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Design and commissioning of coal fly ash filter plant

J Hamelehle *Paterson & Cooke, USA*

C Schmitt *Paterson & Cooke, USA*

J Keat *Paterson & Cooke, USA*

Abstract

Coal-fired power plants have come under stricter environmental regulations for their waste disposal with some requiring the stored fly ash slurry to not have any bleed water as measured by the paint filter test. Slurry at a solids concentration that passes this test is considered a paste by most definitions. Transporting this paste presents significant technical problems. Instead, some coal-fired power plants have opted to filter the fly ash and transport the filter cake using conventional dry material handling methods such as trucking and conveying.

This case study looks at a coal-fired power plant located in the continental northwest USA that decided to filter its fly ash to meet these new environmental regulations. The new filter plant would receive approximately 2,800 metric t/d of fly ash from a pair of existing paste thickeners. The new pressure filter system would filter the fly ash to a cake moisture low enough to be trucked to the storage facility without liquefying in the bed of a truck.

This paper outlines the design process of the fly ash filtration, conveying, and truck loadout performed by Paterson & Cooke. Some vital issues discussed will be deciding on what filter technology to use and designing to ensure continuous operation. Also included in this paper are major lessons learned during commissioning and ramp up to full throughput operation.

Keywords: *coal fly ash, pressure filtration, plant commissioning*

1 Introduction

A power plant in the north western United States consists of two active coal-fired generating units each with about 740 MW of capacity. The plant operator is pursuing dewatering upgrades to the fly ash disposal system. Approximately 2,800 t/d of fly ash is produced by the two generators. The existing fly ash dewatering system currently relies on paste thickening with two operating paste thickeners (called the PPSMs on site) and pipeline transport with hydraulic piston pumps. An environmental agreement was passed to upgrade the fly ash dewatering system by 2022 to produce no bleed water. The plant operator retained Paterson & Cooke and Worley to design a filter plant to allow truck transport and dry disposal of the resulting filter cake. Figure 1 shows an image of the two generators running at the power plant.

Figure 1 Image of coal power plant with two generators running

1.1 Material characteristics

A summary of material characteristics of the fly ash is shown in Table 1. Figure 2 shows the particle size distribution of the fly ash.

Table 1 Material characteristics

Characteristic	Value
Solids S.G.	2.32
Liquid S.G.	1.08
Slurry pH	7.8
Solid concentration range	40% to 60% by mass
Mineralogy	Gypsum – 87% Silica – 11% Other - < 5% Clays - None

