DOE COPY
DOE/CS/24315--T8

EVALUATION OF TROMMELS FOR
WASTE-TO-ENERGY PLANTS, PHASE 1 REPORT OF
THE DONCASTER AND BYKER TEST SERIES

DOE/CS/24315--T8

DE82 008580

by

J. Barton
Warren Spring Laboratory
Stevenage, Herts, England
December 1981

MASTER

DISCLAIMER

This book was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise, does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

prepared under contract to the

National Center for Resource Recovery, Inc.
Washington, D.C.

and

U.S. Department of Energy
Assistant Secretary for Conventional Renewable Energy
Office of Reusable Technologies
Washington, D.C.

Contract DE-AC03-80CS-24315 Task 8

NOTICE

TIC Avail. Only

THIS REPORT IS ILLEGIBLE TO A DEGREE
THAT PRECLUDES SATISFACTORY REPRODUCTION

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency Thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

DISCLAIMER

Portions of this document may be illegible in electronic image products. Images are produced from the best available original document.

CONTENTS

	<u>Page</u>
Figures	iv
Tables	vi
Summary	1
Glossary	2
1. Introduction	3
2. Doncaster	3
Experimental Method	3
Sampling Analysis Procedure	6
Experimental Results	7
Processing Conditions	7
Refuse Processing Results - Weight Basis	7
Refuse Processing Results - Number Basis	17
Refuse Processing Results - Surrogates	22
3. Byker Testwork	28
Experimental Method	28
Sample Analysis Procedure	31
Experimental Results and Discussions	31
4. Comparative Discussion of the Byker and Doncaster Tests	42
Test Procedures	42
Analysis Procedure	42
Results	43
5. Conclusions	45
Doncaster	45
Byker	45

CONTENTS (continued)

	<u>Page</u>
Appendices	
A Size, Category, Weight and Number Results for the Doncaster Tests . .	47
Test Run 1	48
Test Run 2	51
Test Run 3	54
Test Run 4	57
Test Run 5	60

FIGURES

<u>Number</u>		<u>Page</u>
1	Sketch of Doncaster Circuit Operated for Trommel Tests	4
2	Doncaster Plant Trommel	4
	Screen Plates	5
	Spike and Lifter Dimensions	5
	Spike and Lifter Positions	5
3	Test 1, Feed and Product Weight Size Distributions	12
4	Test 2, Feed and Product Weight Size Distributions	12
5	Test 3, Feed and Product Weight Size Distributions	12
6	Test 4, Feed and Product Weight Size Distributions	12
7	Test 5, Feed and Product Weight Size Distributions	12
8	Test 1, Feed and Product Number Size Distributions	21
9	Test 2, Feed and Product Number Size Distributions	21
10	Test 3, Feed and Product Number Size Distributions	21
11	Test 4, Feed and Product Number Size Distributions	21
12	Test 5, Feed and Product Number Size Distributions	21
13	Test 1, 9 r.p.m.	26
14	Test 2, 9 r.p.m.	26
15	Test 3, 9 r.p.m.	26
16	Test 4, 6 r.p.m.	27
17	Test 5, 12 r.p.m.	27
18	Byker Flowsheet for NCRR Testwork	29
19	Screen Configuration of Byker Trommel	29
19a	Screen Configuration (cont'd)	30
19b	Screen Configuration (cont'd)	30
19c	Screen Configuration (cont'd)	30

FIGURES (continued)

20	Testwork - Feed Size Distribution, wet basis	38
21	Testwork - Feed Size Distribution, dry basis	38
22	Testwork - Product Size Distribution, wet basis	38
23	Testwork - Product Size Distribution, dry basis	38
24	Recovery of Size Fractions Against Feed Rate - Doncaster and Byker Tests	44

TABLES

<u>Number</u>		<u>Page</u>
1	Screen Size Adopted for Sample Analysis	6
2	Handsorted Category Definitions	7
3	Testwork - Test Conditions	8
4	Testwork - Mass Balance and Size Distribution	9
5	Testwork - Weight Size Distribution of Feed and Products	10
6	Testwork - Weight Category Assays and Distributions	11
7	Screening Efficiency Results for 40 mm Aperture Screen Section . .	14
8	Weight Distribution of Sized Categories between Fines and Intermediate Product Streams	15
9	Separation Efficiency of the Intermediate Screen Apertures	16
10	Intermediate Products, Effective Cut Points at Various Per Cent Weight Passing	16
11	Ash and Calorific Value Results	17
12	Theoretical Weight per Particle Values for Sphere, Plates and Measured Weights	18
13	Testwork - Number Per Cent Distribution of Size Fractions	19
14	Testwork - Number Size Distribution of Feed and Products	20
15	Category Weight per Particle Values for -2+1" and -1+1/2" Size Fractions in Different Trommel Products	22
16	Per Cent Distribution of Surrogate Particles in Screen Products . .	24
17	Approximate Surrogate Flow Times Along Trommel Axis	25
18	Testwork - Mass Balance and Size Distribution	32
19	Testwork - Wet and Dry Weight Size Distributions - Fines A and B Product Samples	33
20	Testwork - Wet and Dry Weight Size Distributions - Intermediate Product Samples	34

TABLES (continued)

21	Testwork - Wet and Dry Weight Size Distributions - Oversize Product Samples	34
22	Testwork - Calculated Feed Results from Product Samples, Wet and Dry Weight Distributions and Moisture Contents	35
23	Test 1 - Raw Refuse Feed	36
24	Test 2 - Raw Refuse Feed	37
25	Testwork - Wet and Dry Category Assay of Raw Refuse Feed 3 and Wet Assays of Feeds for Tests 1 and 2	39
26	-1/2" Screening Efficiency, Recovery and Grade Results, Fines A and B Screens	39
27	Distribution, Recovery and Grade of Material about the Intermediate Screen Apertures	40
28	Ash and Calorific Value Results	41

EVALUATION OF TROMMELS FOR WASTE TO ENERGY

PLANTS, PHASE 1. REPORT OF THE DONCASTER

AND BYKER TEST SERIES

J. Barton
Warren Spring Laboratory
Stevenage, Herts, England

SUMMARY

This investigation has been sponsored by the US Department of Energy, under the project leadership of the National Center for Resource Recovery, to provide data which will be used in proving and developing a given mathematical model of trommel operations.

The report describes the results obtained from the first phase of the investigations on two commercial scale trommels, one installed at the Doncaster reclamation plant and the other at Byker.

These results highlight the current lack of understanding of trommel processes in that both series unequivocally demonstrate considerable errors in the design ratings assigned to each unit. Accordingly, the results of the Byker tests relate largely to overloaded conditions, particularly in the fine screen section, whilst those from the Doncaster tests represent conditions of considerable underloading. They describe extreme and generally insensitive conditions which, to some extent, have masked positive trends in performance.

The nature and composition of the feed material is shown to be an important parameter; the screening mechanism in trommels being selective and favouring higher recoveries of bulky, dense particles with tendencies towards reduced probabilities of "passing" for the flake-like shapes.

Valuable information relating to the effects of trommel speed, installation of lifters and scrolls, aperture size selection and mode of particle presentation to the screen plate has been reported in addition to the experience and methods of interpreting data resulting from the use of surrogate pulses.

Glossary of Terms and Abbreviations

Fines product:	Material passing the small aperture trommel screens installed at Doncaster (40 mm) and Byker (10 x 50 mm, Fines A), (25 x 100 mm, Fines B).
Intermediate product:	Material passing the large aperture trommel screens installed at Doncaster (200 x 350 mm) and Byker (nominally 150 mm).
Oversize product:	Material not passing any of the apertures in the trommel screens installed at Doncaster and Byker.
Product/feed sample:	Sample of the Doncaster or Byker Trommel products or feeds.
Bulk samples:	Sample of a Trommel feed or product before subsampling for subsequent analysis.
Size fraction:	Screened fraction obtained from the screen analysis procedure carried out on square mesh screens e.g. -2"+1" material.
Sample moisture:	Wet weight basis determined by drying sample at 105°C. i.e. % moisture = $\frac{\text{wet weight} - \text{dry weight}}{\text{wet weight}} \times 100$
Wet size analysis:	Calculated from the undried weights of the size fractions after screening.
Dry size analysis:	Calculated from the weights of the size fractions after screening and drying.
Category:	Individual material components in the refuse e.g. paper, glass, stones etc.
Distribution:	This refers to the proportions (%) in which any category in the feed divide between the products of a process.
Recovery:	Refers to the % distribution of a category into any one product (usually the concentrate) e.g. the % of paper extracted from the feed and collected in the fuel (RDF).
Grade:	Weight percentage of any sample occupied by a particular component.
Screening efficiency:	A technical term used to describe the performance of the trommel in terms of both the recovery and grade of the products. e.g. Screening Efficiency of the -40 mm aperture screen at Doncaster for -1" material would be:-

$$\text{Screening Efficiency } (-1")\% = \frac{R_{-1"} - C}{100 - C} \times \frac{F_{-1"} - f_{-1"}}{100 - f_{-1"}}$$

where $R_{-1"}$ = % recovery of -1" to undersize.
 C = weight (as a percentage of the feed) reporting to the undersize product (-40 mm fines product)
 $F_{-1"}$ = the weight percentage of the undersize product which is finer than 1"
 $f_{-1"}$ = the weight percentage of the feed which is finer than 1".

te h ⁻¹	= tonnes (1000 kg) per hour
nd	= not determined
RPM	= revolutions per minute

1. INTRODUCTION

This report is concerned with the performance testing of two commercial scale trommels, used for size separation of bulk municipal waste, and represents the first phase of the testwork carried out by Warren Spring Laboratory (WSL). The work is sponsored, through the National Center of Resource Recovery (NCRR), by the US Department of Energy, in an attempt to develop and prove mathematical models for use in designing rotary screens and in predicting their performance.

The commercial scale trommels examined during this testwork are sited at Doncaster and at Byker. The former is operated by the South Yorkshire County Council and the latter by the Tyne and Wear County Council. The major difference between the two plants is that raw refuse is processed in the Doncaster plant trommel and pulverised refuse in the Byker plant trommel. Both plants produce a magnetic ferrous fraction as well as a refuse derived fuel prepared by upgrading the intermediate sized product from the rotary screen using air classification, magnetic separation, further size reduction and pelletisation. However, they differ in many respects; the feed to the Byker trommel is preshredded (-7") whilst that at Doncaster is treated as received and the latter plant also has additional facilities for glass and paper recovery.

The contents of this report are intended to provide detailed accounts of the Byker and Doncaster tests and to compare the two screening operations highlighting the effects of the major variables investigated.

The second phase of the test programme, which is scheduled to start in August 1981, is to be carried out on the pilot plant trommel installed at Warren Spring Laboratory, where closer control of trommel operating conditions and more comprehensive sampling facilities should enable a more precise appraisal of the tested variables to be made.

2. DONCASTER TESTWORK

The process design objectives of the Doncaster trommel were as follows:

- (a) Removal of high ash and high moisture content fine material (both "natural" fines and "processed" fines from breakage of friable glass and ceramic categories during trommelling).
- (b) Scalping of an oversize product to remove large, bulky, difficult-to-process items, together with a concentrate of the better quality large size paper category thus leaving an intermediate size fraction amenable to air classification and the production of a high quality light fuel fraction.

The selection of aperture sizes for both the intermediate and fine screen sections was based on pilot scale work, carried out by Warren Spring Laboratory, using Doncaster refuse when the need for efficient removal of fines to ensure a low ash fuel product was seen to be imperative. The intermediate screen aperture size was to be selected from a 200 to 300 mm range based on the relative market requirements for paper fibre and the fuel product. The large aperture size installed (200 x 350 mm) for these tests reflects the current low interest on fibre recovery and the associated need to maximise recovery of combustible components to the fuel circuit.

2.1 Experimental Method

Figure 1 shows the relevant part of the Doncaster circuit which was operated for the trommel testwork. Figs 2a, b, c and d show the basic design of the trommel, including the screen aperture sizes and shape and the size and position of lifters and spikes.

Referring to Fig. 1 the trommel was inspected and cleaned before each run and the rotational speed adjusted to give the desired test conditions. The test feed rate was governed by adjusting the speed of the main plate conveyor (1). For convenience, each run was timed from the moment material discharged from the plate conveyor onto the trommel feed conveyor (2). This conveyor has a reversible drive to enable feed samples to be diverted from the plant into a sample skip placed beneath the open boot of the conveyor. The feed material enters the first blank section of the trommel where spiked lifters mix and liberate it prior to entering the 40 mm fine screen section. The fine material, passing the 40 mm apertures, is collected by a pocketed conveyor (3) which discharges onto the conveyors (4) and (5) before collection in the fines

13263

FIG. 1 SKETCH OF THE DONCASTER CIRCUIT OPERATED FOR TROMMEL TESTS

GENERAL TROMMEL SPEED - VARIABLE: 3-13 RPM

SECTION a - BLANK SECTION WITH 10 'T' SPIKES FOR BAG BURSTING

SECTION b and c - FINES SCREENS 15/8 DIA. APERTURES

SECTION d and e - INTERMEDIATE SCREENS 200 x 350 mm APERTURES, ARCHED LANDS

SECTION f - BLANK SECTION

SCREEN PLATE SIZES - FINES 1302 x 1025 mm (1025 mm CIRCUMFERENTIAL)

INTERMEDIATES 1110 x 1025 mm (1025 mm CIRCUMFERENTIAL)

SCREEN RING - 8 SCREEN PLATES PER SECTION

SCROLLS S1 - 200 mm HIGH, PITCH 2500-2600 mm

S2 - 100 mm HIGH, PITCH 2500-2600 mm

dimensions in mm

13264

FIG. 2a DONCASTER PLANT TROMMEL

compactor skip. Sampling of this stream was effected by a diverter flap and chute installed between conveyors 4 and 5.

Material traversing the 40 mm apertures passes to the next section where it is screened at 200 x 350 mm, the undersize (the intermediate size fraction) reporting onto conveyor 9 and the air classifier feed conveyor 10. With the induced and forced draft fans switched off, this intermediate material reported to the heavy discharge conveyor (11) where it was sampled via a diverter plate installed at the top.

Oversize material from the 200 x 350 mm apertures discharged onto conveyor 6 and, for the purposes of accuracy, via conveyor 8 into a mobile tractor (the weight 1.7 te compared with 12 te for compactor skip and lorry). For sampling, the stream was redirected onto conveyor 7, which was manually controlled to inch the resulting sample to a point where it could be easily removed from the belt and discharged into the sample skips.

The sampling procedure adopted for the tests involved taking three incremental samples at timed intervals during the run. In all cases the feed sample was taken five minutes before product samples to ensure re-establishment of steady state conditions for the latter.

At appropriate intervals during the run surrogate particles were introduced into the refuse feed via conveyor 2 and their distribution between products was established. To determine the distribution of the one inch wooden cubes about the 40 mm screen section the underflow was diverted from the fines compactor by reversing conveyor 4. This resulted in the material falling onto a 17 mm vibrating screen, the underflow (-17 mm) reported back to the fines compactor, the overflow (+17 mm), including the 1 inch cubes, being collected in a sample skip to be hand picked and counted. Also, during surrogate addition, the fines stream was photographed by a cine camera mounted over conveyor 3 to establish exactly when and how the cubes exit from the fine apertures.

The procedure adopted to determine the number distribution for the larger surrogates, i.e. the plastic bottles, white cards and Hollerith computer cards, about the 200 x 350 mm aperture screens involved handpicking from the oversize material as it passed along conveyor 8, followed by counting.

No attempt was made, either for the wooden blocks or large surrogates, to determine directly the number of surrogate particles reporting in the intermediate streams, the distributions being calculated by difference.

2.1.1 Sampling Analysis Procedure

For each run, the three incremental samples of feed and products were combined and the weights and volumes of the resulting 'bulk' samples determined.

Each bulk sample was mixed, coned and quartered to provide a sample for moisture determination, and another sample for size, weight, number and category determinations.

This second sample was screened at the appropriate sizes for the product stream (Table 1) beginning with the largest screen size in each case.

TABLE 1. - Screen Sizes Adopted for Sample Analysis

Sample	Screen sizes (6, 5, 4, 3, 2, 1, 1/2 inch)
Feed	All sizes from 6 to 1/2 inch
Oversize	All sizes from 6 to 1/2 inch
Intermediates	All sizes from 6 to 1/2 inch
Fines	2, 1, and 1/2 inch only

Each of the resulting size fractions was weighed and sealed in plastic bags for handsorting and number counting back at the laboratory.

Handsorting and category number counting was undertaken on all size fractions except the -2 + 1", - 1 + 1/2" and -1/2" of the oversize sample and -1/2" of all the other product samples. The category definitions used are given in Table 2.

A limited number of samples were counted on site, at Doncaster, and it was noted that the presence of grass, particularly in the larger size fractions, caused a significant increase in number of particles for a given weight of sample. As the grass tended to be "tangled together" it was decided that, for number counting purposes, the grass content of a sample would be considered to contribute one particle only.

TABLE 2. - Handsorted Category Definitions

Paper and card	as described
Plastic film	wrapping material, sacks
Textiles	synthetic and natural woven fabric, carpets
Cinder	unburnt and burnt solid fuel
Glass/stones	as described
Putrescible	inc dense plastic, wood, kitchen and garden waste
Metal	ferrous and non ferrous metals
Conglomerates	composite items, bagged items, unliberated items
Fines	all -1/2" material

2.2 Experimental Results

2.2.1 Processing Conditions

The basic processing conditions, including surrogate additions, for the five tests are given in Table 3.

The rag conveyor operated during the first three tests but then sustained damage which resulted in tests 4 and 5 being carried out with its belt stationary. Thus the equipment acted as a static beam inside the trommel with material building up on it during the tests. To prevent further damage the build up was cleared manually at approximately 15 minute intervals. This interrupted the mode of operation and increased control problems with respect to the even loading of the plate conveyor. The front end loader driver tended to overfeed the circuit causing a thicker than normal burden of refuse on the conveyor and resulting in a higher feed rate than expected. Also the feed rates were generally higher than had been anticipated, at the selected plate conveyor speeds, because of the higher-than-normal bulk density of the feed material, collected from "open fire" coal mining districts where the refuse contained a high proportion of fine ash and cinder.

Short term variations in refuse feed rates, caused by the tendency of the raw refuse to discharge from the plate feeder in phase with the upstands (upstand plates (4" depth) at 3 ft intervals), appeared to be smoothed out by the action of the spiked lifters in the first blank section of the trommel. However, there were some longer term feed variations caused by bridging in the feed hopper and these were characterised by a lean period of feed followed by a short 'high load' period representing the 'bridged' and 'bridge collapsed' condition respectively. The effect of bridging was clearly observable in the trommel loading conditions and, although it was not considered to be significant in terms of the overall mass balance and size distribution data, might well have influenced the interpretation of the results of surrogate additions which were essentially "pulse" additions and thus much more dependent on the actual trommel loading at any one instant.

For tests 1 and 2 all surrogate additions were added as a single pulse, however, observation of the trommel conditions for the large surrogates showed them behaving more like discrete plugs of material rather than being intimately mixed with the refuse feed. Therefore, it was decided that incremental additions of large surrogates would be used for tests 3, 4 and 5 with 45 second intervals being selected for the large cards and the Hollerith cards, and 30 second intervals between bottle additions.

2.2.2 Refuse Processing Results, Weight Basis

The basic weight, number, category and size data obtained on all test samples are given in Appendix A to this report and extracts from these data have been tabulated:-

Table 4 gives the mass balance, product moistures and bulk densities and the weight distribution of size fractions to the trommel products. Thus for test 1, 8.593 tonnes of fines, representing 64.8% of the feed, were produced. They had a moisture content of 19.9%, a bulk density of 595 kg m⁻³ and contained 16.3, 84.4 and 92.5% (by weight) respectively of the -2 + 1", -1 + 1/2" and -1/2" fractions in the feed.

