The Use of Ceramics in “The Coal Preparation Plant of the Future”

Not Just a Plant

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PRESENTED BY:

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(Exhibit 1)

Introduction (Exhibit 2)

More tons of production and less man hours define the current 24/7 operation schedules that most plants operate in our industry today. We have experienced a progression since 1980 to greater-more efficient operational performance. By developing ceramic application standards that have redefined and continues to be a progressive platform of maintenance standards, we continue to produce marked improvements in performance resulting in higher per man hour production at reduced per ton cost.

With the near diamond hardness of alumna oxide and ceramic composites, we are now able to extend the life of processing equipment 10-15 times over the AR 400 standard technology of the past. The ceramic standard as applied in new plants and progressive maintenance programs today has become the best practice in lowering cost of coal processing and related operations, to maximize return on investments.

In all coal and related operations, coal handling results in drop impact, sliding abrasion, and corrosion as a result of mild sulfuric oxidation. These elements combine to cost millions of maintenance dollars per facility, yearly. We now are redefining existing standards and applying these new operational standards that are extending monthly and yearly maintenance replacement cycles from to 10 to 15 years. We have many proven applications that have operated greater than 20 years of service.

You Can’t Afford Just Another Plant (Exhibit 3-Just a Plant)

Recently, I was talking to a friend about plant design and the selective process involved when a new coal processing plant comes on line or expands. As we know, it normally involves several layers of management. First, a budget of x dollars is set aside to bring the facility online. Next, a design team puts together a plan which then goes to bid. When the bid comes in higher than expected, the budget team draws in the purse strings, holding the design teams’ feet to the fire. In most cases, the design team caves in to budget restraints and you end up with “JUST A PLANT”.

20 Year Plan

Today, we have at our discretion, unlimited resources of materials and the alternative to mix and match materials to meet target budgets. Unfortunately, the sad reality is: The budget driven response wins out, more often than not. The short term target frames the new operations management and work force with a quickly occurring “catch up situation”.

The old adage of “do it right the first time” becomes more and more imperative in this day of skepticism and disinformation. We must design for high operational efficiency utilizing proven best practice methods, and continue the innovative approach that makes coal the most economical energy source available.

The hard reality is that our industry must continue to lead the way. It is imperative that we keep our coal and resulting industries competitive making correct long range decisions that position us to compete and provide a dependable resource for future generations.

The following presentation will highlight the “best practice application of design” in selecting the right liner system to establish a twenty year maintenance platform, that will result in a much improved efficiency, resulting in lower coal preparation cost.

Ceramic Background (exhibit 4)

Ceramic, as a wear resistant lining, was introduced to the US Coal Processing Industry in the early 1980’s. Many of us today remember when it was necessary to keep massive “maintenance” and “cleanup” crews just to try to keep plants operating.

My first introduction to ceramic lining was at the “old” Moss #3 Prep Plant (Pittston Coal Group) in Clinchfield, VA. One day in 1981, a vendor approached me with ceramic tile brick, for the first time. I decided to try it in a chute that transferred the sink material off a “Primary HM Vessel” at 1.35 sig to a “Secondary Vessel” feed (top size at 8”-10” rock). The corundum brick that we had been using lasted 8-9 months. The ceramic tile lasted five years. The ceramic cost twice the price of the previous material-“No Brainier”. Soon thereafter we tried a 6” diameter ceramic lined pipe ($^1/_2$” lining) in the place of schedule 80 steel pipe, that averaged six months life, on a “Deister Table” feed line. After six months of use with the ceramic lined pipe, there was no wear detected. That pipe was still in use when we shut the old plant down, nine years later. This type of performance is pretty much typical, and many of you have experienced performance of this nature first hand.

Ceramic Properties (Exhibit 5)

- **Ceramic Properties:** "The properties of ceramic materials, like all materials, are dictated by the types of atoms present, the types of bonding between the atoms, and the way the atoms are packed together. This is known as the atomic scale structure. Most ceramics are made up of two or more elements. This is called a compound. For example, alumina (Al_2O_3), is a compound made up of aluminum atoms and oxygen atoms.

  "The atoms in ceramic materials are held together by a chemical bond. The most common chemical bonds for ceramic materials are covalent and ionic. For metals, the chemical bond is called metallic bond. The bonding of atoms together is much stronger in covalent and ionic bonding than in metallic. That is why, generally speaking, metals are ductile and ceramics are brittle." ("What is Ceramic?")

