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Application of paste technology to mitigate the dust emissions from handling of fly and bottom ash at coal fired power plant — CGTEE in Candiota, Brasil

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Abstract

During the coal combustion at Companhia de Geração Térmica de Energia Elétrica (CGTEE), a thermal power plant, located in Rio Grande do Sul state in the South of Brazil, fly ash and bottom ash are generated. At the present time, the fly ash collected in a dry form from several points inside the plant, is pneumatically conveyed to storage silos. Bottom ash is saturated with water and conveyed to storage silos by either a water injection pipeline or conveyor transport system.

Fly ash reclaimed from the storage silos, after being moistened with water in a mixer, is loaded into open box dump trucks. Bottom ash from silos is transported in open box dump trucks as well. Both are transported approximately 6.5 km to a disposal area in the adjacent surface coal mine.

Inside the power plant the air slide and air lift systems are the largest generators of airborne ash. During the transportation and disposal processes, due to the presence of climatically typical high winds, fly ash becomes dry and airborne, resulting in dust emissions. The quenched bottom ash also contributes to airborne ash issues. The deposition methodology in the disposal area allows the dry ash to remain exposed to the environment for a long period of time and makes it susceptible to entrainment in the wind. Resulting dust is transported long distances causing significant environmental issues to the surrounding area.

This paper presents the solution proposed to obtain a sensible reduction in dust emissions generated in the ash handling process inside, as well as outside, the power plant property. The proposed solution was to reduce the airborne ash emissions by the creation of low density fly ash slurry in localised mixing tanks within the power plant. The mitigation method investigated includes pumping of the low density slurry to an ash conditioning plant where the slurry will be mixed with bottom ash, followed by dewatering and densification. The densified slurry produced will be pumped to the adjacent coal mine's disposal area for backfilling in mined areas, thereby eliminating the environmental issue of dust emissions.

1 Introduction

Companhia de Geração Térmica de Energia Elétrica (CGTEE) belongs to the Eletrobrás group which is comprised of three generating units: Usina Termelétrica Presidente Médici (446 Mw capacity); Usina Termelétrica São Jerônimo (20 Mw capacity) and Nova Usina Termelétrica de Porto Alegre - NUTEPA (24 Mw capacity), all located in Rio Grande do Sul state, in southern Brazil.

The study carried out by Golder Associates Brazil and Golder Paste Technology Ltd (collectively "Golder") was focused on the Usina Termelétrica Presidente Médici generating station, located in the municipality of Candiota, Rio Grande do Sul State, 400 km away from Porto Alegre city.

This generating station is located within a predominately agricultural area of the state where the primary livelihoods are dairy farming and cattle ranching.

CGTEE's process at Candiota uses coal from a nearby surface mining operation as a primary fuel source that is burned, producing electric power. In the process, large quantities of residue, fly ash and bottom ash, are generated and collected predominately by dust collecting systems (electrostatic precipitators), and pneumatically transferred to silos prior to disposal. Due to the pozzalanic nature of the fly ash, a part is sold to the local concrete industry and the remainder, as well as the bottom ash, are transported by open box trucks to the disposal area approximately 6.5 km from the plant.

The purpose of Golder's investigation was to assess possible solutions to solve the problem of dust created when the ash becomes airborne. The dust emission problem occurs in three general areas:

- within the power plant at the fly ash collection points
- on the roadways leading to the disposal area
- in the disposal area itself.

This paper discusses the solution proposed by Golder to solve the environmental dusting problem within and outside the plant.

2 CGTEE's process overview

The Power Plant, Usina Presidente Médici, burns Brazilian coal that has specific characteristic and is categorised as a high ash content coal. The burning process to produce power involves multiple electrostatic precipitation, dust collection, and wet collection systems to recover the fly ash and bottom ash generated.