Table 5 gives the per cent weight size distributions of the products, calculated feed and measured feed and these results are represented graphically in Figs 3 to 7 as cumulative weights per cent passing the sieve aperture sizes used for the analyses.

Table 6 gives the weight category assays of the products, calculated feed and measured feed and the weight category distribution in these products.

It should be noted that -1/2" material reported in this table includes material originally reporting in coarser size fractions but which, due to transport and subsequent handling had broken down into additional fines. Thus there is an increase in -1/2" material reported, compared with Table 5, and a similar distortion of the reported weight per cent distribution of -1/2" material compared with Table 4.

TABLE 3. - NCRR Doncaster Testwork - Test Conditions

	Test 1		Test 2		Test 3		Test 4		Test 5	
Date of Test	21.10.80		22.10.80		23.10.80		24.10.80		24.10.80	
Feed Stock										
Area 1 Tonnes	Rossington	7.98 te	Rossington	7.5 te	Armthorpe	6.54 te	Armthorpe	7.12 te	Hyde Park	5.71 te
Area 2 Tonnes	Edlington	6.78 te	Edlington	6.9 te	Rossington	6.58 te	Rossington	6.87 te		
*Target Feedrate Tonnes/H	15		5		10 [13]		10 [13]		10 [13]	
Measured Feed rate Tonnes/H	17.28		8.49		12.4		17.27		14.46	
Plate Conveyor Speed Ft/min	7.2		3.3		4.5		4.5		4.5	
Trommel Speed RPM	9		9		9		6		12	
Rag Conveyor	Operating		Operating		Operating		Static		Static	
Duration of Test Mins	46		63		56		37		35 1/2	
Surrogate Additions										
1 inch wood cubes	1 x 2000		1 x 2000		1 x 2000		1 x 2000		1 x 2000	
261 x 261 mm White Cards	1 x 800		1 x 800		3 x 267		3 x 266/1 x 400		3 x 267	
197 x 147 x 127 mm Large Bottles	1 x 160		1 x 160		1 x 80/2 x 40		1 x 80/2 x 40/1 x 80		1 x 80/2 x 40	
187 x 83 mm Hollerith Cards	1 x 9750		1 x 9750		3 x 1950		3 x 1950/1 x 1950		3 x 1950	

* Feed rates in brackets give revised target feed rates based on results of tests 1 and 2.

TABLE 4. - MCRR Doncaster Testwork, Mass Balance and Size Distribution Test 1 - (Wet Weight basis)

Trommel Speed 9 RPM, Run Time 46 mins, Calculated Feed Rate 17.28 tonnes per hour

Product	Weight Tonnes (te)	Distribution Weight %	Moisture Content Wt %	Bulk Density kg m ⁻³	Distribution of Size Fractions Reporting in Products - Square Mesh Aperture Screens (inches)							
					+6	-6 + 5	-5 + 4	-4 + 3	-3 + 2	-2 + 1	-1 + 1/2	-1/2
Fines	8.593	64.8	19.9	595	-	-	-	-	-	16.3	84.4	92.5
Intermediates	3.998	30.2	22.6	148	40.3	86.8	91.9	98.2	98.4	83.1	15.4	7.3
Oversize	0.667	5.0	17.6	44	59.7	13.2	8.1	1.8	1.6	0.6	0.2	0.2
Calc. Feed	13.258	100.0	20.6	-	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Measured Feed			21.4	360								

Trommel Speed 9 RPM, Run Time 63 mins, Calculated Feed Rate 8.49 tonnes per hour

Product	Weight Tonnes (te)	Distribution Weight %	Moisture Content Wt %	Bulk Density kg m ⁻³	Distribution of Size Fractions Reporting in Products - Square Mesh Aperture Screens (inches)							
					+6	-6 + 5	-5 + 4	-4 + 3	-3 + 2	-2 + 1	-1 + 1/2	-1/2
Fines	5.926	66.5	20.2	648	-	-	-	-	-	40.4	85.4	94.8
Intermediates	2.622	29.4	24.5	134	55.6	93.3	96.8	99.1	99.7	59.4	14.6	5.2
Oversize	0.364	4.1	24.6	36	44.4	6.7	3.2	0.9	0.3	0.2	<1	<1
Calc. Feed	8.912	100.0	21.6	-	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Measured Feed			23.4	224								

Trommel Speed 9 RPM, Run Time 56 mins, Calculated Feed Rate 12.4 tonnes per hour

Product	Weight Tonnes (te)	Distribution Weight %	Moisture Content Wt %	Bulk Density kg m ⁻³	Distribution of Size Fractions Reporting in Products - Square Mesh Aperture Screens (inches)							
					+6	-6 + 5	-5 + 4	-4 + 3	-3 + 2	-2 + 1	-1 + 1/2	-1/2
Fines	7.112	61.6	23.2	600	-	-	-	-	-	26.3	73.8	90.6
Intermediates	3.897	33.8	30.6	134	41.7	93.1	97.9	98.7	98.4	73.2	26.1	9.3
Oversize	0.533	4.6	23.0	45	58.3	6.9	2.1	1.3	1.6	0.5	0.1	0.1
Calc. Feed	11.542	100.0	25.7	-	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Measured Feed			26.0	184								

Trommel Speed 6 RPM, Run Time 37 mins, Calculated Feed Rate 17.27 tonnes per hour

Product	Weight Tonnes (te)	Distribution Weight %	Moisture Content Wt %	Bulk Density kg m ⁻³	Distribution of Size Fractions Reporting in Products - Square Mesh Aperture Screens (inches)							
					+6	-6 + 5	-5 + 4	-4 + 3	-3 + 2	-2 + 1	-1 + 1/2	-1/2
Fines	5.986	56.2	23.5	428	-	-	-	-	-	21.0	78.1	91.8
Intermediates	4.185	39.4	32.9	125	60.1	94.6	97.9	98.7	99.2	78.7	21.8	8.1
Oversize	0.471	4.4	22.4	40	39.9	5.4	2.1	1.3	0.8	0.3	0.1	0.1
Calc. Feed	10.642	100.0	27.2	-	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Measured Feed			28.8	143								

Trommel Speed 12 RPM, Run Time 35 1/2 mins, Calculated Feed Rate 14.46 tonnes per hour

Product	Weight Tonnes (te)	Distribution Weight %	Moisture Content Wt %	Bulk Density kg m ⁻³	Distribution of Size Fractions Reporting in Products - Square Mesh Aperture Screens (inches)							
					+6	-6 + 5	-5 + 4	-4 + 3	-3 + 2	-2 + 1	-1 + 1/2	-1/2
Fines	5.542	64.8	24.3	580	-	-	-	-	-	30.9	77.6	93.7
Intermediates	2.671	31.2	28.4	114	49.3	95.4	97.6	98.9	98.7	68.9	22.3	6.2
Oversize	0.340	4.0	15.1	34	50.7	4.6	2.4	1.1	1.3	0.2	0.1	0.1
Calc. Feed	8.553	100.0	23.2	-	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Measured Feed			23.1	176								

* Moisture content calculated on a wet weight basis, i.e. % moisture = $\frac{\text{wet wt} - \text{dry wt}}{\text{wet wt}} \times 100$

TABLE 5. - NCRR Doncaster Testwork. Weight Size Distributions of Feed and Products Test 1 (Wet Weight basis)

Size (inches)	Fines		Intermediates		Oversize		Calculated Feed Meas.		Measured Feed	
	Wt Distribution %	Cumulative Wt % Passing	Wt Distribution %	Cumulative Wt % Passing	Wt Distribution %	Cumulative Wt % Passing	Wt Distribution %	Cumulative Wt % Passing	Wt Distribution %	Cumulative Wt % Passing
+6	-	-	9.4	100.0	84.0	100.0	7.0	100.0	6.4	100.0
-6 + 5	-	-	7.5	90.6	6.9	16.0	2.6	93.0	4.3	93.6
-5 + 4	-	-	4.0	83.1	2.1	9.1	1.3	90.4	1.5	89.3
-4 + 3	-	-	18.1	79.1	2.0	7.0	5.6	89.1	6.9	87.8
-3 + 2	-	-	15.2	61.0	1.5	5.0	4.7	83.5	4.1	80.9
-2 + 1	2.0	100.0	22.1	45.8	1.0	3.5	8.0	78.8	10.2	76.8
-1 + 1/2	31.9	98.0	12.5	23.7	0.9	2.5	24.5	70.8	20.8	66.6
-1/2	66.1	66.1	11.2	11.2	1.6	1.6	46.3	46.3	45.8	45.8
Total	100.0		100.0		100.0		100.0		100.0	

Trommel Speed 9 RPM, Run Time 63 mins, Calculated Feed Rate 8.49 tonnes per hour

Product	Weight Tonnes	Distribution Weight %	Moisture Content Wt %	Bulk Density kg m ⁻³	Weight Per Cent Distribution of Size Fractions Reporting in Products Square Mesh Aperture Screens (inches)							
					+6	-6 + 5	-5 + 4	-4 + 3	-3 + 2	-2 + 1	-1 + 1/2	-1/2
Fines	5.926	66.5	20.2	648	-	-	-	-	-	40.4	85.4	94.8
Intermediates	2.622	29.4	24.5	134	55.6	93.3	96.8	99.1	99.7	59.4	14.6	5.2
Oversize	0.364	4.1	24.6	36	44.4	6.7	3.2	0.9	0.3	0.2	<1	<1
Calc. Feed	8.912	100.0	21.6	-	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Measured Feed			23.4	224								

Trommel Speed 9 RPM, Run Time 56 mins, Calculated Feed Rate 12.4 tonnes per hour

Product	Weight Tonnes (te)	Distribution Weight %	Moisture Content Wt %	Bulk Density kg m ⁻³	Distribution of Size Fractions Reporting in Products - Square Mesh Aperture Screens (inches)							
					+6	-6 + 5	-5 + 4	-4 + 3	-3 + 2	-2 + 1	-1 + 1/2	-1/2
Fines	7.112	61.6	23.2	600	-	-	-	-	-	26.3	73.8	90.6
Intermediates	3.897	33.8	30.6	134	41.7	93.1	97.9	98.7	98.4	73.2	26.1	9.3
Oversize	0.533	4.6	23.0	45	58.3	6.9	2.1	1.3	1.6	0.5	0.1	0.1
Calc. Feed	11.542	100.0	25.7	-	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Measured Feed			26.0	184								

NCRR Doncaster Testwork. Weight Size Distributions of Feed and Products Test 4

Size (inches)	Fines		Intermediates		Oversize		Calculated Feed Meas.		Measured Feed	
	Wt Distribution %	Cumulative Wt % Passing	Wt Distribution %	Cumulative Wt % Passing	Wt Distribution %	Cumulative Wt % Passing	Wt Distribution %	Cumulative Wt % Passing	Wt Distribution %	Cumulative Wt % Passing
+6	-	-	15.3	100.0	90.9	100.0	10.0	100.0	7.0	100.0
-6 + 5	-	-	5.4	84.7	2.8	9.1	2.3	90.0	6.4	93.0
-5 + 4	-	-	7.1	79.3	1.4	6.3	2.8	87.7	4.2	86.6
-4 + 3	-	-	19.2	72.2	2.3	4.9	7.7	84.9	13.1	82.4
-3 + 2	-	-	12.2	53.0	0.9	2.6	4.9	77.2	3.7	69.3
-2 + 1	3.9	100.0	20.7	40.8	0.7	1.7	10.4	72.3	15.4	59.6
-1 + 1/2	28.8	96.1	11.5	20.1	0.5	1.0	20.7	61.9	17.1	44.2
-1/2	67.3	67.3	8.6	8.6	0.5	0.5	41.7	41.2	27.1	27.1
Total	100.0		100.0		100.0		100.0		100.0	

NCRR Doncaster Testwork. Weight Size Distributions of Feed and Products Test 5

Size (inches)	Fines		Intermediates		Oversize		Calculated Feed Meas.		Measured Feed	
	Wt Distribution %	Cumulative Wt % Passing	Wt Distribution %	Cumulative Wt % Passing	Wt Distribution %	Cumulative Wt % Passing	Wt Distribution %	Cumulative Wt % Passing	Wt Distribution %	Cumulative Wt % Passing
+6	-	-	11.3	100.0	90.5	100.0	7.1	100.0	13.9	100.0
-6 + 5	-	-	10.4	88.7	3.9	9.5	3.4	92.9	4.3	81.1
-5 + 4	-	-	7.3	78.3	1.4	5.7	2.3	89.5	4.0	75.8
-4 + 3	-	-	16.7	71.0	1.5	4.3	5.3	87.2	4.5	72.8
-3 + 2	-	-	12.6	54.3	1.3	2.6	4.6	81.9	6.3	59.3
-2 + 1	3.8	100.0	17.8	41.7	0.4	1.5	8.1	77.9	6.8	53.0
-1 + 1/2	23.3	96.2	13.9	23.9	0.3	1.1	19.4	69.8	15.0	36.2
-1/2	72.9	72.9	13.0	10.0	0.8	0.8	50.4	50.4	41.2	41.2
Total	100.0		100.0		100.0		100.0		100.0	

Test 1

Product	Category Assay % Wt										Category Weight Per Cent Distribution in Products									
	Paper	Pl-Film	Textile	Cinder	Glass/Stone	Putrescible DPL/MC	Metal	Conglomerates	Fines (-1/2")	Total	Paper	Pl Film	Textile	Cinder	Glass/Stone	Putrescible DPL/MC	Metal	Conglomerate	Fines	
Fines	.6	<.1	<.1	13.9	3.5	6.2	<.1	<.1	75.4	100	3	1	<1	78	48	53	1	<1	92	
Intermediates	31.4	1.2	1.7	8.2	8.1	10.8	17.6	6.5	14.5	100	77	75	35	22	52	43	98	66	8	
Oversize	50.4	2.4	19.2	0	0	6.4	1.3	20.2	<.1	100	20	24	65	-	-	4	1	33	<1	
Calc. Feed	12.2	.5	1.5	11.4	4.7	7.6	5.4	3	53.7	100	100	100	100	100	100	100	100	100	100	
Meas. Feed	10.2	.5	2.4	12.6	7.6	9.4	6.5	.9	49.9	100										

Test 2

Product	Category Assay % Wt										Category Weight Per Cent Distribution in Products									
	Paper	Pl Film	Textile	Cinder	Glass/Stone	Putrescible DPL/MC	Metal	Conglomerates	Fines (-1/2")	Total	Paper	Pl Film	Textile	Cinder	Glass/Stone	Putrescible DPL/MC	Metal	Conglomerate	Fines	
Fines	.6	<.1	<.1	14.0	3.5	6.2	<.1	0	75.4	100	4	1	1	87	60	45	1	-	94	
Intermediates	28.9	1.9	3.3	4.7	5.3	14.9	25.6	5.4	10	100	76	52	59	13	40	47	97	95	6	
Oversize	56.6	3.1	16.1	0	0	17.4	4.3	2	.5	100	20	47	40	-	-	8	2	5	<1	
Calc. Feed	11.2	.7	1.6	10.7	3.9	9.2	7.7	1.7	53.3	100	100	100	100	100	100	100	100	100	100	
Meas. Feed	13.0	2.0	1.1	10.8	4.8	12.6	4.4	.4	50.9	100										

Test 3

Product	Category Assay % Wt										Category Weight Per Cent Distribution in Products									
	Paper	Pl Film	Textile	Cinder	Glass/Stone	Putrescible DPL/MC	Metal	Conglomerates	Fines (-1/2")	Total	Paper	Pl Film	Textile	Cinder	Glass/Stone	Putrescible DPL/MC	Metal	Conglomerate	Fines	
Fines	.5	<.1	0	9.6	3.8	7	.1	0	78.9	100	3	1	-	81	34	40	1	-	90	
Intermediates	26.3	2	2.4	4.1	13.5	18	13	4.9	15.8	100	77	78	45	19	66	57	97	72	10	
Oversize	49.5	3.9	22.9	0	0	7	2.2	13.9	.6	100	20	21	55	-	-	3	2	28	<1	
Calc. Feed	12.4	.9	1.9	7.3	6.9	10.7	4.5	2.3	53.1	100	100	100	100	100	100	100	100	100	100	
Meas. Feed	16.8	.6	3.7	6.1	5.6	11.6	3.9	.8	43.7	100										

Test 4

Product	Category Assay % Wt										Category Weight Per Cent Distribution in Products									
	Paper	Pl Film	Textile	Cinder	Glass/Stone	Putrescible DPL/MC	Metal	Conglomerates	Fines (-1/2")	Total	Paper	Pl Film	Textile	Cinder	Glass/Stone	Putrescible DPL/MC	Metal	Conglomerate	Fines	
Fines	.9	<.1	0	11.5	3.9	9.3	.3	<.1	73.9	100	3	1	-	96	45	32	4	1	91	
Intermediates	30.2	2.8	1.6	.6	6.7	25.7	10.9	10.8	10.7	100	81	84	98	4	55	63	95	81	9	
Oversize	53.4	4.5	.3	0	.3	19.2	.5	21.3	.5	100	16	15	2	-	<1	5	1	18	<1	
Calc. Feed	14.6	1.3	.6	6.7	4.9	16.2	4.5	5.2	46	100	100	100	100	100	100	100	100	100	100	
Meas. Feed	17.4	1.9	4.5	3	9.9	18.5	10.1	3.6	31.1	100										

Test 5

Product	Category Assay % Wt										Category Weight Per Cent Distribution in Products									
	Paper	Pl Film	Textile	Cinder	Glass/Stone	Putrescible DPL/MC	Metal	Conglomerates	Fines (-1/2")	Total	Paper	Pl Film	Textile	Cinder	Glass/Stone	Putrescible DPL/MC	Metal	Conglomerate	Fines	
Fines	.5	<.1	0	11	5.6	6	.2	0	76.6	100	3	1	-	80	61	41	2	-	93	
Intermediates	27.4	1.9	8.1	5.6	7.6	15.5	18.4	4.1	11.4	100	79	88	80	20	39	51	97	71	7	
Oversize	47.9	1.7	16.1	0	0	18.9	1.3	13.3	.8	100	18	11	20	-	-	0	1	29	<1	
Calc. Feed	11	.7	3.2	8.9	6	9.5	6	1.8	52.9	100	100	100	100	100	100	100	100	100	100	
Meas. Feed	10.2	.7	16.8	6.8	3.8	8.6	5.6	4.3	43.2	100										

TABLE 6. - ICRR Doncaster Testwork Weight Category Assays and Distributions (Net Weight Basis)

FIG. 3 NCRR DONCASTER, TEST 1,
FEED AND PRODUCT WEIGHT
SIZE DISTRIBUTIONS

FIG. 4 NCRR DONCASTER, TEST 2,
FEED AND PRODUCT WEIGHT
SIZE DISTRIBUTIONS

FIG. 5 NCRR DONCASTER, TEST 3,
FEED AND PRODUCT WEIGHT
SIZE DISTRIBUTIONS

FIG. 6 NCRR DONCASTER, TEST 4,
FEED AND PRODUCT WEIGHT
SIZE DISTRIBUTIONS

FIG. 7 NCRR DONCASTER, TEST 5,
FEED AND PRODUCT WEIGHT
SIZE DISTRIBUTIONS

13268

The nature of the feed materials and the effects of trommel sizing are clearly shown in these tables and figures. For all tests, the refuse feed had an abnormally high fines content; weight per cent $-1/2"$ being typically around 50%. The fine material was predominantly ash and this accounts for the high bulk density and low moisture content of the trommel fines products.