- "Alumina, or aluminum oxide, is a colorless or white solid, occurring in several crystalline forms, and is found naturally as corundum, emery, and bauxite. Solubility in acid and alkali increases with hydration. The melting point of alumina is 2045 degrees centigrade"

  "Sintering is the process of bonding together compacted powder particles at temperatures below their melting point. The driving force is the decrease in surface energy that occurs as the particles merge, and their total surface area lessens. The smaller the powder particles, the faster is the sintering. Sintering is used to consolidate ores in powder metallurgy, and in the making of ceramics." ("Your questions Answered")

- Aluminum Oxide (ceramic) is one of the hardest (resistant to scratching) materials, nearly as hard as diamond.

Moh's Hardness:	
Material	**Moh's Hardness**
Diamond	10
Boron Carbide	9-10
Silicon Carbide	9-10
Tungsten Carbide	9
Aluminum Oxide	9
Zirconium Silicate	7.5
Cuttlebone	7
Quartz	7
Garnet	6.5-7
Porcelain	6-7
Enamel	5
Chalk (Calcium Carbonate)	3
Gold	2.5-3
Pumice	2
Talc	1

"A material's Moh's Hardness value indicates the material's resistance to scratching. A diamond has a maximum hardness of 10." ("Physical and Mechanical Properties of Materials)

- Ceramic is less than half the weight of mild steel, AR steel, and stainless steel; 1 sq ft of ½" thick ceramic weights 9.35 lbs, compared to ½" AR at 20.42 lbs.

Application of Design in Selecting the Right Liner System to Establish 20 Year Maintenance Platform: (Exhibit 6)

True, ceramics are not the "cure all" to be used everywhere in your materials handling, but it is the most vital contributor to be utilized in the efficient operating plants of the future, along with, innovative thought into design and the utilization of a strong preventative maintenance program. The following are some best practice standards that we have developed over many years of operating coal processing plants and providing the products throughout the US Coal Industry to give you the best return on your investments.

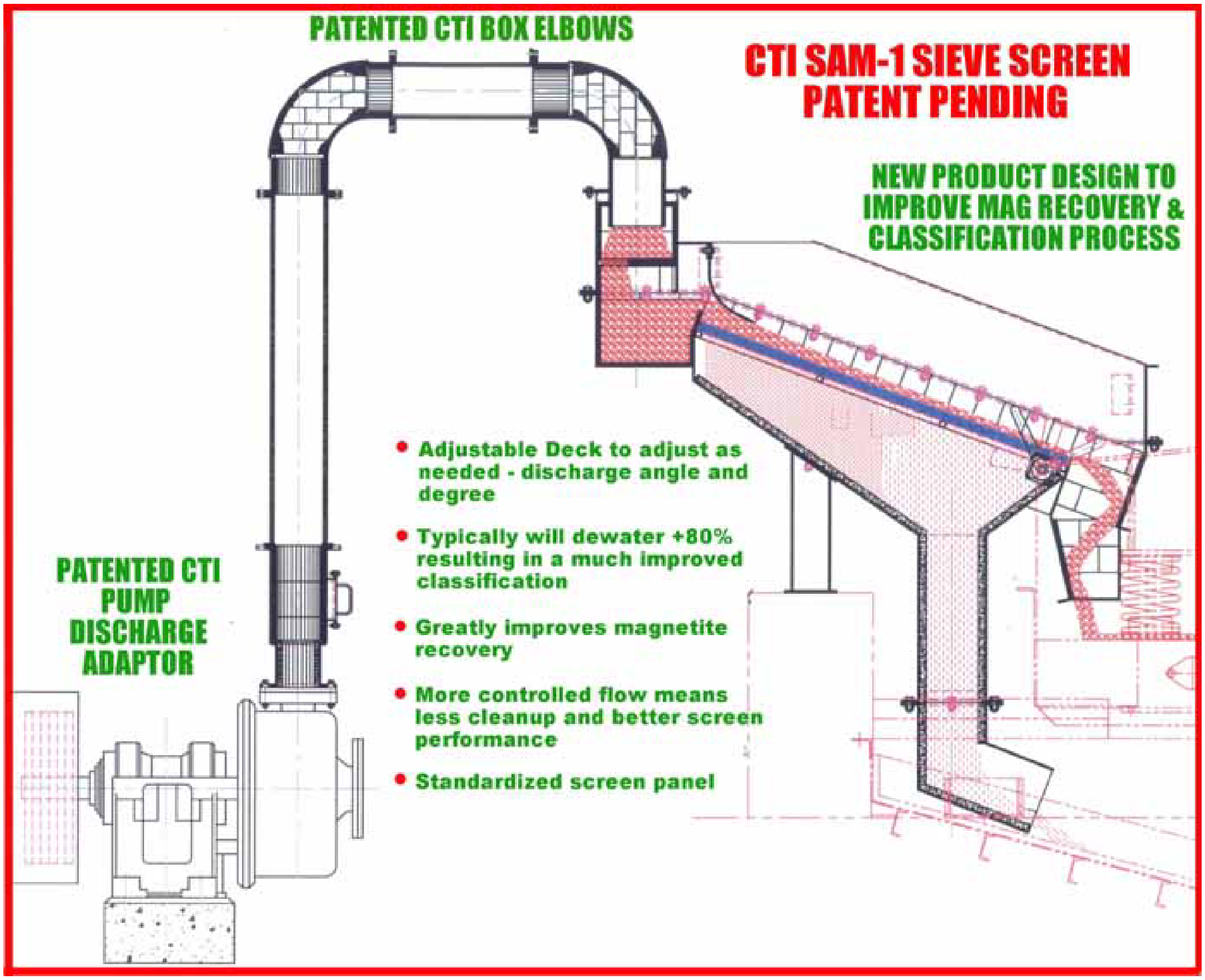
Some of the following specifications may change due to flow pressures, material characteristics, and distance of drop in gravity flow situations. Particle size and drop can vary greatly when events of oversize enter the flow due to screen or mechanical failures. This is normally associated with run of mine, raw coal, and refuses applications. Impact panels-barred and set up to bolt-in to dissipate drop and absorb energy impacts, are the best solution to off-set unexpected events of this nature.