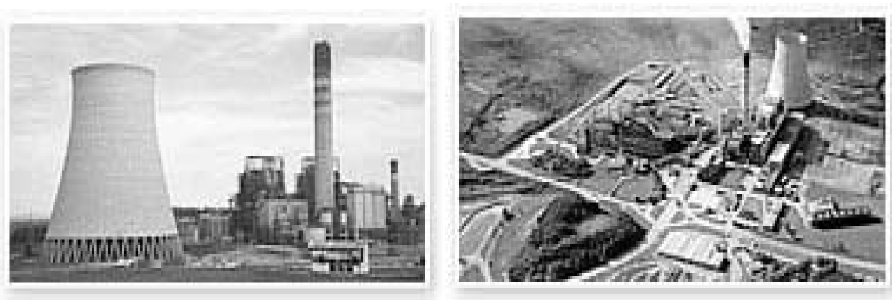

Figure 1 The Usina Presidente Médici Power Plant, southern Brazil

At the present time, the fly ash is collected from a large number of locations in a dry form inside the plant and pneumatically conveyed to storage silos. Bottom ash is saturated with water and conveyed to storage silos by either a water injection pipeline system or conveyor transport.

Part of the fly ash is sold to the cement industry and the remaining (more than 70% of the total produced), is reclaimed from the storage silos, moistened with water in a mixer, and loaded into open box dump trucks. Bottom ash is reclaimed from silos and also loaded into open box dump trucks. Both are transported approximately 6.5 km and are end dumped and contoured into the coal mine's mined out areas and eventually covered with top soil and revegetated.

The dust generated on the roadways leading from the plant to the disposal area results from the wetted ash spilling onto the roadway during transportation, drying out, and being disturbed by vehicle traffic.

The dust generated at the disposal area is primarily due to the unloading of the haulage trucks and final deposition where it is susceptible to entrainment due to the frequent 160 km/hr winds. This has created an environmental and social problem in the surrounding, predominately agricultural, countryside. As well, due to the prevailing wind speed, ash entrained in the wind may be dispersed tens of kilometres away.

Usina Presidente Médici is increasing its generating capacity and this will result in an increase in the total quantity of ash produced by over 50% from current levels. Since it is not anticipated that this additional ash can be directed to the concrete industry, it is likely that it will be disposed of at the coal mine, thus potentially exacerbating an existing problem.

Although it would be expected that the technology and equipment installed in the plant expansion would produce less of an environmental problem in that area, the current problems in the existing plant, as well as all of the associated disposal problems, would remain as at present.

3 Objective

The intent of the study was to reduce, or eliminate, the level of dust currently being experienced. The three primary areas of focus are:

- at the power plant in the current material handling systems
- on the roadways leading from the power plant to the mine disposal area
- within the disposal area during and after deposition of the ash.

4 Project description

Based on the laboratory materials characterisation test results, analysis of the current plant's process and physical layout; and on data obtained from site visits, Golder established concepts and process flow sheets to develop the conceptual project, involving three options.

The conceptual project was based on the disposal of a wet fly ash and bottom ash mixture in an integrated system from inside the plant to the disposal area. The study proposed:

- substitution of portions of the existing pneumatic dry collect system with a wet system to control dust emissions in the plant by:
  - installation of multiple collection points and the preparation of a dilute slurry
  - material handling in a wet form to an intermediate collection tank near the perimeter of the plant.
- installation of an intermediate mixing tank outside the plant, located between the plant and conditioning plant to collect and store slurry coming from inside the plant
- installation of a conditioning plant, between the intermediate mixing tank and disposal area outside the plant, comprised of a slurry dewatering/densification system and high density non-segregating slurry transportation to the disposal area.

Based on the conceptual study it was possible to select the more attractive option proposed as a technical and viable solution to be adopted to develop the basic engineering. The selection of the appropriate solution was based on the optimisation of key criteria being: economics; type of materials handling system (conventional or high density slurry, paste, etc.); degree of complexity; and deposition characteristics.

In addition, flow loop tests and flume deposition tests were carried out at the site to support the basic engineering development.

On-site flow loop testing quantified the capability to use either positive displacement or centrifugal pumps for thickened slurry transportation from the plant to the disposal area. It also quantified the behaviour of the combined fly and bottom ash while in transport.

