THE IMHOFLOT G-CELL – AN ADVANCED PNEUMATIC FLOTATION TECHNOLOGY FOR THE RECOVERY OF COAL SLURRY FROM IMPOUNDMENTS

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ABSTRACT

There is a plethora of former industrial sites where coal mining operations have left large slurry impoundments. These contain raw washed fines, which have previously been too expensive to process to requisite grades for commercial use. New technology has been developed for fine material processing, namely the Imhoflot pneumatic flotation G-Cell. This froth flotation technique is a highly efficient means of concentrating coal and is particularly appropriate to the nature of materials encountered in tailings ponds. The high volumetric throughput resulting from the vastly reduced residence time in the cell allows for drastically reduced equipment sizes when compared to conventional flotation cells. This means the process, when combined with innovative pre treatment and filtration equipment can be developed as a mobile plant concept. This is seen as a minimum requirement when re-treating and rehabilitating fine coal ponds.

INTRODUCTION

It can be speculated that around 5% to 10% of all coal mined can be called ultra fine coal (defined as minus 150 µm for the purpose of this paper). Nearly all this ultra fine coal over many decades of coal production has been deposited as waste coal fines in slurry impoundments of various descriptions. As an example of amounts it has been reported that over two billion tons of recoverable waste coal fines have been deposited in the USA, east of the Mississippi River (Harrison 2002). In Eastern Australia it is estimated that 5 million tons of coal is dumped annually into tailings ponds (Clark 1997). In the United Kingdom there are over 20 million tons of ultra fine coal currently accessible at existing mining operations.

Over the last twenty years efforts have been made to economically recover the ultra fine coal in the coal preparation plant generally by use of froth flotation techniques. In a lot of cases flotation plants have been retrofitted to existing coal preparation facilities. These days the inclusion of an ultra fines recovery process in new operations is the norm rather than the exception. There has always been a lot of interest in the recovery of fines already deposited in impoundments. It has rightly been recognised that these tailings could be classified as a resource if the valuable coal could be recovered economically. It has been mined at a considerable cost and the reclamation cost to bring it back to a process facility is a fraction of the cost of winning new coal from the ground. In addition, the environmental considerations of the impoundments need to be considered. They occupy considerable land space that could be reduced significantly if the coal content is removed and the area rehabilitated. The impoundments can also be considered an environmental hazard with the ability of producing acid mine drainage (AMD) by the leaching of materials contained in the impoundments. Also as they contain large amounts of ultra fine high volatility coal there is the possibility that these ponds can give rise to spontaneous combustion at some time in the future. Both these possibilities pose a major risk to the environment.

There have been many attempts to recover coal from tailings impoundments. Very few have been economically successful no matter which technology has been applied. Whilst there are many different and valid reasons recorded for their failure the most common is that the project had not been able to bear the burden of the capital cost of a plant required to process the material to an acceptable standard. Unlike a new mine where a planned life of mine of twenty years would not be uncommon, a reprocessing facility is faced with a much smaller life, probably of only a few years. Where reprocessing operations have been successful they have been situated in locations that have access to a large amount of waste ultra fine coal that can give a project life of five to ten years or more.

MOBILE PLANT CONCEPT

A way to remove the limitations of a relatively short project life is to be able to relocate the process plant to further locations when a project has been completed. Thus the cost of capital can be amortized over a number of projects. However conventional flotation equipment of a reasonable throughput requires a large footprint and expensive support and infrastructure. The trend to use column cells has reduced the unit cost of flotation but again columns do not lend themselves to mobility. Generally requiring heights of 10m or more and associated foundations and infrastructure. A new type of flotation device, the Imhoflot G-Cell, has been developed which, whilst giving acceptable metallurgical performance, has a very high volumetric throughput. The resultant flotation plant is considerably smaller than conventional or column plants. This lends itself to the concept of mobile ultra fine coal recovery plants.

TECHNICAL DESCRIPTION OF THE IMHOFLOT G-CELL PROCESS

The Imhoflot pneumatic flotation technology has its origins in the work undertaken by Professor Bahr at the Technical University of Clausthal, Germany. Over the last 20 years there have been many modifications and design improvements that have led to the recent development of the G-Cell (Figure 1).