The consistency in calculated feed size distributions and in feed assays throughout the test series is very high with only test 4 material, which contained less fines material, but more paper and putrescible material, showing any significant differences. These differences are also reflected in the mass balance for this test (Table 4) which shows a higher weight yield of intermediate product, lower yield and lower bulk density of fines product. The moisture contents for the products and feed were also higher than measured for the other four tests.

The calculated feed size distributions tabulated in Table 5 and shown in Figs 3 to 7 are all finer than the measured size distribution. For tests 1 and 2 the difference is fairly small but, for tests 3 to 5, larger differences were recorded. As well as sampling errors, these differences can be attributed to the action of the trommel in liberating bagged and composite materials and causing the breakages of friable components (particularly glass) in the feed.

The test screen analysis procedure was intended to prevent further liberation of material by removing oversize bagged items from the screen deck before "spillage" of contents, thus preserving the integrity of the 'particle' as presented to the trommel screen. However, this procedure was not adopted for the feed sample where 'untied' bagged items were emptied, but tied or closed containers were not, thus giving some degree of liberation but probably not as much as that experienced by the refuse in the trommel.

Because the effective sampling weight of the feed was significantly smaller than the product sampling weights and trommel liberation could not be effectively 'mimicked' during the screen analysis procedure, all distributions and recoveries have been based on the calculated feed value.

It is interesting to note the "kink", in Figs 3-7, between 3" and 4" sizes, in feed and intermediate size products. Most of the tin can content of the refuse reports in this size fraction and contributes enough weight, in association with 'lost' coarse combustibles, to effect the recorded distortions. These are not generally noticeable in 'normal' refuse size distributions, particularly for refuse feeds where much lower fines contents are reflected by increases in the weight fraction of other components in the larger size ranges. (Open fire areas burn/convert significant amounts of large sized paper, plastic and putrescible material to fine ash.)

These results demonstrate highly efficient screening operations when considered in terms of the trommel design requirements, i.e.

- (1) to remove as much high ash and high moisture fines as possible without loss of light combustible components from the intermediate product (feed to fuel circuit)
- (2) to scalp off a large size (+8") fraction containing the cleaner paper for subsequent recovery of a fibre rich product, and
- (3) to prevent large bulky items reporting in the intermediate product where they could cause downstream processing difficulties in the subsequent processes.

It is clear from the product assays and category distributions given in Table 6 that the selection of aperture sizes at Doncaster has fully exploited the natural size differences between the categories in the raw refuse and has produced significant concentrations with minimal loss to other products. For example, loss of the lighter combustible categories, paper, plastic, textiles to the fines product was less than 4% in all tests, whereas for high ash, high moisture refuse components, some 80-95% of the $-1/2"$ and cinder categories reported to the fines product together with between 30 and 60% of the glass/stones and putrescible categories. More importantly, with respect to the specific test work under consideration, the recoveries of the sized fraction to undersize efficiencies were not particularly sensitive to the variation in the feed rates tested, (8.5 to 17.3 te h^{-1}) or to the variations in trommel speeds (6 to 12 rpm).

The minimal effect of feed rate on the performance of the 40 mm screen section, where +90% and +70% removal of $-1/2"$ and $-1+1/2"$ material was achieved, is somewhat surprising in view of the fineness of the feeds and the increased effective rates these would impose in this section of the trommel.

Considering total feed rates and calculated fines ($-2"$) feed rates as given in Table 7 it is seen that, even at the lowest feed rate (test 2) of 8.5 te h^{-1} the specific flow rate of $-2"$ material was 6.55 te h^{-1} , compared with a design raw refuse feed rate of 10 te h^{-1} , when a specific flow rate of $-2"$ material (given a more typical 'lower ash' feed stock) of 4 te h^{-1} would be anticipated. In effect, all tests were carried out well above the originally designed ratings for the fines screens and test 1 was operated at 3.4 times its design feed rate.

Included in Table 7 are the calculated screening efficiencies about the 40 mm screen section. Screening efficiency can be calculated in a number of ways and the results presented are based on a more comprehensive formula*, detailed below, which takes into account the grade of undersize as well as the recovery.

TABLE 7. - Screening Efficiency Results for the 40 mm Aperture Screen Section

Test Nos and Trommel speed (rpm)	Feed Rate Raw Refuse te h ⁻¹	Feed Rate -2" Material te h ⁻¹	Flow Rate of Fines Product (-2")	Size Fraction to Undersize Product					
				Screening Efficiency %			Recovery Wt %		
				-1/2"	-1"	-2"	-1/2"	-1"	-2"
1 (9)	17.3	13.6	11.2	29	66	49	93	90	82
2 (9)	8.5	6.5	5.6	32	64	59	95	92	86
3 (9)	12.4	9.6	7.62	35	57	46	91	86	79
4 (6)	17.3	12.5	9.7	36	64	49	92	87	78
5 (12)	14.5	11.3	9.4	37	61	52	94	89	83

Example of a screening efficiency calculation, Test 1, -1/2" material (Tables 4 and 5)

$$\begin{aligned}
 -1/2" \text{ Screening Efficiency } \% &= \frac{R - C}{100 - C} \times \frac{c - f}{100 - f} \times 100 \% \\
 &= \frac{92.5 - 64.8}{100 - 64.8} \times \frac{66.1 - 46.3}{100 - 46.3} \times 100 \% \\
 &= 29.0\%
 \end{aligned}$$

Thus for Test 1 screening efficiencies of 29%, 65% and 49% were achieved for -1/2", -1" and -2" material respectively and these assessments were related to 93%, 90% and 82% recoveries.

The closeness of the calculated efficiencies and recoveries, for any one size parameter, makes it difficult to justify a quantitative analysis of the effects of feed rate and trommel speed on performances about the fine screen section when operating under the selected range of variables. There is an obvious anomaly in test 3 where, at a lower feed rate than test 1 (same trommel speed), lower screening efficiencies and recoveries were recorded. A preponderance of bagged feed material and reduced rates of release might explain this.

At the lowest feed rate (test 2), the recoveries of all size fractions below 2" were consistently the highest as was the screening efficiency (59%) with which the -2" material was removed. The effects of trommel speed can be indicated by examining the results of tests 4, 1 and 5 (6, 9 and 12 RPM) where 'generally' the recoveries of all size fractions and the efficiencies of removal of the -2" materials increase with speed.

There is the expected reduction in recovery as the reference size of the particles increases; the near size pieces having a lower "probability of passing". Thus, from an efficiency assessment, when the grade of the undersize is taken into account, the highest efficiencies for all tests are positively in the -1" size range.

Comparing the -1" screening efficiency results, tests 1 and 4, at high feed rate and at low trommel speed, gave much higher values than might be expected from the -2" recovery and screen efficiency results.

$$* \text{ Screening efficiency } \% = \frac{R - C}{100 - C} \times \frac{c - f}{100 - f} \times 100$$

where R = recovery of desired size fractions in undersize (Tables 4 and 5)
C = percentage weight of undersize (with regard to feed) (Table 4)
f = percentage of size fraction in feed (Table 5)
c = grade of undersize (Table 5)

This indicates a disproportional reduction of oversize (-2"+1") material, under these test conditions, as compared with the low feed rate and higher trommel speeds.

This may simply be due to near size particles being the first to be affected by more difficult screening conditions caused by increased feed rate or, in the case of lower trommel speed, by increased loading in the trommel. Also it might reflect the change in nature of the -2"+1" material, which contained a much higher proportion of flake-like particles contributed by the paper, plastic film and textile categories.

Table 8 gives the weight distribution, between the fines and intermediate products, of various categories in the -2" size ranges. Although there is a large scatter in results presented in this table, probably due to the small weights of samples involved at this stage in the analysis, the results clearly demonstrate the selective nature of trommel screening with consistently higher recoveries of the heavier, bulkier categories to undersize. It would also appear that the lower trommel speeds of test 4 enhance this selectivity, with the lowest recovery of paper and card in the -2"+1" size range coupled with high recoveries for the glass and cinder categories.

TABLE 8. - Weight Distribution of Sized Categories between Fines and Intermediate Product Streams

Test	Size Fraction	Trommel Product	Paper/Cd	Plastic Film	Textile	Putrescible D.Pl MC	Metal	Glass/Stones	Cinder
Test 1 17.3 te h ⁻¹ 9 rpm	-2 + 1"	Fines	4.3	25.0	6.1	21.7	8.9	20.8	25.3
		Intermediates	95.7	75.0	93.9	78.3	91.1	79.2	74.7
	-1 + 1/2"	Fines	34.3	85.8	0	82.8	56.8	70.6	89.9
		Intermediates	65.7	14.2	100	17.2	43.2	29.4	10.1
Test 2 8.5 te h ⁻¹ 9 rpm	-2 + 1"	Fines	13.0	15.5	0	41.5	3.4	37.8	61.2
		Intermediates	87.0	84.5	100	58.5	96.6	62.2	38.8
	-1 + 1/2"	Fines	41.4	67.9	0	72.8	25.0	74.6	92.5
		Intermediates	58.6	32.1	100	27.2	75.0	25.4	7.5
Test 3 12.4 te h ⁻¹ 9 rpm	-2 + 1"	Fines	5.0	3.3	0	28.6	6.8	19.3	65.7
		Intermediates	95.0	96.7	100	71.4	93.2	80.7	34.3
	-1 + 1/2"	Fines	34.8	72.4	0	64.7	37.7	53.1	84.5
		Intermediates	65.2	27.6	100	35.3	62.3	46.9	15.5
Test 4 17.3 te h ⁻¹ 6 rpm	-2 + 1"	Fines	2.9	4.9	0	19.4	53.9	43.4	100.0
		Intermediates	97.1	95.1	100	80.6	46.1	56.6	0.0
	-1 + 1/2"	Fines	46.4	30.8	nr	68.5	62.5	63.3	95.8
		Intermediates	53.6	69.2		31.5	37.5	36.7	4.2
Test 5 14.5 te h ⁻¹ 12 rpm	-2 + 1"	Fines	6.2	7.1	nr	33.8	0.5	28.9	58.1
		Intermediates	93.8	92.9		66.2	99.5	71.1	41.9
	-1 + 1/2"	Fines	27.2	69.4	0	70.7	64.7	74.1	86.7
		Intermediates	72.8	30.6	100	29.4	35.3	25.9	13.3

The effects of the high ash feed must be taken into account when considering the performance of the intermediate screen sections. At the design flow rate of 10 te h⁻¹, with a more typical lower ash content, a feed rate of 6 to 7 te h⁻¹, to the intermediate screen, would be expected.

From Table 9 it can be seen that the theoretical flow rates of the +2" material to the intermediate screen sections are well below these design ratings in fact, of the actual flow rates to this section, only that in test 4 was slightly in excess of this rating.

TABLE 9. - Separation Efficiency of the Intermediate Screen Apertures

Test Nos and Trommel Speed (rpm)	Feed Rate Raw Refuse t h ⁻¹	Feed Rate +2" Material t h ⁻¹	Feed Rate Excluding Fines Product	Size Fraction to Intermediate Product		
				Screening Efficiency % -6"	Recovery % -6"	Grade % -6"
1 (9)	17.3	3.67	6.09	42.3	96.9	90.6
2 (9)	8.5	1.95	2.85	33.9	99.0	83.9
3 (9)	12.4	2.75	4.76	44.6	98.2	91.3
4 (6)	17.3	4.79	7.58	28.5	98.6	84.7
5 (12)	14.5	3.20	5.10	39.7	98.6	88.7

The efficiencies, based on -6" sizes through the 200 x 350 mm (8" x 4") apertures add to the complications of assessing this coarser screen section. The recovery values for -6" material (tests 1, 2 and 3) show decreasing probability with increased feed rate. From the recoveries and grades (tests 4 and 5) the lower trommel speed (6 rpm) appears to have been beneficial in that it produced the same recovery of -6" material together with a greater amount of oversize (e.g. reduced grade) despite the higher feed rate for test 4.

It is interesting to note, from the "intermediates" size distribution curves (Figs 3-7), the sizes dx% at which various proportions of the product are "finer than". These are given in Table 10 and show differences in performance of the trommel intermediate screens for the various test settings. Tests 2 and 4, at lowest throughput and lowest trommel speed respectively, produced the coarsest intermediate products and are automatically associated with higher performances.

TABLE 10. - Intermediate Products, Effective Cut Point Size at Various Per Cent Weight Passing (dx% values)

Test Nos and Trommel Speed (rpm)	Feed Rate to Intermediate Screens t h ⁻¹	Aperture size cut point at various per cent weight passing (inches)			
		d 25%	d 50%	d 75%	d 85%
T1 9	6.09	1.05	2.2	3.7	5.2
T2 9	2.85	1.35	2.9	4.7	6.1
T3 9	4.76	0.86	2.1	4.1	5.2
T4 6	7.58	1.2	2.7	4.4	6.0
T5 12	5.10	1.05	2.7	4.6	5.6

The trends discussed above for both the intermediate and fine screening apertures are based on fairly small changes in measured values and, as such, require confirmation in a wider ranging series of tests. It is clear that the trommel screen in Doncaster was operating well within its feed rate limitations and that rates of 10 t h⁻¹, 20 t h⁻¹ and 30 t h⁻¹ would have provided more useful test conditions and more positive trends. With hindsight it is unfortunate that, in order to ensure consistent feed material over the test period, high ash refuse was chosen because of its ease of identification both by collection area and estimated bulk density. As a result the fine screens were operated at well over design capacity but showed no loss of screening efficiency, suggesting that the efficiency of fine screening is more dependent on the flow rate of larger size material (+2") than on the quantity of undersize material (-2"). However, these results could be explained entirely by the fact that this screen is over designed and was not sufficiently extended in these tests.

The effect of the trommelling operation, in terms of a preconcentrator for fuel recovery, is shown by the ash and calorific value results obtained on selected samples from the screening testwork (Table 11).

These results were obtained as part of the laboratory's current evaluation programme, sponsored by the UK Department of Environment, and are presented in this report to provide relevant background information and to support the category assay information collected as part of the screening test programme.

TABLE 11. - Ash and Calorific Value Results, Doncaster Tests

Test Nos	Product	Dry Basis		Dry and Ash Free Basis Calorific Value kJ/g
		Ash Wt %	Calorific Value kJ/g	
1	Fines	52.3	14.6	30.5
	Intermediates	45.4	13.9	25.4
	Oversize	15.0	20.8	24.4
2	Fines	61.8	11.2	28.3
	Intermediates	43.5	14.1	25.0
3	Fines	57.5	12.5	29.4
	Intermediates	43.8	13.0	23.1
4	Fines	56.6	12.5	28.9
	Intermediates	27.3	15.4	20.9
5	Fines	58.6	12.0	29.0
	Intermediates	45.1	13.9	25.3

The results clearly demonstrate the high ash nature of the fines products in which the calorific values of the associated combustible components approach those of coals. The intermediate products are still relatively high in non-combustibles but, considering 15 to 20% is contributed by the metal content, they are significantly better than the fines products. The calorific values of the associated combustibles are generally slightly higher than expected for cellulosic material such as the paper, putrescibles and wood, indicating the contribution of the high value plastic content in this size fraction. The result for the oversize product from test 1 indicates a very low non-combustible content and, on an ash free basis, a similar composition to that of the intermediate size fraction. This oversize product is, in fact, very similar in its average ash and calorific values to those obtained in the air classified intermediate fuel fractions.

2.2.3 Refuse Processing Results, Number Basis

The results and discussions have so far been restricted to consideration of trommel screening on a weight basis. The following section considers the results in terms of the numbers of particles.

The general trend of decreasing weight with particle size usually results in very high number counts for samples of the finer size ranges. To some extent, with domestic refuse, this effect is tempered by the change in category composition of the size fractions; lighter, flakier particles predominate in the large size fractions whilst heavier "bulky" particles dominate in the smaller. This point can be demonstrated by considering the theoretical weight per particle in the various size ranges for spheres or cubes of constant density and discs or plates of constant density and thickness and comparing these results with the measured weights per particle for the combined feeds for all tests. For ease of calculation mid-point diameters have been selected (i.e. for -1+1/2 size range sphere/cube dimension = 3/4", disc/plate dimension = 3/4"). These values are given in Table 12 and the ratio of increase in weight per particle, between adjacent size ranges, is given. For ease of comparison a nominal value of 1 has been allocated to the smallest size range and the actual weight per particle value calculated for the refuse feeds has been adjusted to give the same unit value for this size range.

Considering the first two size ranges, -1+1/2" and -2+1", at constant density and shape, the minimum weight ratio should have been at least 4. The measured value of 3 indicates either decreased average density of particles or a lower proportion of bulky particles (or both) in the -2+1" compared with the contents of the -1+1/2". This result is repeated when comparing the overall ratio between -1+1/2" and -6+5"; giving a lower overall value than the theoretical 100% plate particle ratio (i.e. 48.2 compared with 53.8) and much lower than the theoretical bulky particle ratio (394). Considering ratios between intermediate size ranges, the effect of the tin can content in the -4+3" size range is also noticeable with a relatively high ratio between -3+2" and -4+3" being followed by a very low value between -4+3" and -5+4" size ranges indicating the high proportion of bulky, dense items in this size range. The final ratio between -5+4" and -6+5" size ranges is higher than expected in that most categories in these size ranges can

TABLE 12. - Theoretical Weight per Particle Values for Sphere, Plates and
Measured Weight per Particle Values on Doncaster Feed Material

Size Range	Constant Density Theoretical Shapes		Refuse Feeds	
	Wt per particle and ratio, spheres cubes	Wt per particle and ratio, plates	Measured Wt per particle kg x 10 ⁻³	Measured Wt per particle - 1.87x10 ⁻³ and ratio
-1+1/2 [3/4"]	1 x 8	1 x 4	1.87	1 x 3.0
-2+1 [1 1/2"]	8 x 4.6	4 x 2.78	5.6	3.0 x 2.82
-3+2 [2 1/2"]	37 x 2.76	11.1 x 1.96	15.8	8.45 x 2.25
-4+3 [3 1/2"]	102 x 2.11	21.8 x 1.65	35.5	19.0 x 1.45
-5+4 [4 1/2"]	216 x 1.82	36 x 1.49	51.6	27.6 x 1.75
-6+5 [5 1/2"]	394	53.8	90.0	48.2

be considered plate like. If this effect is real, and not a statistical distortion caused by the relatively small amounts of material considered in these larger size fractions, it could be attributed to their increased content of textiles whose "measured weight per textile particle" values were significantly higher than those for paper. This also reflects the ability of textiles to deform easily and pass through smaller apertures than their "natural" dimensions would permit.

Generally, the number count data are based on much smaller samples than those used for the refuse weight data and therefore the calculated results are subject to greater sampling errors.

Bearing the above points in mind, the following comments are made on the number per cent distribution of size fractions reporting in the trommel products (Table 13) and on the number count size distributions of the measured feed, calculated feed and products (Table 14, Figs 8 to 12). It should be noted that number counts were not carried out on the -2+1" and -1+1/2" size fractions of the oversize products and -1/2" fractions for all products and feeds.

Considering Table 13, feed rate versus recovery trends, observed previously in the weight distributions (Table 4), are generally reflected in the number distributions with test 2, at lowest feed rate, reporting the highest recoveries of -2+1" and -1+1/2" material in the fines product (31.9% and 76.1%).