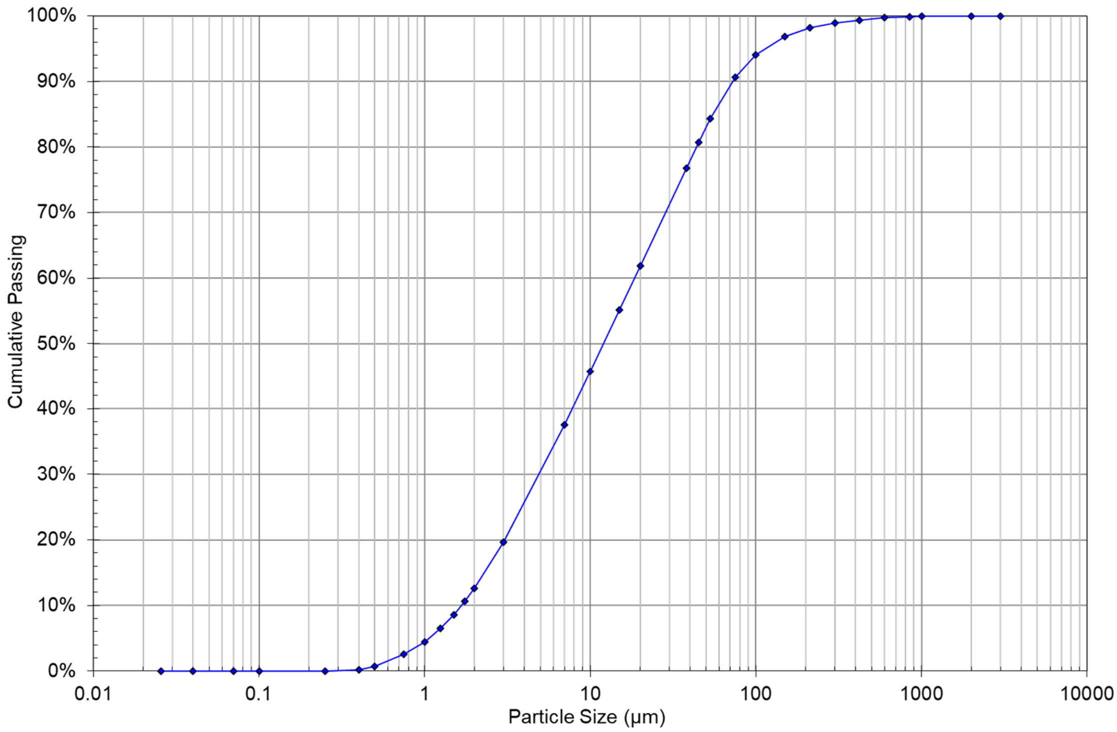

Figure 2 Fly ash particle size distribution

1.2 Cake moisture objective

To meet the environmental guidelines, the material had to pass the EPA Test Method 9095B Paint Filter Liquids Test. This is defined as no liquid passing through a mesh number 60 filter in a 5-minute period. At the passing concentration, shown in Table 2, the material was a pumpable paste. To transport the material by truck, the transportable moisture limit would need to be achieved. The moisture values are in the process definition of mass of the liquid phase divided by the total mass of the mixture.

Table 2 Critical cake moisture characteristics

Parameter	Value
Paint filter passing concentration	24.6% moisture by mass
Transportable moisture limit	18.4% moisture by mass

1.3 Specific challenges

There were several specific challenges to this project:

1. The process water is highly concentrated in soluble solids at approximately 13.5% soluble solids by mass. This created problems for selecting wetted surface materials and the filter's high pressure cloth wash system.
2. The client required the filter plant to have a 100% availability and 100% redundancy despite the additional cost. There can be no single piece of equipment that can bottleneck or shutdown the filtration plant.
3. The slurry concentration feeding the filters would range widely from 40%m to 60%m solids. This created a wide range of flowrates that the filter plant would receive. Fortunately, the yield stress of the slurry in this range of solids concentrations is below 15 Pa.
4. The client required that the filter control system to be centralised in the plant control system.

2 Filtration testwork

Filtration testwork was completed by Paterson & Cooke's in house laboratory using the Druck 200 laboratory pressure filter shown in Figure 3.

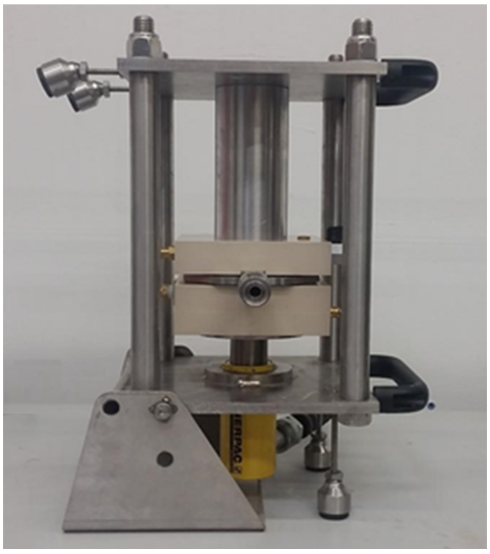

Figure 3 Druck 200 laboratory pressure filter

Exploratory testwork was done to determine the optimal feed pressure and to determine if a membrane press was effective. Figure 4 shows that the feed form pressure has minimal impact on the filter cake form time and form moisture content. At a form pressure of 15 bar, the airflow rate during the cake blow step in the laboratory pressure filter was 4.0 L/min, and at a form pressure of 6 bar the airflow rate during the cake blow step was 8.8 L/min. This is likely due to the cake formed at 15 bar was more dense and less porous. A form pressure of 15 bar was selected to minimise the air consumption. The membrane press was found to be ineffective, dewatering the cake very little.

