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TIVAR®-88 Provides Reliable Gravity Discharge from Coal Storage Silos

A Case Study

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Summary

The intent of this article is to provide a longterm perspective on how TIVAR® - 88 Ultra High Molecular Weight Polyethylene liners perform in a gravity discharge silo. In order to establish this long-term perspective, a case study evaluation of coal flow problems at a central United States power plant is presented along with independent wear test data on TIVAR-88 in gravity discharge silos.

1. Introduction

During the past ten years, the use of Ultra High Molecular Weight Polyethylene (UHMW-PE)-liners in bulk material handling has grown steadily. Its use in applications such as mining equipment, self-unloading ships, chutes, and hoppers has contributed significantly to the improved flow of bulk materials. However, due to UHMW-PE's relatively recent introduction to this industry, in comparison to steel, little documentation has been focused on the overall economic performance of UHMW-PE liners in bulk material handling applications. Thus, the plant engineer, original equipment manufacturer, and design engineer have been left with insufficient data on how to properly specify UHMW-PE liners. The following case study has been prepared on the use of TIVAR-88 liners in coal storage silos at the American Electric Power Indiana Michigan Company - Rockport Plant. It is intended to provide a perspective on the performance of TIVAR-88 liners in gravity discharge silos, based on actual application service.

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Details about the authors of this paper on page 421

2. American Electric Power Company Profile

American Electric Power (AEP) is a public utility holding company which owns several electric utilities that provide electric service to over seven million consumers in the central United States. The AEP system is comprised of forty power plants located throughout a seven state area. Generating capacity of the overall AEP network is 24,000,000 kW with annual production exceeding 100 billion kWh of electricity. Within the AEP system seventeen plants are coal fired, accounting for 89% of the total generating capacity. These nineteen plants consume an average of 40 million tons of coal per year.

3. AEP-Indiana Michigan Rockport Plant

The AEP-Indiana Michigan Rockport Plant is located on the Ohio River in the southern tip of Indiana. This facility is the newest power plant in the AEP system, housing two 1,300 MW electric generating units. Annual output capacity of the Rockport facility exceeds 9,000,000 kWh of electricity. The Rockport Plant began operation in September, 1984 with the start-up of its first generating unit. This was followed by the start-up of a second generating unit in late 1989. Between the two generating units, the Rockport Plant burns approximately 10,000,000 tons of coal annually.

4. Fuel

The type of fuel burned at the Rockport Plant is a sub-bituminous coal mined in the Powder River Basin of Wyoming. This coal is characterized as having a low sulfur content ranging between 0.2% 0.35%), a particle size that averages 2 in. minus, a moisture content between 30% and 40%, and a bulk density of 47.5 lb/ft^3. At a 30% moisture content the coal shows little or no surface moisture, but is considered wet at values over 34%.

5. Fuel Handling System

The Rockport Plant receives coal by barge transportation operating on the Ohio River. Once coal arrives at the power plant site, it is unloaded through one of two barge unloaders. The coal is then transported by belt conveyor and stacked in an outdoor storage area. Bucket-wheel reclaimers or underground reclaim feeders are used to retrieve the coal and transfer-it to a conveyor belt which carries it to the crusher building. From the crusher building the coal is conveyed through transfer towers and conveyors to the storage silos of either Unit #1 or #2.

6. Silo Configuration

Both Unit #1 and #2 at the Rockport Plant have fourteen storage silos which provide indoor coal storage. Within the individual battery of fourteen silos for both units (see Fig. 1), twelve silos have a 27 ft diameter by 49 ft tall cylinder, with a 65° cone hopper and a 2 ft diameter outlet. The individual storage capacity of the 27