Comparing the results for test 4 and 5 (6 and 12 rpm), an increase of trommel speed is seen to increase the recovery of particles from 16.8% and 70.4% (6 rpm) to 23.1% and 77% (12 rpm) in the -2+1" and -1+1/2" size fractions respectively. For the -2+1" material this result is consistent with the weight distributions (12 rpm 31.9%, 6 rpm 21% - Table 4) although, for -1+1/2" material, it was reversed (12 rpm 77.6%, 6 rpm 78.1%) suggesting that the relative difference in weight per particle of material passing compared with material not passing was higher for test 4 at 6 rpm than for test 5 at 12 rpm, i.e. there appears to be less selective screening at higher trommel speeds. If this result is real, and not caused by sampling errors, an explanation may be that the feed rate was higher for test 4 or that different screening principles are involved at different trommel speeds, for example it can be envisaged that at the higher speeds screening only takes place during impact of falling particles on the screen surface, whereas at low speeds preferential screening of bulky particles also occurs during "rolling/sliding" of the refuse on the relatively slower moving screen plate in between the falling/impact mode caused by the installed lifters.

The number count data highlights the problem of comparing size fractions close to or encompassing the aperture size of a screening operation. Table 15 shows the significant difference in "category weight per particle" values for the -2+1" size fraction; the larger values of -2+1" in the intermediates reflecting the preponderance of -2+1 5/8" particles which could not pass the screen apertures compared with the fines fraction largely containing -1 5/8 + 1" particles. Thus, for certain assessments, these sizes are not

TABLE 13. - NCRR Doncaster Testwork. Number Per Cent Distribution of Size Fractions Reporting in Products
Test 1 Trommel Speed 9 rpm, Feed Rate 17.28 t_h⁻¹

	Number Per Cent Distribution of Size Fractions (inches) Reporting in Products						
	+6	-6+5	-5+4	-4+3	-3+2	-2+1	-1+1/2
Fines	-	-	-	-	-	13.6	70.7
Intermediates	68.8	85.8	91.2	96.7	98.5	86.4	29.3
Oversize	31.2	14.2	8.8	3.3	1.5	nd	nd
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Test 2 Trommel Speed 9 rpm, Feed Rate 8.49 t_h⁻¹

	Number Per Cent Distribution of Size Fractions (inches) Reporting in Products						
	+6	-6+5	-5+4	-4+3	-3+2	-2+1	-1+1/2
Fines	-	-	-	-	-	31.9	76.1
Intermediates	71.0	94.2	96.0	98.3	99.1	68.1	23.9
Oversize	23.0	5.8	4.0	1.7	0.9	nd	nd
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Test 3 Trommel Speed 9 rpm, Feed Rate 12.4 t_h⁻¹

	Number Per Cent Distribution of Size Fractions (inches) Reporting in Products						
	+6	-6+5	-5+4	-4+3	-3+2	-2+1	-1+1/2
Fines	-	-	-	-	-	28.4	67.0
Intermediates	61.8	90.1	95.7	98.3	99.2	71.6	33.0
Oversize	38.2	9.9	4.3	1.7	0.8	nd	nd
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Test 4 Trommel Speed 6 rpm, Feed Rate 17.27 t_h⁻¹

	Number Per Cent Distribution of Size Fractions (inches) Reporting in Products						
	+6	-6+5	-5+4	-4+3	-3+2	-2+1	-1+1/2
Fines	-	-	-	-	-	16.8	70.4
Intermediates	75.2	91.5	95.7	98.1	98.6	83.2	29.6
Oversize	24.8	8.5	4.3	1.9	1.4	nd	nd
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Test 5 Trommel Speed 12 rpm, Feed Rate 14.46 t_h⁻¹

	Number Per Cent Distribution of Size Fractions (inches) Reporting in Products						
	+6	-6+5	-5+4	-4+3	-3+2	-2+1	-1+1/2
Fines	-	-	-	-	-	23.1	77.0
Intermediates	77.1	92.8	95.8	98.2	99.2	76.9	23.0
Oversize	22.9	7.2	4.2	1.8	0.8	nd	nd
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0

TABLE 14. - NCRR Doncaster Testwork Number Size Distributions Of Feed and Products

Test 1 Number Size Distribution %						Test 2 Number Size Distribution %					Test 3 Number Size Distribution %				
Size (inches)	Fines	Intermediates	Over-size	Calc. Feed	Meas. Feed	Fines	Intermediates	Over-size	Calc. Feed	Meas. Feed	Fines	Intermediates	Over-size	Calc. Feed	Meas. Feed
+6	-	0.8	40.8	0.5	0.4	-	1.5	57.3	0.7	0.3	-	0.6	55.0	0.4	0.6
-6+5	-	0.9	15.8	0.4	0.3	-	2.0	16.2	0.8	0.4	-	1.1	16.9	0.5	0.4
-5+4	-	0.9	10.0	0.4	0.4	-	1.3	7.1	0.5	0.6	-	1.2	7.9	0.6	0.2
-4+3	-	4.8	18.6	2.2	1.6	-	4.6	10.1	1.7	1.5	-	4.2	10.1	1.9	1.4
-3+2	-	8.8	14.8	3.9	2.6	-	7.6	9.3	2.9	3.1	-	9.3	10.1	4.1	2.1
-2+1	3.8	31.6	nd	15.8	15.6	9.5	34.7	nd	18.8	19.3	7.5	24.5	nd	14.9	15.9
-1+1/2	96.2	52.2	nd	76.8	79.1	90.5	48.3	nd	74.6	74.8	92.5	59.0	nd	77.6	79.4
-1/2	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd	nd
TOTAL	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

Test 4 Number Size Distribution %						Test 5 Number Size Distribution %				
Size (inches)	Fines	Intermediates	Over-size	Calc. Feed	Meas. Feed	Fines	Intermediates	Over-size	Calc. Feed	Meas. Feed
+6	-	0.8	45.0	0.4	0.4	-	0.6	47.4	0.3	0.6
-6+5	-	0.8	13.8	0.4	0.5	-	0.7	15.2	0.4	0.8
-5+4	-	1.5	11.7	0.7	0.7	-	1.1	12.5	0.5	1.1
-4+3	-	4.3	14.6	1.9	3.2	-	2.7	13.5	1.2	1.6
-3+2	-	6.1	14.9	2.7	5.2	-	5.2	11.4	2.3	3.4
-2+1	5.4	34.8	rd	18.2	24.3	7.2	30.6	nd	17.4	14.4
-1+1/2	94.6	57.7	rd	75.7	65.7	92.8	59.0	nd	77.9	78.0
-1/2	nd	nd	rd	nd	nd	nd	nd	nd	nd	nd
TOTAL	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

FIG. 8 NCRR DONCASTER TEST 1.
FEED AND PRODUCT NUMBER
SIZE DISTRIBUTIONS $\pm \frac{1}{2}$
MATERIAL (+ 2" FOR OVERSIZE)

FIG. 9 NCRR DONCASTER TEST 2.
FEED AND PRODUCT NUMBER
SIZE DISTRIBUTIONS $\pm \frac{1}{2}$
MATERIAL (+ 2" FOR OVERSIZE)

FIG. 10 NCRR DONCASTER TEST 3.
FEED AND PRODUCT NUMBER
SIZE DISTRIBUTIONS $\pm \frac{1}{2}$
MATERIAL (+ 2" FOR OVERSIZE)

FIG. 11 NCRR DONCASTER TEST 4.
FEED AND PRODUCT NUMBER
SIZE DISTRIBUTIONS $\pm \frac{1}{2}$
MATERIAL (+ 2" FOR OVERSIZE)

FIG. 12 NCRR DONCASTER TEST 5.
FEED AND PRODUCT NUMBER
SIZE DISTRIBUTIONS $\pm \frac{1}{2}$
MATERIAL (+ 2" FOR OVERSIZE)

13200

comparable. Accordingly, it can be noted from this table that the measured category weights per particle for the -1+1/2" size fractions give much closer agreement between the two product streams. In this size range, the intermediate value for the clinker included a "rogue" result from test 4 which, when excluded, gives an even closer agreement; a mean value of 2.65 and much lower standard deviation of 0.13. Comparisons between the product and feed "weight per particle" results (Table 15) suggest that, for the paper category, there is a slight decrease in weight per particle after processing, but the standard deviations do not suggest that this is very significant. However, if it is a "real effect" it may be caused by a tendency for paper to unfold and become more plate like and/or to dry out during processing in the trommel.

The results for the -1+1/2" cinder category are in reasonable agreement but, in the -2+1" range, the feed result is considerably higher but with a high 's.d.'.

TABLE 15. - Category Weight per Particle Values for -2+1" and -1+1/2" Size Fractions in Different Trommel Products (average all 5 tests)

Trommel Product	-2+1" size fraction		-1+1/2" size fraction	
	Paper gm/particle	Cinder gm/particle	Paper gm/particle	Cinder gm/particle
	$\bar{x} \pm \sigma_{n-1}$	$\bar{x} \pm \sigma_{n-1}$	$\bar{x} \pm \sigma_{n-1}$	$\bar{x} \pm \sigma_{n-1}$
Fines	0.9 $\pm$.13	7.8 $\pm$ 1.6	0.40 $\pm$.01	2.2 $\pm$ 0.1
Intermediates	1.8 $\pm$.45	11 $\pm$ 2.3	0.44 $\pm$.01	2.9 $\pm$ 0.7 [2.65 $\pm$ 0.13]
Feed	2.1 $\pm$.5	15 $\pm$ 8	0.46 $\pm$.01	2.3 $\pm$.2

This latter fraction showed a high scatter in measured values; possibly due to the cinder having a size distribution with a top size close to the 2" limit and rendering it susceptible to increased sampling errors. This is reflected in the weight per particle ratio values for the paper and cinder categories with paper giving close to the theoretical factor of 4, for plate like materials, and cinder between 4 and 6 - somewhat less than the expected 8 for this category. Again, this suggests an uneven size distribution within the -2+1" size fraction giving a lower average size than the 1 1/2" used to calculate the theoretical weight ratio.

The number distribution results (Table 13) for the intermediate screen section show the same trend as the weight results (Table 4) with higher recoveries at low feed rate for constant trommel speed and little difference between tests 4 and 5 at 6 rpm and 12 rpm respectively.

The selective nature of trommelling is noticeable in all size ranges below 6 inch, where the material "passing" at any given size range generally represents a higher weight distribution than number distribution, indicating that either particle shape of the undersize material is generally 'bulkier' or that the material has a higher density or a combination of both factors.

The size distributions relating to the intermediates, the fines and the measured feed, (table 14 and Figs 8 to 12) are based on complete sets of data above 1/2" sizes. However, -2+1" and -1+1/2" data were not available for the oversize product and, although this has little effect on the calculated feed size distribution, it markedly affects the size distribution of the oversize where the disproportionate effect of the numbers in a small weight of fine material can be a major factor.

Therefore comparisons between the number size distributions of the oversize and other products are not valid.

Generally, comparisons between the product number size distributions (Table 14) and the number per cent distribution of size fraction in products (Table 13), do not reveal any additional significant trends especially in the light of the difficulties of interpretation caused by the high weighting of the results by the numbers in the fine sizes. It is interesting to note however that the 'kinks' in the weight size distributions, relating to the intermediates and feeds, caused by the tin can content in the -4+3" size fractions, have been "smoothed out" in the number distributions.

2.2.4 Refuse processing Results, Surrogates

Table 16 details the distribution of surrogate particles about the relevant screen sections.

Previously, in the experimental section, it was noted that the method of introducing surrogates as a single pulse was less than ideal, nevertheless these results highlight some of the interesting trends identified in the refuse analyses.

The effect of feed rate on the probability of the cubes passing the fines section, at a given rotational speed, is compatible with the refuse distribution results where test 2, at lowest feed rate, gave the highest recovery of cubes to undersize. The result for test 3, the intermediate feed rate again gives a lower recovery than expected and no satisfactory explanation of this anomalous trend has been put forward.

The effect of changing trommel speed appears to be quite marked, with a very high recovery of cubes to undersize at 6 rpm (test 4), the lowest recorded recovery at 12 rpm (test 5) and a medium performance at 9 rpm (test 1). This result supports the contention that lower trommel speeds enhance the selectivity of screening for bulky particles when compared with flakes; the refuse weight distributions did not indicate such a significant fall off in recovery for material of this size (the 1" cubes can be considered to equate on behaviour terms with -2+1" size fraction material as minimum and maximum "presented" dimensions are $\sqrt{2}$ " and $\sqrt{3}$ " respectively).

Figures 13 to 17 show the results of monitoring the fines product stream during cube surrogate additions. The film of this stream was analysed by counting the number of cubes visible in batches of 5 frames. As the camera speed and trommel speed are known for each test, the time which elapsed between the first and last cube exit from the trommel, and the number of trommel rotations, can be calculated. Although the set camera speed was 8 frames per second a subsequent check revealed an operating speed of 11 frames per second and hence the unusual calibration of the time axis relative to the number of frames.

It is clear from these graphs that cubes are available for screening for approximately 3 to 4 revolutions, in this section of the trommel, irrespective of its speed. It is also clear from the peaking of the graph that the cubes are being presented to the screen surface at discrete time intervals, the main peaks being in phase with the trommel revolutions. Considering Fig. 2d, showing spike and lifter configuration, and Fig. 13, the cube distribution for the first test, it is reasonable to assume the main peaks coincided with material dropping off the double lifter and the secondary peaks with material dropping off the single lifter positioned 90° later and taking material off the leading edge of the scroll 1 only.

Thus the results indicate that most of the screening occurs in the "drop mode" of presentation with the 'troughs' on the graphs representing periods when material is being carried up the screen surface on the lifters, and rolling or slumping on the screen surface after the material has dropped, and before the lifters pick up the material on the next revolution. It is noticeable, comparing Figs 16 and 17, that the relative difference between the peak and trough heights is greater at the high trommel speed providing confirmatory evidence that the bulky material will pass the screen in the rolling mode if the screen surface speed is low. In view of the high recovery, resulting from the low speed test, the rolling mode would appear to be an acceptable screening principle for bulky materials at the feed rates tested.

The results for the intermediate screens have to be interpreted in two parts; single surrogate charges were introduced for tests 1 and 2 whilst tests 3, 4 and 5 were operated with multi-spaced charges.

The effect of feed rate on the per cent surrogate passing is clearly shown in Table 16, test 2 where higher proportions of all surrogate particles pass at the lower feed rate. Splitting the surrogates into three increments and introducing them at timed intervals has clearly increased their probability of passing the screen apertures for both the large and the hollerith cards (compare test 3 with tests 1 and 2) although the trend with the bottles appears to be minimal and with a reversed effect. The result for the cards certainly indicates that surrogate/surrogate interference effects were a significant factor in the low recovery rates for the first two tests.

It is clear, from the results of tests 3, 4 and 5, that, at the feed rates tested, lower trommel speeds increase the chance of bulky particles passing the screen apertures. At 6 rpm 93.6% of bottles passed compared with only 72.5% at 12 rpm. The effects on the plate like large and hollerith card surrogates are less marked.

Table 17 gives estimates of the surrogate flow times along the trommel based on a visual inspection of the video recording of each test. The video was positioned to look up the trommel from the discharge end and thus conditions near the entrance were not as clearly visible as would have been desired. Consequently it was difficult to judge precisely the entry and exit times of surrogates in the fines screen section.

The description of surrogate conditions, i.e. the "90% past or passing" are based on the judgement of the analyst. They are subjective and not absolute values, but should give reasonable comparative values with which to compare test conditions. The figures given in brackets are theoretical residence times for oversize particles assuming no lifter operation and their automatic transport along the trommel by the action of the scrolls.

The term "leading edge" applies to the first 'significant' batch of particles and not to the "1st" rogue particle observed passing the relevant point. However, with bottles, where only a small number

remained to report to oversize, the first bottle was considered the leading edge.

The times observed for the wooden cube surrogates follow the theoretical trend although the differences are slightly less marked than expected with change in trommel speed. However, this is probably not significant in view of the arbitrary nature of the timing and the fact that the precise time of introduction of the surrogate would effect residence times by as much as $\pm 1/4$ a revolution of the trommel due to the changing position of the double scroll pick up (e.g. ± 1.7 secs at 9 rpm). The observed 90% and 99% past or passing times are in good agreement with the surrogate discharge times taken from the cine film of the -40 mm products shown in Figs 13 to 17.

Comparing the theoretical residence times with the leading edge and 99% past or passing (trailing edge) times it is clear that the actual conditions in the trommel impose residence times which differ by factors of 2 to 3 times that based on scroll transport.

The results for the large surrogates show surprisingly little difference in the observed entry times into the intermediate section of the trommel. Similarly, there was little difference in the residence times in this section except for a very slight tendency for the bottles to move more quickly. In fact this trend tends to be masked by the passage of most of the bottles through the apertures thus tending to increase the time lapse before the emergence of the first bottle to the oversize product. Only in test 5 was the elapsed time for bottles close to the theoretical "minimum".

The times for 90% past or passing the intermediate screens strongly indicate that the large card surrogate particles spent significantly longer in the trommel than both the bottles and the computer cards. However, as already indicated, this effect is magnified by the high screening efficiencies obtained for the bottles and Hollerith cards and it is considered that this increase in residence time for 'plate like' materials, although real, is not as significant as the large card results suggest.

Overall the 'leading edge' elapsed time results indicate that there is a general "hold up" of material in intermediate section resulting in a proportional increase on "theoretical" residence time similar to that recorded for the fines section. However, there is evidence to suggest that bulky particles have lower residence times than flakes and that increased trommel speed magnifies this difference.

Due to a number of factors both the refuse processing and surrogate results have been difficult to interpret. Short and longer term variations in feed rate have introduced problems, as did the damage to the rag conveyor, but the major problem has been the overall lack of sensitivity of the Doncaster trommel performance to changes in operating conditions. Very high screening efficiencies were achieved on the selected material even at feed rates in excess of 1.7 x design rating, clearly indicating operations in a relatively insensitive over-designed area. This has resulted in the recording of only marginal differences in dependent variables and in the masking of positive characteristics. With hindsight, it might have been more effective to have increased the maximum test speed to say 16 instead of 12 rpm but, it is equally relevant to note that the lifters also appear to have a very significant effect on performance at all trommel speeds and thus introduce an added influence on the effects of rotational speed on screening efficiencies. For example, at the feed rates tested, lower trommel speeds increased the resulting screening efficiencies for -1" refuse material and for bulky surrogates, a result that would not have been anticipated for a trommel without lifters.

