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H2GEO

New technology for hydrogen and geopolymer composites production from post-mining waste

Deliverable 3.1

Results of laboratory tests of mine wastes of jig beneficiation

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Appendix

1. Introduction

The legal basis for the work entitled: “New technology for hydrogen and geopolymer composites production from post-mining waste” (acronym H2GEO) is a grant agreement No: 101112386 (RFCS-2022). H2GEO project consortium is composed of seven partners: Instytut Techniki Górniczej Komag (KOMAG), Poland; Główny Instytut Górnictwa (GIG), Poland; Institute of Construction and Architecture Slovak Academy of Sciences (USTARCH), Slovakia; Instytut Technologii Paliw i Energii (ITPE), Poland; VSB - Technical University of Ostrava (VSB), Czechia; Politechnika Wrocławska (PWR), Poland, and Haldex S.A. (HDX), Poland.

2. Objective and scope of work

The main objective of the task was to determine the input data for the mobile system for processing mining waste. This objective was achieved by implementing the research plan, the main component of which was the separation studies of raw material from the selected coal mine dump at the laboratory jig stand.

The scope of work included:

- selection of variable parameters for the experiments,
- preparation of the laboratory stand,
- preparation of test materials,
- conducting tests at the laboratory jig stand,
- analysis of test results,
- development of input data for designing the mobile system.

An additional objective of the project was to obtain jigging separation products (combustible fraction, mineral fraction) from raw material samples sourced from coal mine dumps. The products obtained at the laboratory jig stand will be subjected to analysis in T3.2 of the H2GEO project.

This report summarizes the results of the work carried out in the project task 'Laboratory Tests of Jig Beneficiation'.

3. Characteristics of the laboratory jig stand

The tests involving gravity enrichment of extracted mineral raw materials was conducted at an experimental laboratory jig stand. The device allows for the simulation of real operating conditions of an industrial jig in terms of feed input, the pulsation characteristics of the enriched material/water mixture, and the collection of separation products. The experimental laboratory jig stand (Fig. 1) consists of:

- a laboratory jig model,
- a working (pulsating) air blower,
- a control air compressor,
- an electronic control system.

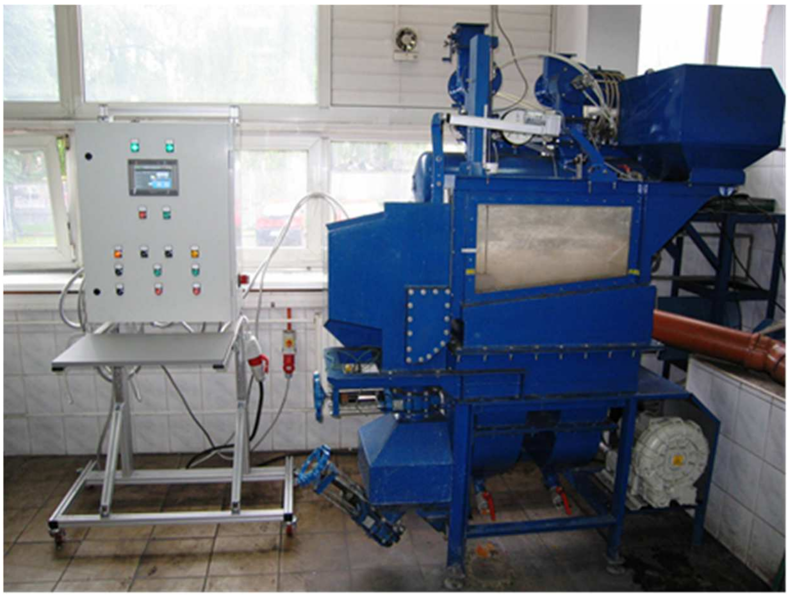

Fig. 1 Laboratory jig stand

The jig was constructed based on the technical documentation W74.300 at the KOMAG Mining Mechanization Institute. The technical data of the jig are presented in Table 1.