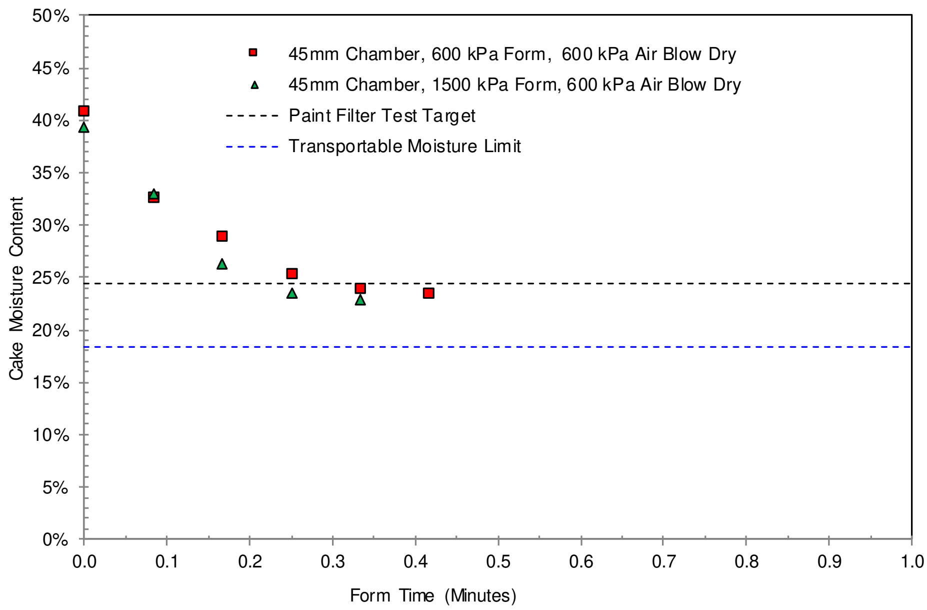

Figure 4 Filter cake form pressure tests

Using the form pressure from the exploratory testwork and no membrane press, different chamber sizes where tested. Figure 5 shows that even up to a 60 mm chamber, the cake forms quickly and to a similar moisture content. A 60 mm, or largest available from the vendor, chamber was chosen as the design chamber depth.

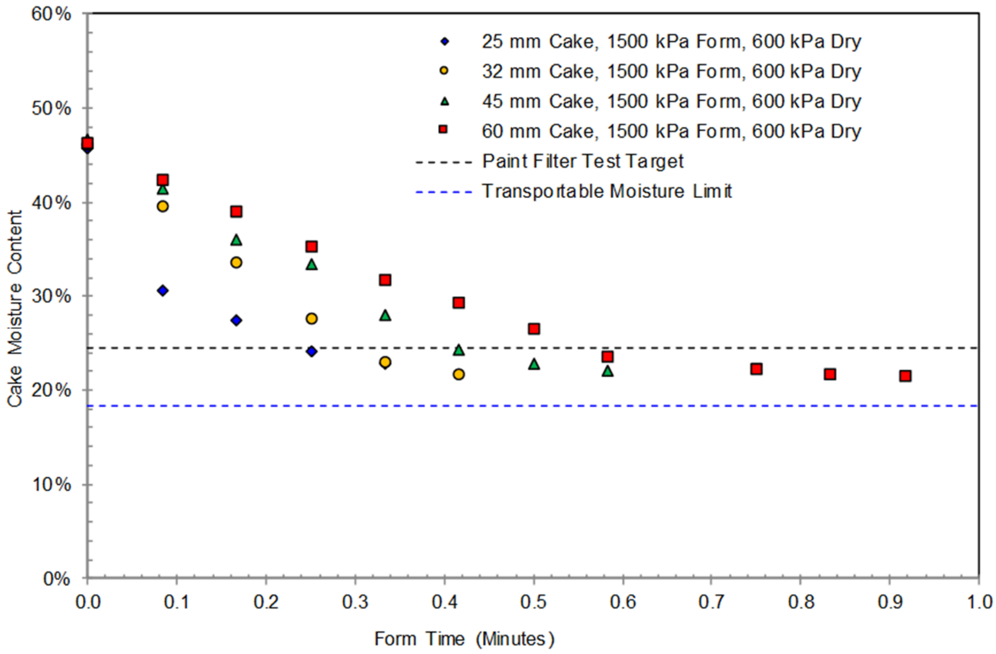

Figure 5 Filter chamber thickness tests at 1,500 kPa form pressure

After the cake form, the rest of dewatering was achieved with 2.5 minutes of cake blowing. After cake blowing, the final cake was less than 18.0% moisture by mass.