Pump and Gravity Piping Recommendations

- **14 M x 0:**

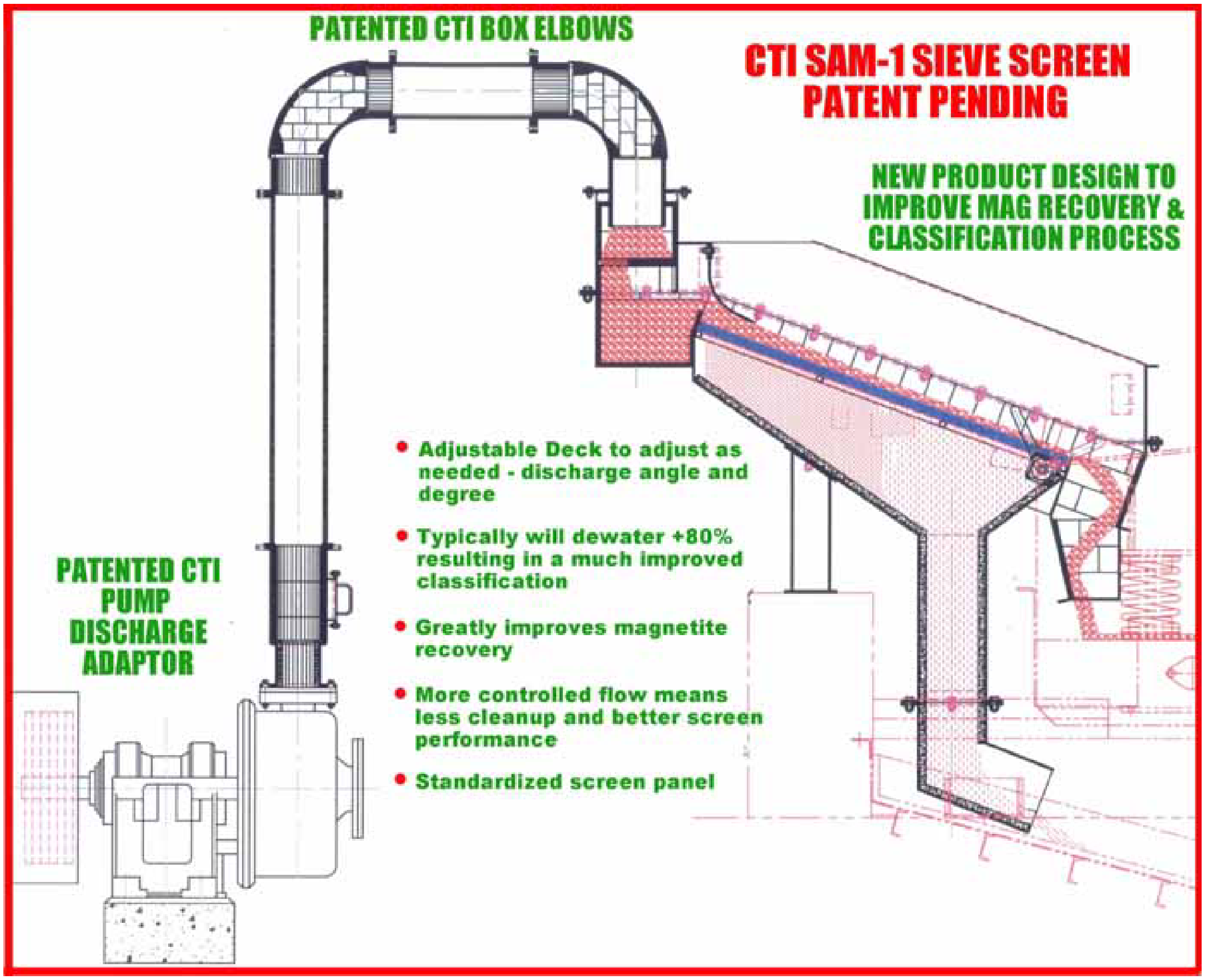
  We have found that due to the abrasive nature of this range in flow turns, the best practice is to use ½" ceramic lined fittings on all turns combining with "High Density Polyethylene Pipe" for the straight spools.