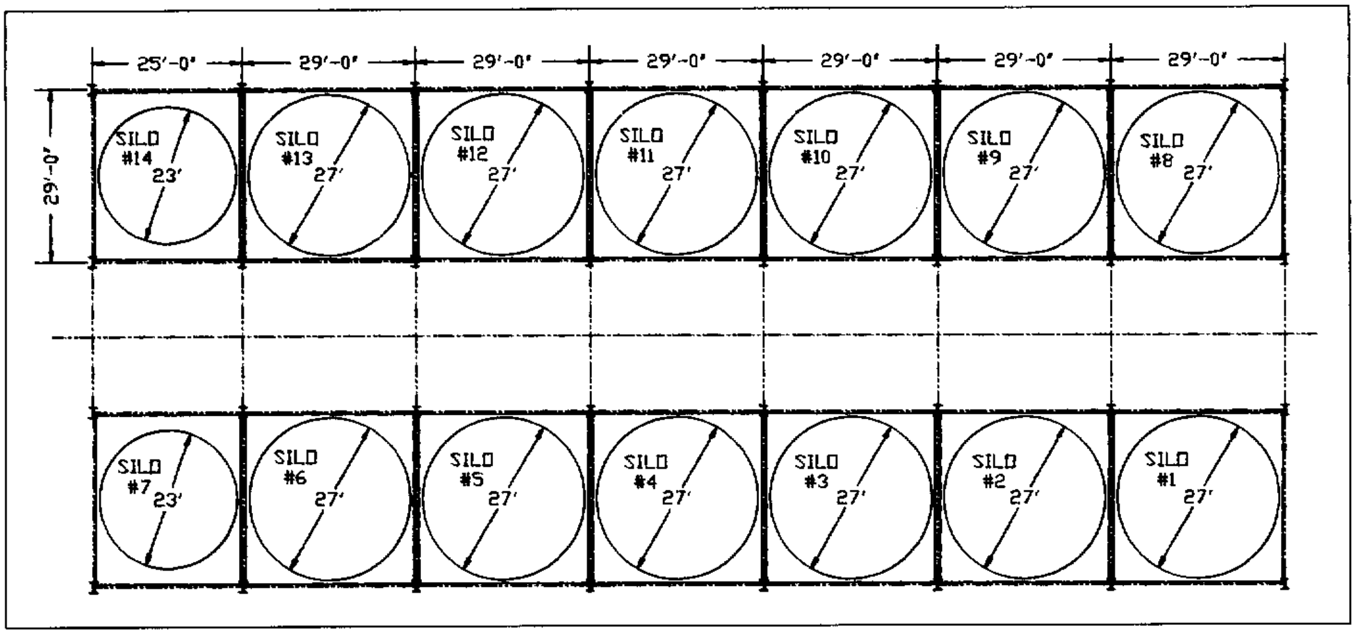


Fig. 1: Plan view of Unit #1 and #2 coal silos

ft diameter silos is 778 tons. The other two silos are 23 ft diameter with 68° cones and have a storage capacity of 553 tons (see Fig. 2). All twenty-eight silos are constructed of 3/8" Cor-Ten (high strength, low alloy steel, USX Corp., Pittsburgh, PA, USA) steel with a 16 gauge 304 stainless steel (SS) 2B finish liner in the hopper cone.

Each coal silo discharges through a 12 ft tall, 24 in. diameter standpipe and gate at a rate of 65 t/h. Below the gate is a 24 in. stock feeder which discharges to a pressurized pulverizer. The section between the stock feeder and the pulverizer is configured with a transition section measuring 17 in. x 25 in. at the top, tapering down at 8° from vertical to an 18 in. diameter pipe.

7. Flow Problem

According to plant personnel, ratholing and bridging problems developed in the storage silos of Unit #1 during its initial start-up in September, 1984. These plugging problems caused disruption in the coal flow and lowered the electric power output of the generating unit.

It was estimated that a plugging problem in any one of the fourteen coal storage silos could result in a loss of up to 100 MW of electric power during the 3 to 4 hours required to restore coal flow. Methods used to alleviate the coal plugging problems included sledge hammers and portable unit heaters directed at the lower hopper section.