The flume tests quantified the characteristics expected upon deposition and desiccation in the mine's disposal area. It also provided insight into the final deposition characteristics to be used in establishing a disposal area closure strategy.

The costs estimated, capital (CAPEX) and operating (OPEX), were prepared for the collection, storage and disposal of the ash aimed at reduction of the airborne ash generated within, as well as outside the power plant. The economical feasibility evaluation was prepared based on a model projecting quantities of material handled, costs involved and simulating the cash flow along a 10 year operating period in order to allow comparison between the existing and proposed systems. The timeline curve of accumulated expenses and Net Present Cost (NPC) were compared.

The key element influencing the solution to the current problem was the need to minimise the quantity of water delivered to the disposal area, and still provide a non-dust generating deposited product. This criteria influenced the selection of a process incorporating the disposal of dewatered ash in the range of 68% solids by weight (wt%) in a paste consistency.

5 Results and discussions

5.1 Laboratory testing

The first step in the process of determining appropriate solutions to the problems at hand was the determination of the material's physical and chemical characteristics. In this process, the ability to produce material with paste-like characteristics was determined.

Material characterisation was based upon testing carried out on ash samples shipped to Golder's laboratory, in Sudbury, Ontario, Canada.

The particle size distribution (PSD) for the fly ash, bottom ash and an 80/20wt% blend of the two, respectively, are presented on Figure 2. The 80/20 blend was tested to simulate the respective distribution of each ash in the final discharge stream.

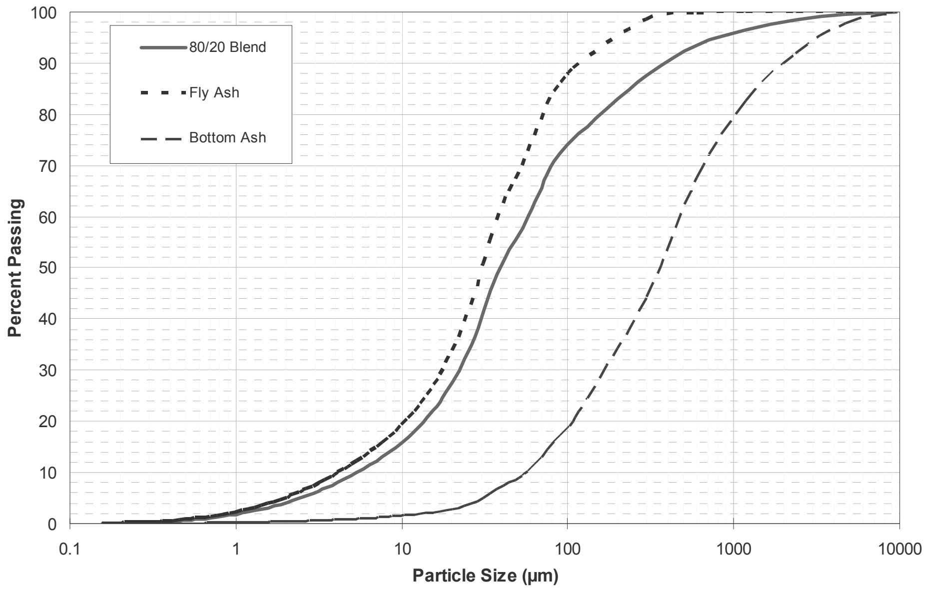

Figure 2 Particle size distribution

Specific gravity (SG) testing was performed in accordance with ASTM Standards and the specific gravity of the blend was determined to be 2.05.

Material of a paste consistency is defined as having a measurable slump, and slump measurement is a process widely used in the concrete industry. Material of paste consistency generally has a slump in the 175 to 254 mm range.

Figure 3 illustrates the relationship between slump and solids content of the combination at 80/20 fly ash sample. It is shown that a 184 mm slump consistency is developed at 68.8 wt% solids and a 254 mm slump consistency at 67.9wt% solids. The difference of 0.9 wt% between these two slump values indicates sensitivity to water contents, which will require more accurate control to facilitate pipeline transport.