It is also advantageous to design ceramic lined flume systems for spiral products flow. (Exhibit A)



- **14 M x ½": Pipe and Chutes**: $^{1}/_{2}$" ceramic

- **½" x 1 ¼": Pump Discharge Lines**: ½" ceramic in straight spools, 1" ceramic in turns (critical to maintain the ID) (Exhibit B)



½" x 1 ¼": Gravity Flow Piping (Clean Coal): ½" ceramic (Note: Depending upon the hardness of the coal, we might recommend CTI Impact Ells with variable Wear Backs which are proven to be cost effective.)

½ x 1 ¼" Gravity Flow Piping (Raw Coal and Refuse): ½" ceramic liner in straights and 1" ceramic in all turns **(Exhibit C)**

(Note: We recommend CTI Impact Ells to be used here, due to the 1" ceramic wear back liner, and to the angled sides of the ceramic tile, which gives a tight/secure fit!) (Exhibit D)

- **1 ¼" x 3": Pumping Discharge Line and Gravity Flow Piping**: 1" ceramic in all cases, and even in specialized situations in turns, utilize 2" on pump turns and impact ells on gravity. We also recommend the CTI pump adapter with clean outs for these upper limit applications.

Chute Recommendations

Note: In all impact conditions, bolt-in impact panels may be considered!

- **½" x 1 ¼" Gravity Flow in Chutework (Clean Coal)**: 1" ceramic in all impact points, ½" ceramic elsewhere. (Exhibit E)


TVA Breaker Feed Chute- Installed October 1992
No Maintenance To Date

- **½” x 1 ¼” Gravity Flow in Chutework (Raw Coal and Refuse)**:

  Less than 8 ft drop: ½” ceramic on sliding situations and 1” ceramic on sides where there is impact, and in all bottoms.

  Greater than 8 ft Drop: 2” ceramic on impact; elsewhere same as with “less than 8 ft drop”.

- **1 ¼” x 3: Gravity flow in Chutework (Clean Coal):** ½” ceramic on sides in sliding conditions, 1” ceramic on sides where there is impact situations; 2” in bottoms where there is impact, and step down to 1” ceramic once material is settled down into sliding. (Exhibit E)

- **3” x 6”: Gravity flow in Chutework (Raw Coal and Refuse):**

  Less than 8 ft Drop: 1” ceramic on sides in sliding conditions and 2” ceramic on impact areas. 2” on bottoms where there is impact and can step down to 1” ceramic once materials are settled down in sliding.

  Greater than 8 ft Drop: 1” ceramic on sides on sliding conditions, and 4” ceramic in akll impact areas. 4” ceramic should be stepped down in bottom slides below impact areas, and can even be stepped down to 1” ceramic once the material is settled into sliding.

- **Greater than 6" (Raw Coal and Refuse):**

  Of course, this is the extreme application that many would be very skeptical and shy away from ceramic liners. But we have found, through many of these operating conditions that we have successfully tackled, that through design and proper application we can meet this need consistently.