TABLE 16. - Per Cent Distribution of Surrogate Particles in Screen Products

Surrogate	Screen Product	Per Cent Distribution of Surrogate				
		Test 1	Test 2	Test 3	Test 4	Test 5
		9 rpm	9 rpm	9 rpm	6 rpm	12 rpm
		17.3 te h ⁻¹	8.5 te h ⁻¹	12.4 te h ⁻¹	17.3 te h ⁻¹	14.6 te h ⁻¹
1" wood cubes	Fines	44.8	51.0	38.9	50.3	35.9
	Intermediates	55.2	49.0	61.1	49.7	64.1
Bottles	Intermediates	88.5	92.8	85	93.6	72.5
	Oversize	11.5	8.2	15	6.4	27.5
Large White cards	Intermediates	25.6	35.2	59.2	78.5	74.6
	Oversize	74.4	64.8	30.8	21.5	25.4
Hollerith cards	Intermediates	75.7	85.7	98.6	98.6	97.3
	Oversize	24.3	14.3	1.4	1.4	2.7

TABLE 17. - Approximate Surrogate Flow Times Along Trommel Axis
(Estimated from video recording)

Surrogate one inch wood cubes

Test Nos	Trommel Speed rpm	Nos of Pulses	Time in Seconds			
			Entry into Trommel	Entry into* Intermediate screen section "leading edge"	~90% past or passing fines screens	~99% past or passing fines screens
1	9	1	0	17 [11]	25	31
2	9	1	0	15 [11]	25	32
3	9	1	0	18 [11]	27	32
4	6	1	0	22 [17]	33	38
5	12	1	0	13 [8.5]	23	27

Large Surrogates

Test Nos	Trommel Speed rpm	Nos of Pulses	Time in Seconds				Elapsed time, seconds	
			Entry into Trommel	Entry into Intermediate screen section* "leading edge"	Exit from Trommel leading edge*	90% past or passing intermediate screen section	Leading edge entry and exit*	Leading edge entry and 90% past or passing
<u>Surrogate large plastic bottles</u>								
1	9	1	0	16 [11]	30 [20]	45	14 [9]	29
2	9	1	0	15 [11]	29 [20]	39	14 [9]	24
3	9	3	0	14 [11]	25 [20]	44	11 [9]	30
4	6	3	0	15 [17]	32 [30]	42	17 [13]	27
5	12	3	0	12 [8.5]	18 [15]	28	6 [6.5]	16
<u>Surrogate large white cards</u>								
1	9	1	0	18 [11]	31 [20]	53	13 [9]	35
2	9	1	0	13 [11]	25 [20]	49	12 [9]	36
3	9	3	0	16 [11]	33 [20]	51	17 [9]	35
4	6	3	0	17 [17]	36 [30]	59	19 [13]	42
5	12	3	0	13 [8.5]	23 [15]	41	10 [6.5]	28
<u>Surrogate computer cards</u>								
1	9	1	0	15 [11]	29 [20]	48	14 [9]	33
2	9	1	0	14 [11]	28 [20]	47	14 [9]	33
3	9	3	0	16 [11]	29 [20]	40	13 [9]	24
4	6	3	0	17 [17]	35 [30]	44	18 [13]	27
5	12	3	0	12 [8.5]	21 [15]	33	9 [6.5]	21

* Figure in brackets give theoretical residence time of a particle based on scroll transport and assuming continuous contact of the particle with the screen surface.

13270

FIG. 13 NCRR DONCASTER TEST 1, (9 r.p.m.)
number distribution of 1" cubes in fine product vs time

13271

FIG. 14 NCRR DONCASTER TEST 2, (9 r.p.m.)
number distribution of 1" cubes in fine product vs time

13272

FIG. 15 NCRR DONCASTER TEST 3 (9 r.p.m.)
number distribution of 1" cubes in fine product vs time

13273

FIG. 16 NCRR DONCASTER, TEST 4, (6 r.p.m.)
number distribution of 1" cubes in fine product vs time

13274

FIG. 17 NCRR DONCASTER, TEST 5 (12 r.p.m.)
number distribution of 1" cubes in fine product vs time

3. BYKER TESTWORK

The Byker plant was built by the TWCC, with support from the UK Department of the Environment. It was designed to process 30 tonnes per hr of household waste, collected in the Newcastle area, for the recovery of ferrous metal and a Waste Derived Fuel. The refuse, pulverised in a vertical shaft, Tollemache 72A mill, is screened in a rotary trommel to separate fines, intermediates and oversize. A conical air classifier extracts light combustibles from the "middling" size fraction for subsequent densification in a ring die pelletiser. Ferrous metals are removed magnetically from the air classifier heavies, and all residues are disposed of on land-fill.

This plant, although mechanically satisfactory, still has a problem with the poor quality of its pellets and this is partly attributed to difficulties in removing 'fines' to provide lower ash contents.

Frequent changes to the screen apertures in this unit introduced a degree of uncertainty when predicting test conditions. Consequently, at the outset of this investigation, the screen plates were inspected and the actual sizes fitted at the time of testing are indicated in Figs 19a, b and c.

3.1 Experimental Method

These tests were designed to investigate the effects of changes in feed rate, at constant trommel rotational speeds (12 rpm), on performance.

The Byker trommel has a nominal design rating of 30 te h^{-1} of pulverised refuse and the original target feed rates for the tests were specified at 45, 30 and 15 te h^{-1} . Difficulties were anticipated at the high feed rate as the Byker management reported experiences of the trommel cutting out above 40 te h^{-1} . They also expressed some concern on the ability of the downstream air classifier heavy product conveying equipment to handle the increased volumetric throughput caused by the need to cut out the air classifier to facilitate sampling of the intermediate size fraction from the trommel. Thus for the high throughput test the plant supervisor was requested to operate the plant at the highest feed rate he considered compatible with a consistent, non interrupted operation. All product and feed samples were collected in three increments during each run, the timing of the increments being 10, 25 and 40 minutes into the run.

Figures 18 and 19 outline the process circuit and trommel configurations. Feed rate is controlled on the vibratory pan feeder and the 'instantaneous' load is monitored, using a belt weigher, on the discharge from the pulveriser. This information is relayed to the control room and to the reception floor so that both the plant controller and front end loader driver can adjust their operating procedures to maintain the desired feed rate.

The pulverised refuse enters the fines section of the trommel where it is screened first on 10 x 50 mm aperture screens (Fines A) and then on 25 x 100 mm aperture screens (Fines B). In normal operations the products from these two fine screen sections are combined for disposal to tip, via 30 yd^3 open lorries. However, for the tests, these products were kept separate and allowed to fall into open 6 yd^3 skips which facilitated sampling and accurate weighing. Sampling was achieved by sliding a tarpaulin into the falling streams.

Oversize from the fines section was screened in the intermediate section at a nominal aperture size of 6 inches (152 mm) (the precise size apertures for this screen section are shown in Fig. 19B), the resulting undersize (the intermediate product) passing on to the air classifier, magnet and heavies reject collection system. To eliminate losses, the air classifier and magnet were not operated during the tests and all of the intermediate product was collected in a 30 yd^3 open topped container placed under one discharge end of a reversible conveyor. Sampling of this product was achieved by reversing the conveyor and discharging the sample into a front end loader bucket. In continuous plant operation, this "sampling position" is required for an empty 30 yd^3 container to take the product once the first container is full and therefore, timing of the incremental samples had to be between container changes.

Due to the excellent cooperation and help given by the Byker plant operators and high skill shown by the vehicle drivers this did not prove to be a problem and the incremental sample times were not more than ± 2 minutes out of phase with the fines and oversize sample times.

The oversize product from the trommel reported to a compactor skip and sampling of this stream was effected by disconnecting the compactor to permit access and removal of uncompacted material directly from the ram. Oversize material in excess of that required for the sample was held in a surge hopper above the compactor until the skip had been reconnected.

It was not possible to sample the pulverised feed to the screen and thus for purposes of assessment a calculated feed, based on the product weights and size distributions, was used. Samples of the feed material before pulverisation were taken on the tipping floor, the front end loader driver collecting and depositing the refuse in yd^3 sample skips at the selected time intervals.

12584

FIG.18 BYKER FLOWSHEET FOR NCR TEST WORK, 5th AND 6th SEPT 1980

GENERAL SCREEN PLATE SIZE = 1000 X 1500mm (1500mm CIRCUMFERENTIAL)
 SCREEN RING = 5 SCREEN PLATES i.e. 1000 WIDE X 7500 INTERNAL CIRCUMFERENCE
 'FINES A' SECTION = 2 SCREEN RINGS
 'FINES B' SECTION = 2 1/2 SCREEN RINGS
 'INTERMEDIATES' SECTION = 6 SCREEN RINGS $a = c \neq b = d \neq e = f \neq a$
 SCROLL PITCH = 940 - 950 mm
 TROMMEL SPEED = 12 rpm (ALL TESTS)

12585

FIG.19 SCREEN CONFIGURATION OF BYKER TROMMEL, 5th SEPT 1980

INTERMEDIATE SCREENS, RING SECTIONS 'a' AND 'c'

SECTION A-A

CROSS SECTION SHOWING VANES ON OUTER SURFACE OF SCREEN PLATE

COMMENTS

APERTURE SIZE ON PLATE =
EFFECTIVE APERTURE SIZE =
Nos. OF EFFECTIVE APERTURES
PER PLATE = 40

TOTAL Nos. OF APERTURES
SECTIONS 'a' AND 'c' = 400

OPEN AREA 68%

Diagram illustrating the layout of a perforated plate with dimensions and hole patterns.

Dimensions:

- Overall width: 1000 mm
- Overall height: 1500 mm
- Distance between centers of adjacent round holes in a row: 150 mm
- Distance between centers of adjacent elongated holes in a row: 340 mm
- Radius of a round hole: 75 mm

Hole Patterns:

- 5 rows of 2 elongated & 1 round apertures
- 4 rows of 1 elongated & 2 round apertures

Comments:

- 6" ROUND HOLES
- 6 x 13 1/2" ELONGATED HOLES
- ROUND HOLES PER PLATE = 13
- ELONGATED HOLES PER PLATE = 14

Calculations:

- TOTAL NOS OF ROUND HOLES SECTIONS 'b' AND 'd' = 130
- TOTAL NOS OF ELONGATED HOLES SECTIONS b AND d = 140
- OPEN AREA = 49%

12588

At the end of each run all products were weighed and the samples sealed either in bags or in skips to prevent moisture loss before processing at the laboratory.

3.1.1 Sample Analysis Procedure

The following analyses were carried out at the laboratory:-

Fines Sample Analysis (Fines A and B)

The weight and volume of each sample was measured to determine bulk density, and one quarter of each was cut out for moisture determination (dried at 105°C). The remaining material was screened, at 3", 2", 1" and 1/2", and each size fraction weighed and dried to provide distributions on both wet and dry bases.

Intermediate and Oversize Sample Analysis

The procedure adopted was the same as that for the fines samples, using screen sizes of 6", 5", 4", 3", 2", 1" and 1/2".

Raw Refuse Feed Samples

The weight and volume of the samples was measured to determine bulk density. One quarter of the sample was cut out for moisture determination (dried at 105°C).

For tests 1 and 2 (39 and 31 t h⁻¹) the remaining material was screened at 6", 5", 4", 3", 2", 1" and 1/2" and each fraction was handsorted to establish the category assay. For test 3 the feed material was handsorted into the various categories but not screened. For this latter test the individual categories were then weighed and dried at 105°C to establish category moisture contents.

3.2 Experimental Results and Discussion

Table 18 gives the mass balance, moisture contents, bulk densities and per cent distributions of the size fractions reporting in the products for each test.

Tables 19, 20, 21 and 22 give the products and calculated feed size distributions, on both wet and on dry weight bases, for each test. Tables 23 and 24 give the measured size distributions of the raw feeds for tests 1 and 2 and the category assays of each size fraction whilst Table 25 gives the category assay of feed 3 and the average category assay of feed material for all three tests.

The size distribution for all products, calculated feeds and measured raw refuse feeds are shown in Figs 20 to 23 on a "cumulative weight passing" against selected "aperture size" basis.

The effect of decreasing feed rate is clearly shown, in Table 18, by the change in the wet weight product distributions and the distribution (or recovery) of selected size fractions in these products. For example the per cent product weights of Fines A and Fines B for test 3 (18.5 t h⁻¹) were 8.3% and 14.9% respectively compared with only 5.2% and 9.2% for test 1 (39.3 t h⁻¹). Similarly the recovery (distribution) of -1/2" material in Fines A and Fines B was reduced from 19% and 27% for test 3 to 10% and 15% for test 1.

None of these performances, with respect to the removal of -1/2" material, is adequate. In all tests, even at the low feed rate (60% of designed rating), less than 50% of the -1/2" material available in the feed was extracted to Fines A + B products.

Table 26 gives the screening efficiencies (calculated on the same basis as the Doncaster results - Table 7), the grades and the recoveries of -1/2" material associated with the undersize products from the three feed rates. It can be noted from this table that the screening efficiencies of both Fines A and Fines B screens are very similar although the recovery of available -1/2" material, for the B screen section, is 1.7 times that of the Fines A. This figure might be less than anticipated, in view of the 2 x 2 increase in aperture size and the 25% increase in screen plate length of the B section. However, the nature of the -1/2" material removed by the first screen will directly effect the performance of the second. Also, under the high loading conditions tested, the chance of presentation of -1/2" material to open screen surface was probably more of a limiting factor than the probability of -1/2" material passing once presented. This latter factor was apparent from observations of the flow patterns in the trommel. The pulverised feed was voluminous and formed a thick bed depth over the fine screen plates where the particulate movements appeared to be mainly in a rolling/ slumping mode with relatively few particles being thrown beyond the lower edge of the "riding angle" of the bulk refuse.

TABLE 18. - NERR Byker Testwork. Pass Balance and Size Distribution

TEST 1. Run Time = 46 minutes. Calc. feed Rate = 39.3 Metric Tonnes Per hour

Product	Wet Wt. Tonnes	Distribution Wet Wt. %	Moist. Cont. Wt. % From Product Samples	Calculated Moist. Cont. Wt. % From Sized Fraction	Bulk Density kg m ⁻³	% Distribution (Wet Wt.) of Size Fractions Reporting in Products							
						+6 Inches	-6 + 5	-5 + 4	-4 + 3	-3 + 2	-2 + 1	-1 + 1/2	-1/2
Fines A	1.56	5.2	34.3	33.1	417	-	-	-	-	<<1	<1	1	10
Fines B	2.76	9.2	39.0	36.2	272	-	-	-	-	<1	2	9	15
Intermediates	24.20	80.2	33.1	33.7	223	-	70	44	85	95	95	89	75
Oversize	1.64	5.4	Ashed (19.3*)	19.3	52	100	30	56	15	5	3	1	<1
Calc. Feed	30.16	100.0	33.0	33.1	[196]	100	100	100	100	100	100	100	100
Measured Feed	30.43 [#]	-	35.6	-	153								

(* calculated value from sized fraction moisture)

TEST 2. Run Time = 50 minutes. Calc. Feed Rate = 31.5 Metric Tonnes Per hour

Product	Wet Wt. Tonnes	Distribution Wet Wt. %	Moist. Cont. Wt. % From Product Samples	Calculated Moist. Cont. Wt. % From Sized Fraction	Bulk Density kg m ⁻³	% Distribution (Wet Wt.) of Size Fractions Reporting in Products							
						+6 Inches	-6 + 5	-5 + 4	-4 + 3	-3 + 2	-2 + 1	-1 + 1/2	-1/2
Fines A	1.76	6.7	35.3	35.6	477	-	-	-	-	<<1	<1	1	14
Fines B	3.02	11.5	38.1	38.6	220	-	-	-	-	<<1	3	12	20
Intermediates	20.73	78.9	34.0	33.9	159	43	56	80	94	98	96	87	66
Oversize	0.78	3.0	26.6	23.1	55	57	44	20	6	2	1	<1	<1
Calc. Feed	26.29	100.0	34.3	34.2	[162]	100	100	100	100	100	100	100	100
Measured Feed	27.63 [#]	-	32.8	-	199								

TEST 3. Run Time = 55 minutes. Calc. Feed Rate = 18.5 Metric Tonnes Per hour

Product	Wet Wt. Tonnes	Distribution Wet Wt. %	Moist. Cont. Wt. % From Product Samples	Moist. Cont. Wt. % From Sized Fractions	Bulk Density (Sample Measurements) kg m ⁻³	% Distribution (Wet Wt.) of Size Fractions Reporting in Products							
						+6 Inches	-6 + 5	-5 + 4	-4 + 3	-3 + 2	-2 + 1	-1 + 1/2	-1/2
Fines A	1.41	8.3	34.2	32.5	440	-	-	-	-	<<1	<<1	1	19
Fines B	2.53	14.9	36.4	35.9	288	-	-	-	-	<<1	3	20	27
Intermediates	12.48	73.5	34.4	30.8	138	19	61	80	97	98	97	79	54
Oversize	0.56	3.3	28.9	15.7	26	81	39	20	3	2	<1	<<1	<<1
Calc. Feed	16.98	100.0	34.5	28.5	[137]	100	100	100	100	100	100	100	100
Measured Feed	17.68 [#]	-	34.1	-	183								

[#] Integrated weight from plant load cell

TABLE 19. - MCRR Byker Tests
Wet and Dry Weight Size Distributions of Fines A and B Product Samples

FINES A	Test 1					Test 2					Test 3				
	Wet Wt. Distribution %	Wet Wt. Cumulative % Passing	Dry Wt. Distribution %	Dry Wt. Cumulative % Passing	Moisture Content %	Wet Wt. Distribution %	Wet Wt. Cumulative % Passing	Dry Wt. Distribution %	Dry Wt. Cumulative % Passing	Moisture Content %	Wet Wt. Distribution %	Wet Wt. Cumulative % Passing	Dry Wt. Distribution %	Dry Wt. Cumulative % Passing	Moisture Content %
-3 + 2	0.05	100.00	0.05	99.99	36.2	0.14	100.00	0.13	100.00	43.8	.03	100.00	0.026	100.00	36.9
-2 + 1	0.31	99.95	0.27	99.94	41.3	0.15	99.86	0.13	99.87	44.1	.06	99.97	0.054	99.97	38.0
-1 + 1/2	3.94	99.64	3.62	99.67	38.5	2.55	99.71	2.41	99.74	38.9	1.92	99.91	1.782	99.92	37.4
-1/2	95.70	95.70	96.05	96.05	32.9	97.16	97.16	97.33	97.33	35.4	97.99	97.99	98.138	98.14	32.4
TOTAL	100		100		33.1	100		100.00		35.6	100.0		100.00		32.5
FINES B															
-3 + 2	0.21	100.00	0.23	100.00	28.3	.09	100.01	0.09	100.00	36.8	.06	100.01	0.06	100.00	35.3
-2 + 1	3.25	99.79	3.50	99.77	40.5	3.56	99.92	3.71	99.91	36.0	3.32	99.95	2.85	99.94	44.9
-1 + 1/2	17.91	96.04	16.71	96.27	40.5	18.72	96.36	17.12	96.20	43.9	20.63	96.63	19.19	97.09	40.1
-1/2	78.83	78.13	79.56	79.56	35.0	77.64	77.64	79.08	79.08	35.3	76.00	76.00	77.90	77.90	34.3
TOTAL	100		100.00		36.2	100		100.00		38.6	100		100.00		35.9

TABLE 20. - NCRR Byker Testwork
Wet and Dry Weight Size Distributions of Intermediate Product Samples

Size (inches)	Test 1 Feed Rate 39.3 te h^{-1}					Test 2 Feed Rate 31.5 te h^{-1}					Test 3 Feed Rate 18.5 te h^{-1}				
	Wet Wt. Distribution %	Cumulative Wet Wt. % Passing	Dry Wt. Distribution %	Cumulative Dry Wt. % Passing	Moisture Content Size Fraction	Wet Wt. Distribution %	Cumulative Wet Wt. % Passing	Dry Wt. Distribution %	Cumulative Dry Wt. % Passing	Moisture Content Size Fraction	Wet Wt. Distribution %	Cumulative Wet Wt. % Passing	Dry Wt. Distribution %	Cumulative Dry Wt. % Passing	Moisture Content Size Fraction
+ 6	-	-	-	-	-	0.85	99.99	.88	99.98	31.4	0.54	99.99	0.62	99.98	19.4
-6 + 5	1.71	99.99	1.92	100.00	25.7	1.27	99.14	1.29	99.10	33.3	1.45	99.45	1.59	99.36	23.9
-5 + 4	0.84	98.28	.91	98.08	28.4	1.67	97.87	2.12	97.81	16.2	2.07	98.00	2.10	97.77	29.3
-4 + 3	4.44	97.44	5.09	97.17	24.0	6.69	96.20	7.39	95.69	27.2	10.82	95.93	12.68	95.67	18.3
-3 + 2	16.34	93.00	11.94	92.08	37.3	11.56	89.51	13.45	88.30	23.3	13.05	85.11	14.04	82.99	25.0
-2 + 1	17.35	82.65	16.33	80.14	37.8	19.93	77.95	20.72	74.85	31.5	24.42	72.06	23.67	68.95	32.5
-1 + 1/2	19.31	65.27	17.81	63.81	38.9	20.53	58.02	19.20	54.13	38.3	16.58	47.64	14.90	43.30	37.4
-1/2	45.96	45.96	46.00	46.00	33.7	37.49	37.49	34.93	34.93	38.6	31.06	31.06	30.40	30.40	31.8
TOTAL	100		100.00		33.7	100		100		33.9	100				30.3

