

Paste Thickeners for Coal Preparation Plants

by

Steve Slottee
PasteThick Associates
Salt Lake City, UT

Introduction

Paste thickening is a relatively new, rapidly growing technology within the minerals industry for thickening solids to a higher concentration than achievable with conventional thickeners. The concentrated solids produced by a paste thickener have the physical attributes commonly associated with the word “paste”: uniform properties throughout and flows slowly or not at all under gravity. An example of coal fines paste is shown in Figure 1. Throughout the minerals industry paste thickening has become an alternative to conventional thickening and filtration for water recovery and tailings disposal.



Figure 1: Coal Fines Paste

In the coal preparation plant there are two applications for paste thickening: concentrating fine coal and producing paste from coal tailings for increased water recovery and elimination of tailings ponding. This paper reviews the characteristics of paste tailings and the paste thickener and discusses applications in the coal preparation plant where the use of paste thickening technology cannot be ignored as an option in plant design and upgrading.

Characteristics of Paste

In the minerals industry paste is a term for a suspension of solids which are relatively non-settling and non-segregating; a characteristic produced from the interaction of naturally occurring clays, silts, and fine sands less than 20 microns in size. As the name implies, paste has a self-supporting structure and when deposited on the ground will form a slope of varying inclinations depending on the solids concentration. Paste properties are produced by the relatively high suspended solids concentrations. “Thickened tailings” is a synonym used in some industries when paste is used for tailings handling.

Mineral pastes are frequently described as Bingham plastics, a type of rheology characterized by the presence of a yield stress. A yield stress is measured in units of pressure and is related to the force required to make a paste flow. Yield stress is manifested by the slope that a paste assumes when deposited on a flat surface and is a function of solids concentration.

Slump is an indirect measurement of yield stress and is used as an indication of the yield stress and solids content of a tailings paste. As shown in Figure 2 a cone is filled with sample, the cone is manually lifted, and the distance the paste sample “slumps” is measured. Slump and yield stress have an inverse relationship. As yield stress increases, the measured slump decreases, all other parameters equal.

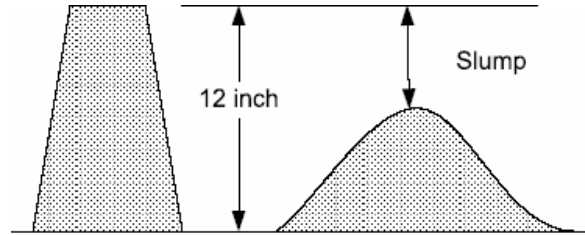


Figure 2: Slump Measurement

The high viscosity of pastes makes pipeline design critical. Coal pastes are generally pseudoplastic where the viscosity decreases with shearing such as in pumping and pipe line flow. More detailed descriptions of a paste can be found in sources such as Boger (1999) and Robinsky (1978) and for pipeline design, Paterson (2003).

Paste Thickener Design

The conventional thickener¹ is a raked vessel that commonly uses flocculant and concentrates a suspension of solids, but not to the levels where paste characteristics are developed. The deep cone style paste thickener was developed in the 1960 and 70s in the British coal industry. (Abbott, 1973) Over the years this paste thickener was combined with modern day flocculation techniques, feedwell design, and improvements on the design of the tank, rake and underflow discharge system to produce the modern deep cone type paste thickener. This thickener is characterized by a height to diameter ratio typically greater than one to one with unit areas (m^2/tph) several times smaller than for conventional thickeners. Figure 3 shows the relative difference in the geometries of the conventional (high-rate) thickener and the deep cone type paste thickener. The mud bed height in a deep cone type thickener is much higher (several meters) than the level in a high rate thickener which more than compensates for the effect of smaller area on underflow solids concentration for the same throughput rate. The combination of the high aspect ratio and steep cone angle also facilitates the discharge of paste underflows. At this time the number of manufacturers of deep cone type thickeners is relatively limited.² Figure 4 is a schematic of the WesTech Deep Bed™ Paste Thickener.

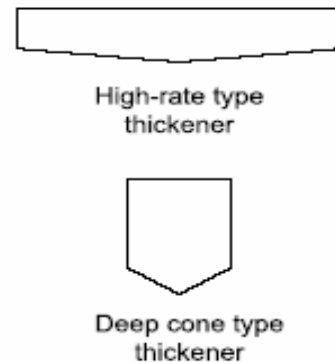


Figure 3: Comparing Conventional and Paste Thickeners

¹ Historically a “conventional thickener” applied to thickening without the used of a flocculant. More recently the term in increasing applied to thickeners which use flocculant, also called “high-rate thickeners”. In this article “conventional thickener” has the more contemporary definition.

² GL&V, Outokumpu, and WesTech are the major suppliers of deep cone type thickeners.