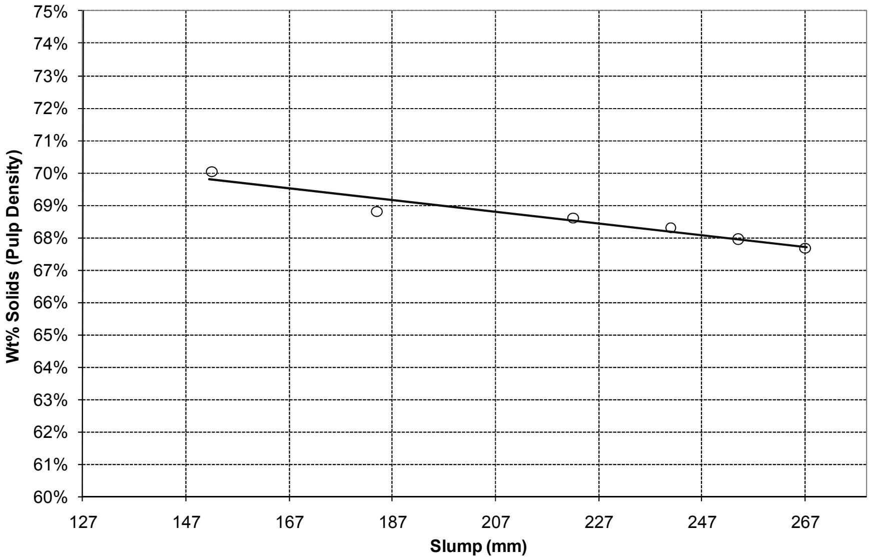

Figure 3 Slump versus solid content

Figure 4 outlines the results of the Yield Stress versus Time tests conducted on fly and bottom ash blended samples. Particular attention focused on the 'M1' fly and bottom ash blend without any binder additive, which indicated little change in the yield stress over a period of 180 minutes.

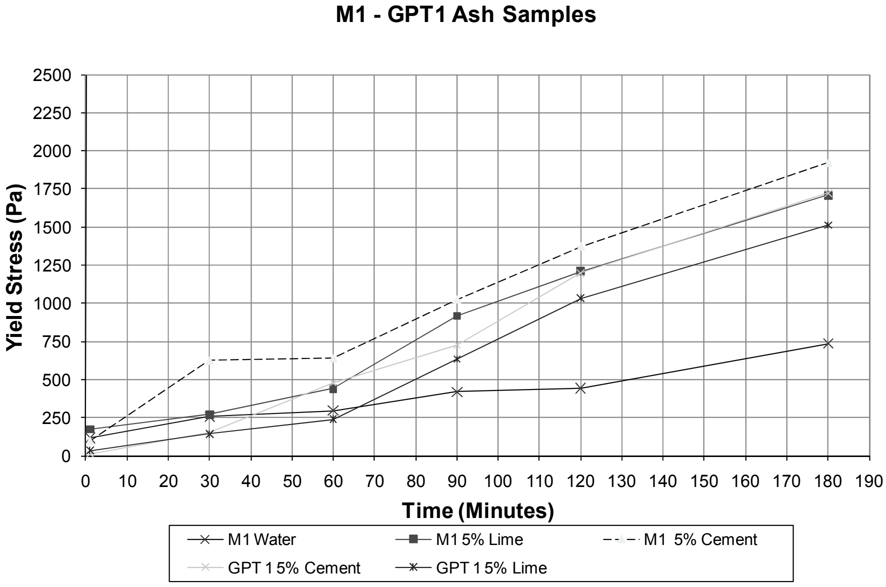

Figure 4 Yield stress versus time

Figure 5, Wt% total water separated and yield stress versus time, demonstrates a gradual increase in yield stress over a 24 hour period. It can be attributed to settlement of the particles and parallels with the water separation expected as a result of particle settlement. Here too, no dramatic increase in yield stress over time as a result of material reaction was evident. The 254 mm slump material bled water steadily up to 24 hours, water separation was 10.6wt% of contained water and the yield stress was less than 800 Pa.

