

DEVELOPMENT AND RECENT APPLICATION

OF WEMCO HMS AND

FLOTATION CELLS



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PART ONE – WEMCO DRUM SEPARATOR

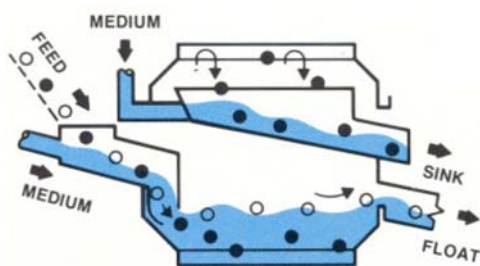
1. INTRODUCTION

The WEMCO Heavy Media Drum Separator was first introduced by WEMCO in California in the 1940's, initially from their base in San Francisco and later when the company moved to Sacramento. The WEMCO Company became a part of EIMCO Process Equipment in 1985. In 2002 EIMCO became a part of the GL&V Group when Dorr-Oliver EIMCO was created, and in turn, Dorr-Oliver EIMCO became a part of FLS Minerals in 2007.

Throughout this period of time the WEMCO Drum has been installed on a variety of different applications and is now operating at the heart of many of the worlds largest Minerals and Coal Processing Plants, as well as being used by many smaller producers and metal re-cycling operations.

This paper looks at the practical aspects of using WEMCO Drums in a representative range of processing applications.

2. THE WEMCO DRUM SEPARATOR – HOW IT WORKS



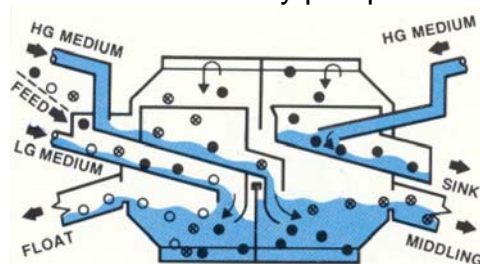
The WEMCO Drum Consists of a steel Shell equipped with two specially designed tyre and collar assemblies. The Shell is supported from and runs on four support roller assemblies. To the inside of the Shell are attached removable and replaceable perforated sinks lifter plates. The drum shell is maintained in its operating position longitudinally on the support rollers by two thrust rollers which engage on both sides of one of the main tyres as required.

The Support and Thrust Roller Assemblies are located on a sub-frame which also carries the Drive Motor, vee belt drive, Gearbox (and protective coupling where fitted), Drive and Idler Sprocket Assemblies and Drive Chain. The Drive Chain engages with the Drive Sprockets bolted around the outside of the Drum Shell to provide a positive non-slipping drive to rotate the drum at the correct operating speed.

All other internal components of the Drum are supported independently of the Drum Shell by 2 longitudinal support beams which are in turn supported by integral steelwork bolted to the base frame. The main internal components of the drum are the feed chute and feed box, sinks hopper, curtains and media addition pipework.

Media of the appropriate density is circulated through the Wemco Drum. It is normally introduced into the feed chute, behind one of the curtains and into the sinks launder.

When feed solids are introduced into the separator the lighter material (below media density) floats and is carried over the outlet of the discharge cone of the Drum. The heavier material (above media density) sinks and is collected by the sinks lifters. As the drum rotates and reaches a certain point each of the sinks lifters discharges by gravity into the sinks launder. Sinks flush medium is used to carry the sinks out of the Drum to its drainage screen. The float material is also carried to a drainage screen. The drained media is recycled back to the WEMCO Drum by pump.



So far we have described a Single Compartment or Two-product WEMCO Drum. There is also a Twin Compartment or Three-product WEMCO Drum. In this design two different media densities are used. The first compartment uses low gravity medium and the second compartment uses high gravity medium. In this way three products can be made namely low gravity floats, high gravity floats (or middlings) and a final sinks.

There is a difference to the media addition points in this case. Primary or low gravity media is added to the Feed Chute and behind the Primary Curtain. Secondary or high gravity medium is added to the Primary Sinks Launder (in order to introduce high gravity media into the second compartment of the Drum) and behind the Secondary Curtain and to the final Secondary Compartment Sinks Launder. The drained media from the screens are re-circulated to the WEMCO Drum by pump.

For certain specific applications it is possible to have a variation on the Twin Compartment Drum design in order to treat two separate size fractions (one in each compartment) and to make a common sinks product.

3. APPLICATION HISTORY

WEMCO Drums have been used on the following applications:-

Iron Ore	Manganese	Crushed Auto Scrap
Bituminous Coal	Fluorite/Barite	Shredded Aero
Anthracite Coal	Gypsum	Components and
Lignite	Gravel + Aggregates	Electronic Equipment
Limestone + Dolomite	+Sandstone Magnesite	Phosphate
Lead/Zinc/Silver	Chrome	Bauxite
Tin	Siderite	Gold/Uranium
Diamonds	Scrap Aluminium	Pyrite
Copper	Ferrochrome Slag	Colemanite

4. PROCESS CONSIDERATIONS

Without going through the laws of particle mechanics, suffice to say that the effectiveness of the separation achievable is dependant upon the difference in specific gravity between the materials to be separated (floats and sinks). It is also dependant upon the particle sizes to be treated, because the rate at which the particles settle or float in the heavy medium is also important. This means that smaller particles require a greater residence time in the Drum to achieve any required separation, than coarser particles.

Returning to the density difference, any ores which have a high degree of near gravity material (material close to the actual separating density) are going to be more difficult to process than those ores which contain very little near gravity material.

Returning to the particle size issue any ore which contains a preponderance of fine particles in the size range fed to the Drum is again going to be more difficult to process than those ores which contain lesser amounts of finer particles.

So the first step in applying a WEMCO Drum is to study the feed size analysis and feed float and sink analysis (or washability analysis of the feed). It is best if this float and sink analysis is available by size fraction. Since this data is a key determinant in equipment selection and indeed plant design, it must be correct data and be entirely representative of the material to be processed. It is surprising how often this is not the case. If there is any doubt about the accuracy of the data it should be disclosed at the design stage because there are some simple precautions that can be taken at the Equipment Selection and Plant Design stages (such as making sure that the Drum is large enough to have some spare capacity and that the sinks lifters also have spare capacity, and that sufficient media flow rates have been recommended etc).