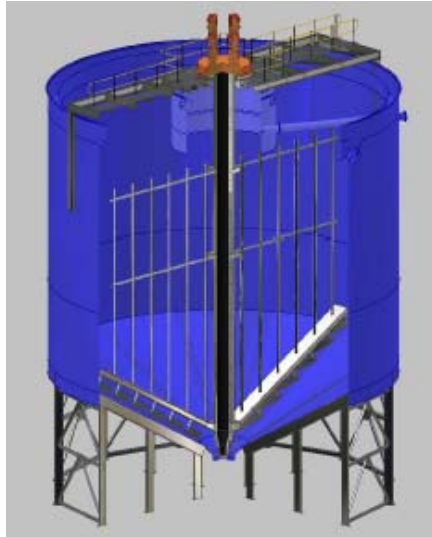


Figure 4: WesTech Deep Bed Paste Thickener

Application of Paste Thickening to Coal Preparation

Fine Coal Thickening

Fine product coal is generated as a result of grinding and sizing steps in the coal preparation plant. Fine coal streams are conventionally dewatered in equipment such as conventional thickeners, cyclones, filters, and centrifuges.

Pilot Paste Thickener Testing

The following is an example of the application of a paste thickener to fine coal dewatering. In a coal prep plant 260 mt/hr of fines (40 wt% less than 20 microns diameter) are thickened in a 35 m diameter conventional thickener to 35 wt% which becomes the feed to a vacuum filter. The filter cake is recombined with coarse coal concentrate. The filtration step is a throughput-rate bottleneck and a paste thickener as an alternative to the conventional thickener was investigated for either eliminating the need for filtration or improving filtration rate by increasing the feed solids concentration to the filter.



Figure 5: Paste Thickener Pilot Plant

To test this application, a 1 m diameter pilot scale paste thickener (supplied by WesTech Engineering) was used to thicken the fine coal stream to paste concentrations. The pilot produced up to 65 wt% solids underflow. At this concentration the solids suspension is in the range for paste characteristics that cannot be handled by a conventional thickener.

After applying scale-up factors the full-scale paste thickener was determined to be 20 m diameter with a height approaching 20 m. By feeding the filter with this concentration of solids, the filtration filter cycle time is expected to be decreased by 40%, removing the bottleneck to production.

Pumping Paste

Pumping paste must always be investigated as part of the systematic development of a paste thickener process. It is not unusual for a paste thickener performance to be limited by the pumping and pipeline design because of the high viscosity associated with paste. An effective approach for designing a paste thickener application is to integrate the thickening, pumping and pipeline design, and application on the same rheological basis. Jewel (2002), Johnson (2004)



Figure 6: Pilot Plant Discharge

For the pilot study described above the paste viscosity decreased with pumping (shear thinning in rheological terms). The tests showed that the paste could be pumped to the filter feed tank at the full throughput rate of the thickener and with good coverage of the filtration surface.

Coal Tailings

Tailings Generation and Impoundments

Tailings in wet-processing circuits are a residue of coal recovery processing (i.e. flotation) and product coal washing. The volume of tailings produced depends on the method of coal mining, coal grade, amount of water used, and characteristics of the coal (i.e. particle size). Tailings which are a combination of silt, dust, water, coal and clay particles are thickened and leave the plant as slurry. This slurry is most commonly disposed in an impoundment. Depending on the source, 20 – 50% of the run-of-mine material ends up in impoundments. (Center for Applied Energy Research, 2004) The financial, environmental, safety and reclamation problems with tailings dams in general and coal tailings impoundments in particular are discussed in the literature in by several sources and specifically by a National Research Council committee addressing coal waste impoundments (National Research Council, 2002).

Conventional Methods of Reducing Tailings Volume

Reducing the volume of tailings is one method to decrease the impact of tailing impoundments. Reduction of tailings volume can be accomplished by changes in preparation plant processing as discussed by National Research Council (2002) and Mine Impoundment (2004). Of interest here are methods to accomplish a reduction in volume reporting to the tailings pond by further concentrating the tailings slurry stream. A

thickener is usually the first and possibly only step in concentrating a tailings stream before deposit in a tailings pond. Conventional thickeners produce typically 30-35 wt% dry solids underflow that is pumped directly into the pond, or filtered to produce a cake which can be disposed of without ponding. For large volume flows filtration may not be practical because of the high filtration area required and the accompanying capital and operating costs. Alternatively, paste thickeners that dewater tailings to a paste consistency are an attractive method to recover more water and reduce many concerns associated with the impoundment site.

Surface Stacking Coal Tails With a Paste Thickener

Surface stacking is the disposal of tailings as a paste (commonly referred to as “thickened tailings”) on the surface of the ground, as a non-settling, non-segregating suspension of solids with minimal water release. There are various methods of accomplishing the stacking

depending on the topography of the disposal site and the rheology of the paste. For slopes up to 5%, paste thickeners can be used.