8. Solution Analysis

Realizing the critical nature of their flow problems, plant personnel set out to develop a workable solution for maintaining reliable coal flow from the storage silos. A recommendation to line the hopper cones with UHMW-PE was made by personnel within the Indiana Michigan Power Company. Liners were subsequently installed in the lower 10 ft of the hoppers as shown in Fig. 3. Two different types of liners were installed in order to evaluate the performance properties of the various grades of UHMW-PE. Two silos were lined with TIVAR -100 (virgin UHMW-PE) and two silos were lined with CASCO 810 (cross-linked and filled UHMW-PE). Both grades of UHMW-PE liners provided an immediate reduction in the coal bridging and ratholing problems.

In order to substantiate the results of the initial UHMW-PE liner installation and to determine the long-term suitability of this

Fig. 2: Elevation view of the two hopper configurations

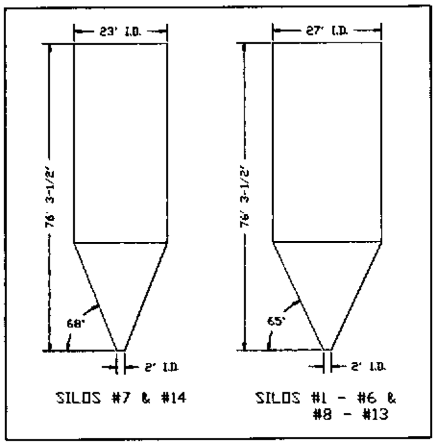
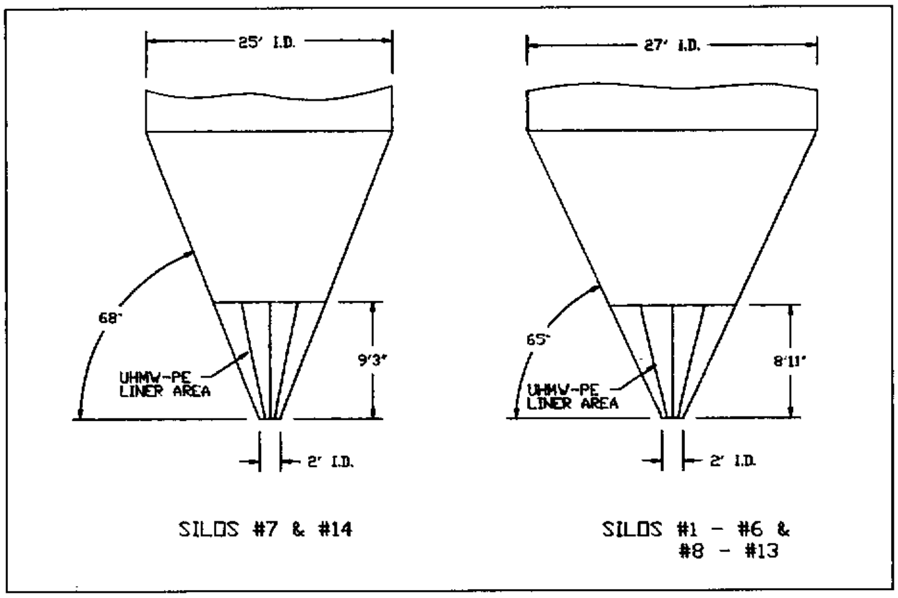


Fig. 3: Drawing showing the liner location



solution, AEP contracted a consulting firm specializing in the field of bulk solids flow. A report on their findings is summarized in the following section.

8.1 Testing

The objective of the testing work done for the Rockport Plant was to determine the parameters necessary to produce a mass flow condition within the storage silos. By obtaining mass flow, reliable gravity discharge of the coal could be maintained without the associated problems of ratholing and arching. In addition, spontaneous combustion of the coal could be minimized through mass flow by preventing areas of stagnation.

