WRAP MDD018/23 WEEE Separation techniques

Allmineral wet jigging trial report

Abstract

This report describes a trial conducted with Allmineral on their small scale wet stratification jig in Germany. The aim of the project was to trial innovative techniques to tackle some of the more difficult separations encountered by primary and secondary WEEE processors. Recovering fine copper from mixed WEEE is a notoriously difficult separation and several techniques have been tested during this project to attempt to find a solution to the problem. Fine copper is left in WEEE plastic by eddy current separation units because thin copper wires and other small metal items are too thin to be able to generate the eddy currents that make the separation happen.

Density separation of mixed WEEE plastics is also complex so this is another separation for which a solution is required.

The wet jigging technique originates from the mineral processing industries and has traditionally been used for density separation of mineral ores and upgrading of aggregates. The particular attractions of wet jig separation for WEEE processors are:

- It is potentially a low cost, high throughput separation, which could allow scale-up of WEEE processing facilities to much larger size; and
- It can separate materials where the density of the particles to be separated from each other is greater than the density of water. This is potentially a major advantage over conventional WEEE plastic separations, which require modified density separation media.

The Allmineral wet jig test facility was chosen for the trial. Two materials were tested.

The first was a mixture derived from processing of plastics from mixed WEEE. It contained copper, plastic, rubber, PVC coated wires, printed circuit boards (PCBs) and glass. The aim of the trial for this material was to separate a copper concentrate stream suitable for sale to smelters.

The results from this trial indicate that 77% of the copper in the feed was successfully separated but the resulting copper fraction, from a single pass, contained only 10% metal which is not a high enough concentration to be marketable.

The second sample was a mixed plastic fraction separated from mixed WEEE by Axion's own WEEE processing plant at Salford. This material is known as Axion grade PS07. It contains mainly acrylonitrile butadiene styrene (ABS) and polystyrene (PS) with other minor quantities of polypropylene (PP), polyethylene (PE), polycarbonate/polycarbonate acrylonitrile butadiene styrene (PC/PCABS) and polyamide (PA). The aim of the trial in this case was to separate the material into different polymer types by exploiting the different densities of the plastics.

The mixed plastic material did not separate successfully as the bed of material did not stratify, which meant the particles could not settle to their respective density level.

Overall the Allmineral wet jig was unable to demonstrate technically viable performance for either fine copper removal or separation of styrenic plastics, both of which are key problem areas in WEEE recycling.

Table of Contents

List of Figures

List of Tables

1. Information from trial

Trial host: Allmineral Aufbereitungstechnik GmbH & Co. KG, test conducted at facility at Finnentrop-Fretter, Germany

Trial equipment: Allmineral ‘Alljig’ wet jigging machine

Trial date: 9th December 2008

1.1 Description of trial equipment

The trial used Allmineral’s wet jig, also known as a stratification jig, sold under the trade name Alljig, and illustrated schematically in Figure 1 and Figure 2. Figure 3 shows the laboratory-scale batch jig unit used during the trial. The laboratory-scale jig unit can demonstrate the principle of wet jigging and give a qualitative indication of the likely separation efficiency at full scale. The laboratory-scale jig cannot provide qualitative results for scale-up, such as throughput or effectiveness of the material removal chutes at the end of the machine. Allmineral’s normal evaluation procedure is to test whether a separation is feasible using the laboratory-scale batch unit and then progress to larger scale trials on a continuous unit if the laboratory-scale work is successful.

The Allmineral wet jig works by using air to create pulses in the water. As shown in Figure 2, there are two water-filled chambers in the jig: one at the front which contains all the particles and is known as the stratification chamber; and a water reservoir at the back which is beneath the air chamber. These chambers are connected by a water column. When a pulse of air is released from the air chamber, it forces the water in the reservoir downwards. This in turn causes the water in the stratification chamber to move upwards, as shown by the arrows in Figure 2. The water in the stratification chamber then drops down and the water rises up in the reservoir whilst the air is vented. The cycle starts again with another pulse of air.