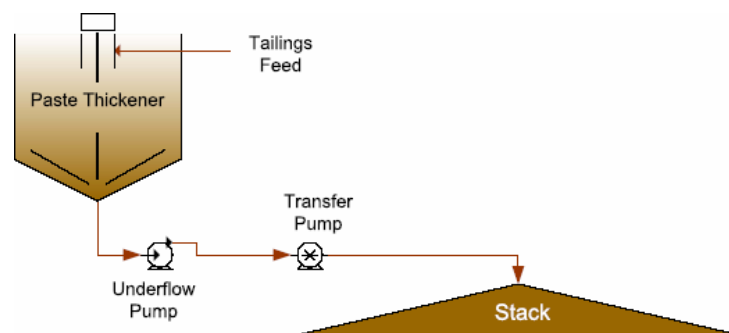


Figure 7: Stacking with a Paste Thickener

Figure 7 shows how a paste thickener is used to produce the disposal stack. The paste thickener’s underflow concentration must meet the requirements of the disposal site (stack slope) and still allow the paste to be pumped out of the thickener. If the disposal site is more than a very short distance from the thickener, a positive displacement pump is used for transporting the tailings.

Stacking as a method of tailings disposal, offers significant advantages over ponding. The most obvious benefit is the smaller impoundment area. In addition, there is less water in the pond, improved water or chemical recovery, a lower risk of containment breach, less groundwater contamination and easier final reclamation of the site.

Mine Paste Backfill

Mine backfill is also employed to reduce surface environmental impacts by storing tailings underground. With the use of binders, such as cement, paste backfill also becomes a process for mine productivity improvement by allowing mining methods such as undercut-and-fill. Information on mine paste backfill can be found in Brackebusch (1994).

In the conventional mine paste backfill process a filter, preceded by a high-rate slurry thickener to reduce the hydraulic loading, is typically used to produce paste backfill. The

filter cake is discharged to a batch mixing hopper or continuous mixer where a binder is added to produce the required strength underground. The cemented paste is then pumped below ground.

There is a range of paste solids content required for any backfill application. A thickener/filter combination can be used for the entire range, by diluting the filter cake as necessary to achieve the paste properties required in the mine, solids concentration and rheology (measured by slump). A paste thickener is an option for mine backfill applications. For mine paste backfill the paste thickener produces a paste at a required solids concentration and slump (Figure 8 is an example). The underflow is pumped with centrifugal pumps to the mixer as shown in Figure 9.



Figure 8: Coal Tailings Paste for Backfill

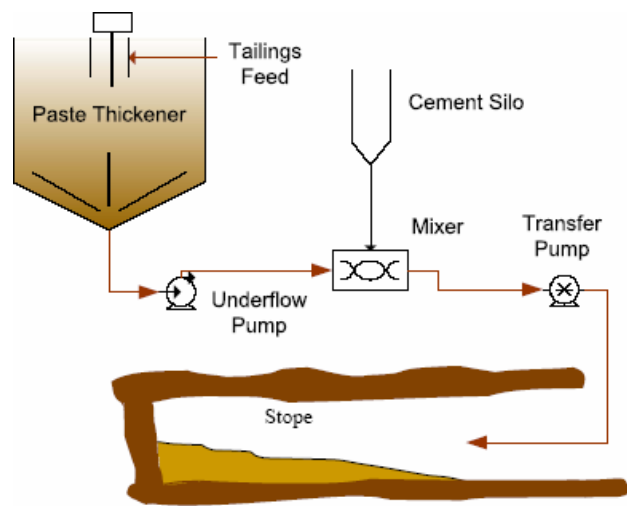


Figure 9: A Paste Thickener Producing Mine Backfill

References

Abbott (1973) J. Abbott et. al., “Coal preparation plant effluent disposal by means of deep cone thickeners”, 6th International coal preparations congress, Paris, October 1973.

Boger (1999) D.V. Boger, “Rheology and the Minerals Industry”, Min. Proc. Ext. Met. Rev., Vol 20, Overseas Publishers Association, 1999.

Brackebusch (1994) F. W. Brackebusch, “Basics of paste backfill systems”. Mining Engineering, October 1994.

Center for Applied Energy Research (2004) www.caer.uky.edu

Jewell (2002) R.J. Jewell, A.B Fourie, and E.R. Lord, “Paste and thickened tailings – A guide”. The University of Western Australia, 2002.

Johnson (2004) J.L. Johnson and J. Stephen Slottee, “Paste technology: Success is in the approach”. Tailings and Mine Waste '04, Vail, October 2004

Mine Impoundment (2004) www.info@mineimpoundment.org

National Research Council (2002) Coal Impoundment Wastes, National Academy Press, Washington, D.C., 2002

Paterson (2003) A. Paterson, “The Hydraulic Design of Paste Transport Systems”, International Seminar on Paste and Thickened Tailings, Melbourne, 2003.

Robinsky (1978) E.I. Robinsky, “Tailings Disposal by the Thickened Discharge Method for Improved Economy and Environmental Control”, Proceedings 2nd International Tailings Symposium, 1978.