The fundamental objectives in pneumatic flotation are the separation of the independent process steps involved in flotation i.e. reagent dispersion, collection, aeration, bubble-particle contact and froth separation. Imhoflot incorporates self-aspirating aerators based on ceramic multi-jet venturi principles, operating at about 2.5 bar (35 PSI) gauge pressure (Imhof, 2000). This provides a highly dispersed fine bubble reaction, but with much lower energy input than with aeration devices that require compressed air. The pre-aeration is the key to the high selectivity of the technology, and, therefore, dispersion and bubble contact should be optimised to ensure collisions, using high turbulence. This process also ensures efficient use of reagents, compared with conventional conditioners or cell addition, which are relatively low shear rate processes.

In the original Imhoflot vertical cell processes separation of froth takes place in the low turbulence cell with a residence time of generally less than 3 minutes. Flow is co-current (unlike column flotation) and so variable froth crowding can be applied. There are no moving parts. The distributor injects the pulp into a separating zone which allows transfer of tailings or bubbles to take place with very short distance of travel (unlike columns). Thus the separation performance is the limiting factor in the size of the vessel. In order to reduce vessel size, gravity in the form of centrifugal motion has been be introduced to separate buoyant and sinking material. The use of a static vessel is also a prerequisite for the process and the design of the G-Cell has evolved with multiple tangential inlets. The residence time is now reduced to 25 – 30 Seconds.

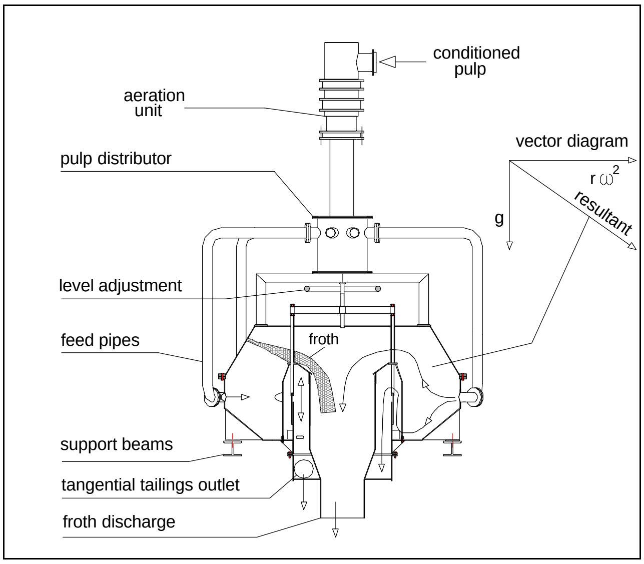

Figure 1. Imhoflot G Cell Schematic Diagram

In the G-Cell the inlet nozzle sizes and flow rate determines the speed of the rotation in the tank. The range of the centrifugal force can vary between 10 and 30 m/s^2. Due to the centrifugal force the interface between pulp and froth is inclined to the centre of the rotation and the froth therefore moves by itself into the central launder. The height of the launder can be adjusted during operation for optimal performance (Figure 4). Since no transport water is needed, the froth can be fed to the filter with an optimal high solids concentration.

PROCESS OUTLINE

Extraction and Plant Feed

The plant design presented is based on European experience of tailings pond treatment, where lagooned impoundments have been drained and allowed to consolidate. Extraction is therefore possible by use of excavators and conventional earth moving equipment (see figure 2).

Figure 2. Lagoon Extraction

Scrubbing and Classification

The mobile plant incorporates an attrition scrubber with a retention time of up to 4 minutes, intended to ensure coal particles have fresh surfaces. The high power input requirement is assumed to be in the region of 0.3-0.5kW/m3. In order to provide a consistent classified feed material a Rotaspiral is included. This provides accurate wet screening of oversize material and trash. The Rotaspiral is a low energy drum screen with stainless steel mesh and an internal spiral for continuous removal of oversize. High pressure sprays provide fluidisation of the screen bed and cleaning of the apertures.

G-Cell Flotation

Two stage flotation is provided based on extensive experience to allow for wide variations in feed conditions and composition. The primary stage is tuned to produce high grade (low ash) product, while the secondary stage acts as a scavenger to ensure efficient recovery of combustibles and high ash tailings. Figure 3 shows a 2.2m diameter G-Cell with a design capacity of 300 m^3/hr.


Figure 3 Imhoflot G-Cell Model IMF G22

Rotational speeds of 6 – 10 m/s are achieved inside the G-Cell vessel. Figure 4 shows the coal concentrate overflowing the internal circular froth launder.