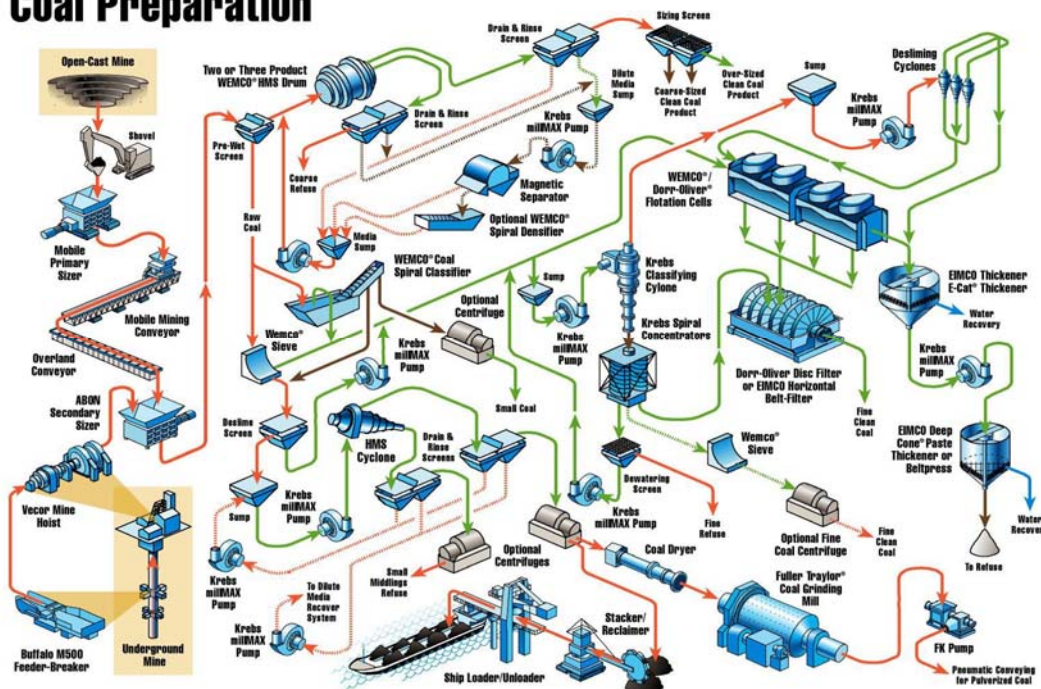
In general it is most economic to treat material as coarse as possible consistent with good liberation of particles. So it is not possible to set a fixed top size for every application, since the top size depends on the liberation size, upon the industry concerned and the actual application. In the Coal Industry top sizes up to 250mm in size have been treated, whereas 150mm top size is perhaps most common. In Coal it is important not to over-crush the feed because this increases the quantity of small material and fines ultimately generated which in turn increased the small coal and fines design capacity requirement of the plant. Small Coal often carries a lower market price than larger Coal. Also fines are notoriously more expensive to treat and to dewater, and the overall economics of the operation can be adversely affected.

In the non-coal minerals industry it is normally required to crush to 150mm or below to achieve adequate particle liberation. The top size needs to be decided on a case- by- case basis.

How low should you go? Regarding the bottom size for treatment in the WEMCO Drum, this depends upon the industry concerned, the size of the processing operation in terms of its ability to afford two different HMS Processing Streams, (bearing in mind the higher medium consumption of small material circuits, and the extra recovery possible) and if two circuits are an economic proposition the top size selected as most appropriate for the small material dense medium circuit.

In the Coal Industry bottom sizes as low as 3mm in size have been treated in special applications whereas 5-6 mm is the normal rule of thumb as the lowest size normally treated by the WEMCO Drum. Where there is a choice of two circuits, it is generally regarded by European Coal Preparation Engineers that 12.5mm is the cross-over point when below this size HMS Cyclones become more suitable in processing this finer material. There is also the question of achieving an appropriate tonnage split for the plant in terms of the relative sizes of the WEMCO Drum and HMS Cyclones, and it is possible to vary the 12.5mm guide-point to suit the tonnages to be processed in each circuit.

Coal Preparation



In the Minerals Industry bottom sizes as low as 2mm in size have been treated by the WEMCO Drum in special applications, whereas 3-6mm is perhaps more common. The same issues apply as discussed previously when two HMS circuits are utilised, but wear becomes a much more serious factor in the choice of circuits, because of the abrasive nature of many mineral ores. The pumping of abrasive solids and the higher quantities of media required to HMS Cyclones have to be considered seriously.

In metals re-cycling the top size tends to be set by the metal shredder and this is around 100-125 mm in size, and the bottom size is normally 10mm, with the small material going to WEMCO Jigs because HMS cyclones tend to become

blocked with metal/plastic wires present in most feeds. Metal re-cycling plant design has its own challenges. For example serious consideration has to be given to remove fibres from the media in order to ensure a suitable separation. The entire feed material needs a very thorough pre-washing and separation stage with water (normally upward current) to remove plastics, light rubber etc. Wear becomes a more serious issue, as does media recovery as the medium tends to be lost on the underside of flat metal pieces and into the crevasses of crushed and mangled metal pieces.

5. WEMCO DRUM PERFORMANCE

WEMCO Drums were successfully introduced into the UK and European Coal Processing Plants in the early 1950's, and soon became the most popular and widely installed coarse coal Heavy Media Separators in the industry. In the early plants WEMCO either constructed the complete coal washeries or supplied the WEMCO Drum, and associated media, screening and cleaning circuits to other main contractors. As time went by WEMCO were asked to replace other types of separator which already existed in older plants, because it became clear that the WEMCO Drum was not only a first class separator in terms of process performance but it cost far less to maintain and operate than other competitive machines. The reason being that there were no chains or wheels operating inside the magnetite media to cause high scraping wear and frequent repair stoppages. Plant availability was improved. A lot of the replacement WEMCO Drums were single compartment units such as at Daw Mill (Tromp replaced), Manvers Main Central Washery (Snail replaced), but some were twin compartment units such as at Markham Colliery (2 separate Drewboys replaced). These jobs were all done in a two week annual colliery summer shutdown period. A number of tricks were learnt from these jobs:

- a) How to split the Drum shells to enable cranes to carry out some of the difficult lifts required, as at Manvers where the WEMCO Drum had to be located in the very centre of a large plant. The split shells were flanged and bolted together and welded in situ after being lifted into place.
- b) How to build up the internals of the WEMCO Drums as much as possible at ground level to minimise the number of lifts and cut down on installation time, eg at Daw Mill and Markham. Following on from the success at Daw Mill a second Tromp was replaced by another WEMCO Drum and finally a third separate WEMCO Drum was installed at this major mine.