TABLE 21. - NCRR Byker Testwork
Wet and Dry Weight Size Distributions of Oversize Product Samples

Size (inches)	Test 1 Feed Rate 39.3 te h^{-1}					Test 2 Feed Rate 31.5 te h^{-1}					Test 3 Feed Rate 18.5 te h^{-1}				
	Wet Wt. Distribution %	Cumulative Wet Wt. % Passing	Dry Wt. Distribution %	Cumulative Dry Wt. % Passing	Moisture Content Size Fraction	Wet Wt. Distribution %	Cumulative Wet Wt. % Passing	Dry Wt. Distribution %	Cumulative Dry Wt. % Passing	Moisture Content Size Fraction	Wet Wt. Distribution %	Cumulative Wet Wt. % Passing	Dry Wt. Distribution %	Cumulative Dry Wt. % Passing	Moisture Content Size Fraction
+ 6	41.49	100.00	42.08	100.00	18.1	29.60	100.00	29.92	100.00	22.3	51.07	100.00	52.30	99.99	13.7
-6 + 5	10.83	58.51	11.41	57.92	15.0	26.26	70.40	26.98	70.08	21.0	20.35	48.93	20.17	47.69	16.5
-5 + 4	14.45	47.68	14.55	46.51	18.7	12.40	44.14	12.10	43.10	25.0	11.38	28.58	11.45	27.52	14.8
-4 + 3	11.17	33.23	11.08	31.96	19.8	11.81	31.74	11.49	31.00	25.2	8.34	17.20	7.29	16.07	26.3
-3 + 2	8.23	22.06	7.81	20.87	23.5	5.83	19.93	6.73	19.51	24.3	4.92	8.86	4.87	8.78	16.5
-2 + 1	7.07	13.83	6.58	13.06	24.9	6.38	13.10	6.07	12.78	26.9	2.60	3.94	2.53	3.91	18.1
-1 + 1/2	2.72	6.76	2.48	6.48	26.3	2.76	6.72	2.65	6.71	26.2	0.57	1.34	0.57	1.38	15.5
-1/2	4.04	4.04	4.00	4.00	29.1	3.96	3.96	4.06	4.06	21.2	0.77	0.77	0.81	0.81	11.4
TOTAL	100		100.00		19.3			100.00		23.1			99.99		13.7

TABLE 22. - NCRR Byker Testwork
Calculated Feed Results from Product Samples, Wet and Dry Weight Distributions and Moisture Contents

Size (inches)	Test 1 Feed Rate 39.3 to h ⁻¹					Test 2 Feed Rate 31.5 to h ⁻¹					Test 3 Feed Rate 18.5 to h ⁻¹				
	Wet Wt. Distribution %	Cumulative Wet Wt. % Passing	Dry Wt. Distribution %	Cumulative Dry Wt. % Passing	Moisture* Content Size Fraction	Wet Wt. Distribution %	Cumulative Wet Wt. % Passing	Dry Wt. Distribution %	Cumulative Dry Wt. % Passing	Moisture* Content Size Fraction	Wet Wt. Distribution %	Cumulative Wet Wt. % Passing	Dry Wt. Distribution %	Cumulative Dry Wt. % Passing	Moisture* Content Size Fraction
+ 6	2.26	100.00	2.72	100.1	19.2	1.55	100.00	1.69	100.00	28.3	2.08	99.99	2.33	100.01	26.6
-5 + 5	1.96	97.74	2.28	97.29	22.3	1.78	98.45	1.92	98.31	29.5	1.74	97.91	1.89	97.68	28.8
-5 + 4	1.46	95.78	1.67	95.01	23.5	1.79	96.67	2.08	96.39	23.6	1.90	96.17	1.96	95.79	37.5
-4 + 3	4.17	94.32	4.79	93.34	22.9	5.64	94.88	6.24	94.31	27.4	8.23	94.27	9.60	93.93	23.6
-3 + 2	8.77	90.15	10.10	88.55	22.6	9.35	89.24	10.90	88.07	23.5	9.76	86.04	10.52	84.23	29.4
-2 + 1	14.70	81.38	13.82	78.45	37.0	16.16	79.81	17.04	77.17	30.9	18.53	76.28	17.92	73.71	36.7
-1 + 1/2	17.49	66.68	16.01	64.63	38.7	18.61	63.73	17.32	60.13	38.9	15.44	57.75	13.92	55.79	41.0
-1/2	49.19	49.18	48.62	48.62	33.8	45.12	45.12	42.81	42.81	37.8	42.31	42.31	41.87	41.87	35.2
TOTAL	100		100		33.0	100		100		34.3	100		100		34.5

* Method of calculation given in notes.

TABLE 23. - NCRR Dyker Tests

Raw Refuse Feed Test 1. Wet Weight Category Assay and Distribution in Size Fractions

Categories Size Inches	Wet Weight Assay							Wet Weight Distribution %							Size Distribution
	Paper/ Card Wt %	Plastic Film Wt %	Metals Wt %	Putr/DPL/ MC Wt %	Glass/ Stones Wt %	Textiles Wt %	Fines* -1/2" Wt %	Paper/ Card Wt %	Plastic Film Wt %	Metals Wt %	Putr/DPL/ MC Wt %	Glass/ Stones Wt %	Textiles Wt %	Fines* -1/2" Wt %	Calculated Feed Size Distribution Wet Wt %
+ 6	61.4	7.6	4.2	11.8	-	14.4	0.6	41.7	48.9	15.1	14.6	-	72.1	1.0	25.2
-6 + 5	73.1	2.3	0.3	9.2	6.8	5.6	2.7	20.9	6.2	0.4	4.8	6.8	11.7	1.9	10.4
-5 + 4	32.3	4.5	6.9	10.6	43.8	1.9	-	7.0	9.3	7.9	4.2	32.8	3.1	-	8.1
-4 + 3	27.4	4.4	27.9	26.8	9.5	2.8	1.2	9.4	14.2	51.0	16.9	11.3	7.0	1.0	12.7
-3 + 2	43.0	6.9	15.3	21.4	10.0	2.2	1.2	8.2	12.5	15.4	7.4	6.6	3.1	0.6	7.0
-2 + 1	29.0	2.2	3.8	41.8	21.1	0.9	1.2	10.7	7.6	7.4	28.2	26.9	2.6	1.1	13.6
-1 + 1/2	7.8	0.5	2.0	47.9	16.6	0.2	25.0	2.1	1.3	2.8	23.9	15.6	0.5	16.8	7.6
-1/2	-	-	-	-	-	-	100.0	-	-	-	-	-	-	77.7	15.2
TOTAL	37.4	3.9	7.1	20.5	10.8	5.1	15.2	100.0	100.0	100.0	100.0	100.0	100.1	100.1	100.0

* Fines content in sized fractions for handsorting screened on a 16 mm screen instead of 1/2" screen in error.

TABLE 24. - NCRR Byker Tests

Raw Refuse Feed Test 2. Wet Weight Category Assay and Distribution in Size Fractions

Categories		Wet Weight Assay						Wet Weight Distribution %							Size Distribution	
Size Inches	Paper/ Card	Plastic Film	Metals	Putr/DPL/ MC	Glass/ Stones	Textiles	Fines** -1/2"	Paper/ Card	Plastic Film	Metals	Putr/DPL/ MC	Glass/ Stones	Textiles	Fines -1/2" 16 mm	Calculated Feed Size Distribution Wet	
	Wt %	Wt %	Wt %	Wt %	Wt %	Wt %	Wt %	Wt %	Wt %	Wt %	Wt %	Wt %	Wt %	Wt %	Wt %	
+ 6	47.1	5.2	3.1	15.2	9.9	18.2	1.4	40.5	30.2	7.6	13.0	14.0	70.4	1.4	20.4	
-6 + 5	37.5	3.5	8.3	14.2	16.3	6.6	13.5*	7.6	4.8	4.9	2.9	5.4	6.1	3.3	4.2	
-5 + 4	26.8	5.1	4.1	26.4	28.0	8.5	1.2	8.7	11.1	3.8	8.5	15.0	12.4	0.5	7.7	
-4 + 3	18.2	2.9	32.9	28.2	17.3	0.5	-	9.7	10.3	50.8	15.0	15.2	1.3	-	12.9	
-3 + 2	33.4	10.9	11.6	26.6	13.2	4.3	-	13.7	29.8	13.7	10.8	8.9	8.0	-	9.8	
-2 + 1	23.9	2.9	6.5	47.7	18.7	0.4	-	16.8	13.5	13.1	33.3	21.5	1.2	-	16.8	
-1 + 1/2	5.7	1.3	4.2	32.4	23.7	0.3	33.6	2.9	0.4	6.1	16.5	19.9	0.7	20.5	8.1	
-1/2	-	-	-	-	-	-	100.0	-	-	-	-	-	-	74.3	20.0	
TOTAL	24.0	3.6	8.3	24.1	14.6	5.3	20.0	99.9	100.1	99.9	100.0	99.9	100.1	100.0	99.9

FIG. 21 NCRR BYKER TEST WORK, FEED SIZE DISTRIBUTIONS, DRY BASIS

FIG. 22 NCRR BYKER TEST WORK, PRODUCT SIZE DISTRIBUTIONS, WET BASIS

FIG. 23 NCRR BYKER TEST WORK, PRODUCT SIZE DISTRIBUTION, DRY BASIS

FIG. 24 NCRR BYKER TEST WORK, FEED SIZE DISTRIBUTIONS, WET BASIS

TABLE 25. - NCRR Byker Testwork

Test 3. Wet and Dry Category Assay of Raw Refuse Feed 3 and Wet Assays of Feeds for Tests 1 and 2

Category	Wet Wt kg	Wet Wt Percent	Dry Wt kg	Dry Wt Percent	Moisture Content Wt %	Wet Wt Feed Assays Test:	Average Wet Wt Assay Tests 1, 2 and 3
						1	2
Paper/Card	37.11	43.3	26.12	42.7	29.6	37.4	24
Pl. Film	3.24	3.8	1.98	3.2	38.7*	3.9	3.6
Metals	7.27	8.5	6.19	10.1	14.8	7.1	8.3
Putr/DPL/MC	13.38	15.6	6.41	10.5	52.1	20.5	24.1
Glass/Stones	9.86	11.5	9.57	15.6	3.0	10.8	14.6
Textiles	4.69	5.5	3.12	5.1	33.5	5.1	5.3
Fines -1/2"	10.08	11.8	7.77	12.7	23.0	15.2	20.0
Total (Calc)	85.63	100.0	61.15	100.0	28.6	100.0	100.0
							100.1

* Moisture content of plastic film is higher than expected (15-20%) suggesting loss of volatiles and degradation of plastic due to hot spots in oven.

TABLE 26. -1/2" Screening Efficiency, Recovery and Grade Results, Fines A and B Screens

Test Nos	Feed Rate te h ⁻¹	Fines A -1/2" material			Fines B -1/2" material			Combined Fines A and B -1/2" material		
		Grade Wt %	Recovery Wt %	Screening Efficiency %	Grade Wt %	Recovery Wt %*	Screening Efficiency %	Grade Wt %	Recovery Wt %	Screening Efficiency %
1	39.3	95.7	10	4.6	78.1	16.7	4.2	85.7	25	10.1
2	31.5	97.2	14	7.4	77.6	23.3	7.7	84.8	34	14.0
3	18.5	98.0	19	11.3	76.0	33.3	12.6	83.9	46	21.4

* Recovery based on -1/2" material available to this screen section i.e. excluding material lost to fines A product.

The effect of feed rate on the screening efficiency of the intermediate aperture sections is less clearly demonstrated in Table 18, where the wet weight oversize distribution for test 1 is greater than those of tests 2 or 3 which are almost identical. The distributions of size fractions again shows a general increased loss of material, from the individual size fractions between +1" and -6" into the oversize product at the higher feed rates. Anomalous recovery results are noted in the higher size ranges, e.g. the highest recovery of -6+5" material into the intermediate product is recorded in test 1, the highest feed rate, but these are influenced significantly by the feed and product characteristics at the extremes of the size ranges.

The effect of feed rate on the screening efficiency of the intermediate screen apertures is more clearly shown when the effects of the varying fines contents are minimised by considering only the +1" material. Table 27 gives the calculated flow rate of all material and of the +1" material to these screens and considers the product weight distribution, the recovery and the grades of +1" material in the two products.

Although there were large differences in the total feed rates of material to the intermediate screen section, changes in the flows of +1" material were not quite so marked and this is reflected in the relatively small changes recorded in recoveries of the intermediate product if only +1-6" material is considered. The difference in grade of the oversize products are due more to the differences in feed size distributions and the difficulty in taking representative samples of large size fraction materials than to a reflection of real changes in the overall quality of this product.

It was noticeable that, with pulverised feed, the action of the trommel occasionally produced "rolling sausage" type tangled conglomerates which at times, were found in some of the samples. On screening such

TABLE 27. - Distribution, Recovery and Grade of Material about the Intermediate Screen Apertures

Test Nos	Feed rate t h^{-1} To intermediate screens		Weight per cent distribution of +1" material		Weight per cent recovery of +1-6" material		Weight per cent grade of +1-6" material	
	all sizes	+1" only	Ints	Overs	Ints	Overs	Ints	Overs
1	33.6	13.0	84.6	15.4	90.8	9.2	100	55.5
2	25.8	11.3	92.3	7.7	94.2	5.8	98	68.3
3	14.2	7.7	92.2	7.8	96.0	4.0	99	48.2

samples, these conglomerates report as +6" material and contribute significant weights for relatively few conglomerate particles thus increasing the chance of non representative sampling.

The intermediate screen section can be considered efficient in terms of the high recoveries and grades of the -6" products, at all feed rates tested. However, from the point of view of maximising recovery of light constituents to the fuel circuit, it was felt that larger apertures could have been introduced, without causing increased handling problems in downstream processing operations, as the "quality" of the reject oversize product was consistently high in plastic film, paper and textiles. In further consideration of the individual feed and product size distributions it can be seen in Fig. 20 that, within the range of feed rates tested, higher feed rates give finer pulverisation of the feed. The order in which the tests were carried out might have contributed to this effect, due to increased hammer wear. However, as the plant was not operated between test runs, only 73 tonnes of refuse were processed between the start of test 1 and the end of test 3 and therefore hammer wear is unlikely to have contributed significantly to this change which is most likely due to the performance characteristic of the pulveriser.

It is interesting to note that the natural size distribution for the raw feeds for tests 1 and 2 give less than 20% -1/2" material which, after pulverisation, increased 2 to 3 times. Considering the raw refuse category size assays for these tests (Tables 23 and 24), the high ash, glass and stones components represent only 10.8% and 14.6% by weight of the feeds and hence a significant weight of the pulverised -1/2" must be from low ash, though possibly high moisture, categories even allowing for 100% of the glass and stone being reduced to -1/2".

Figure 22, showing the wet weight product size distributions, displays an interesting feature for the Fines A characteristic with slightly coarser products being recovered at the higher feed rates. This is an unexpected result which, if real, is difficult to explain.

The more conventional trend of coarser size distributions at lower feed rates is displayed for the Fines B and the intermediate size fractions though the oversize shows some 'cross over' between tests 1 and 2. This is not felt to be significant and is probably due to sampling error and differences in feed category and size distributions (test 2 raw feed sample reported significantly less paper in the feed and a lower proportion of +5" material).

The inefficient fines removal is clearly demonstrated by comparing intermediate size characteristics with those of the pulverised feed. The test 1 intermediate product falls within the range of unscreened pulverised feed size distributions indicating that if the small quantities of +6" material were acceptable to the downstream processing operations, then the unscreened pulverised feed 3 is coarser and therefore a better product than the screened intermediate product from test 1, i.e. the trommel is superfluous in this respect.

The moisture determinations on the individual pulverised feed size fractions (Table 22) indicate that the effective removal of -2" material is required for maximum moisture removal from the intermediate fuel fraction, with the -1+1/2" fraction consistently reporting the highest moisture levels.

The effects of moisture on sample size distributions and recoveries is not significant and the reported distributions do not differ markedly.

The results have been discussed primarily in terms of size, with broad reference to high ash -1/2" material, but no quantitative evidence has been presented to indicate that the ash content of, say, the -1/2" Fines A product is the same as the ash content of the oversize -1/2" material. This information would be of interest in providing evidence to indicate whether selective or non selective screening of plate like (generally low ash) and bulky (generally high ash) particles occurs in the fine screens. Accordingly, as part of the Laboratory's support to UK refuse processing operations sponsored by the UK Department of Environment, ash and calorific values were obtained on selected samples from the NCRB Byker test programme and these are shown in Table 28.

TABLE 28. - Ash and Calorific Value Results, Byker Testwork

Test Nos	Product	Size Fraction	Dry Weight Determinations		
			Ash Wt %	Calorific value KJ/g	Ash free calorific value KJ/g
1	Fines A	Total	n.a.	n.a.	n.a.
1	Fines A	-1/2"	70.6	6.2	21.1
	Fines B	Total	n.a.	n.a.	n.a.
1	Fines B	-1/2"	66.0	6.9	20.3
	*Intermed.	Total	38.3	13.2	21.4
	*Intermed.	-1/2"	48.5	10.8	21.0
	Oversize	Total	n.a.	n.a.	n.a.
	Oversize	-1/2"	51.5	10.4	21.4
	**Calc feed	-1/2"	53.1	9.8	20.9
2	Fines A	Total	67.0	6.7	20.3
	Fines A	-1/2"	66.0	6.9	20.3
	Fines B	Total	54.4	9.3	20.4
	Fines B	-1/2"	62.7	8.0	21.5
	*Intermed.	Total	31.7	14.6	21.4
	*Intermed.	-1/2"	45.4	11.7	21.4
	Oversize	Total	23.7	18.5	24.2
	Oversize	-1/2"	44.9	11.4	20.7
	**Calc feed	-1/2"	51.9	10.2	21.3
3	Fines A	Total	64.7	7.4	21.0
	Fines A	-1/2"	68.5	6.6	21.0
	Fines B	Total	43.9	13.4	23.9
	Fines B	-1/2"	59.4	8.5	20.9
	*Intermed.	Total	32.3	16.0	23.6
	*Intermed.	-1/2"	52.1	10.1	21.1
	Oversize	Total	16.1	20.0	23.8
	Oversize	-1/2"	66.4	7.2	21.4
	Raw feed	-1/2"	10.8	8.6	21.9
	**Calc feed	-1/2"	57.3	9.0	21.1

* Intermediates

** Calculated pulverised feed

The ash contents of the products decrease with increased coarseness for all tests and the decrease is more marked for the intermediate and oversize products from low throughput tests showing the quality of these products to be dependent on efficient fines removal.

The ash contents in the -1/2" size fractions of the products indicate that selective screening is occurring with the -1/2" intermediate ash contents lower than -1/2" Fines B and significantly lower than the -1/2" Fines A ash contents.

This trend is not shown in the ash results for the oversize, probably because the -1/2" size fraction is so small relative to the intermediate screen size that its presence in the oversize stream is not dependent on probability of passing the apertures in terms of particle characteristics e.g. presentation angle, shape, density etc, but on independent factors such as entrainment and non liberation of particles.