Figure 4. IMF G22 in Operation

Steel Belt Filters

The challenge after the recovery of the fine coal by flotation is the dewatering of the concentrate to an acceptable level for handling and downstream usage. The filtration of fine coal is addressed using a Steel Belt Filter (SBF). This is a proven alternative to conventional cloth based vacuum filters (Figure 5). Stainless steel mesh provides a more resilient and more open medium providing high drainage rates and long life. In conjunction with low suction pressures (around –5 to –3 inch mercury) and appropriate flocculant conditions a cake can be quickly formed from flotation froth (generally 20-50 seconds). The cake is then easily compressed with an overbelt and offset rollers using pneumatic bellows. The forces utilised are significantly lower than in conventional belt press systems, which together with smaller wrapping angles (10 compared with 180) ensures roller bearings a longer life.

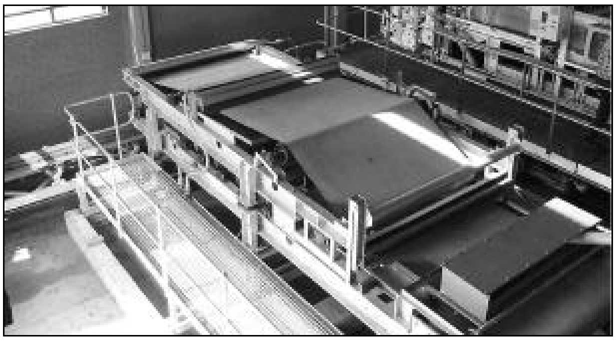
Figure 5. PSS Steel Belt Filter Model SBF1900

Because of their higher drainage rate the SBF are considerably smaller than conventional cloth belt filters and so fit in with the mobile plant concept of ultra fine coal recovery. Experience in coal filtration has shown that lower product moistures can be obtained than rotary vacuum filters and cloth belt filter presses whilst using considerably lower flocculant addition. Reduced maintenance commitments are also significant for this style of operation.

Modular Construction

The mechanical design of the modular process units is intended to allow maximum portability by road transport. Individual process units are accommodated independently in modular frames. Skid mounting of frames would normally suffice, although provisions are made for bolting of higher structures to rudimentary sunken piles. The overall process design is presented in Figure 7 and an example mass balance is based on treatment of typical impoundments in western Europe.

METALLURGICAL PERFORMANCE

Performance of G-Cell pneumatic flotation can be generally illustrated by the relationships between yield and concentrate grade (Figure 6). A compromise exists between these objectives.

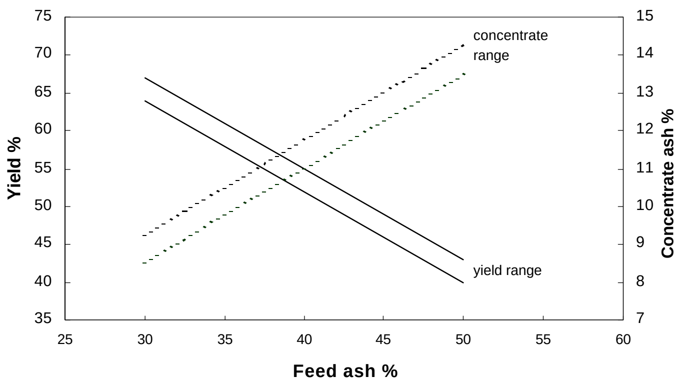

Figure 6. Flotation Recovery and Grade Relationships

The performance of flotation is tuned to high grade (low ash) for the first stage, where perhaps 80% of the total achievable yield is also obtained. The second stage then acts as a scavenger, tuned to mass recovery. Variables that affect the performance include aerator pressures and vent settings, rotational speed and weir levels (froth depth) in the cell.

Product filtration is often as important as grade having large influence on transport economics and achieving customer requirements. Fine rejects from 5 inch cyclones which constitute many lagoon contents have size distributions typically 80% passing 100 microns (150 mesh). SBF performance for 12-13% ash coal has been shown to produce a moisture content of less than 25%. This is quite handleable, and can be stockpiled, where moisture is further reduced by natural drainage over a day or two. Polyacrylamide addition for this type of performance may be in the region of 400g/tonne of dry product, including both anionic flocculant and the cationic dewatering agent.