Following on from the success of the coking coal plants in Yorkshire such as Manvers, Maltby etc two completely new washeries were constructed in 1978 at Dinnington and Thurcroft Collieries. Both these plants had 12 x 20 WEMCO twin compartment Drums for coarse coal separation (125mm-12.5mm), Vorsyl HM Cyclones for small coal separation (12.5mm-0.5mm) and Froth Flotation for fines(0.5mm-0). In 1980 the National Coal Board (NCB) decided that they would like to carry out a major plant performance test at Dinnington in order to generate vital up to date information which could be used in the preparation of computer programs to predict plant performance on other coal feeds. On July 16th 1980 a full days sampling was carried out, with incremental samples taken at 10 minute intervals, with the samples tested

and analysed at the NCB Main Research and Development Centre at Bretby.
The results were as follows:

Size Analysis of Feed and Products

<u>Size Range</u> <u>(mm)</u>	<u>Raw Coal</u> <u>Wt %</u>	<u>Clean Coal</u> <u>Wt%</u>	<u>Middlings</u> <u>Wt %</u>	<u>Rejects</u> <u>Wt%</u>
-125 + 50	19.00	3.00	1.60	19.70
- 50 + 25	32.90	30.00	21.40	38.80
- 25 + 12.5	36.20	58.90	63.20	35.50
- 12.5 + 0	<u>11.90</u>	<u>8.10</u>	<u>13.80</u>	<u>6.00</u>
TOTAL	100.00	100.00	100.00	100.00

The Dinnington WEMCO Drum was installed to handle a feed of 175tph of 125-12.5mm raw coal.

Summary of Washing Performance

	<u>Primary Separation</u>				<u>Secondary Separation</u>			
<u>Size Fraction(mm)</u>	<u>125-50</u>	<u>50-25</u>	<u>25-12.5</u>	<u>125-12.5</u>	<u>125-50</u>	<u>50-25</u>	<u>25-12.5</u>	<u>125-12.5</u>
Yield Clean Coal%	5.96	20.35	32.20	22.12	-	-	-	-
Ash Clean Coal%	2.83	2.60	2.49	2.53	-	-	-	-
Yield Middlings %	-	-	-	-	0.62	4.23	7.47	4.78
Ash Middlings %	-	-	-	-	27.33	22.25	17.75	19.05
Yield Rejects %	-	-	-	-	93.42	75.42	60.33	73.10
Ash Rejects %	-	-	-	-	83.73	86.74	86.10	86.08
Partition Density	1.358	1.356	1.354	1.357	1.666	1.683	1.703	1.684
EPM	0.012	0.015	0.017	0.016	0.016	0.016	0.034	0.031
Imperfection	0.032	0.042	0.048	0.046	0.024	0.023	0.048	0.045

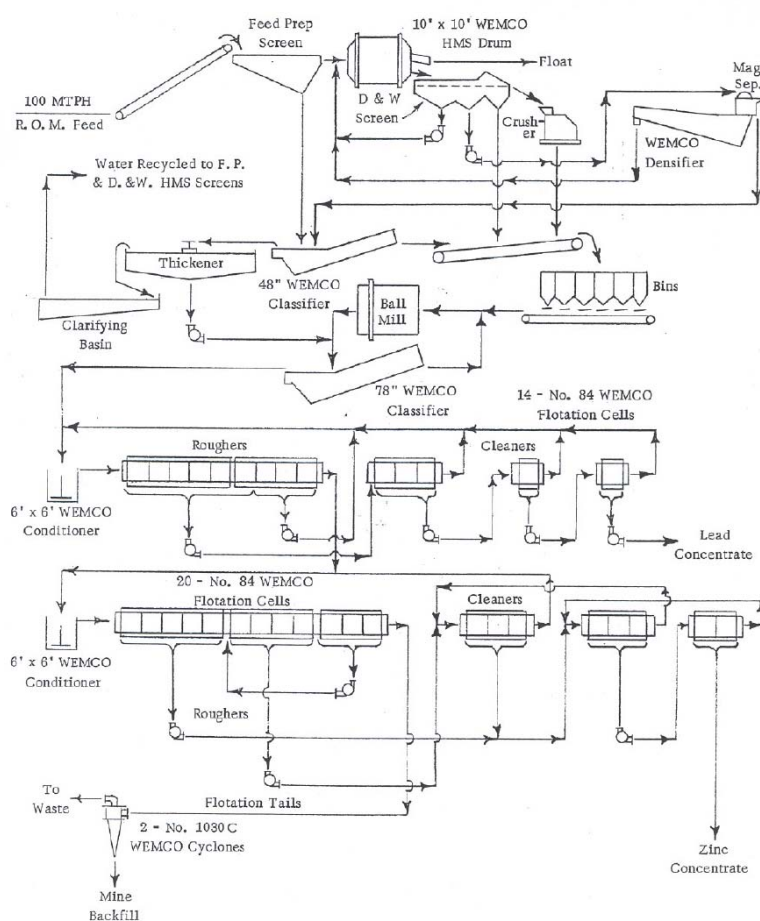
Further WEMCO Drums were installed in the Yorkshire region at Maltby (2- 15 x 23) and at Kellingley (1-15 x 23), all three units were twin compartment, and later at Selby and Maltby further WEMCO Drums were installed to increase capacity and serve special markets. The story continues to this day. Some recent installations are in Siberia at Mezdurechenskaya (15 x 17 and 12 x 14 single compartment units) and in Turkey at Soma (2-12 x 20 twin compartment units).

Over the years WEMCO Drums have been installed as part of WEMCO Mobil-Mills and skid mounted modular plants, one of the first ones installed in 1982 treating down to 3mm, with the Hydrosizer (now known as the TBS) treating 3mm-0. An early installation was at British Coal –Sutton Manor, where a Jigged Coal Product had to be re-treated to remove flats (flat particles containing fine interbanded coal and shale layers), and so retain the Boiler Fuel market for British Coal. Numerous WEMCO skid mounted modular plants have been installed at major ports in the UK

and Holland to treat imported coal from South Africa, Australia, China and Russia. There have also been many modular WEMCO Drum Plants supplied into the CIS.