3 Process description

3.1 General description

Four recessed chamber pressure filters (two operating, two standby) were chosen to filter the fly ash to the target cake moisture of 18.5% by mass. The under filter conveyors are reversible to be able to discharge to two independent take-away conveyors and loadout bins. The standby filters, reversible under filter conveyors, and loadout bins ensure that abundant standby capacity is available to prevent long shutdowns. Figure 6 shows a process flow sketch of the filter plant.

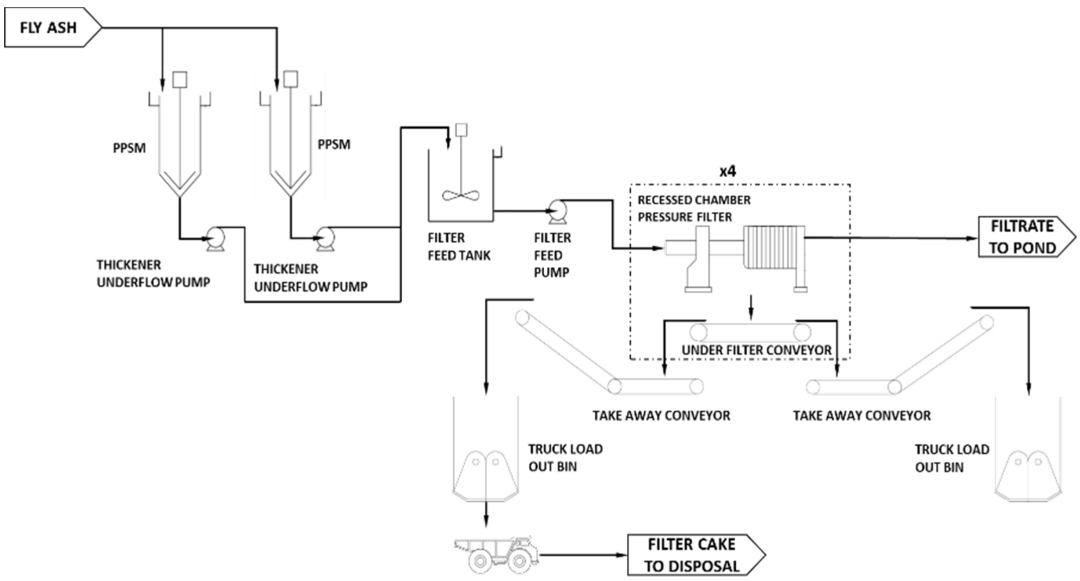

Figure 6 Process flow sketch of filtration plant

3.2 Pressure filter feed

The filters are fed with three (one operating, two standby) 250 kW 6/4 centrifugal pumps. The feed pumps are designed to provide fly ash slurry to the filters at 12 bar. The filtration testwork shows that only 6 bar is needed to properly form a cake; however, 12 bar is used to reduce the airflow consumption during the cake blow step. 12 bar was chosen instead of 15 bar to reduce the number of pumps needed to achieve the target feed pressure. The feed pump would have to run at 1,350 rpm to achieve 12 bar feed pressure at the filter when the feed concentration was above 50% solids by mass. This rotational speed and associated wear on the impellers was determined to be acceptable for short periods of time. When the feed concentration is below 50% solids by mass, it was decided to only feed at 11 bar to prevent this additional wear. Figure 7 shows an image of one of the filter feed pumps.

Figure 7 One of three installed filter feed pumps

3.3 Pressure filters

Each filter is a Diemme GHT2000.P7 with 59 50 mm chambers. The plates are 2 × 2m, and each filter provides a total of 413 m^2 of filtration area. All the filters are equipped with load cells. Two of the filters are operating, and two of them are standby. If one filter is down for maintenance, one filter will still be an online standby, ready to come into service if one of the operating filters is unavailable. The total expected cycle time is approximately 15 minutes which includes all filtration and mechanical steps. Figure 8 shows the four installed filters.

Figure 8 Four installed Aqseptence GHT2000.p7 recessed chamber pressure filters

3.4 Under filter and take-away conveyors

Each of the pressure filters is discharged onto dedicated reversible under filter collector conveyors. Each under filter conveyor is 2.1 m wide and 22 m long. Each under filter conveyor can discharge onto each take-away conveyor. Each take-away conveyor is 0.76 m wide and 95 m long carrying the filter cake to the loadout bins. The two types of conveyors are shown in Figure 9. If one of the take-away conveyors, or any equipment downstream of it, is down for maintenance, the under filter conveyors change direction and deposit cake onto the standby take-away conveyor.