Table 1 Technical specifications of the laboratory jig stand

Technical data		
Parameter	Unit	Value
Length of the working chamber	m	0.7
Width of the working chamber	m	0.25
Volume of the working chamber (range)	m^3	0.007-0.046
Feed tank volume	m^3	2x0.03
Heavy product sluice volume	m^3	0.03
Working air:		
• demand	m^3/min	1.0
• pressure	MPa	0.03
Control air:		
• suction capacity	m^3/min	0.25
• pressure	MPa	0.4
Bottom air:		
• demand	m^3/h	4.5
• pressure	bar	1.0
Electrical supply		
• Electronic control system (power/voltage)	kW/V	0.5/230
• Working air blower	kW/V	1.5/380
Jig weight	kg	674.0

The laboratory jig is a model constructed from a single, dual-chamber working compartment with a working area of 0.175 m^2. At the inlet of the jig, there is a two-part feed tank with a capacity of 0.06 m^3.

The device is equipped with two pairs of inlet and outlet valves that separately supply the two pulsation chambers located beneath the sieve deck. Air dampers are installed before each pair of valves, which can be used to regulate the amount of working air supplied to the jig. The working trough ends with an overflow threshold, over which the "light" product (concentrate) is separated. The "heavy" product (waste) is discharged through the collection system using a sluice made with two knife gates.

The model has a partially closed water supply system, consisting of submersible pumps located in the sump and rotameters. Process water is supplied to the pulsation chambers (lower water) and at the feed inlet (upper water). The water from the concentrate product's draining screen is returned to the sump.

The station is equipped with a modern control system, whose algorithms enable advanced control of water pulsation and product discharge, process monitoring, and the recording and processing of collected data.

4. Laboratory tests

4.1. Selection of parameters for the laboratory jig stand

The research utilized material prepared from sample Haldex 1 sourced from the Panewnicka Heap with a grain size of 30-0 mm.

In accordance with the planned research scope, 24 enrichment trials were conducted at the jigging station using materials in the following grain size classes:

- grain size class 10-3 mm,
- grain size class 30-10 mm,
- grain size class 30-3 mm (formed from the above classes 30-10 mm and 10-3 mm).

These classes were obtained by classifying the entire sample on a laboratory sieve using meshes with openings of 30 mm and 3 mm.

The laboratory tests involved filling the working chamber of the jig with grains of the analysed class, introducing water, and performing density separation of the material based on the established/regulated operating parameters of the device.

The conducted tests aimed to determine the influence of selected factors in the jigging beneficiation operation on the accuracy of separation and to identify input data for designing a new device for the industrial separation of mining waste in a pulsating water medium. Therefore, the goal of the research was not to achieve the most favourable results for product parameters and separation accuracy indicators.

Based on analyses of the raw material (feed), it was determined that the level of filling the working chamber with material would be a rectangular prism with a base of the working sieve (0.7 x 0.25 m) and a height of 0.2 m (volume 0.0035 m^3). For each of the analysed grain size classes, an individual separation boundary for the concentrate product was selected, resulting in the determination of layer thicknesses (product). These thicknesses corresponded to the shares of combustible fractions in the respective feeds and were larger for materials with a higher share of this fraction. The upper layer thicknesses (concentrate) for each grain size class were as follows:

- grain size class 10-3 mm – 7 cm,
- grain size class 30-10 mm – 4 cm,
- grain size class 30-3 mm – 5.5 cm.

In the experiments, the variables were the mesh size of the working sieve, enrichment time, and pulsation frequency. In each trial, the tests were conducted with a constant supply of process water, amounting to 4.5 m^3/h.

The parameters that were analysed were as follows:

- the size of the working sieve opening: s=1.5 mm and s=2.5 mm,
- gravitational enrichment time: t=30s and t=60s, which corresponded to the unit load of 33 $t/h/m^2$ and 16.5 $t/h/m^2$, respectively,
- pulsation cycle frequency: f=40 min^{-1}, f=60 min^{-1} and f=80 min^{-1},
- process water supply flow rate: Q=4.5 m^3/h.

Table 2 presents all the parameters of the experiments.