6. WEMCO DRUMS IN MINERALS

The WEMCO Drum comes into its own in applications with high sinks loadings where the twin advantages of excellent separation performance and minimum wear and running costs are displayed. WEMCO Drums have been successful in Iron Ore and Chrome which are some of the most arduous duties that can be envisaged. In Lead-Zinc and Tin operations the WEMCO Drum has been used very successfully to pre-concentrate ores ahead of the grinding and flotation plants. The benefit here is to reject waste material early on in the flowsheet and save the cost of grinding waste material, whilst at the same time boosting the head grade to the Flotation Plant, which in turn boosts concentrate production and overall profitability.



An example of this is the outline flowsheet for the BBU Pb-Zn Concentrator in Austria, where a 10 x 10 WEMCO Drum Plant was installed for pre-concentration. Ore was crushed underground to minus 60mm in size and then fed to the wet feed preparation screen at the rate of 100tph. The screen removed minus 4mm fines, and the HMS feed to the 10 x 10 WEMCO Drum was 60mm - 4.0 mm in size. Minus 4mm fines reported to a WEMCO Spiral Classifier, with classifier overflow going to a 16m diameter thickener, and classifier underflow going to the Mill. Feed tonnage to the WEMCO Drum depended on which of the three types of ore was treated, and is shown in the table below. HMS Results are shown also.

HMS Tonnages

Ore Type	WFP Screen Feed	4mm-0 Undersize	Drum Feed	Floats	Sinks
	<u>MTPH</u>	<u>MTPH</u>	<u>MTPH</u>	<u>MTPH</u>	<u>MTPH</u>
R	100	34	66	50	16
A	100	29	71	26	45
S	100	26	74	52	22

HMS Results

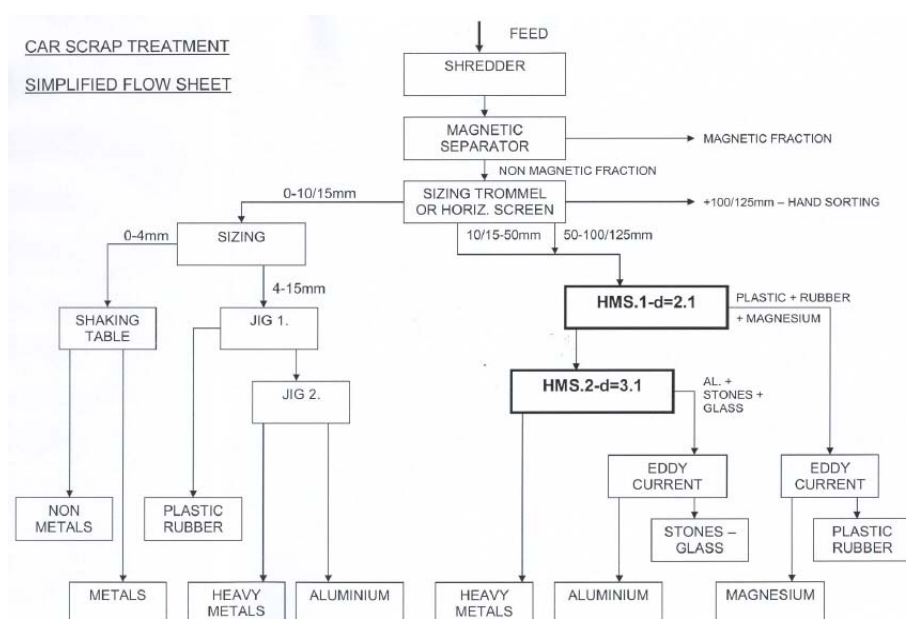
Average Stream	Wt%	Assay %		Distribution %	
		Pb Total %	ZnS %	Pb Total%	ZnS %
R.o.m. Feed	100.0	1.96	5.91	100.0	100.0
Float Product	36.2	0.07	0.72	1.23	4.38
Flotation Feed	63.8	3.03	8.86	98.77	95.62

S.G of the heavy medium varied between 2.8-3.0 gm/cm³. Medium consisted of 75% FeSi – Normal Coarse and 25% magnetite. Average Medium Consumption was 122gm/tonne fed to the feed preparation screen.

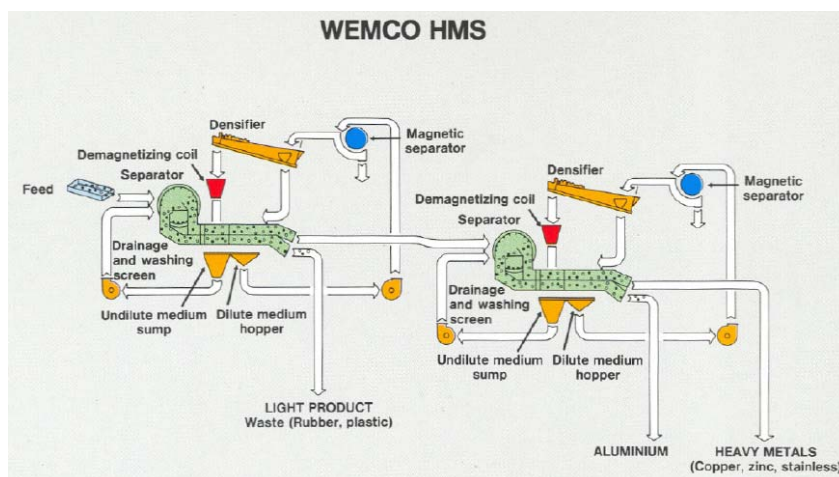
On these types of applications not only is it possible to increase the flotation head grade to the Mill, but the coarse tailings from HMS can be sold for construction use, which has the knock - on effect of reducing tailings disposal costs.

7. WEMCO DRUMS IN METALS RECYCLING

In metals re-cycling these types of plants are normally much smaller tonnage operations, but because of their complexity and size range of particles to be treated it is common to use fairly large sized WEMCO Drums. The Drums are however modified internally to obtain the best results with the types of material encountered. Typical feeds can be the non ferrous components of shredded cars and aero engines etc. The simplified flowsheet below shows the basic process.