Laboratory testing has indicated fly ash samples showed promising results, and it is expected that a good quality paste can be produced. The bottom ash as an element on its own, however, is marginally capable of producing a paste. However, a mixture of bottom ash and fly ash showed good results and was the best 'pumpable' mixture, suggesting either the use of positive displacement or centrifugal pumps, for a paste that would contain 68wt% solids.

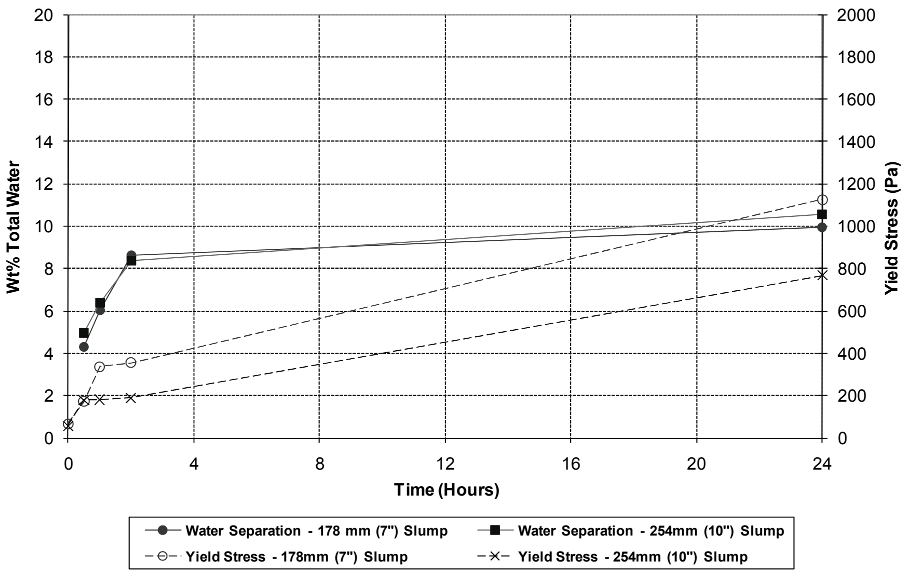

Figure 5 Wt% total water separated and yield stress versus time

5.2 Conceptual study

Based on the laboratory test results, three process options were defined and evaluated. The main difference between the options was only the location of the conditioning plant and a focus on the evaluation of the impact of the location on the transport system configuration.

The process design strategy was to convert dry, or low moisture, ash to diluted slurry, then a combination of ashes to a paste consistency and pumping it through pipelines along the roadways up to the disposal area instead of by open box truck transportation. The production of high density paste slurry will be accomplished at a conditioning plant through use of filters to produce a low moisture filter cake to be combined with low density slurry received from the localised mixing tanks within the power plant via a high intensity mixer. This mixer discharges high density paste slurry to pumps for transport through an overland pipeline some 6.5 km to the mine disposal area.

5.3 Flow loop test

These tests are carried out to determine the pipeline flow friction losses for a given material at various flow rates and slurry consistencies. These friction losses are used to determine the type, size and number of pumps needed to transport the material within a pipeline. The flow loop tests and flow characteristic determinations, conducted at the CGTEE site (Figure 6), were done using both centrifugal and positive displacement (PD) style pumps.

Figure 6 Onsite flow loop tests

For the flow loop tests, ash was prepared in a weight ratio of 80% fly ash and 20% bottom ash. Fly ash and bottom ash were proportioned to reflect the amount expected to be contributed by the generating systems when the power plant is in full production. Material was prepared to target slump consistencies by adding small increments of raw water to a concrete mixer truck containing the blended ash.

Material additions were weighed in batches from previously prepared bulk bags or using a scale. Raw water addition was monitored using an inline flow meter. Scales and meters were provided by CGTEE on site. Approximate moisture contents of ash were determined using a 'speed test' moisture determination unit supplied by the concrete contractor hired by Golder to assist in the test. Moisture determinations were also done by CGTEE's onsite laboratory as well as an independent laboratory in Brazil.