Table 2. Settings of the laboratory jig stand for individual trials

Test number	Grain class, mm	The size of the working sieve opening, mm	Pulsation frequency, min^{-1}	Enrichment time, s
1	30-10	1.5	40	60
2	10-3	1.5	40	60
3	30-3	1.5	40	60
4	30-10	1.5	40	30
5	10-3	1.5	40	30

Test number	Grain class, mm	The size of the working sieve opening, mm	Pulsation frequency, min^{-1}	Enrichment time, s
6	30-3	1.5	40	30
7	30-10	1.5	60	60
8	10-3	1.5	60	60
9	30-3	1.5	60	60
10	30-10	1.5	60	30
11	10-3	1.5	60	30
12	30-3	1.5	60	30
13	30-10	1.5	80	60
14	10-3	1.5	80	60
15	30-3	1.5	80	60
16	30-10	2.5	40	60
17	10-3	2.5	40	60
18	30-3	2.5	40	60
19	30-10	2.5	60	60
20	10-3	2.5	60	60
21	30-3	2.5	60	60
22	30-10	2.5	60	30
23	10-3	2.5	60	30
24	30-3	2.5	60	30

Table 3 summarizes the pulsation parameters in the form of inlet and outlet times of the pulsation disc valves in the individual experiments. These times were directly dependent on the pulsation frequency. A sinusoidal pulsation cycle was used in all experiments.

Table 3 The duration of the pulsation cycle phase

Duration of the pulsation cycle phase, ms	Pulsation frequency, min^{-1}		
	40	60	80
Inlet	345	230	173
Interval	375	250	188
Outlet	345	230	173
Interval	435	290	216

4.2. Description of the jigging test procedure

Before starting the gravity separation process, it was necessary to prepare the jigging station. First, the electrical power supply was turned on (powering the control system and the working air blower), the compressor (supplying control air) was started, and the sump was filled with water (bottom water). The water level in the sump was determined by the need to submerge the bottom water pumps (located in the sump).

The next step involved filling the working space of the jig with material, which was quartered before each test to obtain a representative sample. The material was manually fed to a set height (0.2 m), resulting in a corresponding volume (0.0035 m^3).

Before starting the enrichment process, it was necessary to check the correct settings of the water valves (knife gates closed), air dampers (closed), and the appropriate air pressure level in the compressed air supply system. Then, the desired jig settings were verified or adjusted through the electronic control system (operating cycle frequency). After confirming the accuracy of these settings, the pumps in the sump were activated to fill the jig's working space. Before initiating pulsation, the working water level had to be sufficiently high to allow free water flow over the overflow threshold at the end of the jig's working chamber, from where it was transported in a closed circuit back to the sump.

If the above requirements were met, the enrichment process could begin. The process started by opening the jig air valves and turning on the working air blower, which generated the pulsating movement of the material-water mixture in the working chamber. During the jig's predetermined operating time, the material underwent stratification. After this period, the air valves and pumps supplying bottom water to the jig were turned off. As a result of turning off the pumps, the water from the working chamber was drained gravitationally into the sump.

The classified material, based on density, was divided into two parts according to the established thickness (height) for each feed and was manually collected from the working space. In this way, two products were obtained: a concentrate and waste. The first, upper layer of the material consisted of the concentrate (lower-density material), containing the majority of the combustible fraction grains, while the bottom layer consisted of waste, mainly composed of mineral fraction grains (gangue). The height of each layer was selected individually for each grain size class. The collected layer height was verified continuously using a measuring instrument. Each collected product was placed on steel trays. The trays, along with the material, were dried in a laboratory dryer and weighed (dry material weight) to determine the yield of both products.

After removing the material from the working chamber, the device was prepared for the next test. All valves and water gates remained open to remove the material suspension with the working water remaining in the jig's pulsating chambers. The jig's working chamber was rinsed with clean water to remove any possible contaminants. As a result of draining some of the working water from the jig, it was necessary to replenish the water in the sump. Before starting the jig for the next test, all water and air valves were closed.

