

The Solution Approach To Flow Problems Using Tivar® 88

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SUMMARY

Based on years of global experience the authors describe the thought process or procedure that is typically followed in an attempt to correct bulk solids flow problems in production and process equipment. Most of the time, solutions are temporary without a regard or full understanding of the problem and the associated economic impact to the overall operation of the facility. When a temporary solution does not perform adequately another one is usually tried. Some of these short term attempts will be as simple as a sledgehammer while others will be more elaborate.

To properly understand a bulk solids flow problem and how to correct it, the bulk solid's flow properties should be analyzed. With this information, an engineer can determine whether the equipment is properly designed and whether a flow promotion aid will correct the problem. Sometimes it will be a combination of approaches. It is recognized that most cohesive bulk solids should be handled in hoppers that are designed for mass flow. This type of pattern is reliable and predictable.

In addition to a properly sized outlet, the design of a mass flow bin must consider the hopper wall angles, wall material and its surface finish and the average and worst case condition of the solid's flow properties. The hopper walls must be steep and have a low enough friction for material to flow along them.

In many cases, the design of the bin is proper but the wall material may not have a low enough friction. Then a retrofit with a low friction liner becomes very practical. The choice of a qualified installation contractor is very important. The contractor should be able to perform his work in a variety of adverse conditions with knowledge of bulk solids handling problems.

The SYSTEMTIVAR® solutions approach to flow problems is designed to tackle a project from problem identification to a turnkey installed solution. After determining that a low friction liner is a solution, a study begins on the installation site to fully understand what will be required to complete the project. The engineers at the job site as well as the installation contractor will agree on the procedures to be followed during the installation. Poly Hi Solidur will complete all of the engineering and design that is required for completion of the project to insure that proper effectiveness of the liner can be achieved. Once all parties are in agreement as to what will be done, the preparation begins.

1. FLOW PROBLEMS

1.1 No Flow

In many cases a no flow condition is caused by a stable arch (bridge) or rathole that forms over the hopper outlet as shown in Figure 1. The arch is strong enough to support the weight of material above it and in order to induce flow the arch must be broken. Generally, sledgehammers, air lances and air blasters are used to break an arch. Vibrators have a tendency to strengthen an arch by promoting compaction in some cases. A rathole is formed while a cylindrical flow channel develops in the center of the bin and the remaining material is stationary along the hopper walls because they are not steep enough or may not have a low enough surface friction for the bulk solid to flow along them.

At a 4 x 400 MW power station in Indonesia, the 500 ton coal silos were originally constructed with a carbon steel cylinder section and a 70° (from the horizontal) hopper section of carbon steel clad with a 304 stainless steel with a 2B finish (Fig. 2.). The plant experienced complete blockage or bridging in the lower hopper cone section of the silos on the 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 which would last an average of 15 minutes each.

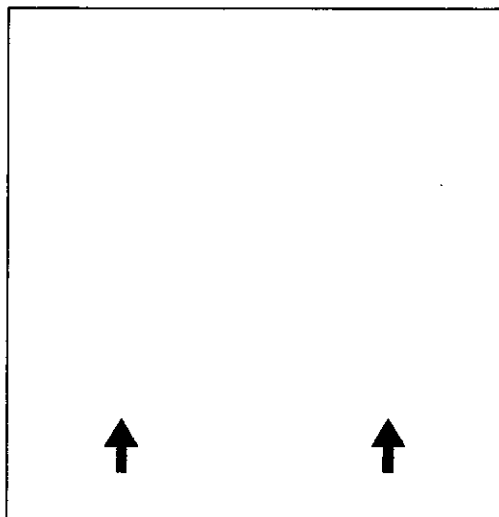


Figure 1: Stable arch or rathole.

