineering group, the hopper lining was designed, manufactured and bundled as a kit for quick installation on-site. The installation involved countersinking screws covered by TIVAR® 88 plugs and advanced butt welding at joints to create a seamless lining surface that would not inhibit mass flow. Leading edge protectors were also installed to prevent the iron ore from migrating behind the liner.

• RESULTS
Iron ore flow problems have been virtually eliminated due to the installation of the TIVAR® 88 lining. LKAB personnel are so satisfied with the results that they have decided to line other areas of the iron ore handling system.

Case Study: Copper Concentrate

TIVAR® 88 HIGH PERFORMANCE LINING SOLUTIONS

CASE IN BRIEF
Application: Transfer Chute
Quantity: 1 Chute
Liner: TIVAR® 88, 3/4" Thick

Bulk Material: Copper Concentrate
Substrate: Mild Steel
Problem: Sticking, no flow conditions
Date Installed: 1999

TIVAR® 88 Chute Liner Solves Copper Concentrate Flow Problems

• BACKGROUND
Chile, the world's largest copper mining country, exports vast amounts of copper concentrate. Copper concentrate is an extremely cohesive bulk material and is very difficult to handle.

• PROBLEM
One of the largest copper mines faced serious problems with their ship loading system because the copper concentrate did not flow as expected. The main load-out chute, handling copper concentrate at 800-900 TPH, was constructed of mild steel in a rectangular shape. Problems occurred in the interior corners of the chute when the concentrate contained a higher percent of moisture (normal moisture levels are 8-9.5%). The material would build-up in the corners, and this build-up would eventually block the chute. High costs associated with having employees monitor and ensure material flow, as well as demurrage charges due to excessive ship loading time, were unacceptable.

• SOLUTION
It was not practical nor economically feasible to have a dedicated group of employees on stand-by during the ship loading process to address the no-flow or restricted flow condition. Quadrant's SystemTIVAR® Engineering Group was contacted to provide insight into a proposed solution. Since the existing rectangular chute presented initial problems in the corners of the chute, the proposed solution was to modify the rectangular chute so it would be round.

Due to the very low coefficient of friction, excellent release properties along with the light weight and easy formability, TIVAR® 88 was the ideal material to use in this modification. The 3/4"-thick TIVAR® 88 liner chosen for this application was easily rolled into the correct diameter and then inserted into the new round steel chute. The beauty of this installation was the ease in which the TIVAR® 88 could be formed without the use of special equipment.

• RESULTS
The TIVAR® 88 chute lining and chute modification improved loading system operation by 35% and is considered a success by the copper mine.

Original rectangular shape transfer chute.

New round steel loading chute is lined with TIVAR® 88.

Wear, Wall Friction Tests Support TIVAR® 88 Flow Promotion Claims

• BACKGROUND

Handling bulk solids that do not flow reliably or uniformly through bins, silos and chutes can be costly for companies that have processes requiring continuous feed rates. Problems occurring in gravity feed operations such as erratic flow, no flow, bridging and ratholing are common throughout the bulk solids handling industry. These problems result in lost production, increased manpower and poor quality control.

In an effort to understand precisely how TIVAR® 88 enhances solids flow, Quadrant's SystemTIVAR® Engineering Group commissioned Jenike & Johanson, Inc., to test TIVAR® 88 with respect to wear properties and coefficient of friction (wall friction).

In the past, TIVAR® 88 has proven through field experience to be a cost-effective wall surface lining that provides consistent flow of solids. Due to its low wall friction and superior sliding abrasion resistance, TIVAR® 88 has been specified by prominent engineering firms as the primary sliding wear surface in new and existing bulk solids handling systems.

TIVAR® 88 has been specified as the primary sliding wear surface in the industry because it promotes mass flow, a flow pattern in which all material in a bin or silo moves when any material is withdrawn. Mass flow eliminates dead regions within a bin and a material's tendency to rathole.

In funnel flow bins, material does not flow along the wall until the bin is emptied. This can give the hopper wall time to corrode, encouraging material to adhere to the wall. TIVAR® 88 has excel-lent corrosion resistance and non-stick characteristics that provide better clean-out.

Now, information has been developed for TIVAR® 88 supporting both wear resistance and wall friction, using recognized testing procedures.

• WALL FRICTION

Wall friction is the resistance that occurs when a bin's substrate opposes the relative motion of a bulk solid sliding along its surface. Wall friction data can be used to anticipate the type of flow that will occur inside a bin and enables calculation of bin loads. Prior to designing or retrofitting a bin, silo or chute, wall friction should be considered.

TIVAR® 88 has an exceptionally low sliding friction angle when compared to stainless steel and carbon steel (Fig. 1). The low sliding friction angles associated with TIVAR® 88 translate into lower construction costs by building more efficiently designed bins with shallower hopper angles.

• WEAR DATA

The associated graphs show results of tests performed by Jenike & Johanson, Inc., with their wear test apparatus (US Patent 4,446,717).[2]

Three coal samples were tested on surfaces at various pressures and velocities. The bituminous coal was a hard, sharp and relatively abrasive type from Pennsylvania. The sub-bituminous came from the Powder River Basin in Wyoming. The lignite was a soft, cohesive coal from North Dakota.

Wear rates shown in Fig. 2 were used to calculate the predicted wear life of TIVAR® 88 and 304-2B stainless steel. The highest wear rate for TIVAR® 88 with the bituminous coal is about 0.028 in/year at the outlet. A 1/2"-thick TIVAR® 88 liner would be useful for about 17 years at this rate. With the lignite coal, a 1/2"-thick liner would have a projected life of more than 100 years. The wear life was based on a 25ft.

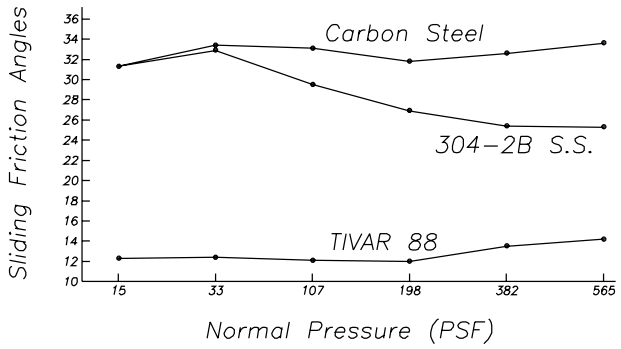


Figure 1: The sub-bituminous coal for this test came from the Powder River Basin in Wyoming. Data is presented for information purposes only and is not intended to be used for design criteria.

diameter circular bin with a conical mass flow hopper converging to a 2ft.-diameter outlet.

It is assumed the coal has a bulk density of 50lbs./ft.^{3} being withdrawn at 50 tons/hr. An illustration of the bin and the calculated solids pressure and velocity profiles are shown in Fig. 3. Here, the solids velocity shown is the wall velocity calculated in accordance with the formulas given in the papers referenced below.

Wear rates are higher near the outlet because of the higher velocity, although even at the highest wear rate for TIVAR® 88 with bituminous coal, it is still considered to be an excellent liner option. It is possible to use thicker liners near the outlet in order to achieve a more uniform wear life throughout the hopper section.

continued on next page >

Wear, Wall Friction Tests Support TIVAR® 88 Flow Promotion Claims (cont.)

• REFERENCES

[1] Jenike & Johanson, Inc., One Technology Park Drive, Westford, MA 01886, USA, tele: 978-392-0300, fax: 978-392-9980.

[2] Johanson, J.R. and Royal, T.A., "Measuring and Use of Wear Properties for Predicting Life of Bulk Materials Handling Equipment," bulk solids handling, Vol. 2, No. 3, Sept. 1982, pp. 517-523.

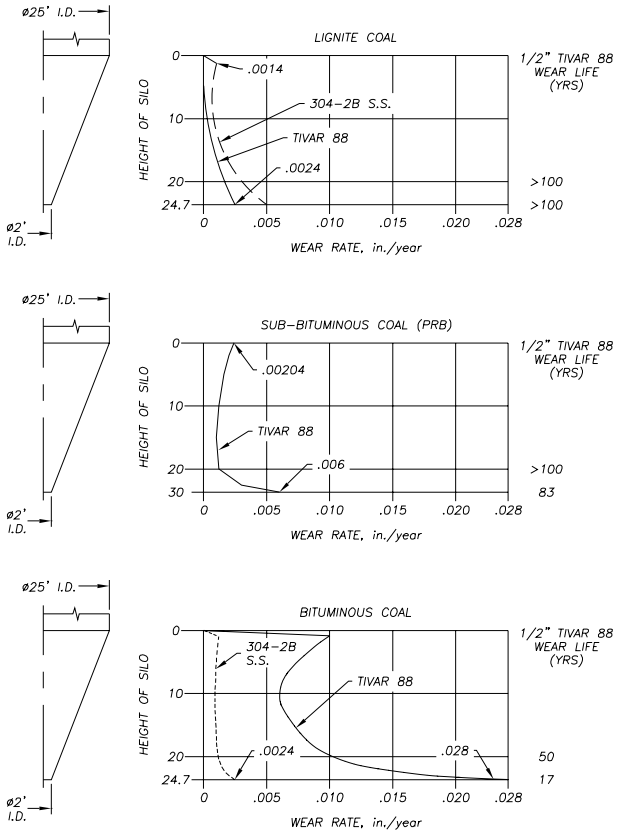


Figure 2: Wear rates in a mass flow hopper based on 24-hour operation 365 days per year.

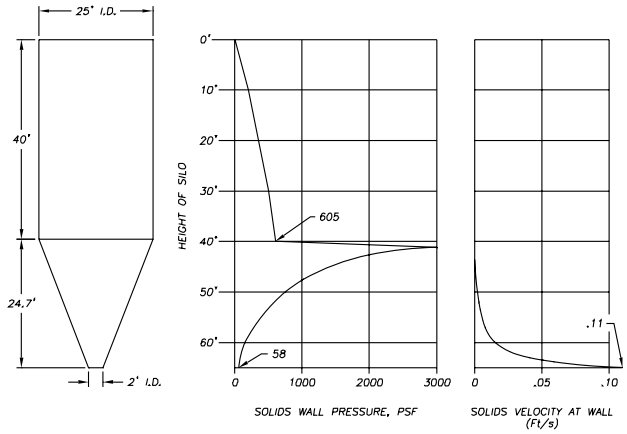


Figure 3: Pressure and velocity graph for a 25′ dia. silo designed for mass flow handling coal with a bulk density of 50 lbs/ft^3 and being discharged at 50 TPH.

TIVAR® 88 HIGH PERFORMANCE LINING SOLUTIONS

Flow of Solids from Bins and Hoppers[1] – Benefits of TIVAR® 88 Lining Systems

• BULK SOLIDS FLOW

Whether designing a new storage bin, bunker or silo or modifying an existing structure to improve flow performance, the engineer must have knowledge of the bulk material characteristics being handled and understand flow of solids theories. Traditionally, 304-2B stainless steel has been the hopper wall material chosen by the engineer for new construction because of the long history of use. To solve flow problems in existing structures, the typical "fix" has been the use of loud, noisy flow promotion devices. People think that if you beat on the structure or shake it you will get flow. However, these remedies often cause as many problems as they solve, and in a number of cases, flow problems continue even with the use of such "active" methods.

TIVAR® 88, an alternative to "hopper beating", is a lining material that has been proven to offer better flow performance than 304-2B stainless steel in a variety of different applications. In many retrofit situations, our experience has been that TIVAR® 88 is installed over the top of existing 304-2B stainless steel liners because the stainless steel lined hoppers were not providing satisfactory or acceptable performance. In new construction, engineers are able to design hoppers with shallower wall angles and still achieve mass flow by using TIVAR® 88 as the wall material because of its low surface friction.

Although traditional may be comfortable, when it comes to flow promotion methods, traditional may not be optimal in terms of performance. In fact, there are many new tested and proven methods available today that successfully achieve reliable solids flow. In many cases, these methods will outperform the traditional methods. But no matter what method is considered, it is imperative that engineers design with a thorough understanding of a bulk solids' characteristics and knowledge about vastly improved flow promotion methods.

For clarification, a bulk solid will be defined as numerous wet or dry solid particles ranging from fine powder to more than several inches in size that are being handled in bulk form. These materials are stored in vessels that are commonly referred to as a bin, bunker, silo, process vessel or elevator. The vertical portion of the vessel is the cylinder and the converging portion is the hopper, as shown in Fig.1.

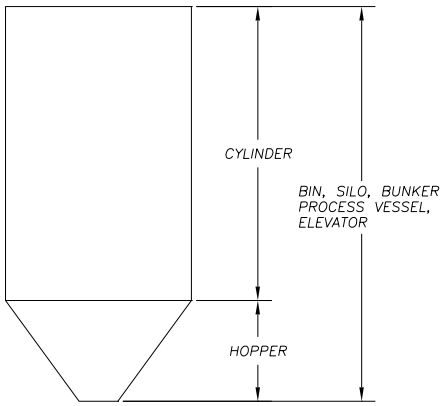


Figure 1: Storage vessel terminology

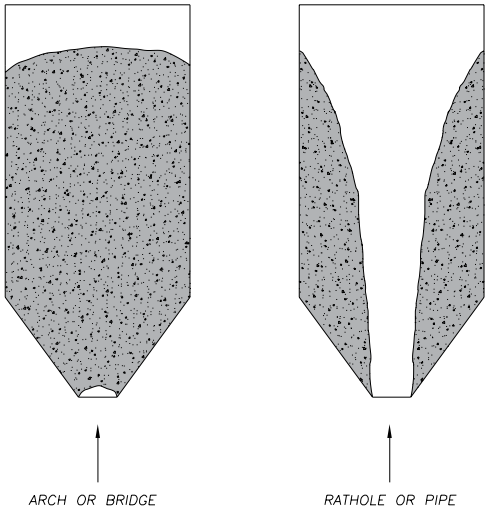


Figure 2: No Flow

• PROBLEMS ASSOCIATED WITH BULK SOLIDS FLOW

1.) No Flow

A stable arch (bridge) or rathole forms over the hopper outlet[2] as shown in Fig. 2. The arch is strong enough to support the weight of mate-rial above it and it must be broken by some method in order to induce flow again. Generally, sledgehammers, air lances and air blasters are used to break the arch. Vibrators have a tendency to strengthen the arch because, in most cases, they promote compaction.