The frequency, amplitude and shape of the pulses can all be controlled during operation to optimise the separation. The pulsation frequency can range from 10 strokes per minute up to around 140 strokes per minute. Generally the amplitude should be three times the largest particle dimension. A high stroke frequency with low amplitude is typically used for small particles whilst a low stroke frequency and high amplitude is used for larger particles.

The effect of the pulsation is to stratify the particles suspended in the stratification chamber, according to differences in density. Low density particles rise to the surface whilst heavy particles settle in the lower levels of the bed.

Other wet jig suppliers produce jigs where the water is pulsed mechanically rather than by air but in other respects the operation of the machine is similar.

The laboratory-scale rig used in this trial is a batch unit. A pre-weighed load of material is added to the stratification chamber. The stratification chamber contains a set of plastic frames, of varying depth. The bottom level is level 1, increasing upwards to level 7 at the top. The jig is then switched on, and the pulsation causes the different density particles to settle within the plastic frames. After a period of time, the pulsation is stopped, and the frames removed one at a time to extract layers of different density. The same plastic frame configuration was used for all the trials. As with the full-scale unit, the jigging stroke can be controlled during operation, adjusting the pulsation frequency, amplitude and shape to optimise the separation.

The laboratory-scale jig can handle particle sizes from 1mm to 50mm and process 30-50kg per batch.

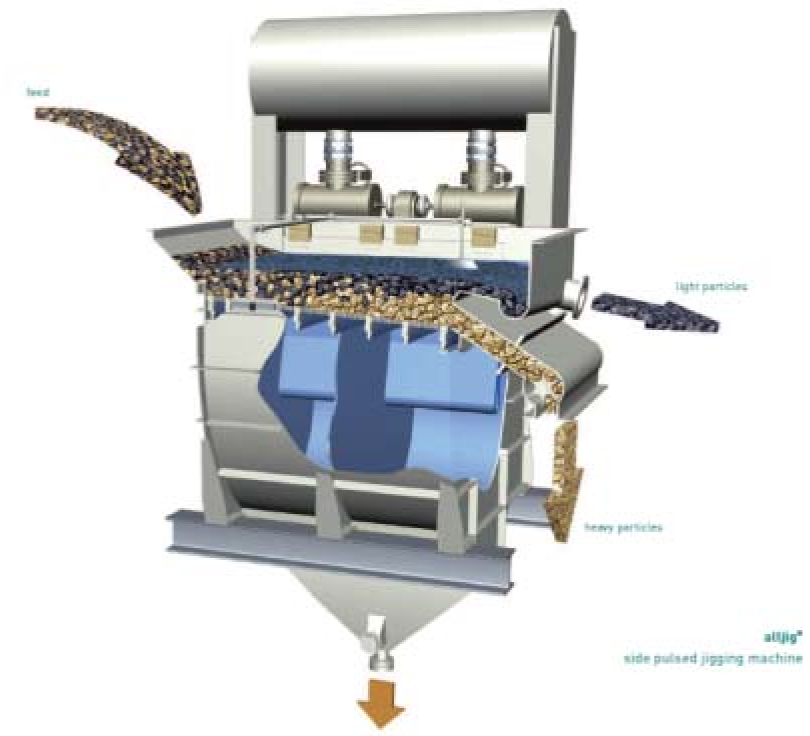

Figure 1: Schematic of an Allmineral wet jig - front view of a side pulsed wet jig