Initial testing showed that the worst flow conditions existed at 35.3% moisture content for continuous flow and after three days storage at rest. This condition was used for further testing to insure flow during the worst case conditions. Complete testing on the coal at 35.3% moisture content revealed that the minimum arching dimension for continuous mass flow is 1.8 ft, but after three days storage this dimension increases to 12.2 ft and any overpressures due to vibration or compaction from filling can easily increase these dimension by a factor of two.

Table 1 shows the required wall angles to force flow along the walls for the various wall liner materials The required angle of 16° from vertical for 304 SS with 2B finish compared to the actual silos with 304 SS 2B finish at 25° from vertical (65° from horizontal) indicates the current design is inadequate. Since the arching dimensions derived from testing this coal after simulated storage at rest are larger than practical equipment design, it would be necessary to use air cannons or other devices to restart the flow from the bins. At this time, no air cannons have been added and the storage time is kept to a minimum since spontaneous combustion can occur after a prolonged storage period.

Table 1: Wall angles for obtaining mass flow in a conical hopper with 2 ft outlet

Wall Liner	Cone Angle Measured from the vertical	
	for continuous flow	after 3 days storage at rest
2B stainless steel sheet	16°	14°
CASCO 810	24°	19°
TIVAR-100	26°	23°
TIVAR-88	29°	24°

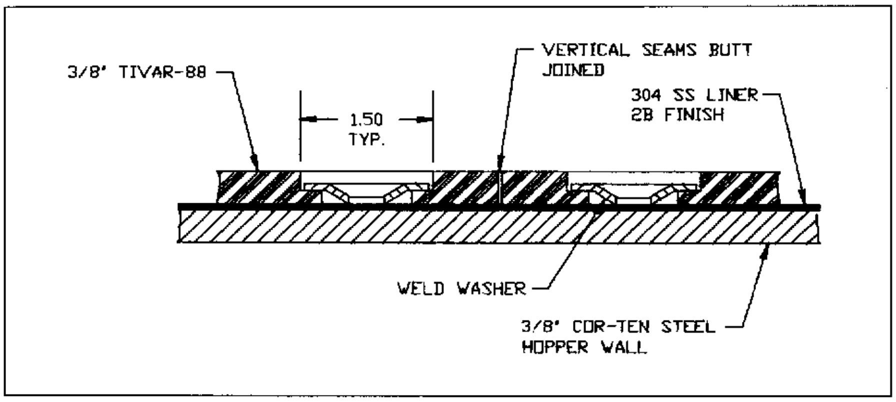


Fig. 4: Cross-section of the weld washer and vertical seams

9. Solution Implementation

Based on the performance results of the UHMW-PE liners in the initial test silo installations and the supportive findings of the consulting firms report, a decision was reached by the Rockport plant management group to proceed with the continued installation of UHMW-PE liners on the remaining unlined silos of Unit #1. The UHMW-PE lining material chosen for final specification was TIVAR-88. This decision was based on the consulting firms findings which showed that TIVAR-88 produced the lowest wall friction angle of any of the tested UHMW-PE materials.

The area of the hopper to be lined was specified as the lower 10 ft. of the cone section (see Fig. 3). This coverage area was chosen based on initial test-lining performance, which proved adequate for the plants needs.

For the remaining 8 silos of Unit #1, 3/8 in. thick TIVAR-88 was selected. Attachment of the TIVAR-88 was completed using a stainless steel weld washer fastening system (see Fig. 4).

The final step in the TIVAR-88 liner installation was the attachment of a stainless steel leading edge protector shown in Fig. 5. The leading edge protector was installed to prevent coal from forcing itself between the TIVAR-88 and the hopper wall.