A rathole is formed when a cylindrical flow channel develops in the center of the bin and the remaining material is stationary along the hopper walls. This generally occurs when the walls are not steep and smooth enough.

2.) Erratic Flow

Alternating formation and collapse of arches and ratholes (Fig. 3) result in fluctuating discharge. This causes thumping and vibrations that can dam-age or destroy the integrity of a bin, leading to structural failure and potential personnel injuries or deaths.

3.) Flushing or Flooding

Fine powders become aerated and discharge uncontrollably from the bin, behaving like a liquid, as shown in Fig. 4. This can happen when a rathole collapses allowing the solids to fall into the open channel under pressure.

4.) Limited Discharge Rate

The flow from the hopper outlet is not adequate for process requirements.

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Flow of Solids from Bins and Hoppers[1] – Benefits of TIVAR® 88 Lining Systems (cont.)

5.) Segregation

Solid particles have a tendency to separate[3] during the filling of a bin, as shown in Fig. 5. The finer particles will be predominate in the center of the bin and the larger particles will roll and collect against the bin wall. If flow does not occur along the bin wall during discharge, the finer particles discharge first and the coarse particles last.

Results of Flow Problems

These very common flow problems will have a variety of effects on a particular process that can result in quality problems, lost production, fire, product spoilage, structural damage, personnel injuries and wasted time and money.

Reduced storage capacity, as shown in Fig. 6, results from the formation of stable ratholes. The bulk solid will cake and cement itself to the bin walls if it is not cleaned from time to time. The severity of these stagnant or "dead" regions will vary according to the material being handled. For example, in the food industry, the bulk solid will spoil, encouraging insect infestation. In coal handling industries, the stagnant coal is highly susceptible to spontaneous combustion the longer the coal is allowed to remain in the bin.

Spontaneous combustion gets a lot of attention in the power industry where large volumes of coal are stored in the silos and bunkers that feed the boilers. Many power companies are plagued with fire problems that can eventually lead to explosions if dusting occurs while they are charging a bin.

In large silos, vibration and thumping can occur during discharge resulting in structural fatigue and collapse[4]. There are documented cases where the entire silo area was declared "off limits" to individuals during the time of discharge for fear that a fatality could occur if the structure collapsed.

Segregation issues make quality control nearly impossible, greatly impacting the bottom line in industries where consistency is required from batch to batch.

• TYPES OF FLOW PATTERNS

Three types of flow patterns have been identified: funnel flow, mass flow and expanded flow. All have profoundly different characteristics that must be understood in order to address bulk solids flow challenges.

1.) Funnel Flow

This pattern is ideal for free flowing, non-segregating bulk materials. A funnel flow pattern is not recommended for bulk materials that are cohesive or segregate. A cylindrical flow channel develops in the center of the bin above the outlet while the material against the bin walls remains stationary, as shown in Fig. 7. Once the center portion is withdrawn, the material along the walls begins to flow until it is empty.

This flow pattern can be referred to as first-in, last-out. If a cohesive bulk solid is handled in this fashion a rathole may develop.

If the hopper walls are not steep enough or if a rough wall condition exists a funnel flow pattern will develop. This is the situation in many coal bunkers today, especially if the coal has a high moisture content or if it contains a lot of fines. When there is no flow along the hopper walls, stagnation results. If the stagnant areas are allowed to remain for extended periods of time, quality may be compromised and spontaneous combustion can occur when handling coal.

The pyramidal shaped hopper, as shown in Fig. 8, is a common design that promotes funnel flow. The walls are generally shallow to keep the overall height of the bin low, but more importantly, the valley angles are shallower than the adjoining walls. Most non-free-flowing solids will begin to pack or cake and then remain stagnant in the valley angle region.

The use of TIVAR® 88 in a funnel flow bin will provide the low surface friction necessary to promote flow along the walls after the center portion empties. Unlike many steels, TIVAR® 88 has the corrosion resistance necessary to prevent a rough wall condition from occurring due to corrosion. Therefore, it enhances the performance of a funnel flow bin by assisting in complete clean-out.

2.) Mass Flow

This is a first-in, first-out flow pattern in which all of the bulk solid is in motion when any of it is withdrawn (Fig. 9).

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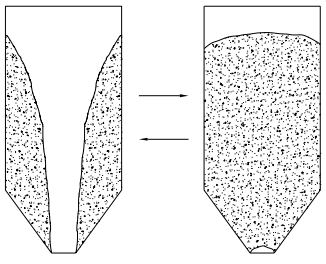

Figure 3: Erratic flow

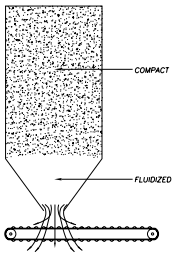

Figure 4: Flushing or flooding

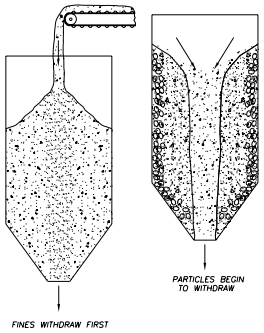

Figure 5: Segregation

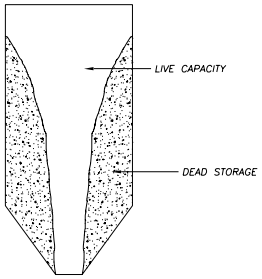

Figure 6: Reduced storage capacity

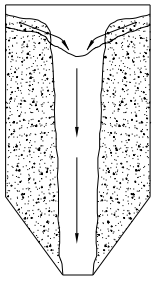

Figure 7: Funnel flow pattern

Flow of Solids from Bins and Hoppers[1] – Benefits of TIVAR® 88 Lining Systems (cont.)

Ratholes are eliminated, because there is flow along the walls and segregation is minimized because the segregated material in the bin re-mixes as the bin empties. This flow pattern is ideal for cohesive solids and those that degrade with time. Stagnant or "dead regions" are eliminated, there-by minimizing the possibilities of spontaneous combustion. See Fig. 10 for examples of mass flow bins.

It is possible to achieve mass flow in a funnel flow bin by lining the hopper walls with TIVAR® 88. The low surface friction of TIVAR® 88 promotes flow along the walls as long as the walls are steep enough for the bulk solid being handled. To quantify the bulk solid's characteristics, flow properties should be run to determine if mass flow can be achieved by lining the hopper walls. The Jenike Shear Tester[5] (ASTM D 6128-97) is a device commonly used for this testing.

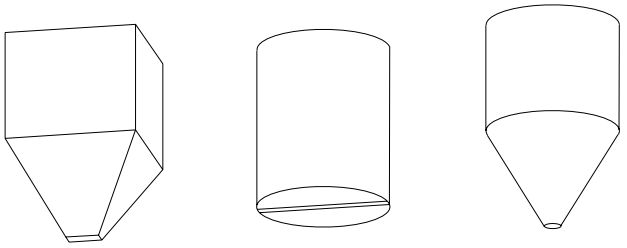

Figure 8: Examples of funnel flow bins

Experience has shown that using TIVAR® 88 as a liner in a new mass flow bin is economically sound when the hopper walls can be designed shallower, resulting in lower overall construction costs. The economic impact is significantly greater in those industries that utilize larger storage bins such as in the mining and power industries.

In a retrofit situation for an existing bin, TIVAR® 88 is a viable option compared to other types of liners because of its light weight and flexibility. It can be easily installed without utilizing special fabrication equipment or cranes to lift the material into the bin.

3.) Expanded Flow

This is a combination of both mass flow and funnel flow. The upper portion is designed for funnel flow and the lower portion is designed for mass flow, in Fig. 11.

• DESIGN CRITERIA

Many bins and hoppers are designed based on the angle of repose (Fig.12) of a bulk material, available space and/or process requirements without consideration given for the bulk solids' flowability characteristics. Unfortunately, this results in many poorly designed systems that do not provide uninterrupted, reliable flow.

In order to quantify the properties of a solid to arrive at design parameters, flowability tests should be conducted using actual samples of the bulk solid. One proven method is the Jenike Shear Tester[5] (ASTM D 6128-97), which allows the technician to measure shear forces of the bulk solid sliding against itself (internal friction) and the bulk solid sliding against the proposed wall material Fig.13. This is also a useful tool in determining the critical arching and ratholing dimensions based on the cohesive strength of the solid (Fig.13).

In a basic sense, the tester is comprised of two circular steel rings approximately 4" in diameter that are machined to slide against each other, a plotter or recording device and a pin that applies the shear force. The rings are placed on top of each other, filled with a bulk solid and an appropriate weight is placed on top of the solid to correspond to the pressures expected in the bin. The shearing pin then applies pressure to the top ring while the bottom is held stationary to shear the bulk solid against itself. The amount of force required to shear the consolidated sample is recorded. A similar procedure is done to measure the force required to shear the consolidated sample against various wall materials and again, the force is recorded. The recorded data are used in calculations to arrive at wall angles, outlet dimensions, etc.

The world's leading flow consultants are available to conduct flowability tests on any bulk solid and will provide clients with a series of design options that include bin geometry, discharge feeder suggestions, wall materials that promote flow, finite element analysis and other related services.

Contact Quadrant's SystemTIVAR® Engineering Group or see the inset box at the end of this paper to find a consultant near you.

In addition to flowability testing, three other factors impacting the flow characteristics of a bulk solid must be taken into consideration – moisture content, temperature and storage time at rest.

Moisture content modifies the properties of a solid affecting its cohesive strength and arching dimensions. It will also affect the frictional properties of a solid. In general, as the moisture increases, the flowability decreases. Once saturation is reached, if the solid is at rest for some period of time the water drains from the solid leaving it at its minimum flowability level.

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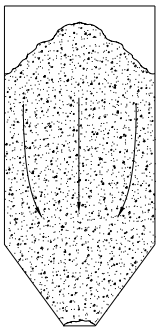

Figure 9: Mass flow pattern

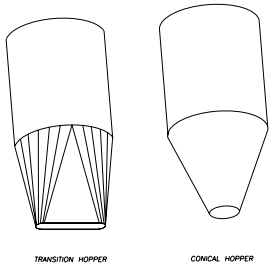

Figure 10: Examples of mass flow bins

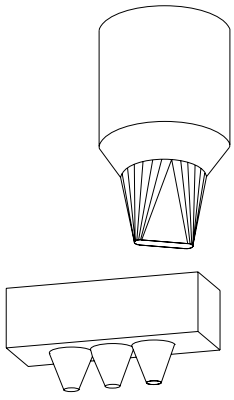

Figure 11: Examples of expanded flow bins

Flow of Solids from Bins and Hoppers[1] – Benefits of TIVAR® 88 Lining Systems (cont.)

Temperature will affect the flow properties of a solid, especially freezing and thawing[6] that takes place around 32° F (0° C). At higher temperatures there is a tendency for increased adhesion as the bulk solid becomes less free flowing.

Storage time at rest will cause some solids to consolidate or compact. Some will gain moisture and some will lose moisture as the moisture migrates to the bin walls. Moisture migration to the bin walls can cause adhesion to take place. If the storage time is extended and the material gains enough strength to arch, some type of mechanical method is required to induce flow. Once flow is induced in a mass flow hopper, the gravity flow will continue. It is critical, however, for the hopper walls to be steep enough and have a low surface friction. The surface friction of TIVAR® 88 is one of the lowest available, which is the reason it is chosen as the hopper wall material in many applications.

• TIVAR® VS. OTHER WALL MATERIALS

Quadrant's SystemTIVAR® Engineering Group maintains a comprehensive database of information on the performance of TIVAR® 88 when used with a variety of bulk materials compared to the performance of other wall materials. This information has been accumulated during the more than 30 years Quadrant's SystemTIVAR® Engineering Group has been in the bulk material handling business. From this data, we are able to provide some examples of the results. It is important to note that these examples are not to be used as design criteria. We recommend that flow property testing be conducted on each bulk material in order to derive design data. In most cases, TIVAR® 88 outperforms 304-2B stainless steel, a fact which has been documented in many full-scale applications. Situations that we see quite frequently are flow problems in a bin that has a hopper section lined with a type 304 stainless steel with a 2B finish.[7] Installing TIVAR® 88 over the top of the stainless steel has been a very effective solution for those flow problems.

Key to TIVAR® 88's success in promoting bulk material flow along hopper walls is its low surface friction. It should be noted, however, that smoothness of surface and low surface friction are not the same characteristic. For example, when tested using Australian brown coal (lignite) with 56% moisture content, TIVAR® 88 exhibits a very low wall friction angle, while the 304-2B stainless steel is entirely unsuitable because it exhibits a high friction despite the smoothness of its surface.[8]

As another example, consider sub-bituminous coal with 35.3% moisture from the Powder River Basin in Wyoming (Table 1). Mass flow can be achieved in a conical TIVAR® 88-lined hopper that has a 61° sloping wall from the horizontal and a 2-foot diameter outlet. However, for mass flow to occur with a 304-2B stainless steel-lined conical hopper, the sloping walls must be 74° from the horizontal with a 2-foot diameter outlet.