4.3. Analyses and determinations

After drying and weighing, the obtained separation products were subjected to the planned analyses and determinations:

- grain size analysis using sieves with mesh sizes of 20, 10, 6, and 3 mm,
- density analysis in heavy liquids with densities of 1.3, 1.4, 1.5, 1.6, 1.7, and 1.8 g/cm^3,
- determination of ash content, sulphur content, and calorific value, with the calculation of the heating value in the obtained density fractions (<1.3; 1.3-1.4; 1.4-1.5; 1.5-1.6; 1.6-1.7; 1.7-1.8, and >1.8 g/cm^3).

In the analysis of the study results, the averaged values of the aforementioned laboratory determinations were used for all tests.

The results of the density analyses served as the basis for determining the fundamental separation accuracy indicators, such as probable error and imperfection, which were determined according to PN-G-07020:1997.

All analyses and determinations were made in accordance with the following applicable standards:

- grain analysis according to PN-ISO 1953:1999,
- density analysis according to PN-G-04559:1997,
- determination of water content according to PN-ISO 589:2006,
- determination of ash content according to PN-ISO 1171:2002,
- determination of total sulphur content according to PN-G-04584:2001,
- determination of the heat of combustion according to PN-ISO 1928:2020-05.

Laboratory tests were carried out in accordance with the requirements of the PN-EN ISO/IEC 17025:2018-02 standard using the measuring equipment ensuring measurement consistency.

The research used supervised measurement equipment in the form of:

- SML 48/250 laboratory dryer,
- chamber furnace for determining ash content PM-6/1100A,
- SC 132 sulphur analyser,
- AC350 calorimeter,
- electronic laboratory scales B200B, WPT 15H2 and HR 120.

Additionally, a stand for density analysis and a laboratory screen with a set of sieves for grain analysis were used.

4.4. Tests results

Density-quality analyses

Detailed results of all analyses concerning density composition and determination of physicochemical parameters in separated density fractions, as well as the results of the grain size composition analyses of the separation products, are included in the appendix at the end of the report.

The following tables present the most important data regarding the impact of experimental parameters on the results of the jigging separation process. Subsequent tables provide results concerning the output of separation products, as well as their corresponding ash content and calorific values. Table 4 contains the results of the feed separation in the grain size class 30-10 mm, Table 5 shows the results from tests on material in the 10-3 mm class, while Table 6 presents the results of the studies on material with a grain size of 30-3 mm.

The obtained results for the tested materials are graphically illustrated in Figures 2 to 7.

Table 4 Summary of Selected Laboratory Test Results – Grain class 30-10 mm

Test number	Test parametrers	Concentrate product			Waste product		
		Product output	Average ash content, A^a	Average calorific value, Q_i^a	Product output	Average ash content, A^a	Average calorific value, Q_i^a
		%	%	kJ/kg	%	%	kJ/kg
1	s=1.5 mm, f=40 min^{-1}, t=60 s	20.39	49.07	14142	79.61	83.38	1777
4	s=1.5 mm, f=40 min^{-1}, t=30 s	20.22	55.26	11813	79.78	81.67	2402
7	s=1.5 mm, f=60 min^{-1}, t=60 s	20.19	49.55	13967	79.81	83.26	1824
10	s=1.5 mm, f=60 min^{-1}, t=30 s	20.31	56.52	11347	79.69	81.28	2546
13	s=1.5 mm, f=80 min^{-1}, t=60 s	20.05	52.12	13001	79.95	82.27	2182
16	s=2.5 mm, f=40 min^{-1}, t=60 s	20.30	49.11	14131	79.70	83.44	1757
19	s=2.5 mm, f=60 min^{-1}, t=60 s	20.18	48.50	14357	79.82	83.47	1744
22	s=2.5 mm, f=60 min^{-1}, t=30 s	20.54	55.22	11845	79.46	82.06	2260

The most favourable results in terms of the quality of separation products were obtained during experiment no. 19, which was conducted using a pulsation frequency of 60min^{-1}, a longer enrichment time, and a larger slot in the screen deck (s = 2.5 mm). For these parameters, the lowest ash content in the concentrate and the highest in the waste were achieved. Very similar results were obtained in other experiments conducted with a longer enrichment time corresponding to a lower load on the device, both for a frequency of 40 min^{-1} (s = 1.5 mm, s = 2.5 mm) and f = 60 for s = 1.5 mm. Significantly worse results were obtained for shorter enrichment times.