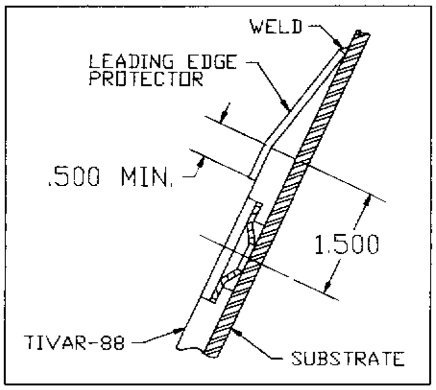


Fig. 5: Typical stainless steel leading edge protector detail

10. TIVAR-88 Performance Evaluation

Since the installation of the TIVAR-88 liners in the coal storage silos of Unit #1, plugging problems have been reduced by 30-50% and the time required to restore coal flow has gone from 1 to 4 hours per incident to less than thirty minutes.

This reduction in silo plugging problems and related downtime has been documented by Rockport plant personnel over the past five years beginning in mid 1985.

During this five year period, an estimated seventeen million tons of coal have flowed through the silos of Unit #1. Maintenance inspections have been conducted on the silos after every 4,000 hours of operation to check the overall condition. Close examination of the TIVAR-88 liners has revealed no apparent wear.

The silo plugging problems that remain at the Rockport Plant typically occur in the Fall and Winter. Re-establishing coal flow is now accomplished through the use of an air lance which is inserted into the lower cone section through a 4 in. ball valve.

The overall results of the TIVAR-88 liner installation at the Rockport Plant have been positive. According to plant personnel the elimination of only one silo plugging occurrence provides enough cost justification for a TIVAR-88 lining system.

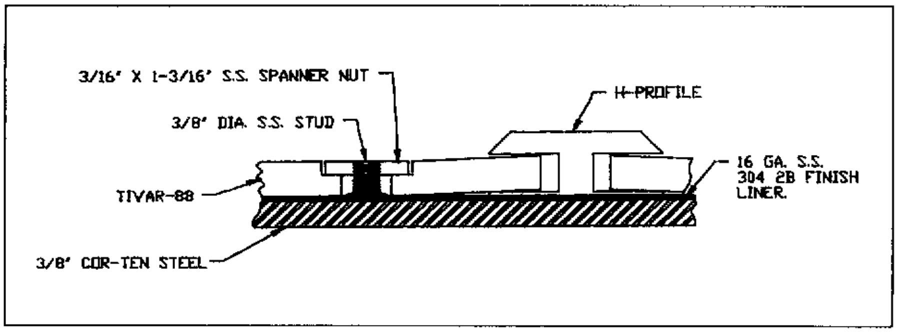


Fig. 6: Cross-section of the weld stud, spanner nut and H-profile

10.1 Unit #2 Lining

Based on the performance evaluation of the TIVAR-88 liners in the silos of Unit #1,the decision was reached to line the silos of Unit #2 prior to its start-up in late 1989.

The liner chosen for installation on the Unit #2 silos was 1/2" thick TIVAR-88. The installation method used was a stainless steel stud and spanner nut combination with a TIVAR H-Profile seam protector (see Fig. 6). The fastener spacing pattern and sheet layout detail are shown in Fig. 7. The purpose of the TIVAR H-Profile was to provide vertical seam protection between the TIVAR-88 liners to prevent the potential migration of coal fines behind the liners.

The installation of TIVAR-88 liners on the silos of Unit #2 was successfully completed prior to its startup in late 1989.