The ash content of the -1/2" raw feed sample, for test 3, indicates that it is naturally high ash. Comparing this with the calculated pulverised ash figure indicates that pulverisation, though undoubtedly reducing most of the glass and stone to -1/2" size range, has also reduced much of the low ash categories thus producing a -1/2" fines of lower ash grade than that found naturally in the feed material. The calculated results for the pulverised feeds for tests 1 and 2 are compatible with this result although direct comparison with natural -1/2" feed material for those tests is not possible with the results available.

The dry ash free calorific values are remarkably similar for both the products and the -1/2" size fractions suggesting that there is little differentiation in composition of the associated combustible components and that this material is mainly cellulosic.

Generally, these results indicate that the Byker plant is overpulverising the feed material and reducing significant quantities of the light cellulosic categories to $-1/2$ " material. The selectivity of the fines screens is demonstrated by the preferential removal of components with high ash contents, however they are not coping adequately with the total weight of $-1/2$ " material present and a large proportion of this undersize reports to the intermediate fuel fraction under all conditions. Clearly, much of this misplaced fines fraction will classify with the fuel product, providing a strong case for increasing the aperture sizes of the fines screens. Inevitably this will result in greater losses of combustibles from the $-1/2$, $-1+1/2$ and $-2+1$ " size fractions but, with the high moisture contents in the latter two size ranges, this would ease subsequent pelletising requirements and could be advantageous to the overall process.

The screening results suggest that increasing aperture size is only part of the answer to improved screening efficiencies with low probability of presentation of particles to open screen plate being a major cause of the poor performance. This may be exaggerated by the nature of pulverised refuse, but the screening mode would appear to be a most important factor which could probably be improved by the introduction of plate lifters in the fines screen section. To some extent, the effect of lifters can be produced by increasing trommel rotation nearer to its critical speed. However, this 'solution' is not readily available at Byker, where the trommel is fitted with a fixed speed drive and, further, considering the Doncaster results, the evidence for improved performance with increased rotational speed has not been particularly encouraging.

As with the Doncaster tests, the conclusions accruing from the Byker testwork have been limited by the selection of an insufficiently wide range of controlled variables. However, in this case, although we have operated about the designed rating (30 te/hr) for the trommel, it proved much too high for efficient fine screening. Lower feed rates and/or coarser fine apertures would have produced more valuable results.

4. COMPARATIVE DISCUSSION OF THE BYKER AND DONCASTER TESTS

4.1 Test Procedures

In terms of consistent feed conditions and target feed rates, the Byker test series demonstrated a much better control than that achieved at Doncaster and the following design factors at Byker are felt to be relevant in this respect.

1. The plant load cell gives feedback information both to the plant control room and the front end loader driver.
2. The position of the Byker control room gives good visual observation of both the tipping floor and the plant, whereas at Doncaster the tipping floor cannot be observed and hence the front end loader driver is effectively isolated from the processing operation.
3. The combination of vibrating pan feeder and pulveriser at Byker appears to even out any short term variations in feed rate whereas the hopper and plate conveyor at Doncaster is prone to short and longer term feed variations at fixed speed.
4. With the high natural fines content of the refuse feed and the high screening efficiencies obtained at Doncaster, large proportions of the feeds exited at the fines section leaving extremely low loadings on the coarser screens and this magnified the visual effect of feed rate changes.

4.2 Analysis Procedure

Considering the 'difficult' nature of the materials, the basic screening procedure adopted for the analyses in both tests was felt to give consistently high screening efficiencies. Some doubts were expressed as to the validity of the results in absolute terms, at large screen sizes, where it was noticeable that, with each handling operation, categories such as paper, textiles and plastic film were generally increasing their size due to unfolding. For example a newspaper would be noted as being small enough to pass a 4" screen size before the screen analysis only to unfold during the first screening procedure at 6" and hence fail to pass the 5" aperture screen.

For the Byker results the range of screen sizes used should probably have included a $1/4$ " screen in order to provide clearer evidence on the limiting factors which effect the screening efficiencies in the fines screen sections. For Doncaster and Byker an 8" screen (even 10" for Doncaster) would have provided useful data in the assessment of the performance of the intermediate screen.

The moisture results obtained on the individual size fractions at Byker were not felt to demonstrate any significant influences on the screening results though they do provide useful information with which to assess the design objectives of the screen which, in the light of the results, should include removal of a significant proportion of $-1+1/2$ material.

The category number counts from the Doncaster tests have provided some useful information with regard to selective screening mechanisms, particularly in terms of the recovery values obtained for specific size fractions. They have also highlighted the problems of calculating recovery of a size fraction close to the aperture size of the screen under consideration indicating that the oversize and undersize material are not directly comparable in terms of the mean size of the particles in the given size range.

The number count data, in terms of product size distributions, do not seem to be particularly useful in describing the quality of a product; the results being heavily weighted towards the fine sizes. However, it does seem to reduce the anomalous distribution caused by specific categories such as ferrous.

The use of surrogates to assess trommel conditions has provided very useful backup information despite the reservations expressed with regard to the effect of feed rate variations. The need to distribute the surrogates evenly into the refuse feed, as opposed to pulse additions, was clearly demonstrated by the card surrogate results where the distributions about the intermediate screens were clearly effected more by surrogate interaction and interference than by changes in the base refuse feed rate.

4.3 Results

As discussed in the Byker and Doncaster results sections, clear interpretation of the results has been hindered by two main factors:

- (a) the Doncaster trommel was too efficient in the range of feed rates tested and thus the quantitative effects of feed rate and trommel speed changes were only marginal, and
- (b) the Byker trommel performed below its design rating with very poor screening efficiencies for the fine screens, even at low feed rates, and, although it showed the effect of feed variations on recovery of $-1/2''$ material, this variation is not fully relevant in normally acceptable practice.

It is difficult to make comparisons between the results from the two trommels because of different screening areas and aperture sizes. Fig. 24 has been drawn up in an attempt to meet this requirement. It reports the recoveries of various size fractions against measured feed rate with the recoveries relating to the Doncaster tests reduced in proportion of the respective screen areas. Also the feed rates for the Byker Fines B screen have been adjusted to account for loss of material to Fines A. Considering screen aperture sizes and differences; Doncaster 40 mm, Byker Fines A 10 x 25, and Fines B 25 x 100 mm, and taking the minimum dimensions for the Byker apertures it might be expected that $-1+1/2''$ material for the Doncaster screens (A in Fig. 24) would be comparable with the $-1/2''$ material for the Byker Fines B (B in Fig. 24) (ratio of 'topsize' to aperture size, Doncaster 0.62:1 Byker 0.5:1). Clearly there is no correlation; the Doncaster recoveries being double those from comparable Byker tests at all trommel speeds. From the graph it would appear that nearest equivalent recoveries are obtained by comparing $-2+1''$ Doncaster material with either $-1/2''$ Byker fines A (C in Fig. 24) or $-1+1/2''$ Byker Fines B (D in Fig. 24). Although the topsize to aperture size ratios are not too dissimilar (for $-1/2$ Fines A comparison, 1.23:1 for Doncaster, 1.25:1 for Byker and, for $-1+1/2''$ Fines B comparison, 1.23:1 for Doncaster, 1:1 for Byker) the fact that a size fraction containing oversize particles needs to be considered before anything like a consistent trend can be observed with feed rate changes between the two test series clearly suggests that differences in performance are not purely related to aperture size and feed rate differences but reflect real changes in other operational variables, i.e. nature of feed material and internal configuration of the trommels. This conclusion is reinforced by noting that the above comparisons are weighted in favour of the Byker tests by effectively considering the Byker apertures to be 10 and 25 mm round hole, by fully discounting the proportional difference in screen area (i.e. ignoring the fact that for the remaining say 20% of extra screen area surface proportionally less material is "available" for screening) and by assuming that $-1/2''$ material can be equated with a limited size range fraction (i.e. $-1+1/2''$) on a topsize basis.

In view of these conclusions the important mid range results relating to realistic design ratings for the fine screens cannot be easily inferred by comparing the "underdesign" situation at Doncaster and the 'overdesign' situation at Byker.

For the intermediate screens it should be noted that the Doncaster screen plate area is 18.0 m^2 , the Byker screen plate area 45 m^2 giving a ratio of 1:2.5. The measured feed rates to the intermediate screens were between 2.8 te h^{-1} and 6.1 te h^{-1} for Doncaster and between 14.2 and 33.1 te h^{-1} for Byker. The feed rates for Byker however include a large weight of $-1''$ material not present in the Doncaster intermediate feed and therefore the effective feed rates of $+1''$ material are much lower, between 7.7 and 13 te h^{-1} and thus closely comparable in terms of refuse throughput per screen area. The measured recoveries of $-6''$ material were higher for the Doncaster screen but, considering its larger aperture size, the results do not suggest a fundamental difference in the efficiency of the coarse screening operations. In this respect, the apertures themselves appear to act as lifters, by hindering the slide of material over the screen plate, thereby promoting a drop mode of presentation and high recoveries. If this were the case, then the installed lifters in the Doncaster intermediate screen section would not be expected to have a marked effect on screening efficiency compared with the Byker intermediate section.

13275

FIG. 24 RECOVERY OF SIZE FRACTIONS AGAINST FEED RATE.
DONCASTER AND BYKER TESTS

5. CONCLUSIONS

Doncaster

At the feed rates and trommel speeds tested the Doncaster trommel screening efficiencies for both the fine screens and intermediate screens were consistently high indicating that, for design testing, a higher range of feed rates and higher trommel speeds should have been investigated.

Analysis of the results indicate that a number of factors are responsible for the high screening efficiencies.

1. The original design criteria were strict, with high recovery of fines having been identified as a priority requirement during pilot scale test work to ensure a low ash fuel product. For the intermediate screens the need to maximise recovery of fuel, due to the current low interest in fibre recovery, also demanded high recovery to undersize and this requirement was met by installing plates of large aperture size and high open area, in conjunction with the installation of a rag conveyor and arched lands to reduce blinding to an acceptable level.
2. The feed material tested, although very high in fines and thus thought to provide a severe test for the fines section of the trommel, appears to be easily screened even at the high feed rates tested. The results suggest that screening efficiency is more dependent on the flow rate of oversize material across the fines section rather than the amount of undersize to be screened out of the feed.
3. The fines material was predominantly bulky, dense categories which are more easily screened than the light flaky materials.
4. The intermediate screen section, because of the high fines content of the feed, was not overloaded beyond the design rating even at high overall throughputs.
5. The apparent insensitivity of the trommel to change in rotational speed, although due in part to the 'low' feed rates, is mainly due to the effect of the installed lifters ensuring, even at low speeds, a "falling" mode of particle presentation to the screen plate and to the transport scroll ensuring a fairly constant number of "drops" irrespective of speed and feed rate.
6. Detailed category and surrogate analyses for both screen sections show that bulky particles are more easily screened than plate like particles and are also less dependent on a falling mode of presentation to the screen plate, particularly at low trommel speeds. Thus lower trommel speeds promote selective removal of bulky particles from a refuse feed irrespective of overall screening efficiency.
7. Although the screening efficiencies were excellent, the unusually high fines content, which contained significant amounts of unburnt cinder, considerably reduced the total fuel recovery to the intermediates product. However, this fuel loss to the fines is atypical of normal commercial practice and is not considered a real problem in this instance.

Byker

The results for the Byker tests gave poor fine screening efficiencies at all throughputs tested indicating that, with the existing screen configuration, a lower range of throughputs should have been investigated.

The intermediate screen section performed well at the tested throughputs, with little loss of -6" material to oversize, but ash and calorific values obtained on the oversize show that good quality material was being lost to the fuel circuit suggesting that larger screen apertures could be installed with advantage.

Analysis of the results indicates that a number of factors are responsible for the poor performance of the fines screens.

1. The fine screen apertures are too small for the process design objectives.
2. The small aperture size does not totally explain the poor performance and the results indicate that low chance of presentation to open screen area coupled with insufficient drop mode presentation of the material to the screen plate are also significant factors. The installation of plate lifters to ensure better presentation and also mixing of the refuse would appear to be desirable.
3. The "fluffy" nature of pulverised feed may in itself increase the screening problems, compared with raw refuse of a similar size range.
4. The category, ash and calorific value results show that the feed is over-pulverised in terms of its

design objectives with much of the fine material present in the pulverised feed being produced from plate like categories such as paper and plastic.

5. The effect of the large screen apertures relative to the top size of the feed material for the intermediate screen section appears to promote drop mode presentation of the material onto the screen plate thus reducing the need for the installation of plate lifters in this screen section.

SIZE, CATEGORY, WEIGHT AND NUMBER RESULTS FOR THE DONCASTER TESTS

Test Run 1, NCRR Doncaster

			Paper	Pl Film	Textile	Cinder	Glass/Stone	Putrescible	Metal	Conglomerates	Fines	Total
<u>Fines</u>												
-2+1	weight kg	Data	0.071	0.006	0.005	0.506	0.264	0.380	0.012	0.027	0.026	1.297
	number	Data	98	15	2	52	21	71	4	1	1	264
-1+1/2	weight kg	Data	0.293	0.032	0	8.369	1.954	3.570	0.032	0	5.796	20.450
	number	Data	912	32	0	4038	586	1065	32	0	1	6676
-1/2	weight kg	Data	0	0	0	0	0	0	0	0	42.350	42.350
	number	Data	0	0	0	0	0	0	0	0	1	1
<u>Ints</u>												
+6	weight kg	Data	3.789	0.172	0.216	0	0	0.136	0.008	0.992	0	5.313
	number	Data	59	11	7	0	0	1	1	2	0	81
-6+5	weight kg	Data	3.119	0.123	0.316	0	0	0.096	0.615	0	0	4.269
	number	Data	68	10	3	0	0	3	2	0	0	86
-5+4	weight kg	Data	1.981	0.102	0.039	0	0	0.006	0.111	0	0	2.239
	number	Data	71	16	1	0	0	3	1	0	0	92
-4+3	weight kg	Data	2.396	0.080	0.210	0.004	0	0.598	6.192	0.731	0.045	10.260
	number	Data	321	30	2	2	0	48	74	7	1	484
-3+2	weight kg	Data	2.448	0.131	0.009	0.009	1.156	1.267	2.747	0.733	0.067	8.570
	number	Data	616	55	3	3	12	125	61	9	1	884
-2+1	weight kg	Data	3.019	0.034	0.146	2.835	1.904	2.599	0.233	1.228	0.514	12.512
	number	Data	1941	90	41	297	199	522	30	23	1	3173
-1/1/2	weight kg	Data	1.063	0.010	0.005	1.781	1.538	1.404	0.046	0	1.197	7.045
	number	Data	2586	57	5	697	403	1481	15	0	1	5245
-1/2	weight kg	Data	0	0	0	0	0	0	0	0	6.350	6.350
	number	Data	0	0	0	0	0	0	0	0	1	1

Test Run 1, NCRR Doncaster

			Paper	Pl Film	Textile	Cinder	Glass/Stone	Putrescible	Metal	Conglomerates	Fines	Total
<u>Oversize</u>												
+6	weight kg	Data	15.551	0.804	6.208	0	0	1.716	0	6.727	0	31.046
	number	Data	112	14	8	0	0	5	0	6	0	145
-6+5	weight kg	Data	1.200	0.044	0.422	0	0	0.079	0.371	0.449	0	2.565
	number	Data	47	1	3	0	0	1	1	3	0	56
-5+4	weight kg	Data	0.208	0.001	0.44	0	0	0.133	0	0	0	0.782
	number	Data	26	1	6	0	0	2	0	0	0	35
-4+3	weight kg	Data	0.282	0.017	0.012	0	0	0.352	0	0.069	0.10	0.742
	number	Data	41	4	1	0	0	19	0	1	1	66
-3+2	weight kg	Data	0.132	0.004	0.019	0	0	.096	0.105	0.207	0	0.563
	number	Data	44	1	1	0	0	2	2	2	0	52
-2+1	weight kg	Data	0	0	0	0	0	0	0	0	0	0.347
	number	Data	0	0	0	0	0	0	0	0	0	1
-1+1/2	weight kg	Data	0	0	0	0	0	0	0	0	0	0.343
	number	Data	0	0	0	0	0	0	0	0	0	1
-1/2	weight kg	Data	0	0	0	0	0	0	0	0	0.580	0.580
	number	Data	0	0	0	0	0	0	0	0	1	1

Test Run 1, NCRR Doncaster

			Paper	Pl Film	Textile	Cinder	Glass/Stone	Putrescible	Metal	Conglomerates	Fines	Total
<u>Feed</u>												
+6	weight kg	Data	4.227	0.083	1.571	0	0	0.045	0	0	0	5.926
	number	Data	36	2	2	0	0	1	0	0	0	41
-6+5	weight kg	Data	1.082	0.006	0.314	0	0.918	1.032	0.014	0.624	0	3.990
	number	Data	25	1	1	0	2	2	1	1	0	33
-5+4	weight kg	Data	0.831	0.07	0	0	0.329	0.019	0.124	0	0	1.373
	number	Data	27	7	0	0	1	3	1	0	0	39
-4+3	weight kg	Data	0.706	0.062	0.068	0	0.442	0.756	4.035	0.109	0.055	6.433
	number	Data	56	15	2	0	2	36	47	1	1	159
-3+2	weight kg	Data	0.875	0.166	0.021	0.012	0.972	0.777	0.998	0.06	0.025	3.856
	number	Data	153	25	2	2	16	37	22	1	1	258
-2+1	weight kg	Data	1.260	0.078	0.254	1.874	2.571	2.593	0.835	0	0.115	9.511
	number	Data	761	78	18	143	106	411	46	0	1	1564
-1+1/2	weight kg	Data	0.531	0.015	0.030	9.802	1.836	3.475	0.045	0	3.626	19.361
	number	Data	1199	15	15	3945	470	2246	45	0	1	7936
-1/2	weight kg	Data	0	0	0	0	0	0	0	0	42.576	42.576
	number	Data	0	0	0	0	0	0	0	0	1	1

Test Run 2, NCRR Doncaster

			Paper	Pl Film	Textile	Cinder	Glass/Stone	Putrescible	Metal	Conglomerates	Fines	Total
<u>Fines</u>												
-2+1	weight kg	Data	0.045	0.002	0	0.291	0.136	0.332	0.001	0	0.056	0.863
	number	Data	34	4	0	46	17	63	1	0	1	165
-1+1/2	weight kg	Data	0.055	0.003	0.006	2.06	0.446	0.714	0.003	0	1.336	4.625
	number	Data	160	13	3	929	130	394	3	0	1	1564
-1/2	weight kg	Data	0	0	0	0	0	0	0	0	11.337	11.337
	number	Data	0	0	0	0	0	0	0	0	1	1
<u>Ints</u>												
+6	weight kg	Data	5.047	0.283	0.562	0	0	0.113	0.852	0.77	0	7.627
	number	Data	72	14	2	0	0	2	4	3	0	97
-6+5	weight kg	Data	2.224	0.126	0.68	0	0	0.126	0.029	0.439	0	3.624
	number	Data	50	15	5	0	0	17	1	4	0	132
-5+4	weight kg	Data	0.980	0.126	0.085	0	0	0.352	0.234	0	0	1.777
	number	Data	48	18	1	0	0	15	2	0	0	84
-4+3	weight kg	Data	1.429	0.22	0.097	0	0.005	0.816	6.777	0.408	0	9.752
	number	Data	135	40	2	0	1	28	84	4	0	294
-3+2	weight kg	Data	1.582	0.034	0	0	0.105	0.952	3.938	0.738	0.033	7.433
	number	Data	300	52	0	0	2	77	52	7	1	490
-2+1	weight kg	Data	1.902	0.069	0.108	1.172	1.417	2.971	0.181	0.167	0.059	8.044
	number	Data	1299	123	25	83	84	574	44	5	1	2237
-1+1/2	weight kg	Data	0.494	0.009	0	1.062	0.965	1.688	0.057	0	0.716	4.994
	number	Data	1045	128	0	397	203	1327	13	0	1	3114
-1/2	weight kg	Data	0	0	0	0	0	0	0	0	3.929	3.929
	number	Data	0	0	0	0	0	0	0	0	1	1