Consider the same sub-bituminous coal that has been allowed to remain in the hopper for 65 hours. Note how the wall angles have significantly increased. It is important that

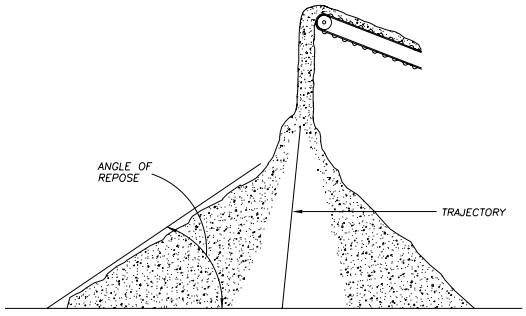

Figure 12: Angle of repose

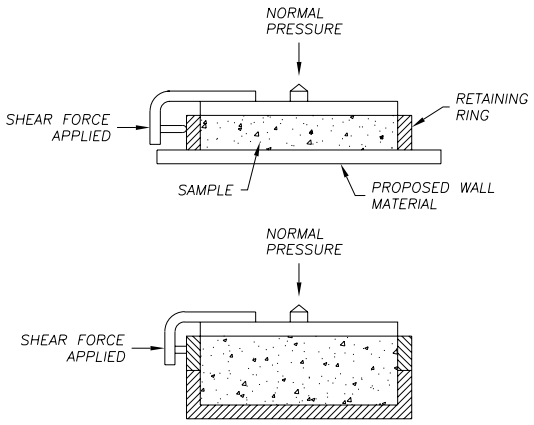

Figure 13: Jenike shear tester measures internal friction

designers understand that each bulk material should be tested for its flow properties using all possible scenarios to arrive at this type of design criteria. It is not possible to use general criteria because all bulk solids behave differently. For example, coal with a moisture content of 33.4% will behave differently than coal with a moisture content of 35.3%.

There is an economic benefit to designing bins with shallower wall angles to lower the overall height of the structure. Fig. 14 shows the overall height relationship of two different bins, both having a 440-ton storage capacity handling a solid with a bulk density of 50 lbs./ft.^{3}. One bin has a 45° hopper and the other has a 70° hopper.

• SUMMARY

On numerous occasions, coal-fired power plants experience flow problems in their coal silos even when hopper sections are designed with 70° cones and are lined with 304 stainless steel with a 2B finish. Many cases of "thumping" or tremendous vibration during discharge and arching occur because the hopper wall is not steep enough or the wall friction is too high.

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Flow of Solids from Bins and Hoppers[1] – Benefits of TIVAR® 88 Lining Systems (cont.)

One theory states the problem will alleviate itself as the flowing coal polishes the stainless steel surface. Unfortunately, this does not always happen. To achieve smooth, uninterrupted flow and eliminate the problems within the hopper, a TIVAR® 88 liner is placed on top of the stainless steel, creating a very low surface friction environment which allows the coal to flow smoothly on 70° hopper walls.

These coal-handling problems are particularly apparent when handling sub-bituminous and lignite coals due to the combination of finer particle sizes and higher moisture levels.

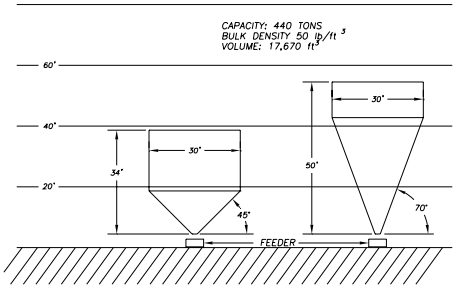
Using partial TIVAR® 88 hopper linings within a silo, while improving mass flow, may not be sufficient to create mass flow in all circumstances.

As noted previously, coal flowability characteristics are different for coal mined in different locations. Once all the bulk material flowability criteria has been determined, it is often necessary to line the entire hopper section with TIVAR® 88 to promote mass flow. Flowability tests can be run on the coal using the Jenike Shear Tester[5] (ASTM D 6128-97) to determine flowability and to allow you to evaluate the performance of a hopper liner in specific applications.

Wall material	Hours of storage at rest	Temp. (f)	35.3% moisture content	33.4% moisture content
TIVAR® 88	0	72˚	61˚	59˚
304-2B S.S.	0	72˚	74˚	76˚
TIVAR® 88	65	72˚	66˚	N/A
304-2B S.S.	65	72˚	76˚	N/A

Conical Wall Angle (deg. from horizontal)

Table 1: Sub-bituminous coal from Powder River Basin, Wyoming



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Technical Paper: Coal Flowability

TIVAR® 88 HIGH PERFORMANCE LINING SOLUTIONS

Coal Flowability Tests Indicate TIVAR® 88 Outperforms Stainless Steel

Whether designing a new storage bin, bunker or silo, or modifying an existing hopper to improve flow performance, the engineer must have knowledge of the bulk material characteristics being handled and understand the flow of solids theories.

Traditionally, 304-2B stainless steel has been the hopper wall material chosen by the engineer for new construction because of its long history of use. To solve flow problems in existing hoppers, the typical "fix" has been the use of loud, noisy flow promotion devices. The theory is, that if you beat on the hopper or shake it, you will achieve mass flow. However, in many cases, these remedies are not the answer.

TIVAR® 88, a hopper lining material recognized worldwide for its low coefficient of friction, offers an alternative solution – one that exhibits better flow promotion properties and performance than 304-2B stainless steel in many applications. In many retrofit situations, SystemTIVAR'S® Engineering experience has been that TIVAR® 88 is installed on top of existing 304-2B stainless steel liners because the stainless steel-lined hoppers were not providing satisfactory or acceptable performance.

For new construction applications, engineers are able to design hoppers with shallower wall angles and still achieve mass flow by using TIVAR® 88 as the wall material due to its low surface friction[1].

As part of an effort to show engineers some performance comparisons of TIVAR® 88 versus 304-2B stainless steel, Quadrant's SystemTIVAR® Engineering Group contracted the services of Jenike & Johanson, Inc., of Westford, Mass., to provide quantitative independent test results. The data presented are not to be used as design criteria; it is for information purposes only.

WALL ANGLE FOR CONICAL HOPPERS

Coal Sample Identification	Wall Material: Time at rest=0 storage hours		Wall Material: After storage time at rest (hours at right)		Hours at rest
	TIVAR® 88	304-2B SS	TIVAR® 88	304-2B SS	
Lignite	69	*	77**	*	72
Western (sub-bitum.)	61	74	66	76	72
Kentucky, -1/4"	61	79	64	79	20
Lignite, pulverized	64	66	***	***	
Lignite, raw	58	77	60	80	72
"Waste" coal	63	66	65	68	24
Minus 1/4"	64	71	73	72	67
Eastern (bitum.)	65	68	65	86	1
Coal, 8% moisture	63	73	64	73	66
Coal, 17% moisture	71	76	75	76	66
Midwestern	64	71	66	84	26
Midwestern	69	74	70	*	26
95% coal, 5% coke (sub-bitum./PRB)	65	81	77	81	65

Table 1: Typical wall friction data from various types of coal found in the U.S. These values represent the hopper angle (degrees from the horizontal) required to achieve mass flow in a conical-shaped hopper having a 2 ft. (610mm) diameter outlet dimension.

*Flow along the walls of either a cone or plane flow hopper is questionable.
**Conical hopper angles steeper than about 75˚ usually require special design considerations such as inserts.
***No tests were run.

In order to quantify the properties of a solid to arrive at design parameters, flowability tests should be conducted using actual samples of the bulk solid. One proven method is the Jenike Shear Tester[2] (ASTM D 6128-97), which allows the technician to measure shear forces of the bulk solid sliding against itself (internal friction) and the bulk solid sliding against the proposed wall material. The recorded data are used in calculations to arrive at hopper wall angles required for mass flow, outlet dimensions, and critical arching and ratholing dimensions based on the cohesive strength of the solid.

Flowability tests were run on various coals mined in the United States to determine the required hopper angle necessary to obtain mass flow. Mass flow is defined as all of the material in the bin in motion whenever any of the material is withdrawn. For flow along the walls to occur, the hopper walls must be smooth and sufficiently steep. Tables 1 & 2 show the results of these tests.

NOTE: In almost every case, TIVAR® 88 allows mass flow to occur at a shallower wall angle compared to stainless steel.

• FACTORS THAT AFFECT FLOW

Moisture content modifies the properties of a solid, affecting its cohesive strength and arching dimensions. It will also affect the frictional properties of a solid. In general, as the moisture increases, the flowability decreases.

Temperature can affect the flow properties of a solid, especially freezing and thawing that takes place around 32°F (0°C). At higher temperatures, there is a tendency for increased adhesion, as the bulk solid becomes less free flowing.

Storage time at rest will cause some solids to consolidate or compact. Some will gain moisture from humidity in the air and some will lose moisture as it migrates to the bin walls. Moisture migration to the bin walls can cause adhesion to take place[3].

One of the reasons for poor flow in a hopper can be attributed to adhesion of the bulk material to the hopper wall because of the moisture content. However, there is much less adhesion to TIVAR® 88 than to stainless steel. TIVAR® is hydrophobic (not readily wet by water) and stainless steel is hydrophilic (has an affinity to water).

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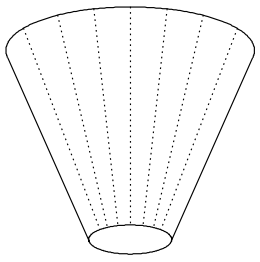
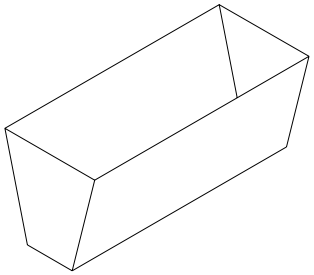


Conical shaped hopper design



Plane flow hopper design

Coal Flowability Tests Indicate TIVAR® 88 Outperforms Stainless Steel (cont.)

• SLIDING FRICTION

In addition, the surface friction of TIVAR® 88 is lower than 304-2B stainless steel. In many examples, the hopper wall angle for TIVAR® 88 can be 3º to 12º from the horizontal (depending on the flow properties of the bulk material) shallower than 304-2B stainless steel for flow to occur along the hopper wall.

As a bulk solid flows along the hopper wall, the wall surface wears, resulting in a change to the angle of sliding friction (Phi Prime). Figures 1 and 2 show the results "before" and "after" wear. The bulk solid used for this test was sub-bituminous coal from the Powder River Basin.

Wall friction is the resistance that occurs when a bin's substrate opposes the relative motion of a bulk solid sliding along its surface. Wall friction data can be used to anticipate the type of flow that will occur inside a bin and enables calculation of bin loads. Prior to designing or retrofitting a bin, silo or chute, wall friction should be considered.

TIVAR® 88 has an exceptionally low sliding friction angle when compared to stainless steel and carbon steel. The low sliding friction angles associated with TIVAR® 88 can translate into lower construction costs by building more efficiently designed bins with shallower hopper angles.

TIVAR® 88 is specified because it promotes mass flow, which eliminates dead regions within a bin and removes a material's tendency to rathole.

In funnel flow bins, material does not flow along the wall until the bin is emptied. This can give the hopper wall time to corrode, encouraging material to adhere to the wall. TIVAR® 88 has excellent corrosion resistance and non-stick characteristics that provide better clean-out.

In the past, TIVAR® 88 has proven, through field experience, to be a cost-effective wall surface lining that provides consistent flow of solids. Due to its low wall friction and superior sliding abrasion resistance, prominent engineering firms have specified TIVAR® 88 as the primary sliding wear surface in new and existing bulk solids handling systems.

WALL ANGLE FOR CONICAL HOPPERS

Coal Sample Identification	Wall Material: Time at rest=0 storage hours		After storage time at rest (hours at right)		Hours at rest
	TIVAR® 88	304-2B SS	TIVAR® 88	304-2B SS	
Lignite	58	81	66	82	72
Western (sub-bitum.)	50	63	55	65	72
Kentucky, -1/4"	49	69	52	69	20
Lignite, pulverized	53	55	***	***	
Lignite, raw	46	67	48	70	72
"Waste" coal	51	55	54	57	24
Minus 1/4"	52	60	61	61	67
Eastern (bitum.)	54	57	54	75	1
Coal, 8% moisture	52	62	52	62	66
Coal, 17% moisture	58	64	62	64	66
Midwestern	51	58	52	72	26
Midwestern	56	61	58	82	26
95% coal, 5% coke (sub-bitum./PRB)	52	70	65	70	65

Table 2: These values represent the hopper angle (degrees from the horizontal) required to achieve mass flow in a plane flow hopper (wedge or transition) with a 1 ft. (305mm) x at least 3 ft. (914mm) outlet dimension.

***No tests were run.

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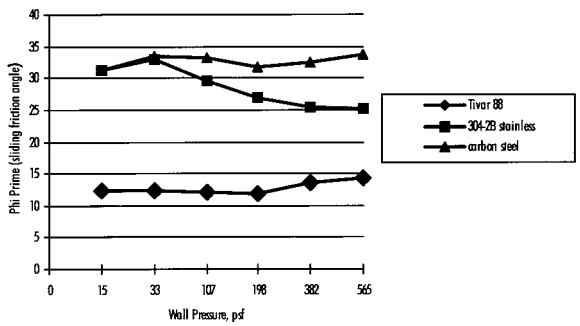


Figure 1: The angle of sliding friction "before" wear changes as a function of the wall pressure that is expected to occur within the hopper.