The crushed and sized feed is normally washed and drained by screen/water sprays or by a specialized Rising Current Washing device such as the WEMCO RCS, which is able to remove some of the lighter plastics and fibres ahead of the plant. (The basic flowsheet assumes that this step has already been carried out). WEMCO Drums are employed on the 10/15mm -100/125mm size fractions. There are usually two separations, firstly a primary separation at 2.0-2.1 SG to float out the magnesium, with any residual plastic and rubber, followed by a secondary separation at 3.0-3.1 SG. This second separation floats out the Aluminium with any residual stones and glass, and concentrates the heavy metals (Copper, brass etc) as a sinks product.



The Magnesium and Aluminium concentrates are usually further treated by eddy current separators to remove the remaining plastic stones and glass.

Depending upon the plant throughput it is possible to have a single WEMCO Drum Plant and operate it on a campaign basis, firstly undertaking the Low Gravity separation, and storing the primary sinks, which can then be treated in a further campaign using an increased media density in the same plant. Some single Drum plants even have separate Media Sumps in order to store the low gravity and high gravity media separately. Media can be magnetite only for the primary separation, and a mixture of ferrosilicon and magnetite for the secondary separation.

More commonly plants usually have twin WEMCO Drum Systems as shown in the flowsheet below. This has the advantage of avoiding storage and double handling of the primary sinks, as well as being able to keep the media circuits entirely separate. WEMCO spiral type Densifiers are used for media densification and storage, and demagnetising coils are used on the thickened Densifier discharge media .

Typical Plant throughputs are as follows;

WEMCO Drum Size	Feed Capacity (tph)
6 x 6	4-8
8 x 8	10-15
10 x10	15-25

These throughputs are of course far lower than is the case in minerals and coal separations. To ensure a precise feed, vibrating feeders are used to present material

into the Drum with a special feed media distribution system inside the Drum to ensure a precise separation.

Due to the difficulty of removing media from the shredded and mangled metals, coupled with the tendency of the screen decks to become partially blocked with fine wires and fibres, media consumption is inevitably much higher than is the case with mineral separations. Typical figures can be as high as 5 kg/tonne of magnetite and 3 kg/tonne of ferrosilicon. However this is tolerable due to the low throughputs and high profitability of these plants.

8. ON-GOING DEVELOPMENT OF THE WEMCO DRUM SEPARATOR

WEMCO have always worked closely with their customers to incorporate design features that work in the local plant and the local situation. Some feeds are more abrasive than others, and always the local plant has a pretty good idea of what works best and (what is locally available) for them in terms of lining materials. Customer preference is taken into account when selecting lining materials. To give an idea of the various options, for coal applications the Drum Shell can be either unlined, or lined with 6mm thick AD1 which is a trowelled-on lining consisting of a mixture of aggregate and epoxy resin, sometimes in turn coated with a red glaze finish (which allows easy checking for wear). More rarely polyurethane or rubber lining, or ceramic tiling of the shell is requested. Kellingley has taken the AD1 Route and this Drum has lasted for 25 years. For coal applications the chutes are normally lined with mild steel or a high chrome steel such as 12-16mm thick Hardox plate. These can be tack welded in or bolted. Non impact areas can be tiled with ceramic tiles, 30-50mm thick. Pipework is normally thick walled mild steel or cast basalt for longest life, or cast basalt/ polyurethane lined for media sluice boxes. For mineral applications again it depends where we are on the Moh's scale of hardness, but on the most abrasive materials such as chromite or iron ore, the Drum Shells are usually rubber lined and the chutes lined with a combination of cast nihard liners up to 50mm thick, 80mm thick rubber and 50mm thick polyurethane. These can be supplied in sections for fitting or bolting in (with the joints running across the chute so they fill with media, and not longitudinally which wears the chute underneath).

It has been found that special reinforced lifter supports fitted to the Drum Shell prevent bowing of the lifters and loosening of the lifter bolts, and large diameter bolts provide a longer service life and avoid bolt breakages.

From the process performance point of view profiled and weighted rubber curtains have now been adopted to avoid such problems as curtains being caught up by contact with the end cones. These also help to channel the flow through the Drum. For high quantities of material floats, flat overflows or elongated conical overflows are adopted. Many other features have also been introduced, some specific to each application such as curved and streamlined feed boxes to make the best use of the Drum length available for high tonnage throughputs. Quick-release media drain valves and special drain launders have been adopted so as to be able to drain the Drum on any stoppage position. Replaceable split and flanged end cones are now available. On the very large Drums protective couplings are available to protect the gearbox. Very high sinks lifting capacities are designed in to each application so as to avoid crowding in the feed box area.



4.2m x 3.6m WEMCO HMS Drum Separator at BHP Mount Newman – iron ore separation.

9. CONCLUSION

The WEMCO Drum has been used very successfully over a great many applications, both in small tonnage metal recycling operations and large tonnage coal and iron ore applications. It continues to be the work-horse of many minerals plants all around the world.

PART 2 – WEMCO FLOTATION CELLS

1. INTRODUCTION

The WEMCO Flotation Cell was first introduced by WEMCO in California in the 1950's as the WEMCO Fagregren cell. The WEMCO Company became a part of Eimco process equipment in 1985 and in 2007 together with Dorr-Oliver became a part of FLS Minerals. Throughout this period of time WEMCO flotation cells have been installed on a variety of different applications and are operating at the heart of many of the world's largest mineral and coal processing plants. Typical applications for WEMCO flotation are copper, platinum, nickel, zinc etc as well as non-metallic applications such as coal, silica sand, phosphate, fluorite etc. this paper looks at the development and application of the WEMCO flotation cells in the coal industry.

2. COAL FLOTATION CIRCUITS

As the generic coal prep plant flow sheet illustrates there are two common options for coal flotation. The first option is the traditional well proven one, of HMS treatment down to a bottom size of 0.5mm, with the 0.5mm - 0 coal fraction pumped to froth flotation. The second option is the introduction of a spirals treatment section to treat the 1.5mm – 0.125mm size fraction, with the 0.125mm – 0 produced by de-sliming cyclone going direct to further de-sliming and / or froth flotation.