5.3.1 Centrifugal pump

The centrifugal pump was supplied by Weir Minerals (Brazil). The pump was specifically designed to pump thick slurries. The pump's specifications are presented below:

- Make: Weir Minerals
- Model: 3 AHF
- Pump rpm: 1500 belt driven
- Flow rate: variable to a maximum of 200 m^3/hr
- Pressure: maximum 25 m head
- Power: 30 kW.

In order to adjust the flow rates, the pump was controlled via a variable frequency drive. The flow rates achieved were better than those achieved using the positive displacement pump; however, they were still low compared to design specifications, especially for conventional slurry transport.

In order to control system back pressure, a pinch valve was installed near the discharge end of the loop. It was later found, however, that the use of this pinch value was not necessary as had been expected, given the information presented on the pump curve.

5.3.2 Positive displacement pump

The selection of the appropriate type of positive displacement (PD) pump, either piston or diaphragm style, is determined based on the particle size distribution and shape of the particles. Both of these two factors are important characteristics in determining the suitability of a diaphragm style PD pump.

The results of the testing provided further information to refine design parameters for such things as:

- The optimum slurry density at the discharge of each of the low density fly ash and bottom ash mixing tanks plus an acceptable operating density range.
- An economic indication of the optimum density range for high density slurry discharged to the disposal area using a PD pump. The goal was to determine the highest practical slurry density, when comparing capital and operating costs to discharge pressures, pipeline sizes, pump sizes and pump styles.
- An indication of the deposition characteristics of the ash slurry through its placement in flume boxes and its resistance to dusting once deposited in the disposal area and allowed to dry.

PD pumps were determined to be effective in the overland slurry transport process. The tests were conducted using a diesel engine driven PD pump, used primarily in concrete pumping. The pump's flow rate capabilities were less than optimal. However, there were no other pumps available within the region with greater capabilities. Testing was carried out using the above mentioned pump while carefully monitoring the system to detect any problems. The pump's specifications are outlined as follows:

- Make: Putzmeister
- Model: BRA 1406
- Maximum flow rate: 60 m^3/hour
- Maximum pressure: 70 Bar
- Motive power: 100 Hp (75 kW) @ 2400 rpm.

To reach optimal flow velocities (about 2 m/sec) through the 204 mm diameter pipeline, a flow rate of approximately 230 m^3/hour would be necessary. For fly ash transport, it is important not to fall below critical flow velocities which can cause sliding bed or plugged line conditions.

The results obtained on flow loop demonstrated that:

- suitable high density slurry can be prepared from the blended ash and transported via PD or centrifugal pumps
- significant material variability occurs in the ash at CGTEE, which must be further quantified, and introduces the need to establish an approach to 'dampen' the variability and establish 'steady state' fixed flow characteristics through mix design
- it is clear that a reagent/retarder additive to control hydration of the ash is a requirement for safely pumping a high density paste slurry
- these test results demonstrated that this can be achieved through the use of a specific retarder, however, a suite of other alternatives should be evaluated prior to the implementation of only this approach (for example, pH adjustment, air entrainment additives, etc.)
- high flow velocities (1.5 to 2 m/sec) are required to prevent particle settling
- it is possible to transport the slurry through the use of less costly centrifugal pumps at lower solids content (64 to 66 wt% solids). This approach would only moderately increase the amount of water reporting to the deposition area.

5.4 Basic engineering

The basic engineering, involving a costs estimate of ±15% accuracy, was developed based on the process, handling and disposal system selected. Figure 7 presents a simplified process flow sheet.