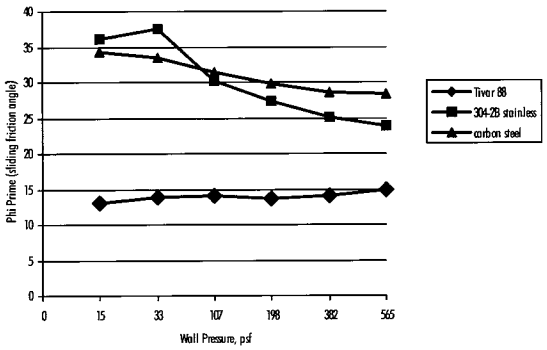


Figure 2: The angle of sliding friction "after" wear changes as a function of the wall pressure that is expected to occur within the hopper.

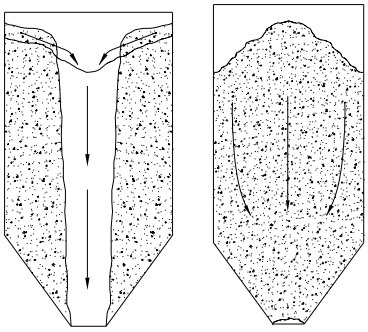
TIVAR® 88 HIGH PERFORMANCE LINING SOLUTIONS

Spontaneous Combustion; Common Sense Safety Procedures and Fastener Options

• SPONTANEOUS COMBUSTION

Most bunker fires are caused by spontaneous combustion and it is a generally accepted fact that stagnant coal (coal that remains stationary in a bunker or bin for an extended time) is one of the main causes for spontaneous combustion. The longer coal is allowed to remain stagnant, the more susceptible it becomes to self-ignition. Therefore, the ideal situation is to keep only fresh coal in the bunker–an environment that can be achieved with a mass flow pattern. Mass flow can be defined as a first-in first-out flow pattern. In fact, according to NFPA 850 Section 5-4 and 8503 Section 2-6, mass flow is necessary in order to prevent stagnant coal build-up, which is one of the main elements leading to bunker fires.

Contrary to mass flow is the funnel flow pattern which can be described as a first-in last-out flow pattern. When a funnel flow pattern exists within a coal bunker or when stagnant coal is allowed to stick or cement itself to the bin walls for an indefinite period of time, the stagnant coal becomes very susceptible to spontaneous combustion. Lining coal bunkers with TIVAR® 88 is a proven method for achieving mass flow and eliminating the potential for stagnant coal and related bunker fires.



Coal will not readily hang-up or cement itself to TIVAR® 88 under normal conditions. The low friction surface of TIVAR® 88 promotes the flow of coal along the bunker walls, which is associated with a mass flow discharge pattern. This flow pattern would eliminate regions of stagnant coal that could lead to spontaneous combustion. And this flow pattern could be achieved by using TIVAR® 88 liners. In fact, it was this attribute that led Xcel Energy (formerly Northern States Power) to choose TIVAR® 88 as the hopper wall liner at its Riverside Plant.

An article in the September 1995 issue of Power Engineering Magazine explained how stagnant coal regions leading to spontaneous combustion were eliminated from the bunkers at Northern States Power (Xcel Energy). The full case history can be found on pages 11–16 in this book or can be downloaded (pdf format) from our website, www.tivar88.com. This technical paper, titled "Case Study: How Xcel Energy Uses TIVAR® 88 to Solve Sub-Bituminous Coal Handling Problems" was also presented at POWER-GEN AMERICAS '94 Conference held in Orlando, Florida, USA, December 7-9, 1994. That TIVAR® 88 liner is still in use today at the power plant and continues to be a success.

• COMMON SENSE SAFETY PROCEDURES

Some power plants have put hot coal into bunkers lined with TIVAR® 88. ***THIS IS NOT A RECOMMENDED PRACTICE,*** although the TIVAR® 88 liner survived in many instances because the hot coal did not elevate the surface temperature of the TIVAR® 88 high enough to start a fire. Although TIVAR® 88 will ignite under certain conditions, it is not considered to be any more toxic than burning wood according to a study conducted by The Earth Technology Corporation. And it is interesting to note, that if a fire is detected within a properly designed mass flow bunker, the TIVAR® 88 will allow a faster and more complete discharge of the coal from the bunker before major damage occurs.

TIVAR® 88 should be treated much like a rubber conveyor belt; therefore, precautions such as the following are necessary to prevent accidental fires from occurring.

- Use ***CAUTION SIGNS OR PLACARDS*** (NFPA 850 Section 5-6.5.3.2) on all equipment having a TIVAR® 88 liner, alerting employees and contractors that the interior liner is flammable. In addition, the caution sign on the structure should include a statement "to have water or some other type of extinguishing media available in case of an accidental fire".
- Continuous ***STRUCTURAL WELDING*** should not be done directly on the structure without removing a portion of the liner first. If it is not possible to remove the liner, ***INTERMITTENT WELDING*** has been used successfully, although it is not recommended. If intermittent welding is attempted, it should be done responsibly ***AND ONLY IF WATER IS READILY AVAILABLE AND ANOTHER PERSON IS PRESENT TO ALERT THE WELDER IF THE LINER STARTS TO BURN.***
- The structure's surface temperature should not be allowed to get so hot that it creates a problem for the liner. If the surface of TIVAR® 88 does catch fire due to welding or some other very hot ignition source, the immediate surface area will degrade, but the material below the surface will not lose its physical properties if it is quickly extinguished.

• FASTENER OPTIONS

It is very common to use weldable fasteners to attach the TIVAR® 88 liner to a steel substrate. The welding equipment used to install a weld washer will be either a MIG welder or a stick welder. The welding electrodes for stick welding should be a maximum diameter of 3mm. Welding in the pre-drilled fastener holes in a TIVAR® 88 sheet does not create a problem if done responsibly. The welder should never use excessive heat.

Stud welding is also a popular installation method in which the molten weld is contained under the ceramic ferule. This method will also reduce human error, compared to MIG or stick welding, if the equipment is properly setup.

Weldable fasteners have been used with tremendous success to install TIVAR® 88 for more than 20 years. ***COMMON SENSE AND PREPAREDNESS IN CASE OF FIRE SHOULD BE SUFFICIENT TO PREVENT PROBLEMS.***

Project Reference List

TIVAR® 88 HIGH PERFORMANCE LINING SOLUTIONS

• POWER

ACE COGENERATION - MILLENNIUM ENERGY
TORONA, CALIFORNIA

Application:	PET Coke Storage Hopper
Quantity:	1
Liner:	TIVAR® 88-2 (1/2″ Thick)
Bulk Material:	Pet Coke
Substrate:	Mild Steel
Problem:	Flow Problem, sticking
Date Installed:	2002

AES PUERTO RICO S.E. - TOTAL ENERGY PLANT
GUAYAMA, PUERTO RICO

Application:	Coal Silos
Quantity:	8 Silos
Liner:	TIVAR® 88 (1/2″-thick)
Bulk Material:	Sub-Bituminous Coal
Substrate:	Stainless Steel Type 304-2B Finish
Problem:	Anticipated flow problems after flow property analysis of the coal
Date Installed:	2001

AIR PRODUCTS & CHEMICAL INC.
CAMBRIA CO-GENERATION
EBENSBURG, PENNSYLVANIA

Application:	500-ton Storage Bunkers
Quantity:	4 Bunkers
Liner:	TIVAR® 88 (3/4″-thick)
Bulk Material:	Bituminous Gob
Substrate:	Mild Steel
Problem:	Poor coal flow resulting from reclaimed refuse
Date Installed:	1991

ALLIANT ENERGY - M.L. KAPP STATION
CLINTON, IOWA

Application:	Receiving Hoppers
Quantity:	2 Hoppers
Liner:	TIVAR® 88-2 (3/4″-thick)
Bulk Material:	Sub-Bituminous Coal (PRB)
Substrate:	Concrete
Problem:	Flow problems, bridging, ratholing, and freezing
Date Installed:	2001

AMERICAN BITUMINOUS POWER PARTNERS, L.P.
GRANT TOWN, WEST VIRGINIA

Application:	850-ton Fuel Bunkers
Quantity:	3 Bunkers
Liner:	TIVAR® 88 (3/8″-thick)
Bulk Material:	Bituminous Gob
Substrate:	Mild Steel
Problem:	New construction, anticipated flow problems
Date Installed:	1991

AMERICAN ELECTRIC POWER - CLINCH RIVER PLANT
CLEVELAND, VIRGINIA

Application:	One Station #4 Feeder
Quantity:	4 outlets
Liner:	TIVAR® 88-2 (3/4″ thick)
Bulk Material:	Bituminous Coal
Substrate:	Concrete and stainless steel
Problem:	Flow problems, sticking and bridging
Date Installed:	2003

AMERICAN ELECTRIC POWER - ROCKPORT PLANT
ROCKPORT, INDIANA

Application:	Coal Silos
Quantity:	1 Hopper
Liner:	TIVAR® 88-2 (1/2″-thick)
Bulk Material:	Bituminous Coal
Substrate:	304-2B Stainless Steel
Problem:	Flow problems, sticking and bridging
Date Installed:	1998

AMERICAN ELECTRIC POWER - GLEN LYN STATION
GLEN LYN, VIRGINIA

Application:	700-ton Receiving Hopper
Quantity:	1 Hopper
Liner:	TIVAR® 88-2 (5/8″ –thick)
Bulk Material:	Bituminous Coal
Substrate:	Mild Steel
Problem:	Flow problems, sticking and bridging
Date Installed:	1997

AMERICAN ELECTRIC POWER - ROCKPORT PLANT
ROCKPORT, INDIANA

Application:	500- to 700-ton Silos
Quantity:	28 Silos
Liner:	TIVAR® 88 (1/2″-thick)
Bulk Material:	Sub-Bituminous Coal (PRB)
Substrate:	Stainless Steel
Problem:	Flow Problems, bridging and ratholing
Date Installed:	1984

ATLANTIC CITY ELECTRIC COMPANY - ENGLAND PLANT
MARMORA, NEW JERSEY

Application:	Transition Discharge Outlet for Fuel Silos
Quantity:	8 Silos
Liner:	TIVAR® 88 (1/2″-thick)
Bulk Material:	Bituminous Coal
Substrate:	Stainless Steel
Problem:	Flow problems, sticking and bridging
Date Installed:	1989

AUSTRIAN ENERGY (FORMERLY BABCOCK BORSIG POWER)
AUSTRIA

Application:	Hoppers
Quantity:	150 m^2
Liner:	10 mm TIVAR®
Bulk Material:	Hard Coal
Substrate:	Carbon Steel
Date Installed:	2000

BABCOCK HITACHI (FORMERLY ZUCKERFABRIK ZEITZ)
GERMANY

Application:	Hoppers
Quantity:	450 m^2
Liner:	10 mm TIVAR Blue Line
Bulk Material:	Lignite
Substrate:	Carbon Steel
Date Installed:	2004

BAN YU PAPER MILL COMPANY LTD.
CHIYI, TAIWAN

Application:	5,000-ton Storage Silos
Quantity:	2 Silos
Liner:	TIVAR® 88 (3/8″-thick)
Bulk Material:	Bituminous Coal
Substrate:	Concrete
Problem:	Anticipated flow problem, new const.
Date Installed:	1989

Project Reference List

TIVAR® 88 HIGH PERFORMANCE LINING SOLUTIONS

BASIN ELECTRIC POWER COOPERATIVE
ANTELOPE VALLEY STATION
BEULAH, NORTH DAKOTA

Application:	Bottom Ash Hopper
Quantity:	1 Hopper
Liner:	TIVAR® 88-2 (3/8″-thick)
Bulk Material:	Bottom Ash
Substrate:	Mild Steel and 304 Stainless Steel
Problem:	Flow problems, sticking and bridging
Date Installed:	1999

BASIN ELECTRIC POWER COOPERATIVE
ANTELOPE VALLEY STATION
BEULAH, NORTH DAKOTA

Application:	Ash Dewatering Hopper
Quantity:	2 Hoppers
Liner:	TIVAR® 88-2 (3/8″-thick)
Bulk Material:	Flyash (Wet)
Substrate:	Concrete
Problem:	Flow problems, ratholing, bridging and wear
Date Installed:	1998

BASIN ELECTRIC POWER COOPERATIVE
ANTELOPE VALLEY STATION
BEULAH, NORTH DAKOTA

Application:	1,000-ton Storage Silos
Quantity:	18 Silos
Liner:	TIVAR® 88 (3/8″-thick)
Bulk Material:	Lignite Coal
Substrate:	Mild Steel & Stainless Steel
Problem:	Coal sticking to hopper sidewalls at transition point
Date Installed:	1987

CENTRAL IOWA POWER COOPERATIVE - FAIR STATION
MUSCATINE, IOWA

Application:	Receiving Hoppers
Quantity:	2 Outlets
Liner:	TIVAR® 88-2 (1/2″-thick)
Bulk Material:	Bituminous Coal
Substrate:	Concrete
Problem:	Flow problems, sticking, freezing, arching, ratholing and poor discharge
Date Installed:	2000

CENTRAL LOUISIANA ELECTRIC COMPANY
RODEMACHER STATION
LENA, LOUISIANA

Application:	1,000-ton Coal Storage Silos
Quantity:	1 Silo
Liner:	TIVAR® 88 (1/2″-thick)
Bulk Material:	Lignite Coal
Substrate:	Mild Steel
Problem:	Vibrational thumping
Date Installed:	1983

CHINA LIGHT & POWER COMPANY, LTD.
CASTLE PEAK A & B STATIONS
KOWLOON, HONG KONG

Application:	Coal Storage Bunkers and Feeders
Quantity:	12 Bunkers and 20 Feeders
Liner:	TIVAR® 88 (1/2″-thick)
Bulk Material:	Bituminous Coal
Problem:	Existing basalt tiles fell out and restricted flow
Date Installed:	1985