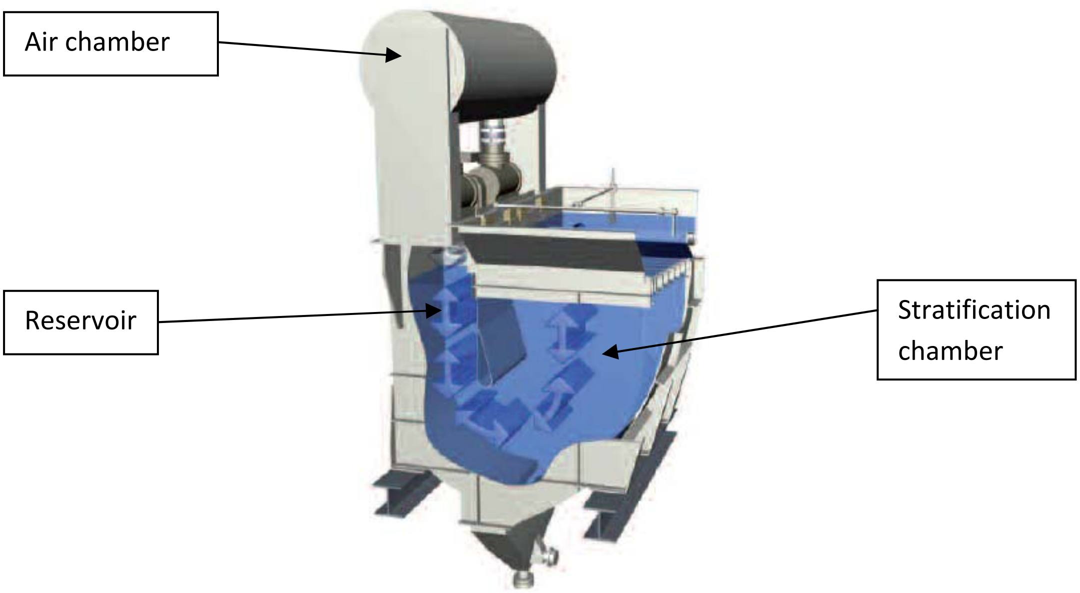

Figure 2: Schematic of an Allmineral wet jig - side view of a side pulsed wet jig