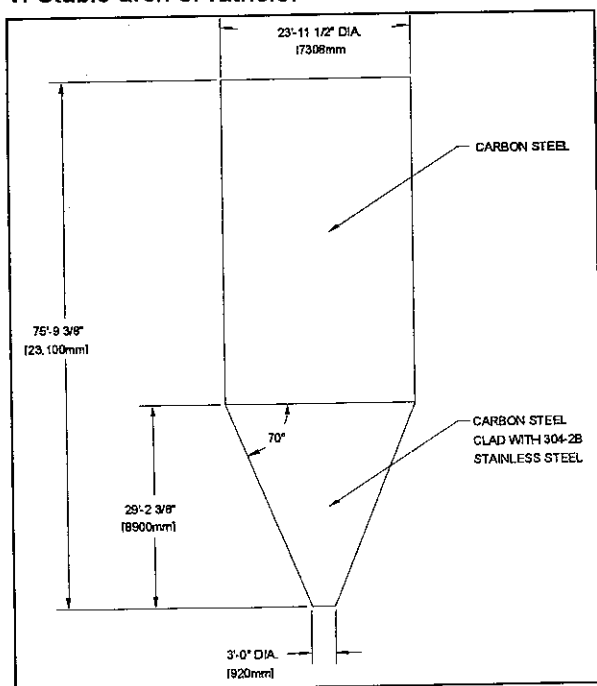


Figure 2: Original hopper designed with a 304-2B stainless steel liner.

In July 1992 the hopper portion of 5 silos was lined with 12,7mm (1/2") thick TIVAR 88 installed directly over the 304 stainless steel (Fig. 3) as a flow improvement solution. During the next one year period from August 1992 to August 1993 the power plant only had one blockage with the TIVAR 88 lined hoppers as compared to the 200 occasions per year of blockage in the stainless steel lines hoppers. This has proven to be a very successful solution and continues to perform well as of the writing of this paper (August 1996)

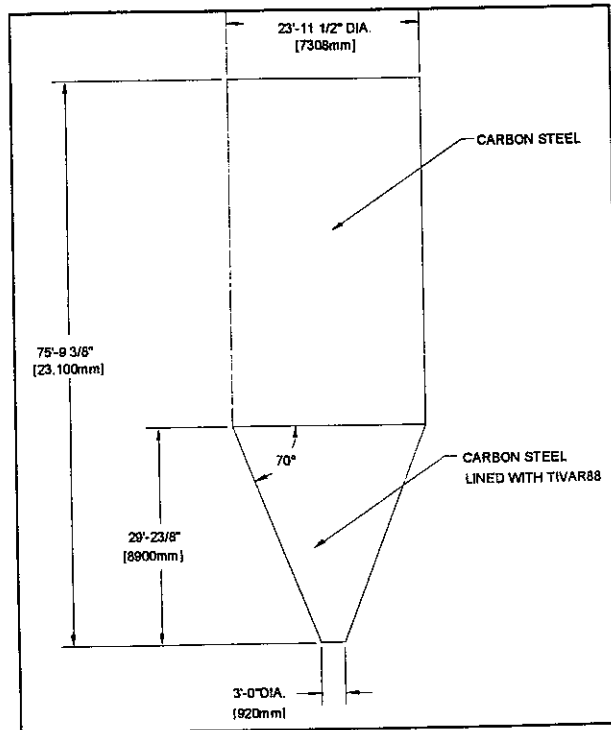


Figure 3: TIVAR 88 lined hopper to provide reliable uninterrupted coal flow.

In a similar application in Sydney, Australia, a customer experience a loss of production in a 260 ton salt bin due to hang ups, bridging, caking and material clinging to the bin walls. The blockages occurred 3-4 times a day. Air lances and sledgehammers were used to restart flow. In 1992, the bin was lined with 15mm thick TIVAR which eliminated the problem by changing the flow pattern from funnel flow to mass flow in the bin. Mass flow is a condition in which all of the material in the bin is in motion when any is withdrawn. (Fig 4).

In addition to correcting the salt flow problem, corrosion attack of the mild steel substrate was a major factor according to the end user. Poly Hi Solidur and Cadillac Plastics (SYSTEMTIVAR installation contractor) proposed a completely welded seamless TIVAR installation system to prevent corrosion attack of the substrate. This new installation method requires that the work be performed by a qualified knowledgeable installer in order to be successful.