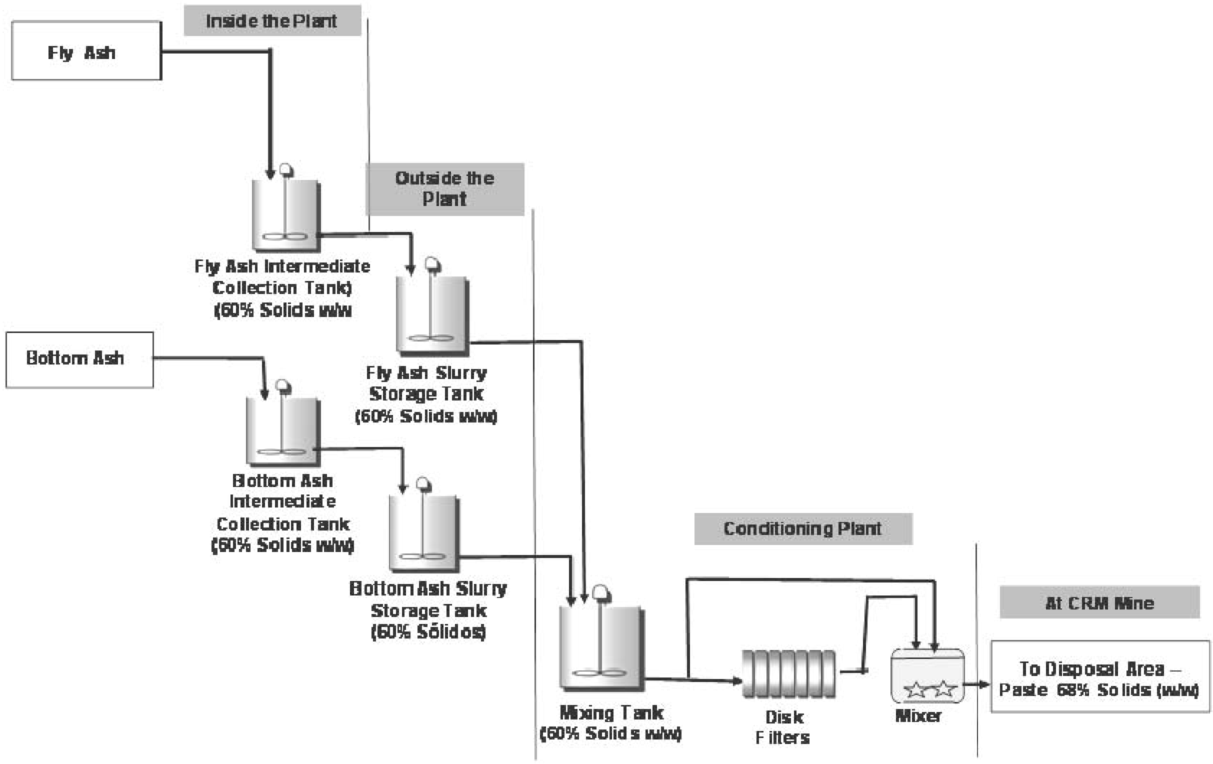

Figure 7 CGTEE simplified flow sheet

5.5 Economic evaluation

The economical evaluation demonstrated that the system proposed presents technical and economic feasibility advantages when compared with the current system used, through a discounted cash flow analysis. The simulations of cash flow projection comparing the implementation and operation of the proposed system with the current system, based on similar conditions of material handled, showed that the NPC of the proposed system (R$ 130 million) presents estimated values below the NPC of the current system (R$ 148 million) when conducted for an operating period of 10 years discounted at 12% per year.

The proposed system requires an investment (CAPEX) in the order of R$ 71 million and has its OPEX estimated at R$ 4.53 per tonne of material disposed to the mine. The current system, if kept, will require an investment of R$ 6 million and presents an OPEX in the order of R$ 11.85 per tonne of material disposed (value presented in 2007 Brazilian currency — to be 'factored for inflation').

Also, the proposed system presents operating costs (OPEX) are lower than the current system's operating costs and the effects of the capital cost (CAPEX) for the new process can be recovered within the timeframe of the operation projection. NPC results for the new process, even with the CAPEX investment, become favourable after 6 years, as shown in Figure 8.