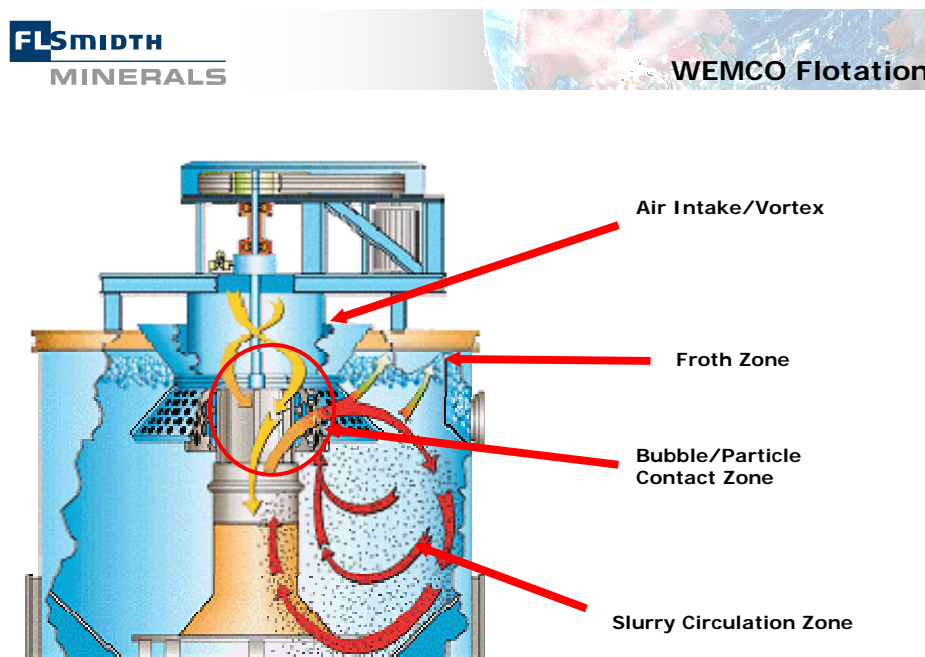
While not as efficient as DM Cyclones, spirals were seen in the days of low coal prices as a low cost method of treating this particular size fraction. Column type flotation cells were also introduced at the same time in order to treat the minus 125 micron fraction. Again column flotation was perceived as a lower cost option, whilst at the same time targeting a lower ash coal product than that produced by conventional single stage flotation. Many different types of column cells were introduced in different countries. In the UK WEMCO introduced the Leeds column cell (Markham colliery) and the EIMCO Pyramid column cell (Gascoigne Wood –

Selby). The WEMCO Leeds column was a development of Chris Dell's Leeds Column, i.e. a mechanical cell with a rod column section through which the froth could be washed. It was an attempt to harness the better mixing efficiency of a conventional cell with the principles of controlled froth washing to remove trapped slimes. The EIMCO – WEMCO pyramid cell was a conventional tall column unit purely to treat fines. From these installations a lot was learned and WEMCO decided not to proceed with column flotation, preferring instead to focus on the development of WEMCO Smart cell and WEMCO 1 + 1 cell technology especially adapted for the various types of coal flotation applications.

In the mid 1960's the largest flotation cell installed in the UK coal industry was around 2.8 m³ in size (100 cubic ft.) and there were many 1.6m³ (60 cubic ft.) units working. The same was true of the world wide minerals industry although the 8.5m³ (300 cubic ft.) cells were soon to be introduced there. WEMCO always had a well respected and dominant position in this market due to the recognised superior performance of the WEMCO 1 + 1 machines, in terms of metallurgical recovery, reliability with virtually no downtime and low operating costs.

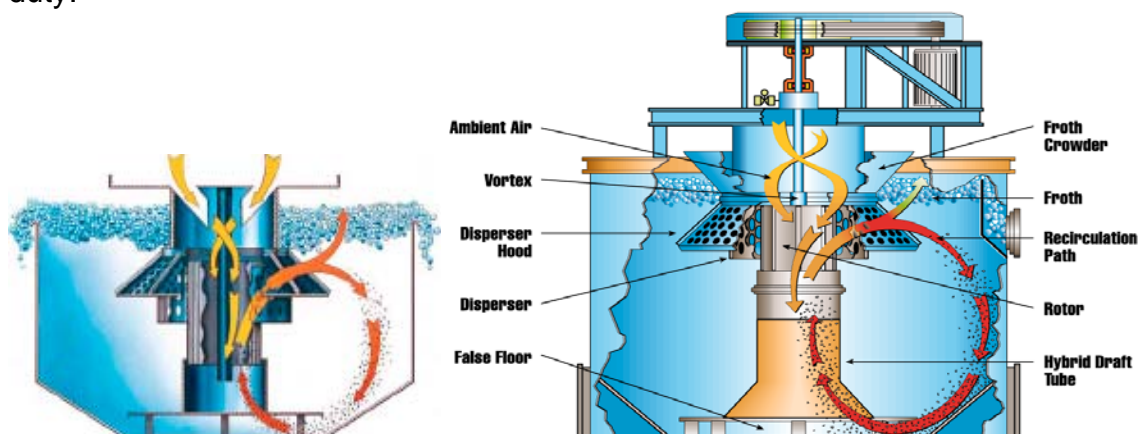
Today WEMCO has cells installed and operational up to 257 m³ in size and has full scale 300m³ units on test at Kennecott Copper in the USA. This represents an increase in cell volume of 100 times over the past forty years.

3. WEMCO FLOTATION CELLS – HOW THEY WORK



Ambient air is drawn through an air intake pipe and control valve by the action of the rotor. A disperser is used to produce the air bubbles. The air is distributed throughout the pulp providing optimum air / particle contact. A false bottom and draft tube channel slurry flow and ensure high recirculation. This combination of efficient aeration and optimum solids circulation gives WEMCO 1 + 1 cells the highest specie recovery available and reduces reagent consumption. The froth is removed from the

cell surface into froth launders either by natural flow sometimes enhanced by froth crowders or external skimmers depending upon cell selection and application for the duty.