CHOCTAW GENERATION LTD. PARTNERSHIP
RED HILLS GENERATION FACILITY
ACKERMAN, MISSISSIPPI

Application:	Day Silos
Quantity:	8 Day Silos w/ 73 Degree sloping wall and Chutes
Liner:	TIVAR® 88-2 (1/2″ thick)
Bulk Material:	Mississippi Lignite
Substrate:	304 #4 Stainless steel
Problem:	Flow problems, sticking and bridging
Date Installed:	2001-2002

CHOCTAW GENERATION LTD. PARTNERSHIP
RED HILLS GENERATION FACILITY
AKERMAN, MISSISSIPPI

Application:	Euro-silos
Quantity:	2
Liner:	TIVAR® 88-2 (1/2″ thick)
Bulk Material:	Mississippi Lignite
Substrate:	Mild steel
Problem:	Flow problems, sticking and bridging
Date Installed:	2001

CINERGY - ZIMMER PLANT
MOSCOW, OHIO

Application:	Traveling Loading Hopper & Gypsum Loading Hopper
Quantity:	2 Outlets
Liner:	TIVAR® 88-2 (1/2″ & 3/4″-thick)
Bulk Material:	FGD Sludge & Gypsum
Substrate:	Mild Steel
Problem:	New construction anticipated flow problems
Date Installed:	2000

COLUMBUS SOUTHERN POWER COMPANY
CONESVILLE STATION
CONESVILLE, OHIO

Application:	FGD Belt Conveyor Transfer Points
Quantity:	2 Transfer Housings
Liner:	TIVAR® 88-2 (3/8″-thick)
Bulk Material:	FGD Sludge
Substrate:	Mild Steel
Problem:	FGD sludge build-up on steel surfaces
Date Installed:	1992

COMMISSION FEDERAL DE ELECTRICIDAD (C.F.E.)
CARBON II STATION
PIEDRAS NEGRAS, COAHUILA, MEXICO

Application:	Receiving Bunkers
Quantity:	1 Bunker
Liner:	TIVAR® 88 (1/2″-thick)
Bulk Material:	Sub-Bituminous Coal
Substrate:	316 Stainless Steel
Problem:	Ratholing, no flow conditions
Date Installed:	1993

COMMISSION FEDERAL DE ELECTRICIDAD (C.F.E.)
JOSE LOPEZ PORTILLO POWER STATION
PIEDRAS NEGRAS, COAHUILA, MEXICO

Application:	480-ton Fuel Silos
Quantity:	5 Silos
Liner:	TIVAR® 88 (1/2″-thick)
Bulk Material:	Sub-Bituminous Coal
Substrate:	304 Stainless Steel
Problem:	Vibrational thumping during discharge
Date Installed:	1992

Project Reference List

TIVAR® 88 HIGH PERFORMANCE LINING SOLUTIONS

DOMINION GENERATION - MT. STORM / UNIT #3
MOUNT STORM, WEST VIRGINIA

Application:	Mass Flow Conversion Project
Quantity:	6 outlets
Liner:	TIVAR® 88-2 (1/2″ thick)
Bulk Material:	Bituminous coal blend
Substrate:	Mild Steel
Problem:	New Construction
Date Installed:	March/2007
Engineering Firm:	Recommended liner by J&J

DOMINION GENERATION - MT. STORM / UNIT #1
MOUNT STORM, WEST VIRGINIA

Application:	Mass Flow Conversion Project
Quantity:	6 outlets
Liner:	TIVAR® 88-2 (1/2″ thick)
Bulk Material:	Bituminous coal blend
Substrate:	Mild Steel
Problem:	New Construction
Date Installed:	March/2006
Engineering Firm:	Recommended liner by J&J

DOMINION GENERATION - MT. STORM / UNIT #2
MOUNT STORM, WEST VIRGINIA

Application:	Mass Flow Conversion Project
Quantity:	6 outlets
Liner:	TIVAR® 88-2 (1/2″ thick)
Bulk Material:	Bituminous coal blend
Substrate:	Mild Steel
Problem:	New Construction
Date Installed:	March/2005
Engineering Firm:	Recommended liner by J&J

EASTMAN KODAK
ROCHESTER, NEW YORK

Application:	Coal Bunkers for 13 & 14 Stoker Boilers
Quantity:	3 Outlets
Liner:	TIVAR® 88-2 (1/2″-thick)
Bulk Material:	Sub-Bituminous Coal
Substrate:	304 Stainless Steel
Problem:	Flow problems, sticking and bridging
Date Installed:	1999

ELEKTROWNIA TUROW S.A. - TUROW PLANT
BOGATYNIA, POLAND

Application:	Units 1, 2, & 3 Coal Bunkers
Quantity:	18 Bunkers
Liner:	TIVAR® 88 (1/2″-thick)
Bulk Material:	Lignite (Brown) Coal
Substrate:	Mild Steel
Problem:	Anticipated flow problems in modernization project involving new fuel source, lignite (brown) coal
Date Installed:	1998

ENBW STUTTGART (FORMERLY KRAFTWERK GAISBURG)
GERMANY

Application:	Hoppers
Quantity:	550 m^2
Liner:	15 mm TIVAR® Blue Line
Bulk Material:	Hard Coal
Substrate:	Carbon Steel
Date Installed:	2006

ENBW NECKARWERKE (FORMERLY STEINMÜLLER)
GERMANY

Application:	Hoppers
Quantity:	800 m^2
Liner:	10 mm TIVAR®
Bulk Material:	Hard Coal
Substrate:	Carbon Steel
Date Installed:	2002

FLORIDA POWER & LIGHT - POSDEF POWER
STOCKTON, CALIFORNIA

Application:	2,500 Ton Coal Silo
Quantity:	1 - 40′ diameter silo
Liner:	TIVAR® 88 (3/4″ thick)
Bulk Material:	20% Coke and 80% Skyline Bit. Coal
Substrate:	Stainless Steel
Problem:	Flow problems sticking and bridging
Date Installed:	April/2006
Engineering Firm:	Recommended liner by J&J

GEMEINSCHAFTSKRAFTWERK WESER (FORMERLY KRAFTWERK VELTHEIM)
GERMANY

Application:	Hoppers
Quantity:	300 m^2
Liner:	15 mm TIVAR® Blue Line
Bulk Material:	Hard Coal
Substrate:	Carbon Steel
Date Installed:	2006

HEALY CLEAN COAL
HEALY, ALASKA

Application:	Coal Silo
Quantity:	2 Conical Hoppers
Liner:	TIVAR® 88-2 (3/8″-thick)
Bulk Material:	Sub-Bituminous Coal
Substrate:	Mild Steel
Problem:	Sticking and arching
Date Installed:	1996

INFRACOR (FORMERLY INFRACOR/RAG)
GERMANY

Application:	Hoppers
Quantity:	140 m^2
Liner:	15 mm TIVAR® Blue Line
Bulk Material:	Hard Coal
Substrate:	Concrete
Date Installed:	2007

INFRACOR
GERMANY

Application:	Hoppers
Quantity:	440 m^2
Liner:	10 mm TIVAR®
Bulk Material:	Hard Coal
Substrate:	Carbon Steel
Date Installed:	1999

INTERPOWER/AHLCON PARTNERS
COLVER COGENERATION PLANT
EBENSBURG, PENNSYLVANIA

Application:	2,000-ton Fuel Silo
Quantity:	1 Silo
Liner:	TIVAR® 88 (1/2″-thick)
Bulk Material:	Anthracite Culm
Substrate:	Mild Steel
Problem:	New construction, steep wall angles resulted in unacceptable silo height
Date Installed:	1994

Project Reference List

TIVAR® 88 HIGH PERFORMANCE LINING SOLUTIONS

KENTUCKY UTILITIES - BROWN STATION
BURGIN, KENTUCKY

Application:	Receiving Hoppers
Quantity:	8 Outlets
Liner:	TIVAR® 88-2 (1/2″-thick)
Bulk Material:	Synfuel
Substrate:	Concrete
Problem:	Flow problems, sticking, freezing, and bridging
Date Installed:	2000

KENTUCKY UTILITIES - GREEN RIVER STATION
CENTRAL CITY, KENTUCKY

Application:	Receiving Hoppers
Quantity:	2 Outlets
Liner:	TIVAR® 88-2 (1/2″-thick)
Bulk Material:	Synfuel
Substrate:	Concrete
Problem:	Flow problems, sticking, freezing, and bridging
Date Installed:	1999

KOHLEKRAFTWERK
BORSELE, NETHERLANDS

Application:	Bunkers
Quantity:	2
Liner:	TIVAR® 88, 12 mm thick
Bulk Materials:	Hard coal
Substrate:	Steel
Problem:	Caking and bridging
Date Installed:	2003

KRUPP HAZEMAG FRANCE
TURKEY

Application:	Hoppers
Quantity:	1,150 m^2
Liner:	15 mm TIVAR®
Bulk Material:	Lignite
Substrate:	Concrete
Date Installed:	2004

KRUPP HAZEMAG FRANCE
TURKEY

Application:	Hoppers
Quantity:	15,000 m^2
Liner:	10 mm TIVAR®
Bulk Material:	Lignite
Substrate:	Carbon Steel
Date Installed:	2003

LABRIS TÜRKEI
TURKEY

Application:	Excavators
Quantity:	3,000 m^2
Liner:	20 mm TIVAR® Blue Line UV/Antistatic
Bulk Material:	Lignite
Substrate:	Carbon Steel
Date Installed:	2008

LOGANSPORT MUNICIPAL UTILITIES
LOGANSPORT, INDIANA

Application:	Flyash Pugmill (Conditioner)
Quantity:	1 Pugmill (Ash Conditioner)
Liner:	TIVAR® 88-2 (1/4″ thick)
Bulk Material:	Flyash / Bottom Ash (Wet)
Substrate:	Mild Steel
Problem:	Wear and sticking problems
Date Installed:	2000

LOUISVILLE GAS AND ELECTRIC - CANE RUN PLANT
LOUISVILLE, KENTUCKY

Application:	Receiving Hopper
Quantity:	1 Hopper
Liner:	TIVAR® 88-2 (1/2″-thick)
Bulk Material:	Bituminous Coal
Substrate:	Concrete
Problem:	Coal sticking, freezing and bridging
Date Installed:	1998

MIDWEST GENERATION - WILL COUNTY STATION
ROMEOVILLE, ILLINOIS

Application:	Chutes & Hopper
Quantity:	2 Chutes & 1 Hopper
Liner:	TIVAR® 88-2 (3/4″-thick)
Bulk Material:	Sub-Bituminous Coal (PRB)
Substrate:	Rubber & Mild Steel
Problem:	Wear and flow problems
Date Installed:	2001

MIRANT MID-ATLANTIC LLC
DICKERSON GENERATING STATION / UNIT #2
DICKERSON, MARYLAND

Application:	Auxiliary Coal Bunker
Quantity:	6 hoppers
Liner:	TIVAR® 88-2 (1/2″ and 3/4″ thick)
Bulk Material:	Eastern Bituminous
Substrate:	304 2B SS
Problem:	Flow problems sticking and bridging
Date Installed:	January/2007
Engineering Firm:	Jenike & Johanson

MONONGAHELA POWER COMPANY - ALBRIGHT STATION
ALBRIGHT, WEST VIRGINIA

Application:	Fuel Bunkers
Quantity:	4 Bunkers
Liner:	TIVAR® 88-2 (1/2″-thick)
Bulk Material:	Bituminous Coal
Substrate:	Carbon Steel
Problem:	Flow problems, sticking and bridging
Date Installed:	1993

MUSCATINE POWER AND WATER
MUSCATINE, IOWA

Application:	Coal Chute
Quantity:	1 Chute
Liner:	TIVAR® 88-2 (3/4″-thick)
Bulk Material:	Sub-Bituminous Coal (PRB)
Substrate:	Mild Steel
Problem:	Flow problems, sticking and freezing
Date Installed:	1999

MUSCATINE POWER AND WATER
MUSCATINE, IOWA

Application:	Units 7 & 8 Coal Receiving Hoppers
Quantity:	2 Outlets
Liner:	TIVAR® 88-2 (3/4″-thick)
Bulk Material:	Sub-Bituminous Coal (PRB)
Substrate:	Concrete
Problem:	Flow problems, sticking, freezing and bridging
Date Installed:	1994

Project Reference List

TIVAR® 88 HIGH PERFORMANCE LINING SOLUTIONS

MUSCATINE POWER AND WATER
MUSCATINE, IOWA
Application: Vibratory Pan Feeder
Quantity: 3 Feeders
Liner: TIVAR® 88-2 (1/2″-thick)
Bulk Material: Sub-Bituminous Coal (PRB)
Substrate: Stainless Steel
Problem: Flow problems, sticking
Date Installed: 2000

NORTHAMPTON COGENERATION
NORTHAMPTON, PENNSYLVANIA
Application: 2,000-ton Fuel Silo
Quantity: 1 Silo
Liner: TIVAR® 88 (1/2″-thick)
Bulk Material: Anthracite Culm
Substrate: Mild Steel
Problem: New construction, steep wall angles resulted in unacceptable silo height
Date Installed: 1994

OHIO POWER COMPANY - KAMMER PLANT
MOUNDSVILLE, WEST VIRGINIA
Application: Station #1 Truck Hoppers
Quantity: 2
Liner: TIVAR® 88-2 (3/4″ thick)
Bulk Material: Bituminous Coal
Substrate: Stainless steel
Problem: Flow Problems, bridging and sticking
Date Installed: 2003

OHIO POWER COMPANY - MUSKINGUM RIVER STATION
BEVERLY, OHIO
Application: Unit 3 & 4 Coal Bunkers
Quantity: 10 Outlets
Liner: TIVAR® 88-2 (1/2″-thick)
Bulk Material: Bituminous Coal
Substrate: Stainless Steel
Problem: Flow problems, sticking and bridging
Date Installed: 2001