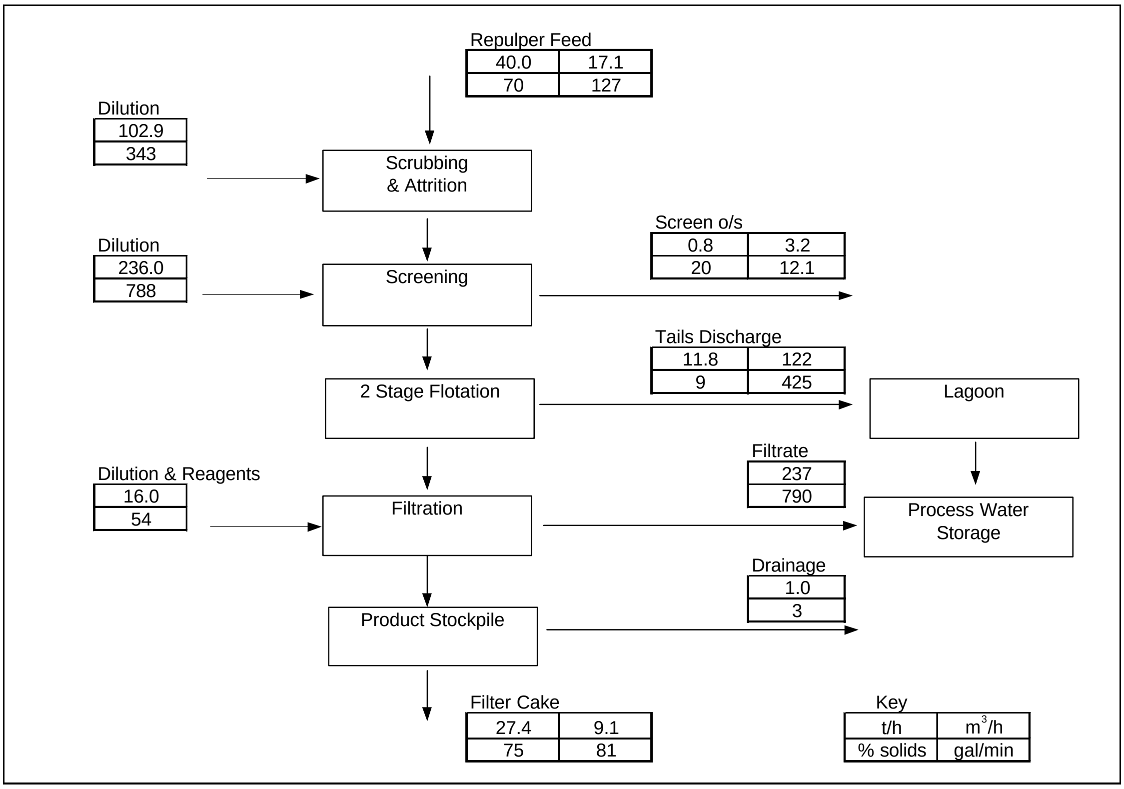

Figure 7. Process Flow Diagram and Typical Mass Balance

PROCESS ECONOMICS

In order to illustrate the concept of portable treatment plant it is necessary to present the case for operation of the typical European impoundment shown in the mass balance diagram. After many years of preferential treatment of coarse material impoundments may contain extensive reserves of relatively low ash coal. Thus a feed stock of 30-40% ash is not uncommon. A scale of operation required to be profitable, and remain portable is presented in Table 1 corresponding with the flow diagram and mass balance. These design criteria form the basis for economic appraisal. The layout of equipment is illustrated in Figure 9. An engineered and operating plant for the criteria presented in Table 1 will require a capital investment of approximately $750,000 and may be constructed to last for 10 years or more.

Operating parameter	units	value
Mass flows		
Feed rate (dry solids)	Tonnes / hour	40
Rotaspiral reject	%	2
Flotation yield	%	70
Operating Hours per day	Hours	20
Grades Flotation		
Feed Ash	%	32
Product Ash	%	12
Tailings Ash	%	79
Product Grade		
Ash	%	12
Moisture	%	25
Inerts	%	37
Coal Calorific Value	GJ/tonne	30
	BTU/lb	15,673
Gross CV Product	GJ/tonne	17.96
	BTU/lb	9,380

Table 1. Design Criteria for Pond Treatment

For the purposes of this exercise, however, a 5 year life is assumed. The financial projection does not take into account the continued returns after this period and a final salvage value is assumed to be negligible. While appreciating that economic assessment is subjective and specific to each organization and application a typical case can be projected. Based on estimated operating costs a five year viability has been assessed, while assuming capital expenditure occurs at the commencement of production and corporate taxation and costs associated with capital finance are not taken into account.