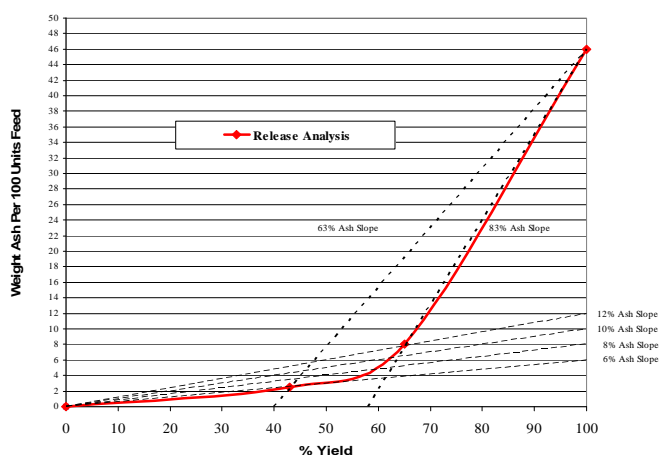


WEMCO 1 + 1 Cell.

WEMCO Smart Cell.

4. WEMCO FLOTATION CELL PERFORMANCE

To all metallurgists, flotation cell performance is crucial and should be optimised for each application constantly striving for that extra degree of recovery consistent with meeting required product grade and specifications. This always enhances plant and mine profitability. During his time as a plant metallurgist Chris Dell developed the concept of release analysis – a very intelligent method of defining the best possible flotation results on any defined coal sample. Chris later refined this method for coal and published on it during his time at Leeds University. A typical coal release curve is shown below. It is generated by a bulk float followed by cleaning of the resultant concentrate after re-dilution, with gradual increase of impeller speed, air and reagent. This way the pure coal which literally wants to jump out of the cell floats first followed in gradual stages by the slightly inferior coal present up to the maximum yield possible. At this point no further coal floats and only pure tailings remain. The results can be presented as a graph as shown and concentrate and tailings grades at different yields interpreted.



On the actual flotation cell installation there are some key factors which can be controlled to maximise recovery and optimise the product grade. These are:-

- a) Good air control along the bank of cells. WEMCO cells always pull more than enough air for coal flotation. Therefore air needs to be regulated along the bank. There is an air intake valve provided to control the air introduced by each cell.
- b) Stage addition of reagent. Sometimes preconditioning is required, sometimes not. It is possible with WEMCO cells to introduce reagent into the feed box or connection box or directly into the air intake for good direct mixing. This gives a high degree of flexibility of where the reagent is added.
- c) Control of froth depth and staged froth removal over groups of cells. This is done by using automatic pulp level controls at each connection and discharge box fitted along the bank. For example, a row of five cells could be two cells and three cells with a connecting box between the two groups and a discharge box at the end of the bank. Alternatively a row of six cells could be two cells, two cells, and two cells with two intermediate connection boxes and a final discharge box.
- d) Utilisation of a minimum of four or preferably five cells in a row. Since the flotation process involves probability of particle / bubble contact, particle drop-off etc, in order to maximise recovery a minimum number of cells is required. It is not sufficient just to consider total residence time.
- e) Matching of the rotor size to the application. If coarse particles are present large rotors should be used operating at the correct speed for the application. If there is a high proportion of fine particles, standard rotors are suitable.
- f) Consideration of yield. High yielding coals require a larger surface area for well controlled froth removal and this may sometimes become a serious consideration when using a minimum number of large volume cells.

Excellent results can be produced utilising these principles. As in the release analysis air is precisely controlled, stage addition of reagent is used and stage removal of froth is likewise used. Furthermore, slimes are prevented from bailing over into the product when the coal has floated (something that can occur when there is no connecting box fitted). Finally froth washing can be fitted on the WEMCO Smart cells, but it has not so far proven to be necessary.

Good flotation in turn leads to good product filtration. The filtration rate depends on particle size and in particular the ash content of the fines (<40 microns). So the finer the material the lower the filtration rate and the higher the cake moisture. Slimes tend to blind the cake and must be controlled. Hence the need to apply the aforementioned guidelines.

5. TYPICAL OPERATING RESULTS

A) Tower colliery – South Wales. Bank of 5 WEMCO 14.2m³ cells and EIMCO 36m² horizontal belt vacuum filter.

- Feed to cells – 60tph of 0.5mm – 0 raw coal at 40 – 45 % ash.
- Coal concentrate up to 30tph.
- Tailings up to 30tph

Typical results

Date	Cell Feed % Ash	Coal conc. % Ash	Filter Cake % moisture	Tailings % Ash
09/08/98	-	4.7	17.7	75.5
10/08/98	-	4.3	19.6	72.3
14/08/98	-	4.7	18.5	73.8
15/08/98	-	4.1	19.5	71.9
16/08/98	-	4.3	17.9	74.5
04/04/02	42.2	4.6	18.1	76.5



Tower filter Cake 4.6% Ash, 18.1% moisture.

One of the problems with 0.5mm stainless steel wedge wire pre-screening is that these screens always wear to a larger aperture size and there can be 1mm particles and above in flotation. It is necessary to recover the coal from them. Note the coarseness of particles in the above filter cake.

B) Celtic Energy – Onllwyn – South Wales. Bank of four WEMCO 14.2 m³ cells and EIMCO 32 m² horizontal belt vacuum filter.

- Feed to Cells – 40tph of 0.125mm by 0 raw coal of varying feed ash content (opencast multi-seam processing)
- Coal Concentrate up to 36tph
- Tailings up to 12tph

Typical 2007 results

COAL GROUP	S.G. OF FEED	FEED TO PLANT		FILTER CAKE		CELL TAILINGS		OIL RATE	DIESEL RATE	% DIESEL	% YIELD
		SOLIDS (g/l)	% ASH	% MOIST	% ASH	SOLIDS (g/l)	% ASH				
GP 1	1.015	51.7	11.0	27.5	4.0	38.7	73.7	160	95	37.3	90.0
GP 1	1.025	66.5	25.7	28.9	6.2	77.1	76.8	160	110	40.7	72.4
GP 1	1.025	61.9	26.8	28.2	4.3	33.0	72.2	165	110	40.0	66.9
GP 2	1.020	38.4	22.3	28.0	5.5	15.3	59.6	165	110	40.0	68.9
B.D.	1.025	73.4	11.4	27.8	3.4	57.4	64.1	165	100	37.7	86.8
GP 1	1.020	53.6	14.4	25.8	3.7	31.3	78.5	150	100	40.0	85.7
GP 1	1.015	43.5	12.9	23.9	3.0	75.6	75.3	150	90	37.5	86.3
B.D.	1.015	49.9	12.0	26.2	4.2	43.7	77.2	160	120	42.9	89.3
GP 2	1.020	56.7	21.7	29.0	6.7	34.5	74.0	160	120	42.9	77.7
GP 1	1.010	29.3	16.7	25.3	6.4	20.6	72.5	140	85	37.8	84.4
B.D.	1.020	56.7	14.8	23.7	3.3	48.6	67.9	185	80	30.2	82.2