(a) (b)

Figure 9 (a) 2.1 m wide reversible under filter conveyor; (b) Take-away conveyor with transfer chute from under filter conveyor discharge

3.5 Loadout system and trucking

Each take-away conveyor discharges filter cake into a dedicated truck loadout bin. Each bin is designed to hold 1 hour worth of fly ash filter cake. The walls of the bin are very steep and lined to prevent the filter cake from bridging. The filter cake is slightly cementitious and cannot be left in the bin for more than 24 hours. Each bin has a clamshell-style gate which opens to discharge the filter cake into haul trucks (CAT 777) to be taken to the fly ash disposal site. The trucks are large enough to hold a full bin load. Figure 10 shows the clamshell gate bottom of the bin.

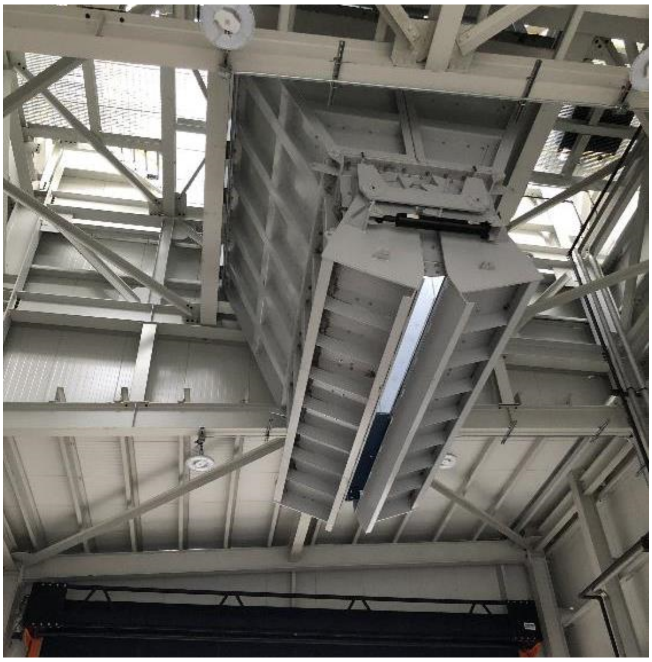

Figure 10 Loadout bin with clamshell gate

4 Plant commissioning

Commissioning started in July of 2022. During commissioning, several challenges arose. This section summarises those challenges and solutions.

4.1 Central filtration control system

Normally, pressure filters are controlled by a local PLC that contains the entire filter cycle and high pressure wash system ladder logic. For this project, the control would be from a central control system in the control room. This required 600 pages of code to be rewritten into the distributed control system and for communication lines to be routed to the control room. This was largely done to address cyber security concerns common in power plants.

This caused several challenges. Each filter had to be run several times to work out bugs in the code and each filter had their own bugs. Most critically, the response time for controlling the wash arms was not fast enough for the fine control required to precisely move the wash arm between plates and other fine control movements.

These issues were eventually solved by diligently troubleshooting the programming bugs and retrofitting VFDs into the motors controlling the high pressure wash system to properly control the wash arms.

4.2 Pressure filters

During commissioning, the filter load cells were used successfully to troubleshoot problems and optimise the filter cycle. They should be used during the life of the filters to monitor the cycles and help adjust the cycle parameters to meet cake dryness and filter cycle time objectives.

4.2.1 Filter feeding

The filter feed system is designed to feed the filter up to a maximum of 12 bar. However, during filter trials, the feed volumetric rate would change from its maximum of 500 m^3/hr to no flow (dead head) in less than

15 seconds. During this decrease in flow rate, the pump speed and feed pressure would increase, but by the time the pressure reached 3–5 bar, the flow rate would be zero. Even when the feed pressure is increased beyond 5 bar, after the flow rate reaches zero, no additional volume could be fed into the filter. To prevent dead heading the pump for too long, thereby damaging the pump, the pump was switched to recycle back to the feed tank.

After several trials and troubleshooting, the pump speed response to feed volumetric flow rate changes was improved. In the end, the flow rate would still decrease from maximum flow to no flow in less than 30 seconds and 8 bar is reached at the end of filter feeding. This still produced an adequately compact cake that could be efficiently blow dried to reach the target cake moisture. This lower feed pressure will also reduce the wear of the feed pump impellers for the long-term. High air consumption was not a problem despite the lower feed pressure.