OHIO POWER COMPANY - MUSKINGUM RIVER STATION
BEVERLY, OHIO
Application: Unit 2 Coal Bunker
Quantity: 8 Outlets
Liner: TIVAR® 88-2 (1/2″-thick)
Bulk Material: Bituminous Coal
Substrate: Mild Steel
Problem: Flow problems, ratholing, and bridging
Date Installed: 2000

OHIO POWER COMPANY - MUSKINGUM RIVER STATION
BEVERLY, OHIO
Application: Unit 1 Coal Bunker
Quantity: 8 Outlets
Liner: TIVAR® 88-2 (1/2″-thick)
Bulk Material: Bituminous Coal
Substrate: Gunite
Problem: Flow problems, ratholing, and bridging
Date Installed: 1999

OHIO POWER COMPANY - KAMMER PLANT
MOUNDSVILLE, WEST VIRGINIA
Application: Station 3 Receiving Bin
Quantity: 4 Outlets
Liner: TIVAR® 88-2 (1/2″-thick)
Bulk Material: Bituminous Coal
Substrate: Stainless Steel
Problem: Flow problems, sticking, and bridging (eliminated need for vibrators)
Date Installed: 1998

OHIO POWER COMPANY - KAMMER PLANT
MOUNDSVILLE, WEST VIRGINIA
Application: Units 2 & 3 Coal Bunker
Quantity: 10 Outlets
Liner: TIVAR® 88-2 (1/2″-thick)
Bulk Material: Bituminous Coal
Substrate: Stainless Steel
Problem: Flow problems, sticking and bridging
Date Installed: 1998

OHIO POWER COMPANY - KAMMER PLANT
MOUNDSVILLE, WEST VIRGINIA
Application: Unit 1 Coal Bunker
Quantity: 5 Outlets
Liner: TIVAR® 88-2 (1/2″-thick)
Bulk Material: Bituminous Coal
Substrate: Stainless Steel
Problem: Flow problems, sticking and bridging
Date Installed: 1997

OHIO POWER COMPANY - GAVIN PLANT
CHESIRE, OHIO
Application: Receiving Bin
Quantity: 4 Outlets
Liner: TIVAR® 88-2 (1/2″-thick)
Bulk Material: Bituminous Coal
Substrate: Concrete
Problem: Flow problems, sticking and bridging
Date Installed: 1997

OHIO POWER COMPANY - GAVIN PLANT
CHESIRE, OHIO
Application: FGD Belt Conveyor Transfer Points
Quantity: 21 Transfer Housings
Liner: TIVAR® 88-2 (3/8″-thick)
Bulk Material: FGD Sludge
Substrate: Mild Steel
Problem: Anticipated flow problems in new construction
Date Installed: 1993

OHIO VALLEY ELECTRIC CORP. - KYGER CREEK STATION
GALLIPOLIS, OHIO
Application: Unit 1 through 5 Coal Bunkers
Quantity: 35 Outlets
Liner: TIVAR® 88-2 (1/2″-thick)
Bulk Material: Bituminous Coal
Substrate: Gunite with Stainless Steel Valleys
Problem: Flow problems, sticking and bridging
Date Installed: 2001

PERUSAHAAN UMUM LISTRICK NEGARA (PLN)
SURALAYA POWER STATION
SURANG, WEST JAVA, INDONESIA
Application: Coal Silos
Quantity: 5 500-ton Silos
Liner: TIVAR® 88 (1/2″-thick)
Bulk Material: Sub-Bituminous Coal
Substrate: 304 2B Stainless Steel
Problem: Complete blockage or bridging in lower portion of cone
Date Installed: 1992 & 1995

Project Reference List

TIVAR® 88 HIGH PERFORMANCE LINING SOLUTIONS

PERUSAHAAN UMUM LISTRICK NEGARA (PLN)
BUKIT ASAM STATION
TANJUNG, INDONESIA

Application:	Units 1-4 Coal Silos
Quantity:	12 100-ton Silos
Liner:	TIVAR® 88 (1/2″-thick)
Bulk Material:	Sub-Bituminous Coal
Substrate:	Mild Steel
Problem:	Ratholing, arching and no-flow
Date Installed:	1992 & 1994

PROGRESS ENERGY INCORPORATED
ASHEVILLE PLANT / UNIT #2
ASHEVILLE, NORTH CAROLINA

Application:	Silos
Quantity:	4
Liner:	TIVAR® 88-2 (1/2″ thick)
Bulk Material:	Synfuel coal / Bituminous blend
Substrate:	Mild Steel
Problem:	Flow problems sticking and bridging
Date Installed:	2006
Engineering Firm:	Worley Parsons

RELIANT ENERGY H L & P - W.A. PARISH
THOMPSONS, TEXAS

Application:	Flyash Mixer
Quantity:	1 Pugmill (Ash Conditioner)
Liner:	TIVAR® 88-2 (3/8″-thick)
Bulk Material:	Flyash (Wet)
Substrate:	Mild Steel
Problem:	Abrasion and sticking problems
Date Installed:	1999

RELIANT ENERGY (FORMERLY PENELEC)
KEYSTONE GENERATING STATION
SHELOCTA, PENNSYLVANIA

Application:	Elephant Snout Chutes
Quantity:	Chutes
Liner:	TIVAR® 88-2 (1/2″-and 1″-thick)
Bulk Material:	Bituminous Coal
Substrate:	Mild Steel
Problem:	Sticking and build-up
Date Installed:	1994

RWE POWER
GERMANY

Application:	Hoppers
Quantity:	770 m^2
Liner:	10 mm TIVAR® Blue Line
Bulk Material:	Lignite
Substrate:	Carbon Steel
Date Installed:	2007

RWE POWER KRAFTWERK NEURATH
GERMANY

Application:	Hoppers
Quantity:	3,400 m^2
Liner:	12 mm TIVAR® Blue Line
Bulk Material:	Lignite
Substrate:	Carbon Steel
Date Installed:	2009

RWE POWER KRAFTWERK WEISWEILER
GERMANY

Application:	Hoppers
Quantity:	600 m^2
Liner:	12 mm TIVAR® Blue Line
Bulk Material:	Lignite
Substrate:	Carbon Steel
Date Installed:	2008

RWE (FORMERLY KRAFTWERK NIEDERAUSSEM)
GERMANY

Application:	Hoppers
Quantity:	1,000 m^2
Liner:	12 mm TIVAR® Blue Line
Bulk Material:	Lignite
Substrate:	Concrete
Date Installed:	2006

RWE POWER STATION WESTFALEN
HAMM, GERMANY

Application:	Hopper and Chute
Quantity:	2
Liner:	TIVAR® 88 antistatic (10 mm thick)
Bulk Materials:	Meat and Bone Meal
Substrate:	Steel
Problem:	Flow problems, sticking and ratholing
Date Installed:	2001-2002

SANTEE COOPER GENERATING STATION - UNIT #4
CROSS, SOUTH CAROLINA

Application:	Storage Silo
Quantity:	1
Liner:	TIVAR® 88-2 (1/2″ liner)
Bulk Material:	Limestone
Substrate:	Mild Steel
Problem:	New Construction
Date Installed:	September/2006
Engineering Firm:	Roberts & Schaefer

SANTEE COOPER GENERATING STATION, UNIT #3
CROSS, SOUTH CAROLINA

Application:	Storage Silos
Quantity:	2
Liner:	TIVAR® 88-2 (1/2″ thick)
Bulk Material:	Limestone
Substrate:	Mild Steel
Problem:	New Construction
Date Installed:	March/2005
Engineering Firm:	Roberts & Schaefer

SASKATCHEWAN POWER - POPLAR RIVER STATION
CORONACH, SASKATCHEWAN, CANADA

Application:	Drag Chain Conveyor
Quantity:	1 Conveyor
Liner:	TIVAR® 88-2 (1″-thick)
Bulk Material:	Lignite Coal
Substrate:	Mild Steel
Problem:	Wear problems and excessive noise
Date Installed:	1994

SOUTH CAROLINA ELECTRIC AND GAS COMPANY
WATEREE, SC

Application:	Silo
Quantity:	1
Liner:	1/2″ thick TIVAR 88-2
Bulk Material:	Limestone
Substrate:	Carbon Steel
Problem:	New Construction
Date Installed:	2008

Project Reference List

TIVAR® 88 HIGH PERFORMANCE LINING SOLUTIONS

SOUTH CAROLINA ELECTRIC AND GAS COMPANY
WILLIAMS, SC

Application:	Silo
Quantity:	1
Liner:	1/2″ thick TIVAR 88-2
Bulk Material:	Limestone
Substrate:	Carbon Steel
Problem:	New Construction
Date Installed:	2008

SOUTH CAROLINA PUBLIC SERVICE AUTHORITY
JEFFERIES STEAM PLANT
MONCKS CORNER, SOUTH CAROLINA

Application:	800-ton Fuel Silos
Quantity:	8 Silos
Liner:	TIVAR® 88 (3/8″-thick)
Bulk Material:	Bituminous Coal
Substrate:	Mild Steel
Problem:	Corrosion and wear
Date Installed:	1989

SOUTHERN INDIANA GAS & ELECTRIC - CULLEY STATION
NEWBURGH, INDIANA

Application:	Transition Hopper & Pant Leg
Quantity:	1 Hopper & 1 Pant Leg
Liner:	TIVAR® 88 (1/2″-thick)
Bulk Material:	Limestone
Substrate:	Mild Steel
Problem:	Wear and flow problems
Date Installed:	2001

SOUTHERN INDIANA GAS & ELECTRIC - BROWN STATION
MT. VERNON, INDIANA

Application:	Chute
Quantity:	1 Chute
Liner:	TIVAR® 88-2 (1/2″-thick)
Bulk Material:	FGD Sludge
Substrate:	Mild Steel
Problem:	Flow problems
Date Installed:	1998

SUNNYSIDE COGENERATION ASSOCIATES
650 TON COAL SILO
EAST CARBON, UTAH

Application:	Modified Coal Storage Silo
Quantity:	1 silo
Liner:	TIVAR® 88-2 (1/2″ thick)
Bulk Material:	Waste Bituminous Coal
Substrate:	Mild Steel
Problem:	Flow problems sticking and bridging
Date Installed:	February/2006
Engineering Firm:	Recommended liner by J&J

TAIWAN POWER COMPANY
LINKOU THERMAL POWER STATION
TAIPEI, TAIWAN

Application:	Chemical Sludge & Flyash Hoppers
Quantity:	7 Hoppers
Liner:	TIVAR® 88-2 (1/2″-thick)
Bulk Material:	Chemical Sludge & Flyash
Substrate:	Mild Steel
Problem:	New construction incorporated into original design
Date Installed:	1992

TUCSON ELECTRIC POWER SPRINGERVILLE
SPRINGERVILLE, ARIZONA

Application:	Under Chain Liner
Quantity:	1
Liner:	TIVAR 88 with BurnGuard
Bulk Material:	Sub-Bituminous Coal (PRB)
Substrate:	Carbon Steel
Problem:	New Construction
Date Installed:	2009

TUCSON ELECTRIC POWER SPRINGERVILLE / UNIT # 4
SPRINGERVILLE, ARIZONA

Application:	Primary Fuel Storage silos
Quantity:	4
Liner:	3/4″ thick TIVAR 88 with BurnGuard
Bulk Material:	Sub-Bituminous Coal (PRB)
Substrate:	Carbon Steel
Problem:	New Construction
Date Installed:	2008

TUCSON ELECTRIC POWER - SPRINGERVILLE / UNIT #3
SPRINGERVILLE, ARIZONA

Application:	Primary Fuel Storage Silos
Quantity:	4
Liner:	TIVAR® 88-2 (1/2″ thick)
Bulk Material:	Sub-Bituminous Coal (PRB)
Substrate:	Mild Steel
Problem:	New Construction
Date Installed:	June/2005
Engineering Firm:	Bechtel Power

TXU / SANDOW/UNIT # 5
ROCKDALE, TEXAS

Application:	Four End Silos and Four Middle Silos
Quantity:	8 silos
Liner:	3/4″ thick TIVAR 88 with BurnGuard
Bulk Material:	Sub-Bituminous Coal (PRB)
Substrate:	Carbon Steel
Problem:	New Construction
Date Installed:	2008

UPPER PENINSULA GENERATING STATION
PRESQUE ISLE STATION
MARQUETTE, MICHIGAN

Application:	500-ton Receiving Bin
Quantity:	1 Bin
Liner:	TIVAR® 88 (3/4″-thick)
Bulk Material:	Sub-Bituminous Coal & Limestone
Substrate:	Carbon Steel
Problem:	Corrosion and wear
Date Installed:	1988

VATIS (FORMERLY SIDMAR – ARCELOR)
BELGIUM

Application:	Hoppers
Quantity:	300 m^2
Liner:	15 mm TIVAR® Blue Line
Bulk Material:	Hard Coal
Substrate:	Concrete
Date Installed:	2007

Project Reference List

TIVAR® 88 HIGH PERFORMANCE LINING SOLUTIONS

VATIS
NETHERLANDS
Application: Hoppers
Quantity: 75 m^2
Liner: 12 mm TIVAR® 88
Bulk Material: Hard Coal
Substrate: Carbon Steel
Date Installed: 2003

VW KRAFTWERKE AG
GERMANY
Application: Hoppers
Quantity: 600 m^2
Liner: 10 mm TIVAR®
Bulk Material: Hard Coal
Substrate: Carbon Steel
Date Installed: 2005

WISCONSIN PUBLIC SERVICE CORP. - PULLIAM STATION
GREEN BAY, WISCONSIN
Application: Coal Bunker
Quantity: 2 Bunkers
Liner: TIVAR® 88-2 (1/2″-thick)
Bulk Material: Sub-Bituminous Coal (PRB)
Substrate: Gunite
Problem: Flow problems, plugging and ratholing
Date Installed: 1995