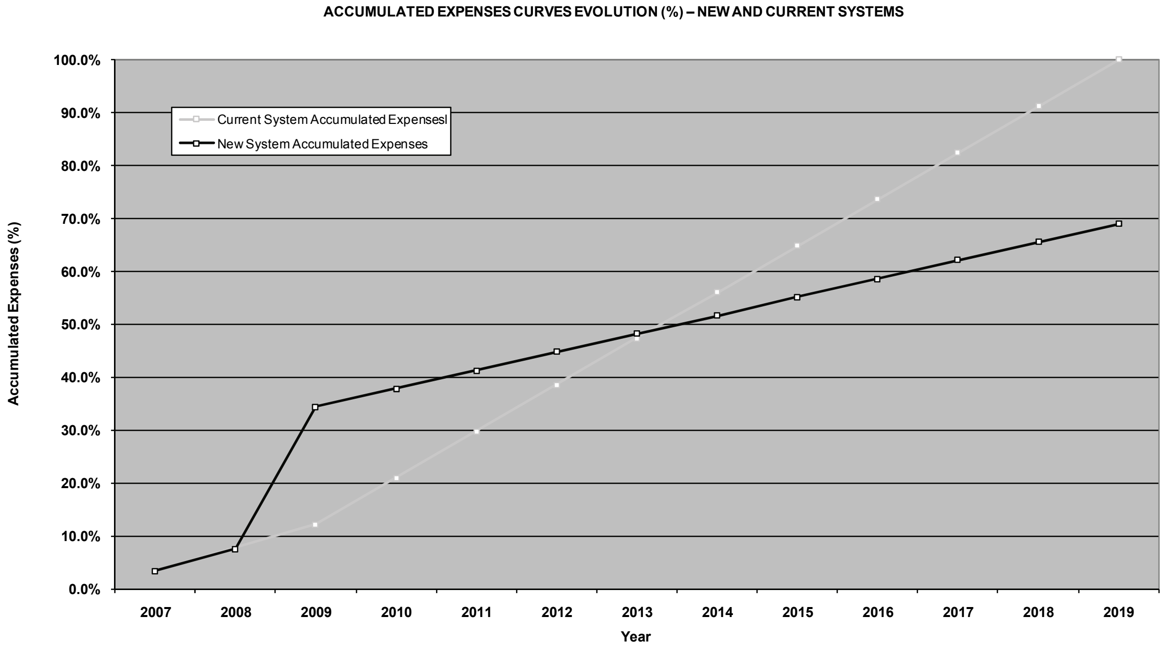

Figure 8 Cost evolution curve

6 Conclusions

The proposed system is technically, economically, and socially feasible and presents the following advantages:

- provides a process that incorporates environmental and economical viability in less than 10 years for an operation that has a projected life of 30 years
- substantial reduction in the traffic of disposal trucks in the existing plant and on the truck scale for the removal of ash, and also on the road to the mine and within the disposal area (truck traffic estimated at more than 8,000 trucks/month)
- substantial reduction in the emissions of dust within the power plant, resulting from off-site truck traffic, and at the disposal site, thereby contributing to an improvement in air quality, improvements in occupational health conditions, decreased cost of spraying water on the roads, and most importantly, public perception from the surrounding and distant communities
- more usable space for expansion or process improvements within the plant area due the elimination of the fly ash silos and associated ash handling equipment
- improvement of the equipment performance, reducing maintenance requirement due the reduction of suspended solids in the air inside the plant
- the proposed process will allow continuity of supply of fly ash to the local concrete industry thus sustaining their viability as well as recycling fly ash for useful purposes rather than it being disposed of as a waste material
- reduces the disposal footprint of ash within the mine and allows for the progressive closure of filled areas on a trafficable surface
- offers demonstrable improvements in the realm of environmental stewardship and furthers relationships with the local, state and federal environmental regulators.

Similar types of fly ash disposal methods, designed by Golder, are currently in use at North American coal fired generating stations. Furthermore, the technology has the capability to be used in other applications such as those dealing with coal plant wash products.