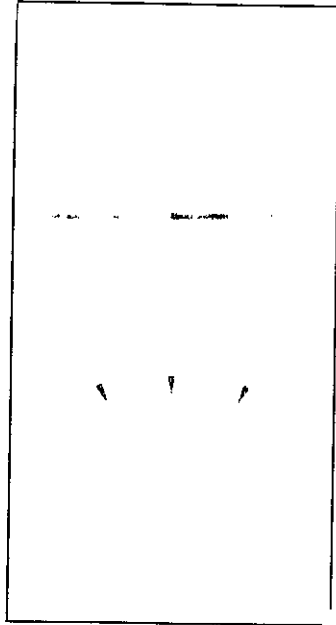


Figure 4: Mass flow pattern

1.2. Erratic Flow

The alternating formation and collapse of arches and ratholes (Fig. 5) result in a fluctuating discharge. This type of flow causes thumping and vibrations to occur that can damage or destroy the integrity of a bin, leading to structural failure.

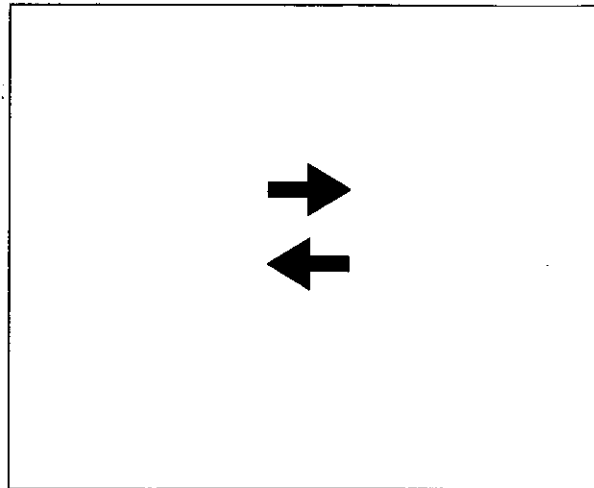


Figure 5: Erratic Flow

On numerous occasions coal-fired power plants experience many types of flow problems in their coal silos even when hopper sections are designed with 70° cones 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. One theory states the problem will alleviate itself as the flowing coal polishes the stainless steel surface. Unfortunately, this does not always happen. As a result, in order to achieve smooth uninterrupted flow and eliminate the problems within the hopper, a TIVAR 88 liner is placed on top of the stainless steel. The surface friction of TIVAR 88 is extremely low, allowing the coal to flow smoothly on the 70°-hopper wall.

1.3 Others

Some other problems that occur such as flushing or flooding and limited discharge rate are not addressed in this paper. Segregation is only mentioned briefly.

2. CONSEQUENCES OF FLOW PROBLEMS

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

2.1 Reduced Storage Capacity

Reduced storage capacity, as shown in figure 6, results from the formation of stable ratholes or from material clinging to the bin walls because of a rough wall condition. A cohesive bulk solid will cake and cement itself to the bin walls if the bin is not cleaned from time to time. The severity of these stagnant or "dead" regions will vary depending on the material being handled. For example, in the food industry solids will *spoil and insect infestations* is more likely. In the coal handling industries, the stagnant coal is highly susceptible to spontaneous combustion the longer the coal is allowed to remain in the bin.

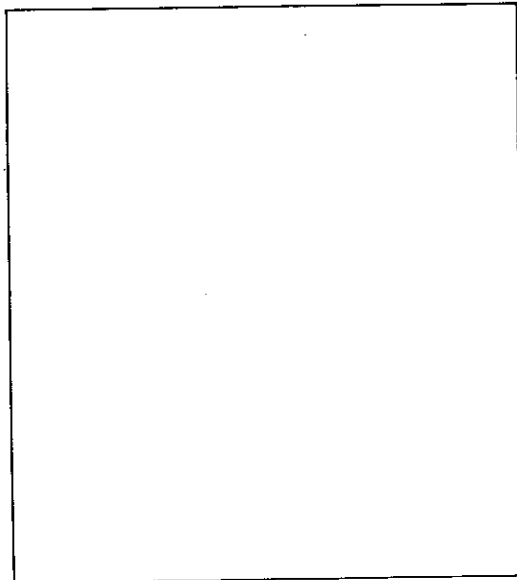


Figure 6: Reduced storage capacity.