WISCONSIN PUBLIC SERVICE CORPORATION
WESTON GENERATING STATION
WAUSAU, WISCONSIN
Application: Unit 2 Coal Bunker
Quantity: 4 Outlets
Liner: TIVAR® 88 (1/2″-thick)
Bulk Material: Sub-Bituminous Coal (PRB)
Substrate: Mild Steel
Problem: Flow problems, sticking and bridging
Date Installed: 1993

WISCONSIN PUBLIC SERVICE CORPORATION
WESTON GENERATING STATION
WAUSAU, WISCONSIN
Application: 1000-ton Coal Storage Silos
Quantity: 1 Silo
Liner: TIVAR® 88 (1/2″-thick)
Bulk Material: Sub-Bituminous Coal (PRB)
Substrate: Stainless Steel
Problem: Vibrational thumping
Date Installed: 1986

WTW ENGINEERING
GERMANY
Application: Hoppers
Quantity: 470 m^2
Liner: 10 mm TIVAR®
Bulk Material: Lignite
Substrate: Carbon Steel
Date Installed: 2000

XCEL ENERGY - SHERCO PLANT
BECKER, MINNESOTA
Application: Wet Scrubber System Modules
Quantity: 24
Liner: TIVAR® 88-2 (1/4″-thick)
Bulk Material: Sub-Bituminous Coal (PRB)
Substrate: 10 Gauge Stainless Steel
Problem: Wear, abrasion, cost
Date Installed: 1999-2000

XCEL (FORMERLY NORTHERN STATES POWER)
RIVERSIDE GENERATING STATION
MINNEAPOLIS, MINNESOTA
Application: Unit 8 5,000-ton Bunkers
Quantity: 5 Outlets
Liner: TIVAR® 88 (1/2″-thick)
Bulk Material: Sub-Bituminous Coal (PRB)
Substrate: Gunite & Stainless Steel
Problem: Spontaneous combustion due to stagnant coal (result of funnel flow pattern)
Date Installed: 1994

XCEL (FORMERLY NORTHERN STATES POWER)
BLACK DOG PLANT
BURNSVILLE, MINNESOTA
Application: 250-ton Rail Car Receiving Bunkers
Quantity: 2 Bunkers
Liner: TIVAR® 88 (3/4″-thick)
Bulk Material: Sub-Bituminous Coal (PRB)
Substrate: Gunite
Problem: Coal sticking, stagnation
Date Installed: 1986

• RAILCARS

ALABAMA POWER
BIRMINGHAM, ALABAMA
Application: Bottom Dump Rail Cars
Quantity: 200 Cars
Liner: TIVAR® 88-2 (3/8″-thick)
Bulk Material: Bituminous Coal
Substrate: Aluminum
Problem: Poor discharge
Date Installed: 2001

BASIN ELECTRIC POWER COOPERATIVE
LELAND OLDS STATION
STANTON, NORTH DAKOTA
Application: Ortner Rapid Discharge Railcars
Quantity: 75 Cars
Liner: TIVAR® 88-2 (3/8″-thick)
Bulk Material: Lignite Coal
Substrate: Corten®
Problem: Flow problems, sticking and freezing
Date Installed: 1997

CANAC
NEW BRUNSWICK, CANADA
Application: Bottom Dump Hopper Railcars
Quantity: 44 Cars
Liner: TIVAR® 88-2 (1/2″ and 3/4″-thick)
Bulk Material: Zinc and Lead Concentrate
Substrate: Mild Steel
Problem: Poor discharge
Date Installed: 1996

NEW YORK CITY TRANSIT
BROOKLYN, NEW YORK
Application: Demolition Railcars
Quantity: 23
Liner: TIVAR® 88-2 (1/2″ Thick)
Bulk Material: Misc. debris
Substrate: Mild Steel
Problem: Sticking
Date Installed: 2002

Project Reference List

TIVAR® 88 HIGH PERFORMANCE LINING SOLUTIONS

VULCAN - ROCKINGHAM GRANITE QUARRY
ROCKINGHAM, NC
Application: Bottom Dump Railcars
Quantity: 52 Cars
Liner: TIVAR® 88-2 (3/8"-thick)
Bulk Material: Crushed Stone
Substrate: Mild Steel
Problem: Maintenance, safety and poor discharge
Date Installed: 1995 & 1996

• SHIP LININGS

CANADIAN SHIP LINES
Ship Name: Atlantic Erie
Application: Ship Hold Linings
DWT Dimension: 38,400
Lining Area: 1,300 m^2
Shipyard: Hyundai Mipo, Bremerhaven/Germany
Date Installed: 1992

CANADIAN SHIP LINES
Ship Name: Atlantic Superior
Application: Ship Hold Linings
DWT Dimension: 30,000
Lining Area: 1,300 m^2
Shipyard: Amsterdam, Netherlands
Date Installed: 1992

CHINA
Ship Name: Hai Wang Xing
Application: Ship Hold Linings
DWT Dimension: 35,000
Lining Area: 4,920 m^2
Shipyard: Bremer Vulkan/Germany
Date Installed: 1995

CHINA
Ship Name: Tian Long Xing
Application: Ship Hold Linings
DWT Dimension: 35,000
Lining Area: 4,920 m^2
Shipyard: Bremer Vulkan/Germany
Date Installed: 1994

HARTMANN
Ship Name: Splitnes
Application: Ship Hold Linings
DWT Dimension:
Lining Area: 3,600 m^2
Shipyard: Norderwerft/Hamburg, Germany
Date Installed: 2006

HARTMANN
Ship Name: Sandnes
Application: Ship Hold Linings
DWT Dimension:
Lining Area: 3,560 m^2
Shipyard: Sietas Werft/Germany
Date Installed: 2005

HARTMANN
Ship Name: Kvitnes/Rocknes
Application: Ship Hold Linings
DWT Dimension: 36,000
Lining Area: 3,600 m^2
Shipyard: Sietas Werft/Germany
Date Installed: 2001

HARTMANN
Ship Name: Stones
Application: Ship Hold Linings
DWT Dimension: 36,000
Lining Area: 3,600 m^2
Shipyard: Sietas Werft/Germany
Date Installed: 2000

JEBSEN
Ship Name: Torgness/Enterprice
Application: Ship Hold Linings
DWT Dimension: 20,000
Lining Area: 1,500 m^2
Shipyard: Unithai/Bangkok, Thailand
Date Installed: 1996

JEBSEN
Ship Name: Tinnes
Application: Ship Hold Linings
DWT Dimension: 23,000
Lining Area: 1,800 m^2
Shipyard: Kleven/Norway
Date Installed: 1984

JEBSEN
Ship Name: Telnes
Application: Ship Hold Linings
DWT Dimension: 23,000
Lining Area: 1,800 m^2
Shipyard: Kleven/Norway
Date Installed: 1984

OLDENDORFF
Ship Name: Harmen Oldendorff
Application: Ship Hold Linings
DWT Dimension: 70,000
Lining Area: 6,600 m^2
Shipyard: Cheng Xi/China
Date Installed: 2006

OLDENDORFF
Ship Name: Yeoman Bank
Application: Ship Hold Linings
DWT Dimension: 39,000
Lining Area: 4,200 m^2
Shipyard: Eleusis Shipyard/Greece
Date Installed: 1992

OLDENDORFF
Ship Name: Yeoman Brook
Application: Ship Hold Linings
DWT Dimension: 70,000
Lining Area: 6,500 m^2
Shipyard: Loyd-Werft, Bremerhaven/Germany
Date Installed: 1992

Project Reference List

TIVAR® 88 HIGH PERFORMANCE LINING SOLUTIONS

• CEMENT

AKMENES CIMENTAS
AKMENES, LITHUANIA
Application: Hopper
Quantity: 1
Liner: TIVAR® 88 (15 mm thick)
Bulk Materials: Limestone
Substrate: Steel
Problem: Flow problems, sticking, freezing and ratholing
Date Installed: 2001

ALSEN CEMENTWORKS
HANNOVER, GERMANY
Application: Chute and Hopper
Quantity: 2
Liner: TIVAR® 88, 15 mm
Bulk Materials: Limestone
Substrate: Steel
Problem: Sticking, abrasion
Date Installed: 2000

ARABIAN CEMENT COMPANY
JEDDAH, SAUDI ARABIA
Application: Transition Hopper
Quantity: 1 Hopper
Liner: TIVAR® 88 (1/2″-thick)
Bulk Material: Clay
Substrate: Mild Steel
Problem: Flow problems, ratholing, bridging, lost capacity
Date Installed: 1995

ASH GROVE CEMENT
CHANUTE, KANSAS
Application: Transition Hopper
Quantity: 1 Hopper
Liner: TIVAR® 88 (1/2″-thick)
Bulk Material: Limestone
Substrate: Mild Steel
Problem: New construction, anticipated flow problems
Date Installed: 2001

ASH GROVE CEMENT
DURKEE, OREGON
Application: Chute
Quantity: 1 Chute
Liner: TIVAR® 88-2 (1/2″-thick)
Bulk Material: Clay
Substrate: Mild Steel
Problem: Flow problems, ratholing, bridging, lost capacity
Date Installed: 2001

ASH GROVE CEMENT
DURKEE, OREGON
Application: Conical Hopper
Quantity: 1 Hopper
Liner: TIVAR® 88-2 (3/8″-thick)
Bulk Material: Clay
Substrate: Mild Steel
Problem: New construction, anticipated flow problems
Date Installed: 1997

AUMUND RHEINBERG
RHEINBERG, GERMANY
Application: Feeding Hoppers
Quantity: 3
Liner: TIVAR® 88, 10 mm thick
Bulk Materials: Gypsum
Substrate: Steel
Problem: Caking
Date Installed: 2002

CALMAT CO.
SUN VALLEY, CALIFORNIA
Application: Chute
Quantity: 1 Chute
Liner: TIVAR® 88-2 (1/2″-thick)
Bulk Material: Rock, Sand
Substrate: Mild Steel
Problem: Flow problems, ratholing, bridging, lost capacity
Date Installed: 1997

GULF CEMENT COMPANY
UNITED ARAB EMIRATES, DUBAI
Application: Pyramidal Hoppers
Quantity: 4 Hoppers
Liner: TIVAR® 88 (1/2″- & 3/4″-thick)
Bulk Material: Limestone, Iron Ore, Clay
Substrate: Mild Steel
Problem: Flow problems, ratholing, bridging, lost capacity
Date Installed: 1991

HOLNAM CEMENT
DUNDEE, MICHIGAN
Application: Bunker
Quantity: 1 Bunker
Liner: TIVAR® 88-2 (1″-thick)
Bulk Material: Gypsum
Substrate: Concrete
Problem: Flow problems, ratholing, bridging, lost capacity
Date Installed: 2001

KEDAH CEMENT PLANT
LANGKAWI, MALAYSIA
Application: Cement Plant
Quantity: 1 320-ton Clay Hopper
Liner: TIVAR® 88 (1/2″-thick)
Bulk Material: Clay, Gypsum
Substrate: Mild Steel
Problem: Flow problems, sticking, blockage
Date Installed: 2000

KHD – KÖLN YANBU ZEMENTWERKE
SAUDI ARABIA
Application: Bunkers
Quantity: 4
Liner: TIVAR® 88, 20 mm thick
Bulk Materials: Limestone, clay, sand
Substrate: Steel
Problem: Caking, bridging and wear
Date Installed: 1999/2001

Project Reference List

TIVAR® 88 HIGH PERFORMANCE LINING SOLUTIONS

LAFARGE
BUCHANAN, NEW YORK
Application: Gypsum Rock Bin Cone and Transition
Quanity: 1
Liner: TIVAR® 88-2 (1/2″ Thick)
Bulk Material: Natural Gypsum Rock
Substrate: Mild Steel
Problem: Flow Problem, Sticking
Date Installed: 2002

LAFARGE NORTH AMERICA
PAULDING, OHIO
Application: Feeders
Quantity: 12 Vibratory Pan Feeders
Liner: TIVAR® 88 (1/2″-thick)
Bulk Material: Limestone
Substrate: Carbon Steel
Problem: Sticking
Date Installed: 1990

MISSOURI PORTLAND CEMENT CO.
SUGAR CREEK, MISSOURI
Application: Conical Hopper
Quantity: 1 Hopper
Liner: TIVAR® 88 (1/2″-thick)
Bulk Material: Limestone & Clay
Substrate: Mild Steel
Problem: Flow problems, ratholing, bridging, lost capacity
Date Installed: 1986

NATIONAL GYPSUM COMPANY
MOUNT HOLLY, NORTH CAROLINA
Application: FGD Conical Silo
Quantity: 1 silo
Liner: TIVAR® 88-2 (1/2″-thick)
Bulk Materials: Synthetic gypsum
Substrate: Mild steel
Problem: New Construction
Date Installed: 2007
Engineering Firm: Cole Engineering

NATIONAL GYPSUM
SHIPPINGPORT, PENNSYLVANIA
Application: Wet FGD Silo
Quanity: 1
Liner: TIVAR® 88-2 (1/2″ Thick)
Bulk Material: Synethic Gypsum
Substrate: Mild Steel
Problem: No Flow - sticking
Date Installed: 1999

NATIONAL GYPSUM
SHIPPINGPORT, PENNSYLVANIA
Application: Dry Land Plaster Bin
Quanity: 1
Liner: TIVAR® 88-2 (1/2″ Thick)
Bulk Material: Gypsum
Substrate: Mild Steel
Problem: No Flow - sticking
Date Installed: 1999

NESHER CEMENT
RAMLA, ISRAEL
Application: Transition Hoppers
Quantity: 2 Hoppers
Liner: TIVAR® 88 (3/4″-thick)
Bulk Material: Raw Mix Feed
Substrate: Mild Steel
Problem: Mass Flow was not possible in the transition style bins without a TIVAR® 88 liner. Stainless steel 304-2B did not work and resulted in no-flow.
Date Installed: 1994 and 1997
(Two expansion projects.)