  By studying the nature of the material, the amount of fines and clay mixed in, and the amounts of force of the flows, we have come up with viable solutions. It involves creative designs, utilizing 4" and 6" thick ceramic. The utilization of turn shelves where applicable, and last but certainly not least, the utilization of "bolt-in" or "weld-in" impact panels. We also recommend leading in edge barring with minimum of ¾" AR strips to protect leading edges of ceramic and sufficient barring to maintain and hold monolithic integrity of ceramic panel system.

At Arch Coal's Cumberland River Processing Plant, we designed a Raw Coal Chute feeding the Raw Coal Stockpile, with 6" thick ceramic bolt-in pads. (Exhibit G) Previously, the operation had extreme difficulty in maintaining a chute in this application. The new chute has been in for nine months, and has held up extremely well. Whenever, if ever there is a need to repair the chute, it will only involve bolting in new panels. (Exhibit F)

Also, at Arch Coal's Lone Mountain Processing Plant, the operator has a scalped rock chute (rock up to 16") feeding onto a collecting belt that was not only a constant maintenance problem, but also a terrible noise problem. They had tried several different wear resistant materials in the lower impact panel, but had found nothing to be successful. We designed a 6" ceramic weldable impact pane that was installed. It solved all their problems. Being in now for six months, the panels remains in excellent condition, and is performing the job of transfer at a much lower decibel. (Exhibits G, H, and I)

- Another best practice “Rule of Thumb” is with ceramic lined ells, “Extend tangents off of all ells by 1 ½ times the diameter of the pipe, beyond the radius.” Also, if the ell tangents are designed equal lengths on each end of the ell, the operator will be able to rotate the ell once the ceramic eventually wears (many years in the future).

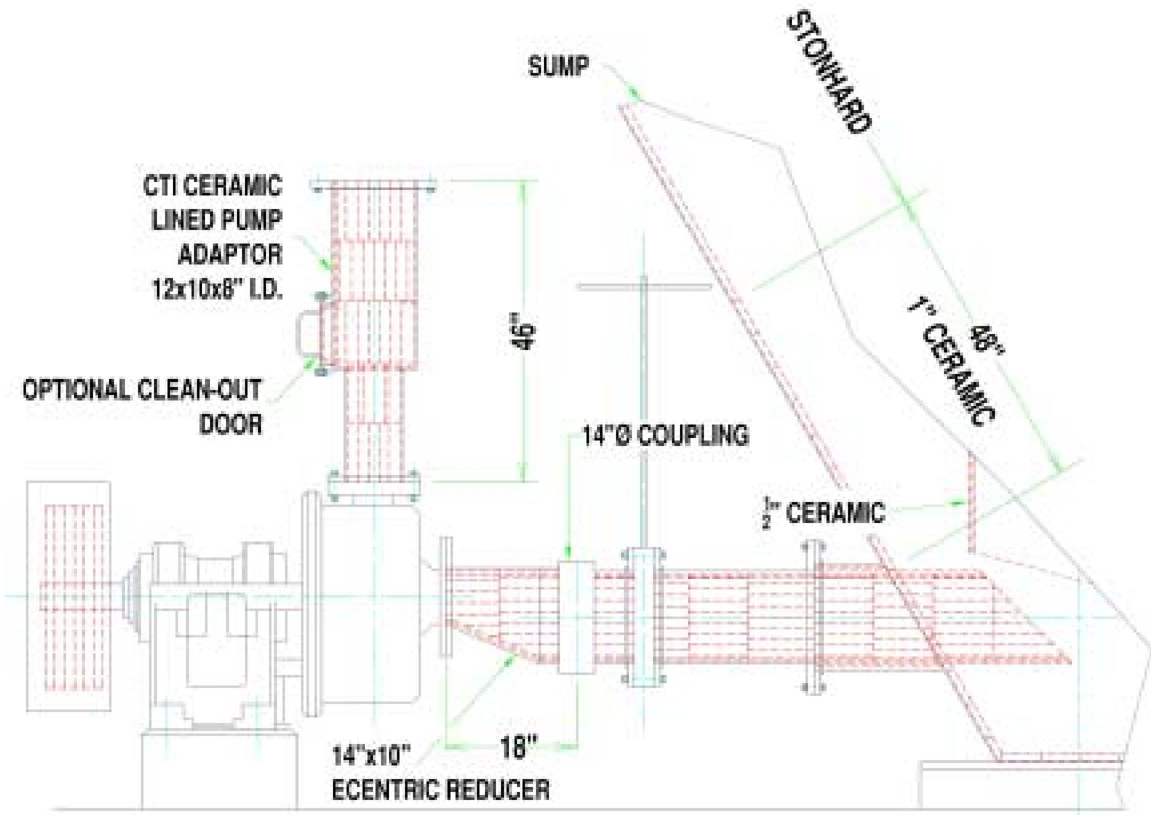
  When the ell is taken down to rotate, repair the worn section with ceramic beaded wear compound and you will be able to obtain many more years without the cost of replacing the ell.