1.2 Photograph of trial equipment

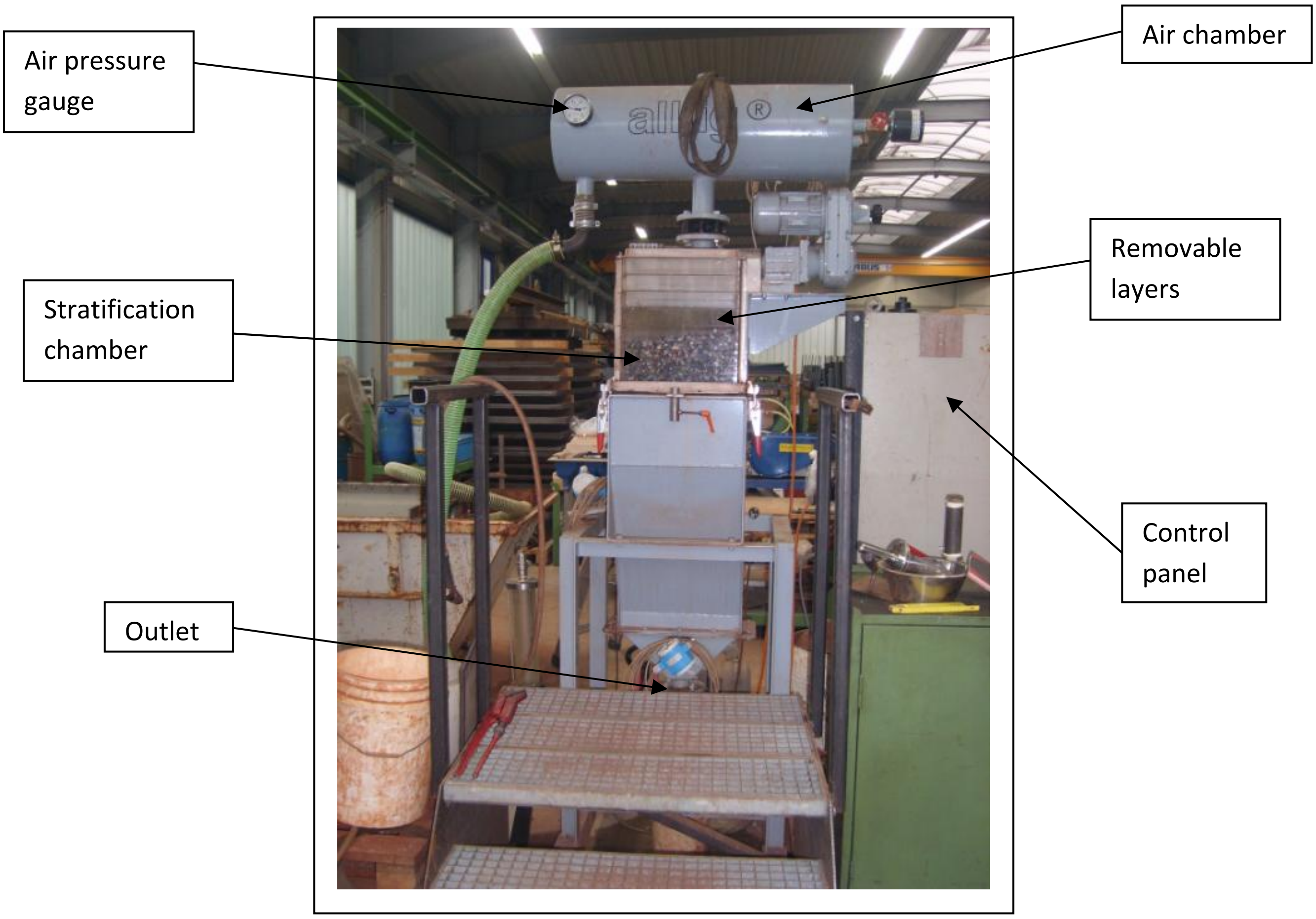

Figure 3: Photograph of the trial equipment

1.3 Trial objectives

Two trials were performed, each using a different feed material and with a different objective:

a) The objective of the first trial was to test whether the wet jig could successfully separate a saleable copper rich fraction. Axion's market research indicates that the copper fraction will be saleable to conventional copper smelters if it contains less than 5% combustible material. Glass and stone in the copper fraction do not create a major problem for smelters but plastic and other combustibles cause excessive gas flows in the furnace; and

b) The objective of the second trial was to test whether the wet jig could successfully separate different density plastics - for example polypropylene (Specific Gravity (SG)

~0.95), polystyrene (SG ~ 1.02-1.05), ABS (SG ~1.04-1.08) from other heavy plastics (for example filled plastics and PVC SG ~1.2-1.3).

1.4 Sample material

The following samples were tested during the trial:

a) Copper rich plastics mixture from small WEEE (8-12mm plastic particle size); and
b) A sample of mixed plastics from small WEEE (Axion product PS07) for bulk plastic separation (8-12mm).

All of the material was sourced from Axion's own WEEE processing plant in Salford, UK.

For the trial on the laboratory-scale jig at Allmineral approximately 30 litres of each sample was required to fill the stratification chamber.

1.5 Trial methodology

Each of the samples of material were weighed and added to the stratification chamber.

The Allmineral engineer used his experience to determine the settings for the machine in order to achieve a separation. These results including the feed quantity, pulsation frequency and pulsation amplitude are shown in the individual trial section.

After the jigging had stopped the samples were collected from the chamber, weighed, bagged and labelled for return to Salford.

The samples from trial 1 were analysed by hand sorting of the different components present. Typically this included wood, plastic, rubber, copper, PVC coated wires, PCBs, stone/glass, other metals and fines. The analysis was based on a sample taken from each of the product levels.

2.0 Trial 1: Recovery of copper from a copper plastic mixture

2.1 Trial objective

The objective of this trial was to recover the copper from a copper-rich WEEE plastics mixture in order to produce a copper fraction which can be sold on for smelting. Copper has a density of 8.96 g/cm^3 and the plastic has a density in the range of 1-1.5 g/cm^3. With this difference in densities a separation using a wet jig should be possible.