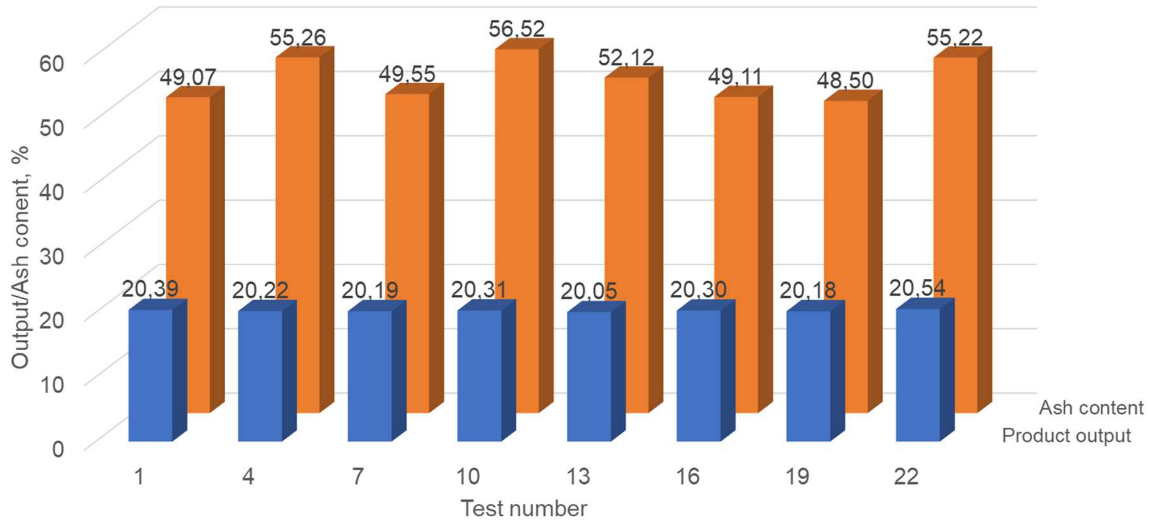

Fig. 2 Yield and ash content of the concentrate product - grain class 30-10 mm

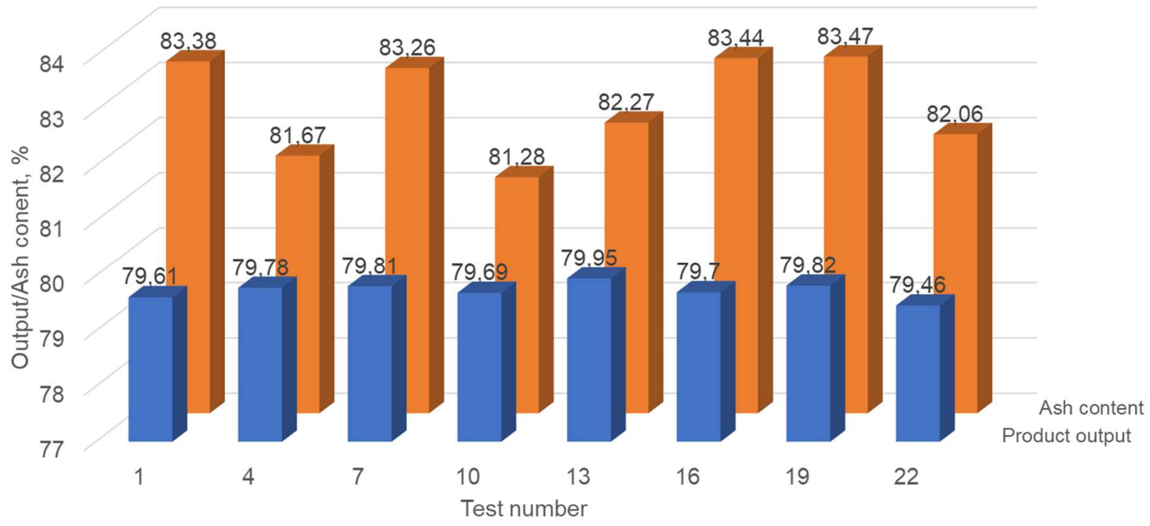

Fig. 3 Yield and ash content of the waste product - grain class 30-10 mm

Table 5 Summary of Selected Laboratory Test Results – Grain class 10-3 mm

Test number	Test parametrers	Concentrate product			Waste product		
		Product output	Average ash content, A^a	Average calorific value, Q_i^a	Product output	Average ash content, A^a	Average calorific value, Q_i^a
		%	%	kJ/kg	%	%	kJ/kg
2	s=1.5 mm, f=40 min^{-1}, t=60 s	29.36	40.63	17360	70.64	79.81	3090
5	s=1.5 mm, f=40 min^{-1}, t=30 s	29.54	46.96	14965	70.46	76.56	4283
8	s=1.5 mm, f=60 min^{-1}, t=60 s	29.31	40.66	17351	70.69	79.93	3045
11	s=1.5 mm, f=60 min^{-1}, t=30 s	29.69	46.53	15129	70.31	76.69	4235
14	s=1.5 mm, f=80 min^{-1}, t=60 s	29.53	42.87	16621	70.47	78.50	3558
17	s=2.5 mm, f=40 min^{-1}, t=60 s	29.45	40.57	17381	70.55	79.83	3083
20	s=2.5 mm, f=60 min^{-1}, t=60 s	29.54	40.38	17453	70.46	80.07	2993
23	s=2.5 mm, f=60 min^{-1}, t=30 s	29.19	46.09	15294	70.81	76.55	4288

The best qualitative results were obtained during the experiments in which a slot size of s = 2.5 mm was used, with frequencies of 40 min^{-1} and 60 min^{-1}. Slightly worse quality parameters, for the same frequencies, were achieved in experiments where the jig unit was equipped with a screen deck with a slot size of s = 1.5 mm. Acceptable results, compared to the others, were obtained using a frequency of 80 min^{-1}. At the same time, for these tests, the highest calorific value of the concentrate product and the lowest for the waste product were obtained.