Other Applications of Interest

- CTI Pump Adapters (Patented)

  Our Pump Adapters utilized off the volute of pumping applications, eliminates the use of “Bell Reducers” which have historically been a huge maintenance problem. By maintaining the pump volute ID and swelling out to the larger pipe diameter in the main flow (utilizing 1” and ½” ceramic linings), we have found that the pump adapters have outlasted the “Bell Reducers” up to 20 times. (Exhibit J)

SUMP & PUMP SUCTION LINE DETAIL



GENERAL SPECIFICATIONS

LINING - Alumina Oxide Ceramic, Standard 1/2" Thick With 1" On Impact.

OUTLET SPECIFICATIONS - Any Combination Pipe Size And Quality Can Be Obtained

PAINT - White Primer
FINISH - Customer Option

FITTING CONNECTIONS - Standard Flanges Are Fixed, However, Rotating Flanges Or Any Combination Can Be Provided To Suit Requirements

PIPE SPECIFICATIONS - Can Be Engineered To Fit Steel, Ceramic, SDR 11 Polyethylene

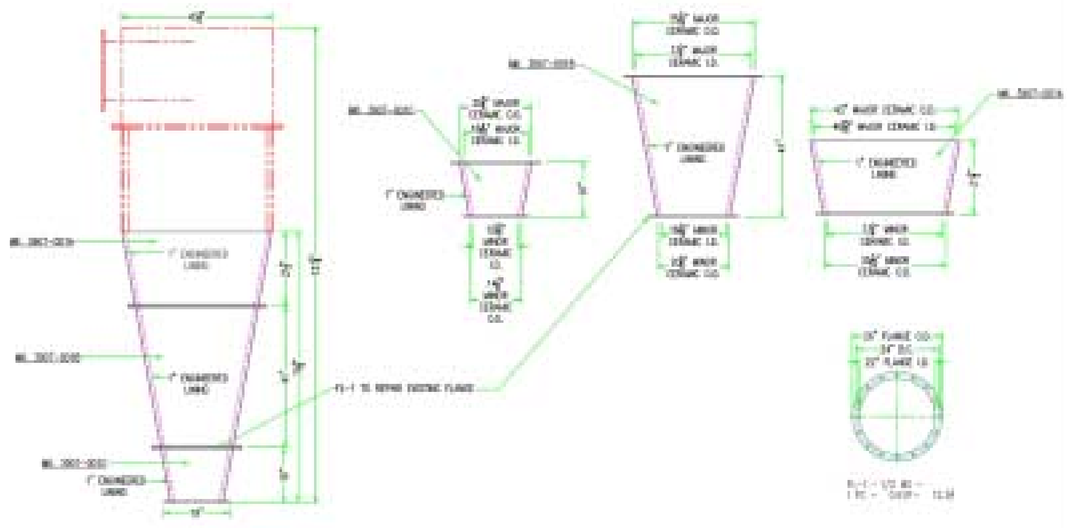
- Cyclone Tubs with Distributors (Exhibit K)

  We advise that pump lines from cyclone pumps be straight and vertical, with bottom feed to the distributor or top feed. Feed pipes should be lined with ½” or 1” tile and the tub overflow should be lined with 1” Stonhard and #9 expanded metal.

The Cyclone Underflow side of tub should be lined with ½” ceramic on the bottom and 6” up the sides. Discharge stubs lined with ½” tile and overflow pipes from cyclones made of schedule 80 or high density polyethylene piping, with feed inlet spools lined with ½” ceramic. The distributor wall should be lined with ½” ceramic and the top to be 1” AR, bolt-in cover lid. All tangent feed lines lined with ½” tile.

- Cyclones and Repairs (Exhibit L)

Most heavy media and classifying cyclones have engineered 1” and ½” ceramic liners. We recommend new fabricated sections with engineered liner as needed, to rebuild to original specifications.