2.2 Feed material

The feed material is illustrated in Figure 4 .

Figure 4: Photograph of copper-rich plastic feed material

2.3 Result

The initial results of the trial are shown in

Table 1.

	Trial		1
Feed	Material		Copper-rich plastic fraction
	Weight	kg	10.84
Equipment Set up	Frequency of stroke	stroke/min	76
	Amplitude of stroke	mm	30-35
	Air Pressure	bar	0.2
		Weight (kg)	Sample Description
Level	7	1.25	Wood, plastic & PVC coated wires
	6	1.59	Wood, plastic & PVC coated wires
	5	1.71	Concentrated wood, plastic and PVC coated wires
	4	1.86	Wood, plastic & PVC coated wires
	3	1.8	Wood, plastic & PVC coated wires
	2	1.15	Plastic, PVC wires, small amount of copper wires
	1	1.65	Plastic, PVC wires, larger amount of copper wires
	Underflow	0.38	Wood & fine wire, little organic silt, water content approx. 50%
	Total	11.39	
	Gain	0.55	Due to water

Table 1: Initial results taking during Trial 1

The mass balance was adjusted to account for the underflow being dried after the trial which reduced the overall gain, as shown in Table 2.

	Kg
Input	10.84
Output	11.39
Underflow (wet)	0.38
Underflow (dry)	0.18
(Wet)-(Dry)	0.20

New Output	11.19
Gain	0.35

Table 2: Adjusted mass balance to take into account dried underflow

2.4 Photograph of result samples

Photographs of the seven samples collected from the stratification chamber are shown in Figure 5 to Figure 11, in order from the top sample, level 7, to the lowest sample, level 1. Figure 5 shows the top level which formed in the jig and it can be seen in the photographs that there is only plastic in this fraction. Moving down the jig levels the photographs show the material changing. It can clearly be seen in Figure 11 that at the bottom of the jig, level 1, the copper and PVC coated wires are concentrated.

Figure 5: Photograph of Trial 1 level 7

Figure 6: Photograph of Trial 1 level 6

Figure 7: Photograph of Trial 1 level 5

Figure 8: Photograph of Trial 1 level 4

Figure 9: Photograph of Trial 1 level 3

Figure 10: Photograph of Trial 1 level 2

Figure 11: Photograph of Trial 1 level 1

2.5 Analysis of results samples

Hand sorting of samples from each of the levels was conducted at Axion's laboratory in Salford, the results of which are shown in Table 3.

Trial	Material	Level	Total Level Weight (wet)		Composition																Weight of hand sorted material	Hand sort weight as % of total sample
					Wood		Plastic		Rubber		Copper		PVC wires		Stone/		PCB's		Fines			
			kg	g	g	%	g	%	g	%	g	%	g	%	g	%	g	%	g	%	g	%
1	Copper rich plastic fraction	Feed	10.84	10840	38.5	3%	920.2	67%	204.8	15%	23.8	2%	52.0	4%	21.0	2%	14.4	1%	96.1	7%	1370.8	12.6%
		7	1.25	1250	12.7	4%	234.4	78%	37.9	13%	0.6	0.2%	2.2	1%	0.0	0%	1.3	0%	12.8	4%	301.9	24.2%
		6	1.59	1590	6.6	3%	188.4	77%	36.8	15%	0.1	0.0%	0.9	0%	0.0	0%	1.2	0%	11.6	5%	245.6	15.4%
		5	1.71	1710	8.4	3%	175.4	71%	47.9	19%	0.4	0.2%	1.7	1%	0.0	0%	0.7	0%	11.7	5%	246.2	14.4%
		4	1.86	1860	3.8	3%	99.7	70%	23.3	16%	0.6	0.4%	2.2	2%	0.0	0%	1.6	1%	11.7	8%	142.9	7.7%
		3	1.8	1800	4.3	3%	96.8	67%	28.4	20%	0.9	1%	2.1	1%	0.0	0%	1.8	1%	11.2	8%	145.5	8.1%
		2	1.15	1150	2.1	1%	85.0	58%	22.2	15%	2.6	2%	15.3	10%	2.4	2%	3.5	2%	12.7	9%	145.8	12.7%
		1	1.65	1650	0.2	0.2%	41.1	33%	6.3	5%	12.8	10%	20.8	17%	4.8	4%	3.6	3%	34.4	28%	124.0	7.5%
		Underflow dry	0.179	179																		
	Total weight OUT		11.189	11189											Total weight of hand sort						1351.9	12%
	Gain due to water		0.349	349																		