Spontaneous combustion sometimes occurs when large volumes of coal are stored in silos and bunkers. Many coal-fired power plants are plagued with problems of fire that can lead to explosions if dusting occurs while charging a bin. In large silos, vibration and thumping can occur during discharge resulting in structural fatigue and collapse. There have been cases cited where the entire silo area was "off limits" to individuals during the time of discharge for fear that safety would be compromised if the structure collapsed.

2.2 Lack of quality Control

Segregation, as a result of a funnel flow pattern, will cause severe quality problems for many industries where consistency is required from batch to batch. Many of us can relate to seeing household detergent colored particles in the package when we opened it. If these different colors represent different ingredients then it is desirable have the proper quantity of each. One might conclude that something is wrong if the color is drastically different from the previous time.

2.3 Economic Impact

The economic impact of flow problems is made up of many contributing factors.

- The process requirements are not up to design specifications
- Additional manpower required either in the form of cleaning the bin from time to time or in the added charging frequency necessary to keep up with the process demands because of reduced capacity.
- Lost productivity in the case of an unexpected shutdown due to no flow.
- The initial and operating cost of flow promotion devices
- Damage from structural fatigue or collapse
- Compromised personnel safety.

3. SOLVING FLOW PROBLEMS

There are numerous attempts made to solve flow problems. Some are as simple as using a sledgehammer to beat on the structure and others will be more elaborate in the case of installing a vibrating bin discharger. Other flow promotion devices include the installation of a vibrating bin discharger. Other flow promotion devices include the installation of vibrators or air cannons and if these do not perform adequately, more of them are added. There is nothing wrong with these devices but as with any application they should be matched properly to the particular situation after the bulk material's flow properties are understood.

Similarly, there are a variety of different wall materials used in the hopper section of bins and bunkers. Some of these include: basalt, gunite, mild steel, stainless steel with a mill finish, stainless steel with a polished surface, TIVAR 88 and different types of epoxies. Sometimes experiments are made to change from one type of liner to another that may or may not be successful depending again on the structure's geometry and the flow properties of the bulk solid.

At a Mexican state run 4 x 350 MW coal-fired power plant, there are five 1,000 ton capacity storage silos that are designed with a carbon steel cylinder section and a 316 stainless steel eccentric hopper section (Fig 7). During the rainy season in the fall and winter of 1992 the $\frac{3}{4}$ " 2 subbituminous coal (45 – 60% fines) adhered to the interior vertical walls of the standpipes and to the stainless steel hopper walls. 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.

The power plant wanted to eliminate ratholing by changing the funnel flow pattern to mass flow within their silos.