The results are illustrated in terms of sensitivity to sales price, a variable that inevitably controls most projects. From this basic assessment it can be seen that pre-tax profitability starts at a sales price level around 60 to 80¢ per GJ (Figure 8).

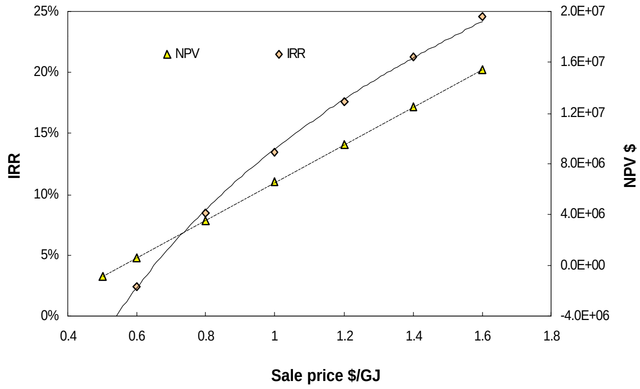

Figure 8. Financial Projection

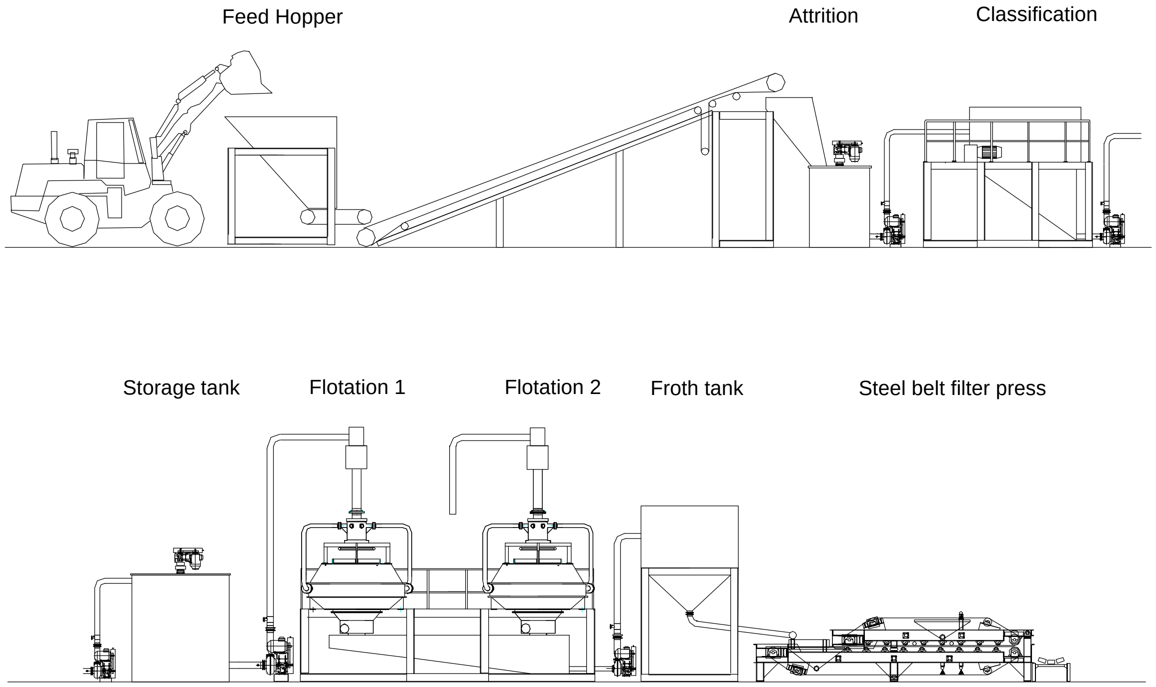

Figure 9. Plant Layout

SUMMARY

Fine coal impoundments represent large resources of low cost coal. Their extraction and treatment provide economic means and incentives for rehabilitation while saving the need to resort to expensive mining. The obstacle to re-processing is often the lack of low cost, but high efficiency technology. This concept largely addresses these needs and provides an environmentally acceptable and profitable enterprise.

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