PHOENIX CEMENT
CLARKSDALE, ARIZONA
Application: Transition Hoppers
Quantity: 2 Hoppers
Liner: TIVAR® 88 (1/2″-thick)
Bulk Material: Coal, Coke
Substrate: Mild Steel
Problem: Flow problems, ratholing, bridging, lost capacity
Date Installed: 2002

READYMIX CEMENT PLANT
BECKUM, GERMANY
Application: Silo and Chute
Quantity: 2
Liner: TIVAR® 88 Antistatic (10 mm)
Bulk Materials: Meat and Bone Meal
Substrate: Steel
Problem: Flow problems, sticking and ratholing
Date Installed: 2000

RIGIPSWERK
HEINEBACH, GERMANY
Application: Chutes
Quantity: 5
Liner: TIVAR® 88, 15 mm thick
Bulk Materials: Gypsum and cement
Substrate: Steel
Problem: Caking and wear
Date Installed: 2001

ST. LAWRENCE CEMENT
MISSISSAUGA, ONTARIO, CANADA
Application: Pyramidal Hopper
Quantity: 1 Hopper
Liner: TIVAR® 88-2 (1″-thick)
Bulk Material: Silica Fume
Substrate: Concrete
Problem: Flow problems, ratholing, bridging, lost capacity
Date Installed: 2001

SIGNAL MOUNTAIN CEMENT
CHATTANOOGA, TENNESSEE
Application: Pyramidal Hopper
Quantity: 1 Hopper
Liner: TIVAR® 88 (3/4″-thick)
Bulk Material: Slate
Substrate: Mild Steel
Problem: Flow problems, ratholing, bridging, lost capacity
Date Installed: 1990

Project Reference List

TIVAR® 88 HIGH PERFORMANCE LINING SOLUTIONS

ZHONG GUO CEMENT
CHINA

Application:	Pyramidal Hopper
Quantity:	1 Hopper
Liner:	TIVAR® 88 (1/2″-thick)
Bulk Material:	Clay
Substrate:	Mild Steel
Problem:	Flow problems, ratholing, bridging, lost capacity
Date Installed:	1994

• CHEMICALS

CARGILL - FORT MEADE
FORT MEADE, FLORIDA

Application:	Hydro-cyclonic Launderer (Flume)
Quantity:	2 (96′ Long) Launderers
Liner:	TIVAR® 88-2 (3/4″-thick)
Bulk Material:	Phosphate Fines
Substrate:	Abrasion Resistant Steel
Problem:	Corrosion and abrasion problems
Date Installed:	2000

KRONOS TITAN
NORDENHAM AND LEVERKUSEN GERMANY

Application:	Bunkers and Hoppers
Quantity:	12 bunkers; 8 hoppers
Liner:	TIVAR® 88 & TIVAR® 88 Antistatic - 10mm
Bulk Materials:	Titanium Ore, Titanium Dioxide
Substrate:	Steel and concrete
Problem:	Sticking, ratholing
Date Installed:	1990-2002

SACHTLEBEN CHEMIE
DUISBURG, GERMANY

Application:	Hoppers
Quantity:	6
Liner:	TIVAR® 88 – 20 mm
Bulk Materials:	Pyrit
Substrate:	ST 50 Steel
Problem:	Sticking, abrasion, corrosion
Date Installed:	1998

• MINERALS & METALS

CIA. CONTRACTUAL MINERA CANDELARIA
COPIAPO, CHILE

Application:	Sample Collector
Quantity:	1 Welded Hopper
Liner:	TIVAR® 88-2 (1″-thick)
Bulk Material:	Copper Concentrate
Substrate:	Stainless Steel
Problem:	Abrasion resulting in contamination of ore & wide variations in moisture content
Date Installed:	2000

CIA. MINERA INES DE COLLAHUASI
IQUIQUE, CHILE

Application:	Transfer Chute in Ship Loader
Quantity:	1 Chute
Liner:	TIVAR® 88 (3/4″-thick)
Bulk Material:	Copper Concentrate
Substrate:	Steel
Problem:	Erratic flow, sticking
Date Installed:	1999

FMC CORPORATION / GREEN RIVER PLANT
GREEN RIVER, WYOMING

Application:	Mono I Calciner Feed Bin
Quantity:	1
Liner:	TIVAR® 88-2 (1/2″ thick)
Bulk Materials:	1/4″ Trona Ore
Substrate:	Mild steel
Problem:	No flow and erratic discharge
Date Installed:	September/2006
Engineering Firm:	Jenike & Johanson

LKAB
KIRUNA, SWEDEN

Application:	Concrete Bunker
Quantity:	24
Liner:	TIVAR® 88 (15 mm)
Bulk Materials:	Iron Ore
Substrate:	Concrete
Problem:	Flow problems, sticking, abrasion and freezing
Date Installed:	2001

• OTHER INDUSTRY PROJECTS

BASF
LUDWIGSHAFEN, GERMANY

Application:	Bunkers, chutes, feeding hoppers
Quantity:	5
Liner:	TIVAR® 88, 15 + 10 mm thick
Bulk Materials:	Fertilizer
Substrate:	Steel
Problem:	Caking, chemical abrasion
Date Installed:	2001

HÖVELER SPEZIALFUTTERWERK
LANGENFELD, GERMANY

Application:	Chain Conveyor
Quantity:	4
Liner:	TIVAR® 88 anti-static, 10 mm thick
Bulk Materials:	Animal food
Substrate:	Steel
Problem:	Caking, wear, corrosion
Date Installed:	2001

ORIENTAL CHEMICAL INCORPORATED
GREEN RIVER, WYOMING

Application:	Silo
Quantity:	1 - 42′ diameter silo
Liner:	TIVAR® 88-2 (1/2″ thick)
Bulk Materials:	Sub-Bituminous Coal (PRB)
Substrate:	Mild steel
Problem:	New Construction
Date Installed:	2006
Engineering Firm:	BE&K

Project Reference List

TIVAR® 88 HIGH PERFORMANCE LINING SOLUTIONS

USX (U.S.STEEL) - CLAIRTON WORKS
CLAIRTON, PENNSYLVANIA

Application:	Unit # 1 Surge Bin Feedoweight Feeder Chutes
Quantity:	2
Liner:	TIVAR® 88-2 (1″ Thick)
Bulk Material:	Bituminous Coal
Substrate:	Mild Steel
Problem:	Flow problems, sticking and bridging
Date Installed:	2002

USX (U.S. STEEL) - CLAIRTON WORKS
CLAIRTON, PENNSYLVANIA

Application:	Surge Bins
Quantity:	3 Hoppers
Liner:	TIVAR® 88-2 (1/2″-thick)
Bulk Material:	Bituminous Coal
Substrate:	Gunite
Problem:	Flow problems, sticking and bridging
Date Installed:	2001

USX (U.S. STEEL) - CLAIRTON WORKS
CLAIRTON, PENNSYLVANIA

Application:	2 Coal Bunkers
Quantity:	56 Outlets
Liner:	TIVAR® 88-2 (1/4″-thick Drop-in Liners)
Bulk Material:	Bituminous Coal
Substrate:	Stainless Steel
Problem:	Flow problems, sticking and bridging
Date Installed:	1995

WESCAST INDUSTRIES
WINGHAM, ONTARIO

Application:	Return Sand Silo
Quantity:	1
Liner:	TIVAR® 88-2 (3/8″ and 1/2″ Thick)
Bulk Material:	Green Molding Foundry Sand
Substrate:	Mild Steel
Problem:	Flow Problems, bridging, ratholing, inconsistent material discharge
Date Installed:	2003

TIVAR® 88 FAQ's

TIVAR® 88 HIGH PERFORMANCE LINING SOLUTIONS

What makes TIVAR® 88 an effective solution for bulk material flow problems?
TIVAR® 88 was specifically designed for applications in the bulk material handling field. It has a very low coefficient of friction and excellent abrasion and corrosion resistance which helps materials flow smoothly and freely, eliminating arching, ratholing or the need for other flow promotion devices. Quadrant also has a bulk material handling engineering group dedicated to assist in the design of linings for chutes, bins and hoppers.

Why do engineers specify TIVAR® 88?
TIVAR® 88 has been utilized and tested in bulk material applications for many years. The success rate of these applications, along with other testing by engineering firms and flow consultants around the world, have given many the confidence to specify TIVAR® 88 more often than any other polymer liner. In addition, they are confident that our engineering group will assist the customer to ensure proper installation of the product.

Where can I use TIVAR® 88?
TIVAR® 88 is generally utilized as a liner for chutes, bins and hoppers. It can also be used in off-road trucks, drag conveyors, pugmills, or any other process equipment where there is sliding abrasion or poor flow of bulk materials.

What is the relationship and/or difference between TIVAR® 88 and virgin UHMW-PE?
The answer is both simple and complex, but basically, TIVAR® 88 is a unique formulation of UHMW-PE. The addition of selected additives to UHMW-PE, coupled with special processing, results in TIVAR® 88, a material that exhibits outstanding wear resistance, toughness and low frictional properties. Change that formulation a little, and you get TIVAR® 88-2, a material with enhanced weldability properties. Or, increase the UV-resistant or antistatic characteristics of TIVAR® 88 with additives specifically designed to enhance those properties.

The following equations probably best illustrate this relationship, particularly for those who are familiar with iron, which is the base material for all steels, and is not, in its own right, an extremely useful material. Brittleness, poor to non-weldability and other problems limit its usefulness. So, to dramatically enhance the properties and improve its usefulness, iron, like UHMW-PE, must be modified and specially processed. It should be noted, however, that unlike the properties of UHMW-PE which are not negatively impacted with additives, one key property of iron, the hardness, is significantly altered with just a small amount of additive.

UHMW-PE + Additives and Special Processing =	TIVAR® 88
TIVAR® 88 + Additives and Special Processing =	TIVAR® 88-2 **or** TIVAR® 88 UV-resistant **or** TIVAR® 88 Antistatic **or** TIVAR® 88-2 UV-resistant **or** TIVAR® 88-2 Antistatic
Iron + Additives and Special Processing =	Abrasion Resistant Steel **or** Mild Steel **or** Stainless Steel

Hopper Evaluation Form

TIVAR® 88 HIGH PERFORMANCE LINING SOLUTIONS

Company:_____Date: _____
Contact Name: _____Title: _____
Address: _____
_____
_____
City: _____State: _____
Zip: _____
Country: _____
Telephone: _____ FAX: _____E-mail:_____

SECTION I

Bulk Material

Material: _____
Particle size(s): _____percent of sizes (if applicable): _____
Moisture content: _____ % to _____
Operating temperature: _____ (°C or °F)
Material characteristics (sharp, angular, hard, soft, cohesive, free-flowing, etc.):_____
Weight: _____ lb./ft.^{3} or_____ kg/cm^3

Hopper System Operation

Storage capacity of bins:_____tons
Discharge rate: _____tons/hour
Annual throughput: _____tons/year
Frequency of complete discharge: _____ ("x" times per day, month or year - please specify)
Charging method: (belt conveyor, railcar, truck, ship unloader, etc.) _____
Is the bin center loaded? ____Yes ____No

Description and Location of the Hopper

Structural material (steel, concrete, wood, etc.): _____ Located: ____Indoor ____Outdoor
This bin is: _____ existing ____ planned for construction
Present wall material or liner (be specific): _____
Current thickness of wall material or liner: _____
Original thickness of wall material or liner: _____

Flow Pattern (check one):

The hopper was designed for: ____Mass Flow ____Funnel Flow ____Expanded Flow
The actual flow pattern is: ____Mass Flow ____Funnel Flow

Hopper Evaluation Form

TIVAR® 88 HIGH PERFORMANCE LINING SOLUTIONS

Identify Existing Flow Problems (check all that apply):

Describe the problem in detail and explain what temporary actions are necessary to deal with the problem (Use separate paper if necessary) _____

_____

_____

_____

_____

Do You Have: ____Sticking ____Arching ____Ratholing ____Other

The problem occurs in the: ____Transition Area ____Outlet Area ____Valley Angle

Problem Occurrence (check all that apply):

The problem occurs in: ____Summer ____Fall ____Winter ____Spring

Frequency: ____Daily ____Weekly ____Monthly ____Continually

SECTION II

Can the hopper be detached and shipped to our facility to be lined? ____Yes ____No

Currently, what is the largest accessible opening into the hopper? _____

Can a larger opening be made if necessary? If so, how large? ____Yes ____No

Please check the method(s) that you wish to be quoted:

____ Drop-in liner only

____ Installation at Quadrant

____ Turn-key site installation

Are there any interior obstructions that need to be addressed? _____

_____

Drop-in liners will be built to the dimensions supplied to us. Please confirm that all dimensions are accurate. THIS FORM MUST BE ACCOMPANIED BY A BLUEPRINT OR SKETCH SHOWING ALL DETAILS.

Send To: Quadrant Engineering Plastic Products
SystemTIVAR® Engineering Group
2710 American Way
Fort Wayne, IN 46809

FAX: (260) 478-1074
Telephone: (260) 479-4100
Toll-free (US/Canada) 1-877-476-5944
Email: systemtivar@qplas.com

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TIVAR® 88 HIGH PERFORMANCE LINING SOLUTIONS

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Learn more online at www.quadrantplastics.com

Quadrant has extensive product and machining resources available online. Our website is a portal to a wealth of technical data and the easiest way to engage our application specialists. Our team stands ready to help offer solutions to your toughest problems.

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