- Sumps-Heavy Media Pulping Columns (Exhibit M)

  In sumps, pulping columns, kill boxes, and suction liners the application of ceramic has become the required specification. We adhere to ½" ceramic inside the columns tube. In some cases, 1" on the impact cones and kill box arrangements. Apply ½" ceramic in suction lines. The lower 48" to 60" of the outside of the column is to have ½" ceramic with the remainder lined with Stonhard.

  Suction lines are normally fabricated out of standard wall pipe lined with ½" ceramic.

Best Practice Liners for the Sumps and Media Pulping Column: Heavy media sumps 12-14 ft diameter are normally fabricated in four pieces due to weight and shipping restrictions. These are built in plant and flanged as an inner cross section to re-bolt once onsite with minimum labor. The sump is lined with 1" Stonhard above sink elevations.

½" ceramic is used in vertical column and sink column. Stonhard liner is applied to inner cone to water line just below screen.

- Non Radial Cyclone Feed Headers (Exhibit N)

  When you need to feed a smaller number of classifying cyclones than is needed for a round tub (normally less than four cyclones)-“Pipe Header Systems” are applicable and give efficient distribution. This takes up very little area to install.

- Static Box Systems (Exhibit O) (Replacing Rotating Sieve Assemblies and Utilizing Feeding Banana Screens)

  These have proven to work very effectively in many applications, Deslime and HMC Clean Coal and Refuse D&R Feed for Horizontal and Banana Screens. The feed headers are completely ceramic lined, and are designed to kill the velocity of the feed, and to give great distribution onto the feed end of the screening.

- Rotating Distributors

  These are essential to give efficient distribution of feed to multiple processing items (raw coal, spirals, deslime screens, etc.). The inside of the distributors are completely ceramic lined. Due to ceramic liners we are now able to restrict flow rates to a controlled flow-Slower rates in some applications promote classification and media recovery.

- Heavy Media Vessel Bottoms (Exhibit P)

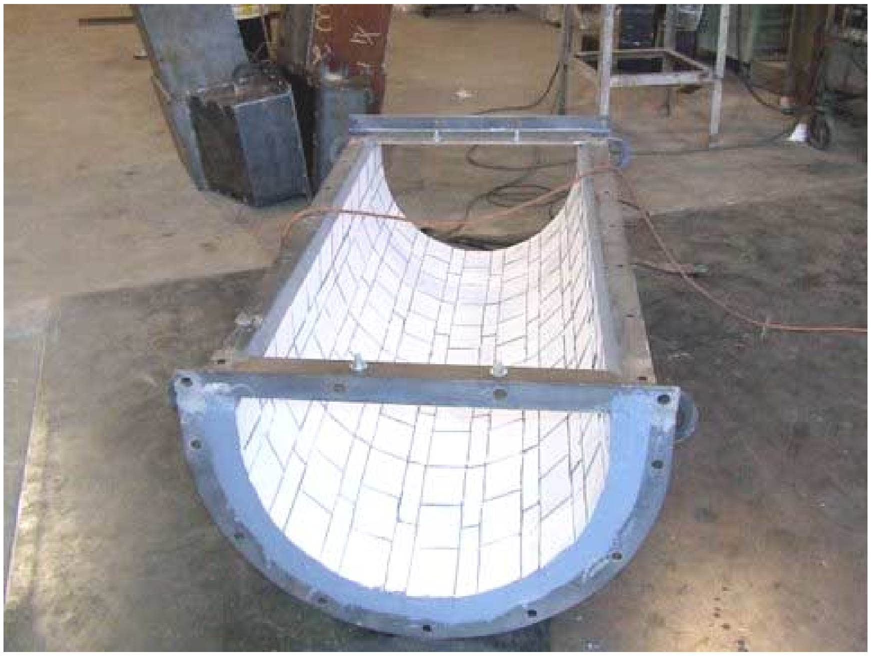
  We have lined three vessels in the past and have had great results. One application has been in for over ten years! Ok maintenance planners, don't you think it's time to get away from changing your vessel bottom liners every one to two years? We will point out that Consol Energy installed a 2" bottom in their HM Washer at Robinson Run Prep Plant and it is also performing to spec to date.