Test Run 2, NCRR Doncaster

			Paper	PI Film	Textile	Cinder	Glass/Stone	Putrescible	Metal	Conglomerates	Fines	Total
<u>Oversize</u>												
+6	weight kg	Data	18.394	1.049	5.553	0	0	6.14	1.293	0.596	0	33.025
	number	Data	110	17	15	0	0	9	5	1	0	157
-6+5	weight kg	Data	1.124	0.055	0.065	0	0	0.007	0.142	0	0	1.413
	number	Data	32	6	2	0	0	2	2	0	0	44
-5+4	weight kg	Data	0.281	0	0	0	0	0.025	0	0	0	0.306
	number	Data	17	0	0	0	0	2	0	0	0	19
-4+3	weight kg	Data	0.108	0	0.132	0	0	0.004	0.103	0.125	0	0.471
	number	Data	13	0	1	0	0	5	2	1	0	27
-3+2	weight kg	Data	0.05	0.003	0	0	0	0.032	0.014	0	0	0.099
	number	Data	13	3	0	0	0	3	1	0	0	25
-2+1	weight kg	Data	0	0	0	0	0	0	0	0	0	0.156
	number	Data	0	0	0	0	0	0	0	0	0	1
-1+1/2	weight kg	Data	0	0	0	0	0	0	0	0	0	0.077
	number	Data	0	0	0	0	0	0	0	0	0	1
-1/2	weight kg	Data	0	0	0	0	0	0	0	0	0.177	0.177
	number	Data	0	0	0	0	0	0	0	0	1	1

Test Run 2, NCRR Doncaster

			Paper	Pl Film	Textile	Cinder	Glass/Stone	Putrescible	Metal	Conglomerates	Fines	Total
<u>Feed</u>												
+6	weight kg	Data	1.408	0.465	0	0	0	0	0	0	0	1.873
	number	Data	11	3	0	0	0	0	0	0	0	14
-6+5	weight kg	Data	0.613	0.028	0.330	0	0	0.008	0.087	0	0	1.066
	number	Data	12	2	1	0	0	1	1	0	0	17
-5+4	weight kg	Data	0.805	0.028	0	0	0	1.133	0.211	0.028	0	2.205
	number	Data	12	2	0	0	0	7	1	1	0	23
-4+3	weight kg	Data	0.777	0.086	0.082	0	0	0.152	0.914	0.091	0	2.102
	number	Data	32	6	1	0	0	9	12	1	0	61
-3+2	weight kg	Data	0.595	0.058	0	0	0.295	0.294	0.362	0.034	0	1.638
	number	Data	77	14	0	0	4	20	9	1	0	125
-2+1	weight kg	Data	0.529	0.059	0	0.619	0.893	1.757	0.067	0.005	0.076	4.056
	number	Data	356	34	0	91	41	239	13	4	1	778
-1+1/2	weight kg	Data	0.111	0.003	0	3.41	0.602	1.354	0.017	0	1.089	6.588
	number	Data	327	24	0	1597	181	866	21	0	1	3017
-1/2	weight kg	Data	0	0	0	0	0	0	0	0	17.829	17.829
	number	Data	0	0	0	0	0	0	0	0	1	1

Test Run 3, NCRR Doncaster

			Paper	Pl Film	Textile	Cinder	Glass/Stone	Putrescible	Metal	Conglomerates	Fines	Total
<u>Fines</u>												
-2+1	weight kg	Data	0.028	0.001	0	0.318	0.139	0.327	0.011	0	0.015	0.839
	number	Data	34	2	0	43	13	81	4	0	1	177
-1+1/2	weight kg	Data	0.091	0.005	0	1.848	0.721	1.253	0.011	0	1.346	5.342
	number	Data	165	10	0	935	208	823	21	0	1	2174
-1/2	weight kg	Data	0	0	0	0	0	0	0	0	16.391	16.391
	number	Data	0	0	0	0	0	0	0	0	1	1
<u>Ints</u>												
+6	weight kg	Data	3.213	0.104	0.674	0	0	0	0.289	0.213	0	4.518
	number	Data	39	6	2	0	0	0	1	1	0	49
-6+5	weight kg	Data	2.603	0.263	0.033	0	0.011	0.908	0.521	0.072	0	4.411
	number	Data	49	18	1	0	4	10	2	1	0	84
-5+4	weight kg	Data	1.576	0.079	0.075	0	1.455	0.43	0.484	0.396	0	4.595
	number	Data	55	15	3	0	3	11	4	3	0	94
-4+3	weight kg	Data	2.033	0.268	0.227	0	0.012	0.531	3.229	0.856	0	7.156
	number	Data	169	38	5	0	1	55	46	7	0	321
-3+2	weight kg	Data	2.797	0.204	0.052	0	0.427	1.183	1.481	0.537	0	6.684
	number	Data	466	43	2	0	4	142	49	4	0	709
-2+1	weight kg	Data	2.24	0.122	0.136	0.694	2.429	3.423	0.635	0.015	0.095	9.793
	number	Data	903	70	9	56	129	648	48	4	1	1867
-1+1/2	weight kg	Data	0.714	0.008	0.051	1.42	2.67	2.866	0.076	0	1.05	7.926
	number	Data	1446	17	68	561	604	1743	51	0	1	4490
-1/2	weight kg	Data	0	0	0	0	0	0	0	0	7.034	7.034
	number	Data	0	0	0	0	0	0	0	0	1	1

Test Run 3, NCRR Doncaster

			Paper	PI Film	Textile	Cinder	Glass/Stone	Putrescible	Metal	Conglomerates	Fines	Total
<u>Oversize</u>												
+6	weight kg	Data	17.511	1.448	8.239	0	0	2.484	0.746	5.24	0	35.668
	number	Data	128	20	16	0	0	1	2	4	0	171
-6+5	weight kg	Data	1.029	0.058	0.583	0	0	0.032	0	0.124	0	1.826
	number	Data	39	4	3	0	0	4	0	2	0	52
-5+4	weight kg	Data	0.428	0.005	0.058	0	0	0.052	0	0	0	0.543
	number	Data	21	1	1	0	0	1	0	0	0	24
-4+3	weight kg	Data	0.252	0.008	0.027	0	0	0.136	0.071	0	0	0.504
	number	Data	20	2	1	0	0	7	1	0	0	31
-3+2	weight kg	Data	0.047	0.023	0.222	0	0	0.088	0.04	0.194	0	0.614
	number	Data	13	3	1	0	0	10	2	2	0	31
-2+1	weight kg	Data	0	0	0	0	0	0	0	0	0	0.362
	number	Data	0	0	0	0	0	0	0	0	0	1
-1+1/2	weight kg	Data	0	0	0	0	0	0	0	0	0	0.178
	number	Data	0	0	0	0	0	0	0	0	0	1
-1/2	weight kg	Data	0	0	0	0	0	0	0	0	0.230	0.230
	number	Data	0	0	0	0	0	0	0	0	1	1

Test Run 3, NCRR Doncaster

			Paper	P1 Film	Textile	Cinder	Glass/Stone	Putrescible	Metal	Conglomerates	Fines	Total
<u>Feed</u>												
+6	weight kg	Data	4.056	0.031	0.471	0	0	0	0	2.205	0	6.738
	number	Data	12	1	2	0	0	0	0	2	0	17
-6+5	weight kg	Data	0.272	0.009	0.682	0	0	0	0	0	0	0.973
	number	Data	6	1	3	0	0	0	0	0	0	10
-5+4	weight kg	Data	0.076	0.013	0	0	0	0.051	0.183	0.210	0	0.533
	number	Data	1	1	0	0	0	1	1	1	0	5
-4+3	weight kg	Data	0.251	0.062	0.012	0	0.283	0.014	0.540	0	0.017	1.179
	number	Data	20	8	1	0	1	2	7	0	1	40
-3+2	weight kg	Data	0.258	0.053	0.046	0	0.196	0.473	0.420	0.113	0	1.605
	number	Data	22	13	1	0	3	9	10	2	0	61
-2+1	weight kg	Data	0.384	0.026	0.063	0.370	0.785	1.399	0.052	0.087	0.031	3.197
	number	Data	162	24	1	28	35	196	10	2	1	458
-1+1/2	weight kg	Data	0.201	0.005	0	1.639	0.563	1.856	0.07	0	0.704	5.082
	number	Data	382	50	0	714	116	1011	15	0	1	2287
-1/2	weight kg	Data	0	0	0	0	0	0	0	0	13.475	13.475
	number	Data	0	0	0	0	0	0	0	0	1	1

Test Run 4, NCRR Doncaster

			Paper	Pl Film	Textile	Cinder	Glass/Stone	Putrescible	Metal	Conglomerates	Fines	Total
<u>Fines</u>												
-2+1	weight kg	Data	0.029	0.003	0	0.236	0.16	0.366	0.038	0.017	0.005	0.854
	number	Data	20	9	0	34	16	88	7	1	1	176
-1+1/2	weight kg	Data	0.173	0.004	0	2.294	0.709	1.679	0.02	0	1.473	6.355
	number	Data	371	24	0	978	210	1469	29	0	1	3082
-1/2	weight kg	Data	0	0	0	0	0	0	0	0	14.863	14.863
	number	Data	0	0	0	0	0	0	0	0	1	1
<u>Ints</u>												
+6	weight kg	Data	6.508	0.152	0.158	0	0	0.303	0.954	1.418	0	9.493
	number	Data	58	10	2	0	0	3	1	4	0	78
-6+5	weight kg	Data	2.03	0.26	0.02	0	0	0.208	0.257	0.553	0	3.378
	number	Data	36	27	2	0	0	14	1	4	0	84
-5+4	weight kg	Data	1.604	0.305	0.041	0	0.604	0.481	1.045	0.314	0	4.394
	number	Data	61	37	4	0	1	34	9	2	0	148
-4+3	weight kg	Data	2.401	0.398	0.347	0	0.513	3.102	3.195	1.928	0	11.888
	number	Data	187	82	15	0	2	84	50	8	0	429
-3+2	weight kg	Data	1.437	0.353	0	0	0.524	2.619	1.152	1.454	0.034	7.576
	number	Data	291	82	0	0	10	182	38	10	1	614
-2+1	weight kg	Data	3.943	0.232	0.428	0	0.837	6.091	0.13	1.013	0.167	12.824
	number	Data	2046	149	102	0	65	1069	37	28	1	3496
-1+1/2	weight kg	Data	0.799	0.036	0	0.399	1.647	3.088	0.048	0	1.09	7.11
	number	Data	1671	109	0	97	303	2943	60	0	1	5184
-1/2	weight kg	Data	0	0	0	0	0	0	0	0	5.306	5.306
	number	Data	0	0	0	0	0	0	0	0	1	1

Test Run 4, NCRR Doncaster

			Paper	Pl Film	Textile	Cinder	Glass/Stone	Putrescible	Metal	Conglomerates	Fines	Total
<u>Oversize</u>												
+6	weight kg	Data	26.43	2.49	0	0	0	10.853	0.137	12.68	0	54.726
	number	Data	162	38	0	0	8	14	2	8	0	224
-6+5	weight kg	Data	1.491	0.127	0	0	0	0.06	0	0	0	1.678
	number	Data	45	14	0	0	0	9	0	0	0	68
-5+4	weight kg	Data	0.562	0.038	0.028	0	0	0.128	0.001	0.069	0	0.826
	number	Data	34	6	1	0	0	14	2	1	0	58
-4+3	weight kg	Data	0.465	0.646	0.03	0	0.171	0.404	0.164	0.095	0	1.375
	number	Data	45	6	1	0	1	15	3	1	0	72
-3+2	weight kg	Data	0.273	0.01	0.114	0	0	0.131	0.015	0	0	0.543
	number	Data	54	6	3	0	0	8	3	0	0	74
-2+1	weight kg	Data	0	0	0	0	0	0	0	0	0	0.415
	number	Data	0	0	0	0	0	0	0	0	0	1
-1+1/2	weight kg	Data	0	0	0	0	0	0	0	0	0	0.326
	number	Data	0	0	0	0	0	0	0	0	0	1
-1/2	weight kg	Data	0	0	0	0	0	0	0	0	0.293	0.293
	number	Data	0	0	0	0	0	0	0	0	1	1

Test Run 4, NCRR Doncaster

			Paper	PI Film	Textile	Cinder	Glass/Stone	Putrescible	Metal	Conglomerates	Fines	Total
<u>Feed</u>												
+6	weight kg	Data	1,249	0.065	0.671	0	0	0	0	0	0	1.985
	number	Data	10	3	1	0	0	0	0	0	0	14
-6+5	weight kg	Data	0.672	0.089	0.347	0	0	0.392	0.106	0.233	0	1.839
	number	Data	7	3	3	0	0	2	1	1	0	17
-5+4	weight kg	Data	0.461	0.04	0	0	0	0.122	0.358	0.219	0	1.200
	number	Data	10	4	0	0	0	8	2	2	0	26
-4+3	weight kg	Data	0.755	0.139	0.064	0	0.663	0.14	1.76	0.227	0	3.748
	number	Data	49	21	2	0	2	14	22	2	0	112
-3+2	weight kg	Data	0.623	0.124	0.02	0	0.517	0.598	0.541	0.342	0.016	2.781
	number	Data	90	22	1	0	14	41	13	2	1	183
-2+1	weight kg	Data	0.833	0.079	0.094	0.391	0.956	1.922	0.072	0	0.072	4.42
	number	Data	314	36	19	31	72	376	12	0	1	862
-1+1/2	weight kg	Data	0.376	0.004	0.083	0.478	0.687	2.117	0.056	0	1.081	4.883
	number	Data	86	28	46	213	200	1727	28	0	1	2330
-1/2	weight kg	Data	0	0	0	0	0	0	0	0	7.75	7.57
	number	Data	0	0	0	0	0	0	0	0	1	1

Test Run 5, NCRR Doncaster

			Paper	PI Film	Textile	Cinder	Glass/Stone	Putrescible	Metal	Conglomerates	Fines	Total
<u>Fines</u>												
-2+1	weight kg	Data	0.031	0.002	0	0.371	0.124	0.300	0.001	0	0.009	0.838
	number	Data	34	5	0	43	15	82	1	0	1	180
-1+1/2	weight kg	Data	0.074	0.003	0	2.034	1.085	1.011	0.051	0	0.801	5.069
	number	Data	222	19	0	922	323	840	19	0	1	2346
-1/2	weight kg	Data	0	0	0	0	0	0	0	0	15.857	15.857
	number	Data	0	0	0	0	0	0	0	0	1	1
<u>Ints</u>												
+6	weight kg	Data	4.089	0.084	0.603	0	0	0	0.246	0.342	0	5.364
	number	Data	45	5	2	0	0	0	1	1	0	54
-6+5	weight kg	Data	2.091	0.105	1.701	0	0	0.039	0.477	0.514	0	4.927
	number	Data	39	9	9	0	0	5	1	3	0	66
-5+4	weight kg	Data	1.404	0.133	0.869	0	0	0.18	0.745	0.137	0	3.468
	number	Data	57	16	7	0	0	6	6	2	0	94
-4+3	weight kg	Data	1.319	0.273	0.458	0	0.172	0.977	4.346	0.734	0	7.939
	number	Data	114	32	9	0	1	24	59	4	0	243
-3+2	weight kg	Data	1.457	0.203	0.187	0.036	0.322	1.604	1.997	0.171	0.027	6.004
	number	Data	307	40	8	1	4	57	44	4	1	465
-2+1	weight kg	Data	2.122	0.119	0	1.215	1.384	2.664	0.823	0.039	0.109	8.471
	number	Data	1354	89	0	139	84	565	40	5	1	2723
-1+1/2	weight kg	Data	0.838	0.006	0.011	1.413	1.716	1.905	0.126	0	0.537	6.61
	number	Data	2746	74	28	503	406	1447	46	0	1	5251
-1/2	weight kg	Data	0	0	0	0	0	0	0	0	4.743	4.743
	number	Data	0	0	0	0	0	0	0	0	1	1

Test Run 5, NCRR Doncaster

			Paper	PI Film	Textile	Cinder	Glass/Stone	Putrescible	Metal	Conglomerates	Fines	Total
<u>OverSIZE</u>												
+6	weight kg	Data	21,971	0.724	8.074	0	0	9.242	0	6.367	0	46.378
	number	Data	103	10	5	0	0	12	0	5	0	135
-6+5	weight kg	Data	0.907	0.092	0.175	0	0	0.403	0	0.404	0	1.981
	number	Data	26	10	1	0	0	3	0	3	0	43
-5+4	weight kg	Data	0.457	0.026	0	0	0	0.052	0.156	0.035	0	0.726
	number	Data	29	3	0	0	0	1	1	1	0	35
-4+3	weight kg	Data	0.277	0.009	0	0	0	0	0.46	0	0	0.746
	number	Data	28	3	0	0	0	0	7	0	0	38
-3+2	weight kg	Data	0.393	0.003	0	0	0	0.011	0.058	0	0	0.65
	number	Data	24	1	0	0	0	5	2	0	0	32
-2+1	weight kg	Data	0	0	0	0	0	0	0	0	0	0.180
	number	Data	0	0	0	0	0	0	0	0	0	1
-1+1/2	weight kg	Data	0	0	0	0	0	0	0	0	0	0.171
	number	Data	0	0	0	0	0	0	0	0	0	1
-1/2	weight kg	Data	0	0	0	0	0	0	0	0	0.422	0.422
	number	Data	0	0	0	0	0	0	0	0	1	1

Test Run 5, NCRR Doncaster

			Paper	Pl Film	Textile	Cinder	Glass/Stone	Putrescible	Metal	Conglomerates	Fines	Total
<u>Feed</u>												
+6	weight kg	Data	0.891	0.067	4.870	0	0	0.088	0	0	0	5.916
	number	Data	10	4	2	0	0	2	0	0	0	18
-6+5	weight kg	Data	0.722	0.042	0	0	0	0.059	0	0.518	0	1.341
	number	Data	17	4	0	0	0	2	0	2	0	25
-5+4	weight kg	Data	0.272	0.007	0	0.006	0.439	0.049	0.277	0.195	0.009	1.248
	number	Data	16	2	0	3	2	5	5	1	1	34
-4+3	weight kg	Data	0.317	0.029	0.009	0	0	0.119	0.63	0.327	0	1.431
	number	Data	21	7	1	0	0	8	8	2	0	47
-3+2	weight kg	Data	0.311	0.048	0.262	0	0.034	0.164	0.569	0.262	0.006	1.656
	number	Data	45	15	12	0	2	14	12	2	1	102
-2+1	weight kg	Data	0.386	0.032	0.077	0.37	0.328	0.719	0.173	0.033	0.009	2.127
	number	Data	177	27	10	32	25	140	14	1	1	426
-1+1/2	weight kg	Data	0.276	0.005	0.031	1.746	0.374	1.5	0.097	0.005	0.645	4.681
	number	Data	481	70	41	701	87	886	36	5	1	2308
-1/2	weight kg	Data	0	0	0	0	0	0	0	0	12.885	12.885
	number	Data	0	0	0	0	0	0	0	0	1	1