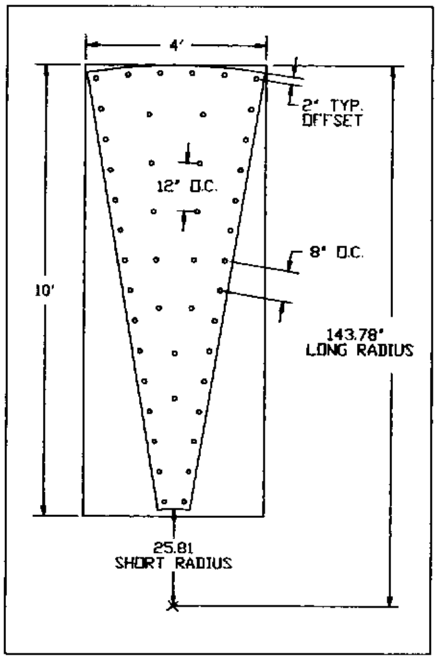


Fig. 7: Fastener spacing pattern and sheet layout

In order to provide quantitative values of TIVAR-88's slide abrasion wear resistance in gravity discharge silo applications, Poly-Hi hired Jenike & Johanson to conduct a wear life study. The wear life study compared TIVAR-88 to 304 stainless steel with a 2B finish using a western low volatile high ash coal (LVHA) and an Eastern high volatile low ash coal (HVLA). (Fig. 8 shows the example coal silo used in the calculations along with the pressures and velocities occurring in the silo.) Fig. 9 shows a profile of the estimated wear life which can be expected in the example silo handling the two coals tested. The highest wear rates occur in the outlet area for both coals on both liner materials. The Western coal developed a higher wear rate on the 304 SS than on the TIVAR-88, 0.005 in/yr and 0.0024 in/yr, respectively. This results in a useful life of over 100 years for a 1/2 in. thick TIVAR-88 liner. The Eastern coal had a significantly higher wear rate on the TIVAR-88 of 0.028 in/year which results in a wear life of approximately 17 years.

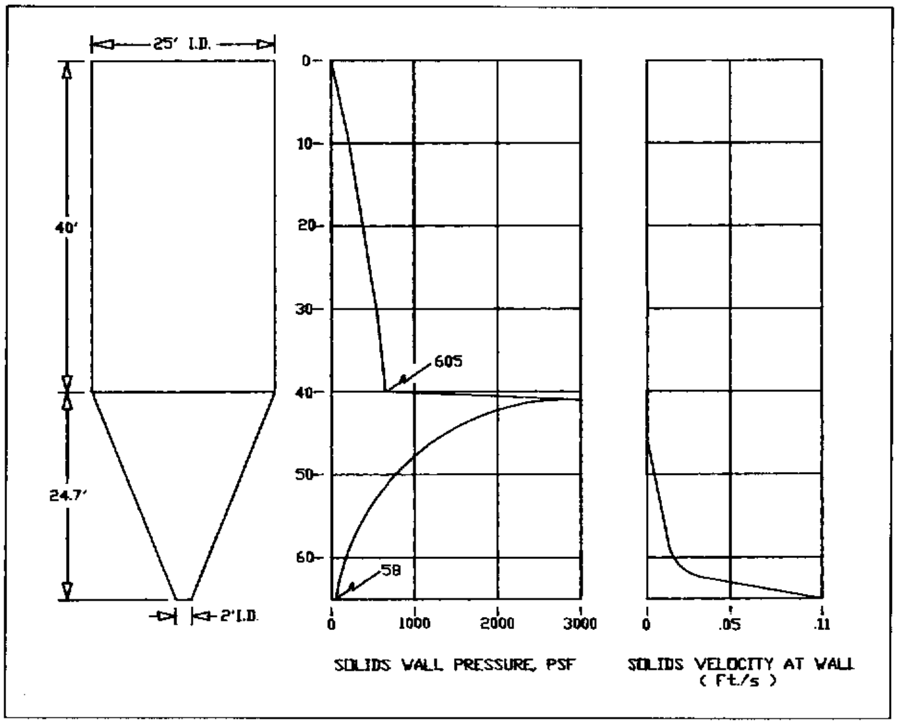
Although this example provides some insight into the prospective wear life of liners, testing and evaluations should be conducted for individual cases to quantitatively predict wear life.

11. Supportive Data

The AEP-Indiana Michigan Rockport Plant case study provides an example of how TIVAR-88 liners can perform in coal silos with gravity discharge flow. Two key aspects of this case study are the performance benefits of TIVAR-88 over other grades of UHMW-PE liners and the projected service life of TIVAR-88 in gravity discharge applications.