GP 1	1.020	65.2	13.9	26.2	2.9	50.7	62.5	180	90	33.3	81.5
GP 1	1.020	60.0	19.1	23.1	4.0	26.4	76.0	185	105	36.2	79.0
GP 1	1.015	49.2	13.6	26.2	4.3	32.2	73.1	180	100	35.7	86.5
GP 2	1.020	56.5	22.1	25.5	6.1	46.7	75.7	150	150	50.0	77.0
B.D.	1.020	54.6	24.1	23.6	5.3	37.6	75.6	150	150	50.0	73.3
GP 1	1.025	55.5	26.9	24.3	3.6	41.5	77.7	145	145	50.0	68.6
GP 1	1.020	54.3	15.3	25.7	4.0	20.7	74.2	165	165	50.0	83.9
GP 1	1.020	56.9	13.5	24.6	3.6	42.6	80.5	165	140	45.9	87.1
GP 2	1.020	45.4	20.2	24.5	5.5	13.4	67.8	165	140	45.9	76.4
B.D.	1.015	47.1	21.2	22.6	3.9	42.7	77.2	160	125	43.9	76.4
GP 1	1.015	49.7	17.9	23.8	3.3	36.6	77.4	160	120	42.9	80.3
GP 1	1.015	50.5	13.8	21.8	3.8	47.8	76.5	170	115	40.4	86.2
GP 1	1.015	42.7	17.8	23.3	4.7	48.1	70.4	170	120	41.4	80.1
GP 2	1.020	55.2	23.1	20.7	5.4	48.9	67.3	175	100	36.4	71.4
B.D.	1.015	48.8	20.9	23.7	3.9	36.9	77.9	175	120	40.7	77.0
GP 1	1.020	44.5	19.6	26.9	3.8	63.5	75.1	175	115	39.7	77.8
GP 1	1.030	71.8	23.5	26.0	4.2	62.2	71.9	175	115	39.7	71.5
GP 2	1.020	47.9	17.4	24.5	7.3	87.4	73.4	175	120	40.7	84.7
GP 1	1.015	45.0	14.6	27.2	4.0	26.9	67.2	175	125	41.7	83.2

One of the problems with 0.125mm de-sliming is that there is a slightly coarser cut on a coal basis than on a shale basis and preferentially more coal reports to overflow. An additional problem, often overlooked is that the spiral circuit which is designed at Celtic Energy on 1.5mm – 0.125mm feed requires centrifuge dewatering of the 1.5 – 0.125mm coal product by screen scroll unit. This process actually leads to a high degree of coal losses in the centrifuge effluent. At Celtic Energy the WEMCO flotation cells recover these losses.

C) SIBCOAL – Mezdurechenskaya – Siberia. Two banks of six WEMCO 14.2m³ smart cells.

Typical 2006 operating results (based on separate diesel oil collector and pine oil frother).

Feed Ash %	Product Ash %	Tailings Ash %	Feed size analysis
12-15	6.0 – 8.5	65 – 70	95% minus 125 microns

D) Capricorn Coal – German Creek, Australia Two banks of 5 WEMCO 14.2m³ cells

Typical operating results

Date	Feed Ash %	Product Ash %	Tailings Ash %	Yield	Combustible Recovery %
22/06/04	12.4	7.1	72.0	91.9	97.4
22/06/04	13.2	7.5	77.9	91.9	97.9

6. CURRENT DEVELOPMENTS IN AUSTRALIA

It has been noticed that numerous existing Australian coal prep plants utilising column cells have flotation tailings containing very significant amounts of low ash coal. Tailings of 30-50% ash are not unusual.

A 6m³ WEMCO smart cell was trialled at Stratford coal, NSW Australia in order to quantify and validate the viability of recovering the lost coal from their flotation tailings. The test cell indicated that in excess of 10tph of power station quality coal could be recovered.

Consequently, in 2007 a WEMCO 130m³ capacity smart cell was installed as a secondary flotation unit operating on the primary Jameson cell tailings. A reconditioned 16tph capacity rotary vacuum filter was also installed in order to dewater the additional recovered flotation product.

It should be noted that the WEMCO original recommendation was for a row of 3 40m³ smart cells, but due to capital restraints one larger 130m³ machine was selected by Stratford Coal.



WEMCO 130m³ Smart Cell at Stratford Coal

In late December 2007 the coal recovered by the 130m³ WEMCO smart cell operating on the Jameson cell tailings was estimated by the plant to be 17tph.

While the circuit is still being optimised latest details reported from the plant as a result of the new smart cell installation the plant is now getting a 2% increase in clean coal yield resulting in additional 60,000 tonnes per year of coal recovered.

Reported Jameson cell tailings feeding the new smart cell range from 33 – 58% ash carrying a significant amount of wasted frother. Smart cell tailings ashes above 70% have been recorded. Smart cell product ashes as low as 12.6% ash have also been recorded.

Reported advantages are that there is now far less frother in the flotation tailings (because it is carried by the smart cell product) and this has improved the performance of the tailings co-disposal pumping system and has dramatically improved the thickener surface and water quality.

A further significant benefit to Stratford Coal is that the new smart cell installation has enabled them to optimise the primary flotation circuits as well because the primary cells are now receiving more frother without upsetting the rest of the plant.

An unexpected benefit to Stratford Coal has been that on the better coking coal feed the Smart cell product, which was targeted as a high ash thermal product can be directed to the coking coal product fraction thereby further increasing its value. The plant is currently optimising the circuit and looking at installing additional materials handling equipment to direct the WEMCO product from the RVF filter thermal product conveyor to the coking coal product conveyor.

7. CONCLUSION

WEMCO flotation cells have been used very successfully over a wide range of applications both in large tonnage mineral ore and coal processing plants. Careful equipment selection and careful design leads to highly successful installations.

Keith Wilkes