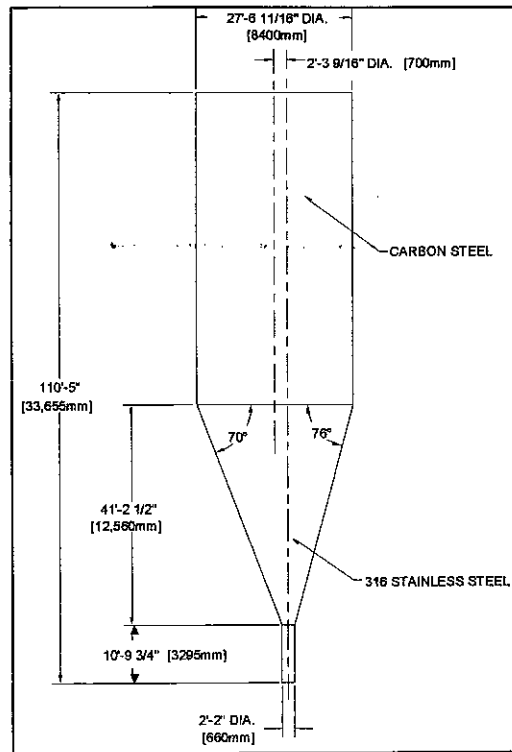


Figure 7: Original Eccentric Hopper

In 1993, the standpipes and the lower part of the hopper cones were lined with 12,7mm (1/2") thick TIVAR 88 during regularly scheduled shut downs.

The TIVAR 88, a low friction liner, was placed directly on top of the stainless steel in the hopper sections of the silos (Fig. 8) using a weldable fastener and covered with a TIVAR plug (Fig 9) to maintain surface continuity along the hopper wall. The 12,7mm (1/2") thick TIVAR 88 sheet was easily formed by the installer for lining the standpipes.

The performance of TIVAR 88 achieved the desired mass flow within the hoppers, thus eliminating the ratholing due to the funnel flow pattern. Now, the fully designed storage capacity of the silos is realized.

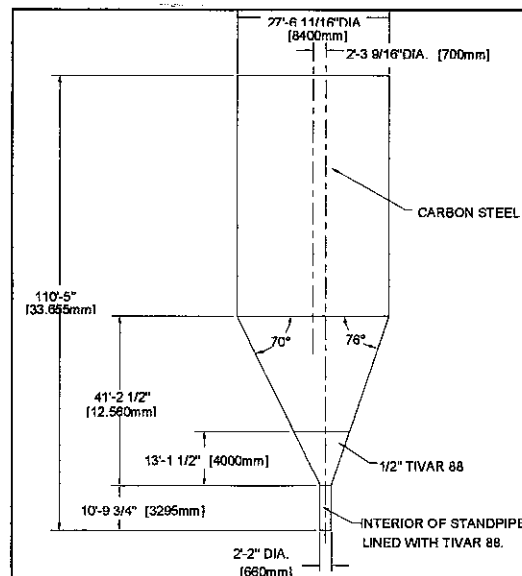


Figure 8: Eccentric hopper and standpipe lined with 1/2" thick TIVAR 88,

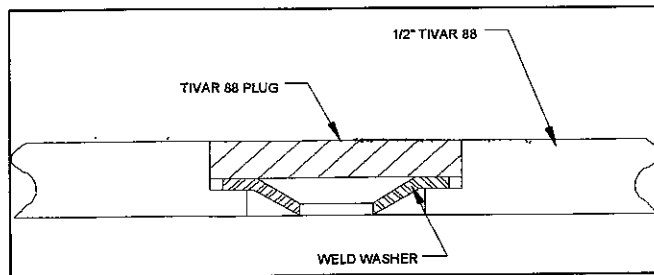


Figure 9: Weld washer and TIVAR plug assembly.

4. SOLUTION ORIENTED APPROACH TO FLOW PROBLEMS

The following example explains a SYSTEMTIVAR approach from problem identification to a complete turnkey solution. It has worked effectively in achieving mass flow to eliminate the spontaneous combustion problems at this power plant in the United States.

NSP's Riverside plant is a two-unit, 384 MW coal-fired station located in Minneapolis, Minnesota. After switching to low-sulfur subbituminous coal from the Powder River Basin for environmental reasons, the coal storage bunkers at this plant experienced several fires and an explosion resulting from spontaneous combustion.

It was determined that coal in the bunker ignited 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 bunker explosion, NSP 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. The task force was known as "Operation Cease Fire".

The coalbunker 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 subbituminous coal and rough surface of the gunite wall lining. Eventually, these regions of stagnant coal severely reduced a large portion of the bunker's "live" capacity. This coal is soft with a moisture content up to 37 % that allows it to easily compact or consolidate during storage. The situation was not expected to improve as long as this flow pattern continued in the bunker.