Table 3: Results of hand sort for Trial 1

Level	% copper	% copper in level / % copper in feed
Feed	2%	1
7	0.2%	0.1
6	0.0%	0.0
5	0.2%	0.1
4	0.4%	0.2
3	1.0%	0.5
2	2.0%	1.0
1	10.0%	5.0

Table 4: Results to show how the copper concentrated down the jig levels

Table 4 shows the effect of the copper concentration within the levels of the jig. Using the ratio of the percentage of copper in a level to the percentage of copper in the feed a number greater than 1 shows a concentrating effect whilst a number less than 1 indicates the opposite. Level 1 value is 5.0 which means the copper has concentrated into this level as all the other values are 1 or below.

Figure 12 shows the hand sorted results, scaled up from the hand sort sample to the entire trial mass balance.

Feed	kg	%
Total	10.84	100%
Wood	0.30	3%
Plastic	7.28	67%
Rubber	1.62	15%
Copper	0.22	2%
PVC Wires	0.41	4%
Stone & Glass	0.17	2%
PCBs	0.11	1%
Fines	0.76	7%

WET JIG
Trial 1
Copper Rich Plastic

Total	9.36	86%
Wood	0.29	3%
Plastic	6.71	72%
Rubber	1.50	16%
Copper	0.04	0.4%
PVC Wires	0.19	2%
Stone & Glass	0.02	0.2%
PCBs	0.08	1%
Fines	0.55	6%

Level 1	kg	%
Total	1.65	15%
Wood	0.00	0%
Plastic	0.55	33%
Rubber	0.08	5%
Copper	0.17	10%
PVC Wires	0.28	17%
Stone & Glass	0.06	4%
PCBs	0.05	3%
Fines	0.46	28%

Underflow	kg
Wet	0.38
Dey	0.178

Figure 12: Schematic of the Trial 1 results

For the purpose of the analysis levels 2 to 7 have been grouped together whilst level 1 remains by itself. This in effect gives a binary separation into two product streams and is required in order to apply the Q and R separation efficiency convention to the results.

For this trial the product separation efficiency, Q, is the probability that the target product, copper, is correctly sorted into the product stream, level 1.

The reject separation efficiency, R, is the probability that the secondary products, in this case everything else, is correctly sorted into the second stream, levels 2 to 7.

The results are shown in Table 5.

Q	77%
R	80%
% Copper in Level 1	10%
% Copper in Levels 2-7	0.4%
% Other material in Level 1	90%
% Other material in Levels 2-7	99.6%

Table 5: Results of Trial 1

2.6 Discussion of results

The results show that the copper did concentrate in the lowest level of the jig. 77% of the copper present in the feed was recovered to the product stream, which was upgraded from a concentration of 2% to a concentration of 10%.

The product separation efficiency, Q, of 77% means that over three quarters of the feed copper was correctly sorted into the product fraction. The reject separation efficiency, R, of 80% means that a high proportion of the other material is sorted into levels 2 to 7. However the fact that level 1 contains 90% of other material means that the copper purity is not high enough for the fraction to be saleable. The material could not be processed by copper smelters as the plastic concentration at 33% is well above the acceptable combustible material limit of 5%.

Discussions with the Allmineral engineers operating the test unit indicated that it would be difficult to improve the separation significantly given the wide range of particle sizes and shapes in the feed.