As it was shown in the findings of the consultant's test data, TIVAR-88 provided the lowest wall friction angle of the three grades of UHMW-PE tested. TIVAR-88 represents a special grade of UHMW-PE which is chemically cross-linked and filled. These modifications to the base resin of UHMW-PE serve to lower the surface coefficient of friction of TIVAR-88, as evidenced by the wall friction data in Table 1, and improves the liners slide abrasion wear resistance. The enhancement of these performance characteristics makes TIVAR-88 well suited for many bulk material applications.

Fig. 8: Solids pressure and velocity in a mass flow bin



12. Conclusions

Through evaluation of the AEP-Indiana Michigan Rockport Plant Case Study it can be concluded that TIVAR-88 UHMW-PE liners provide workable solu-

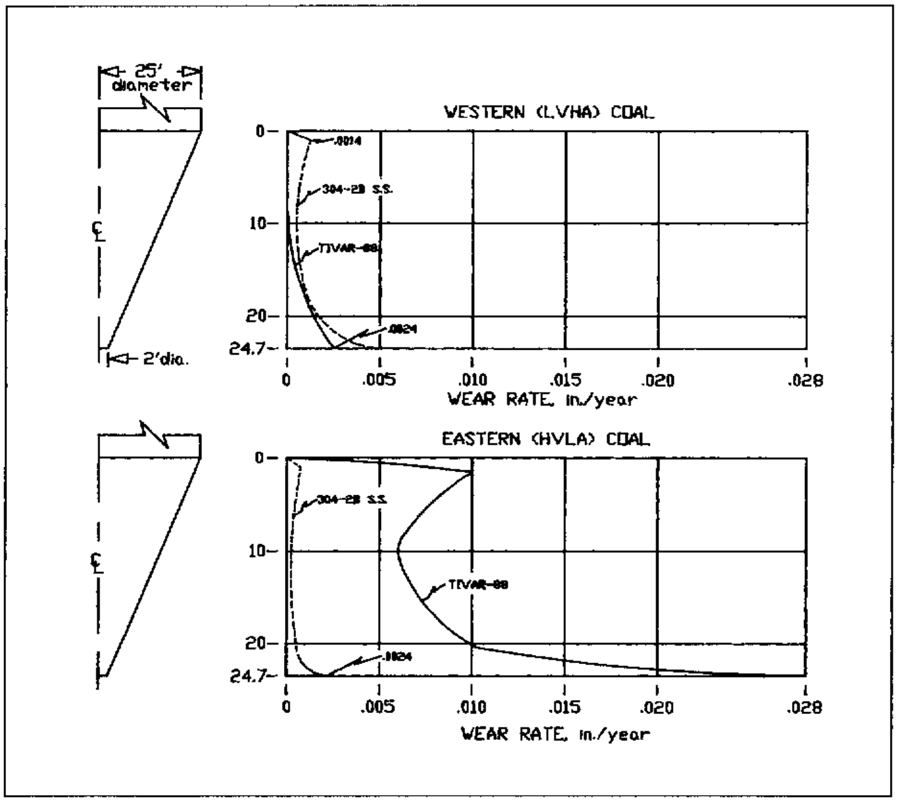


Fig. 9: Wear rates in a mass flow hopper based on 24 hour operation 364 days per year, assuming the coal has a bulk density of 50 lb/ft^3 being withdrawn at 50 t/h.

tions to flow problems in gravity discharge silos. The benefit of TIVAR-88's low surface coefficient of friction can induce the flow of bulk solids along hopper sidewalls thus reducing or preventing flow problems such as bridging and arching.

In addition, the performance evaluation time frame of the AEP Indiana Michigan Rockport Plant Case Study and the supportive data provided by the Jenike & Johanson wear tests show TIVAR-88 to be an economically justified flow promotion solution based on projected wear life.

Today the use of TIVAR-88 liners in gravity discharge silos is expanding well beyond its use in coal handling and reaches into industries such as mining and mineral processing, grain handling, food processing, soap manufacturing, and chemical processing.

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