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. Theoretically, the stagnant coal may never discharge if it solidifies along the bunker walls.

The task force concluded that the coal stagnation caused the fires because the longer coal remains stagnant the more susceptible it is to spontaneous combustion. They began their search for a solution to eliminate the "dead" regions within the bunker. Their choices were limited to doing nothing, installing more flow promotion devices, changing the hopper wall material to one with a lower surface friction or modifying the existing bunker geometry.

The original coalbunker, as shown in Figure 10, was equipped with 20- air cannons, 2 on each of the 5 pyramidal shaped hoppers and 10 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 that were constructed of stainless steel.

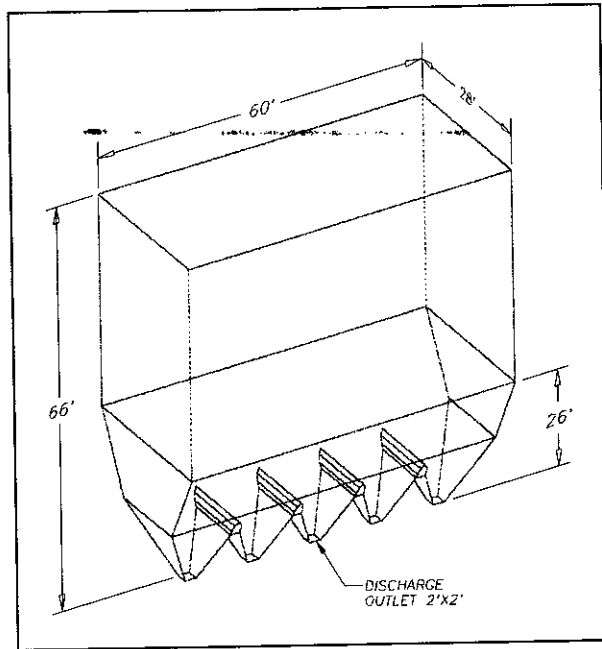


Figure 10: Original design of the bunker in Unit 8. The vertical and sloping walls were coated with 2" thick gunite and the hoppers were constructed of stainless steel. The 20 air cannons are not shown. NSP contacted Poly Hi Solidur and inquired about the performance of a TIVAR 88 liner thinking it may be the complete solution to the flow problems since they had a previous experience with TIVAR 88 at their Black Dog plant (Burnsville, Minnesota) in a rail dump receiving hopper. Poly Hi Solidur engineers studied the current design of the bunker along with the current coal flow problems and determined that a solution was possible, but knew that it would require further analysis in order to substantiate the effectiveness of a TIVAR 88 liner. Poly Hi Solidur referred NSP to Jenike & Johanson, Inc., consultants having expertise in the flow of solids from bins and hoppers.

Samples of the coal were collected and flow property testing began using the Jenike Shear Tester (Fig.11), which measures friction between the coal and various wall materials. Coal samples are placed in a retaining ring that sits on top of the proposed wall material. Weights are applied on 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 304-#2B stainless steel.²

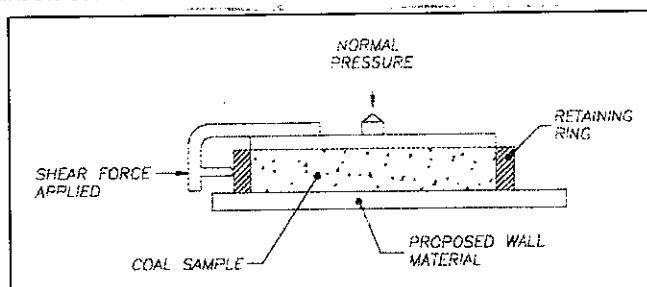


Figure 11: Jenike Shear Tester measures the shearing force required for a solid to slide along a wall material.

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: replace the bottom section of each pyramidal hopper with new conical extensions; a BINSERT®3 (cone-in-cone design used to achieve mass flow with minimum headroom), as discussed by Carson and Dick^{4,5}, 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 12,7mm (1/2") thick TIVAR 88. The complete modification is shown in Figures 12 and 13. NSP 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 channel⁶.