- Screen Underflow Pans (Exhibit Q)

  In pans under Raw Coal and media D&R screens where high volumes are flowing it is best to line the bottom of pans with ½"or 1" ceramic in the first 6ft to 8 ft and in the lower trough section. Stonhard can be used in other areas in most instances. Under raw coal scalping screens, it is advisable to utilize 2” and 4” ceramic pad applications.

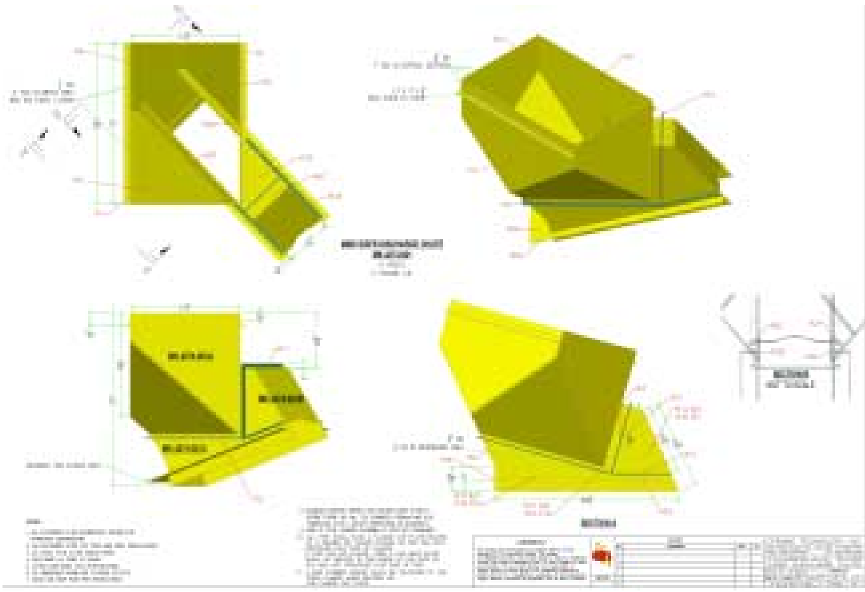
- Flume Systems Replacing Piping Networks (Exhibit R)

  In many applications where you have a need of gravity flow, especially with multiple converging pipes, it is advantageous to design ceramic lined “Flume Systems”. A prime example of applying this: carrying the products off of the spirals.



- Innovative Design and Utilization of New Computer Technologies (Exhibit S)

  3-D CAD capabilities have become a tremendous aid in proving designs. These new tools allow the designer to identify potential problems with a greater degree of accuracy, allowing correction out front, instead of after the fact. Modeling capabilities along with new cutting technology allow us to continually improve the design to flow criteria that now support 24/7 schedules of our operations.



- Last, but not least, “Noise Reduction” and “Clean Housekeeping”

  A huge benefit of a ceramic program that is often not appreciated is the degree that plant noise decibels is lowered. Raw coal and refuse flows can create decibel levels that can damage your hearing permanently, impact energy levels in you work force, complicate communications, and contribute to a poor work environment making your work force irritable at best.

Ceramic applications dissipate the load and do not amplify the noise energy created by coal flows.

Facing the onslaught of political pressure and the overall media babble as to coal operations being poorly kept, federal and state inspectors show little compassion for operators that maintain poor operations. Fines and closer orders are a common direct expense occurring in coal operations.

This kind of attention creates a domino effect that increases cost, exponentially, and adds to the direct cost of lost production.

Having a good ceramic program in place will deliver a tremendous return as to fewer hours expended on cleanup and a better focus on production. Bringing all the elements together to combat the political and operational realities will result in overall improved operational performance creating a more positive work force that takes pride in their operation.

Conclusion

As designers, fabricators, and product suppliers, we feel that we are in partnership with you as the coal operators. We have learned from each other. A major part of our lives, like yours, is the coal industry. We have outlined a program that is a conservative estimate of a 15 to 1 return on investment. These practices and procedures are proven to make a marked improvement in your operations.

We look to the future in knowing that we can and do make the difference that will make the processing plant of today, and of tomorrow, “Not Just a Plant”, but a much improved operation, that will provide the resources to support our present and future generations.

References

"Physical and Mechanical Properties of Materials." 19 October 2007. Omega Slate. 2000. http://www.omegaslate.com/mechanic.htm.

"What is Ceramic." 19 October 2007. http://www.acers.org/acers/aboutceramic.asp?id=outreach#Definition.

"Your Questions Answered." 19 October 2007. Omega Slate. 2000. http://www.omegaslate.com/question.htm.