4.2.2 Filter cake blow

The cake blow is controlled by an airflow rate controller. This allowed the airflow to have constant airflow rate, but not pressure. This was different from the filtration testwork that sets a constant pressure. The airflow controller was adjusted until the cake blow design time of 2.5 minutes produced a filter cake of less than 18.5%m moisture. The airflow should be adjusted during operation to achieve the cake moisture objective with changing fly ash characteristics.

4.2.3 Filter plate shifting

During dry cycles with the filter (cycles with no slurry or water), it was found that the plates would often not shift open properly. This only happened when the filter was empty. The weight of the filter cake would aid in separating the plates during the opening process. It was found that the hooks in the plate shifting system had slight imperfections in the welding that was causing the hook to not properly grab the filter plate when the filter was empty. These imperfections were grinded down to smoothness. This solved the problem and the filter plates now open and close reliably. Figure 11 shows the plate shifting system and removed hook.

(a) (b)

Figure 11 (a) Hook removed from plate shifting system; (b) Plate shifting system

4.3 Conveyors

The reversible under filter conveyors had several issues that had to be troubleshooted:

1. The belts were difficult to keep aligned. This was due to the large width, the force of the cake dropping, and the fact that the belt had to be aligned in both directions. Many vertical idlers were added to keep the belt aligned. This can cause additional wear on the edges of the belt and will be monitored during operation.

2. Cake is able to discharge from both sides of the belt. On one side of the belt is the tensioner roller. This roller maintains tension to keep the belt moving with the roller and prevent slipping. A problem arises when this tensioner roller changes position, thereby changing the discharge location in relation to the transfer chute. This dynamically changing discharge location affects the loading and operation of the take-away conveyor.
3. The cake loading onto the belt was difficult to control to prevent excessive piling of the cake on the belt. Excessively large piles would discharge onto the take-away conveyor in batches, overloading the take-away conveyor. To solve this, the under filter conveyor speed and direction needed to be controlled based on the direction of the cake discharge. For one direction, the conveyor would run relatively fast at 9 m/min during cake discharge to spread the cake loading and then slow to 2 m/min to slowly discharge the filter cake onto the take-away conveyor. In the other direction, the conveyor would run in the opposite direction of the cake discharge to spread the cake. Then the conveyor would reverse towards the discharge point to discharge the cake onto the take-away conveyor.

The take-away filter conveyors had several issues that had to be troubleshooted:

1. The width of the take-away conveyors (0.76 m) is on the cusp of being too small. The cake loading from the under filter conveyors was often off center and inconsistent.
2. It was difficult to find the right height setting for the skirting at the bottom of the chute between the under filter conveyor and take-away conveyor. If the skirt was set too low, the unloaded conveyor would rub excessively into the bottom of the skirt. If the skirt was set too high, the impact of the cake onto the take-away belt would push the belt down just creating a gap between the belt and the bottom of the skirt. This caused filter cake to spill out the side. Figure 12 shows the start of the spillage pile after a few filter cycles.

Figure 12 Filter cake spillage at take-away conveyor loading point after three filter cycles

The off-center loading caused the belt to shift on the idlers. Tracking the belt was difficult. Metal plates were installed to recenter the filter cake on the belt and additional idlers were added to keep the belt tracked.

4.4 Loadout bin and trucking

There were several cake loads produced that were well below the 18.5%m moisture target. This produced a light and fluffy filter cake with a lower bulk density due to air entrainment. This caused several problems such as lowering the amount of solids that the loadout bin and trucks could hold. Dust issues and spillage along the truck route also became a problem with the excessively dry cake. Figure 13 shows the excessively dry cake in a haul truck. When excessively dry cake reaches the haul truck, it is very fine and can create dust issues.

Figure 13 Excessively dry filter cake in haul truck

To fully load the trucks, it was found that loading the bin first and discharging the cake with the clamshell gate helped spread the cake over the bed lengthwise. Live loading the truck directly from the take-away conveyor created a conical pile in the truck, reducing the load volume that the truck could hold. Figure 13 shows the conical shaped load and Figure 14 shows the load spread lengthwise from the clamshell gate.

Figure 14 Cake load spread length wise from using the clamshell gate

5 Conclusion

The filter plant design and commissioning were successful. All standby equipment and process flexibility have been thoroughly commissioned to ensure that the filter plant can run with 100% availability at the design throughputs.