2.7 Conclusions from trial

A wet jigging trial with WEEE plastic material containing 2% fine copper demonstrated recovery of 77% of the metal into a heavy stream containing 10% copper. However a stream of this composition is not suitable for processing by copper smelters because of the low copper content and high combustibles content. A continuous system is likely to achieve greater levels of metal purity than demonstrated within this trial and it is thought would achieve the less than 5% combustibles requirement.

3.0 Trial 2: Mixed plastic from WEEE

3.1 Trial objective

The objective of this trial was the separation of a mixed plastic material to produce well defined density fractions of 1.0-1.08 and 1.08-1.2. This was to see if the technique could be used to separate polystyrene (PS), acrylonitrile butadiene styrene (ABS), polypropylene (PP) etc from heavier plastics such as PVC using water rather than a higher density liquid as the separation medium.

3.2 Feed material

The feed material used for this trial was a bulk plastic mixture known as Axion grade PS07 which comes from processing WEEE at Axion's plant in Salford, illustrated in Figure 13 .

Figure 13: Photograph of mixed plastic feed material

3.3 Results

The stratification chamber was observed whilst the jig was running and it became apparent that the particles could not move around in the chamber and that the bed was not stratifying correctly. It was unclear why this was occurring.

The 3kg of material formed only three product levels and was removed from the stratification chamber.

11kg of new material was added and the test was repeated. Again the same problem occurred. The particles were unable to move freely as the bed was too closely packed.

Figure 14: Photograph of the wet jig in operation with the mixed plastic material

Figure 14 shows the stratification of the wet jig during trial 2 with the second load of feed material. As the water pulsed up and down it was observed that the particles only moved up and down slightly and some particles blocked the movement of other particles.

3.4 Photographs of product samples

The following three photographs show the three levels of plastic which were collected.

Figure 15: Photograph of Trial 2 level 1

Figure 16: Photograph of Trial 2 level 2

Figure 17: Photograph of Trial 2 level 1

3.5 Analysis of results samples

From visual inspection of the samples, it was clear that no separation had occurred, so the decision was made not to do any further analysis.

3.6 Conclusions from trial

Initial indications from the trial are that wet jigging of a plastic mixture in the 8-12mm particle size range is unlikely to achieve a separation between lighter plastics such as polystyrenes and heavier plastics such as PVC.

There are several possible explanations for why the separation did not work.

The PS07 sample contains plastic in the density range 1.0 to 1.2. The aim of the trial was to produce a 1.0 to 1.08 fraction and a 1.08 to 1.2 fraction.

The Allmineral technicians advised that from their observations of this trial it appears that the density differences between the particles are too small to be resolved by a wet jig.

One suggestion was that the particles were too closely packed within the chamber, which inhibited free movement of the material into the correct density levels.

One possible way to improve the separation could be to increase the amplitude of the pulses further in order to reduce the packing density of the particles. This was attempted during the trial but the limit of the adjustment of the trial rig was reached. It is likely that running with a very high pulse amplitude could cause other problems with the operation of a continuous wet jig.

4.0 Overall final conclusion of trial

Wet jigging of a copper-rich plastic material containing 2% copper resulted in recovery of 77% of the copper present in the feed, into a heavy stream containing 10% copper. A stream of this composition is not suitable for processing by copper smelters because of the low copper content and high combustibles content. In order to increase the concentration of copper to a high enough level to be acceptable to metal processors it would be necessary to combine the level 1 layer from several batch runs and then process them together as a single batch, which is what would happen in a continuous system.

Initial indications from the trial are that wet jigging of a plastic mixture in the 8-12mm particle size range is unlikely to achieve a separation between lighter plastics such as polystyrenes and heavier plastics such as PVC.

Therefore wet jigging has some potential for recovering fine copper from WEEE materials, although the copper concentrate produced from a single run is still too high in plastics. Wet jigging does not appear to be suitable for separating plastics where the density differences between particles are very small.