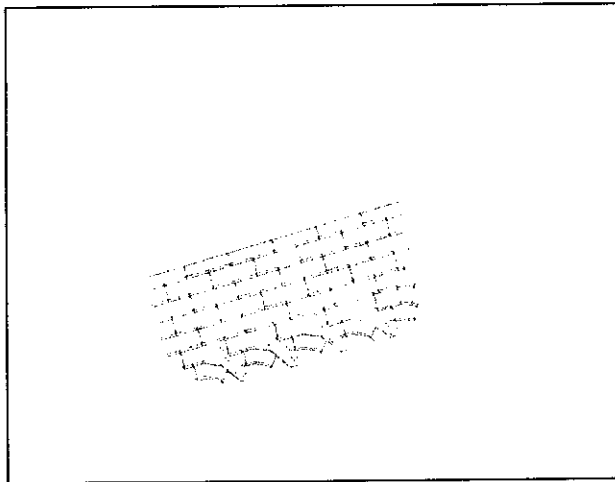


Figure 12: Partial view of modification as recommended by Jenike & Johanson. The sheets of TIVAR 88 are placed in a shingle (overlap) fashion.

Once NSP agreed to perform the modifications recommended by Jenike & Johanson, all contractors met with the NSP engineers at the Riverside Plant to lay out the plan details. This planning meeting included the NSP engineering staff, Poly Hi Solidur engineers, a SYSTEMTIVAR installations contractor and NSP's Special Construction Unit. The sequence of steps required to complete the modification had to be understood by all parties involved in the project since the group would be working as a team.

Poly Hi Solidur 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 Poly Hi Solidur were at the job site during different phases of the installation to monitor the procedures and progress of the work.

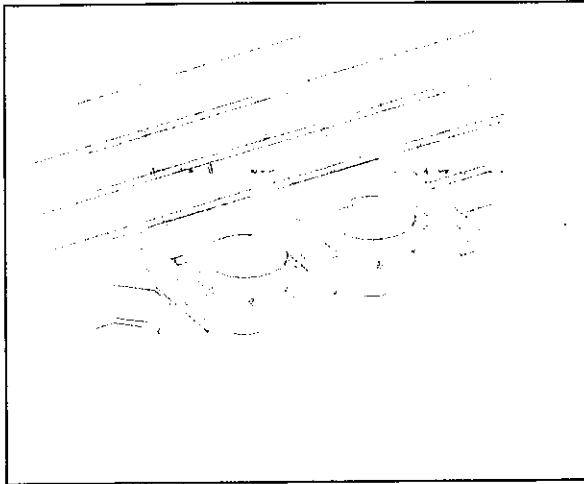


Figure 13: Exploded view of the hopper modification, showing two hoppers fitted with the BINSERT® designed by Jenike & Johanson, Inc. The BINSERTS and outer hopper cones are lined with TIVAR 88.

Upon completion of the modification within the scheduled time period, the bunkers were filled with sub-bituminous coal and the Unit went back on line. After one year, service reports indicate the modification was successful. Prior to the modification, they were only able to obtain 11 hours of fuel from the bunker before it required charging. Now, they do not have to refuel for almost 18 hours since the full capacity of the bunker is available⁷.

5. CONCLUSION

Although many flow-correcting devices exist, they are only effective if they are properly matched to the unique situation. The installation and use of various devices requires a thorough understanding of flow problems, solutions and project management. The same is true for hopper wall liners; these should be installed by qualified contractors with knowledge and understanding of bulk solids flow. The new installation techniques for TIVAR 88 would only be considered if they properly match the requirements of the particular application.

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Experience :

Has over 19 years of experience in bulk solids handling with a primary emphasis on the flow of solids from bins and hoppers. Lectures extensively around the world on this subject and is actively involved in a multitude of international projects in both new construction and existing facilities. Has published several papers on the use TIVAR 88 liners in material handling equipment.