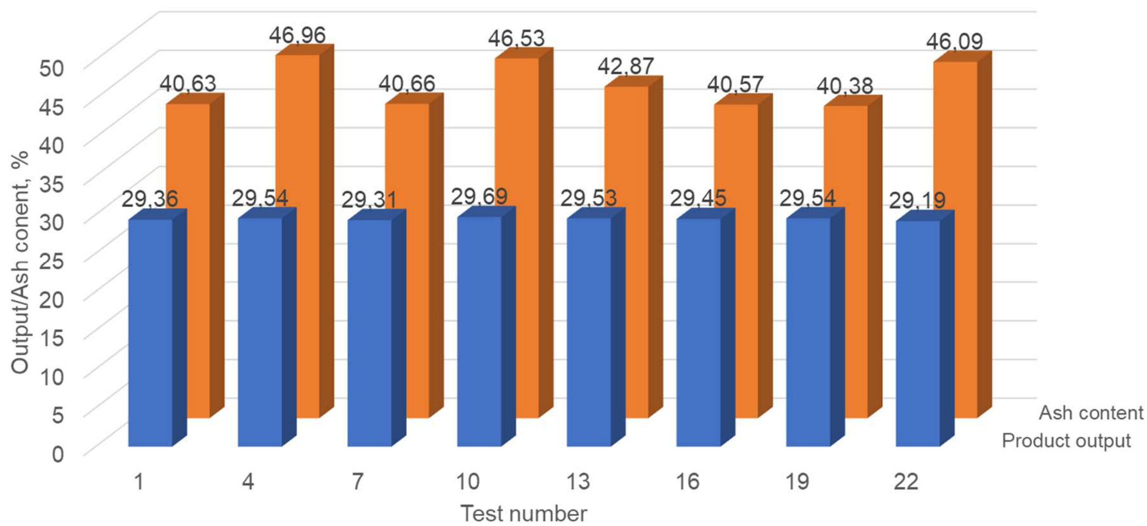

Fig. 4 Yield and ash content of the concentrate product - grain class 10-3 mm

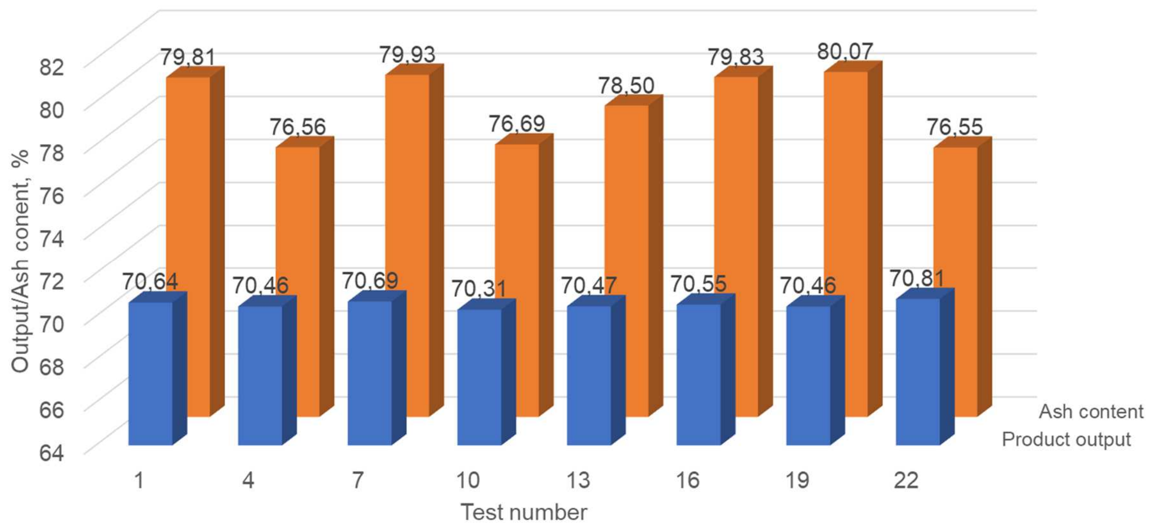

Fig. 5 Yield and ash content of the waste product - grain class 10-3 mm

Table 6 Summary of Selected Laboratory Test Results – Grain class 30-3 mm

Test number	Test parametrers	Concentrate product			Waste product		
		Product output	Average ash content, A^a	Average calorific value, Q_i^a	Product output	Average ash content, A^a	Average calorific value, Q_i^a
		%	%	kJ/kg	%	%	kJ/kg
3	s=1.5 mm, f=40 min^{-1}, t=60 s	27.39	44.80	15705	72.61	84.12	1481
6	s=1.5 mm, f=40 min^{-1}, t=30 s	27.76	50.17	13705	72.24	81.79	2328
9	s=1.5 mm, f=60 min^{-1}, t=60 s	27.68	44.38	15857	72.32	84.14	1475
12	s=1.5 mm, f=60 min^{-1}, t=30 s	27.73	48.85	14194	72.27	82.28	2148
15	s=1.5 mm, f=80 min^{-1}, t=60 s	27.62	46.25	15162	72.38	83.35	1757
18	s=2.5 mm, f=40 min^{-1}, t=60 s	27.43	44.40	15847	72.57	84.15	1471
21	s=2.5 mm, f=60 min^{-1}, t=60 s	27.58	43.67	16118	72.42	84.26	1430
24	s=2.5 mm, f=60 min^{-1}, t=30 s	27.60	47.86	14557	72.40	82.34	2128

The enrichment test results for the 30-3 mm grain size class confirmed the relationships observed during the separation tests of other grain size classes. Once again, the most favourable results were obtained with a frequency of 60 min^{1} and a slot size of s = 2.5 mm. Slightly worse results were achieved with a frequency of 40 min^{-1}. For these parameters, the highest quality concentrate products and waste products with minimized combustible content were obtained. As with other grain size classes, shortening the enrichment time had a very negative impact on product parameters.

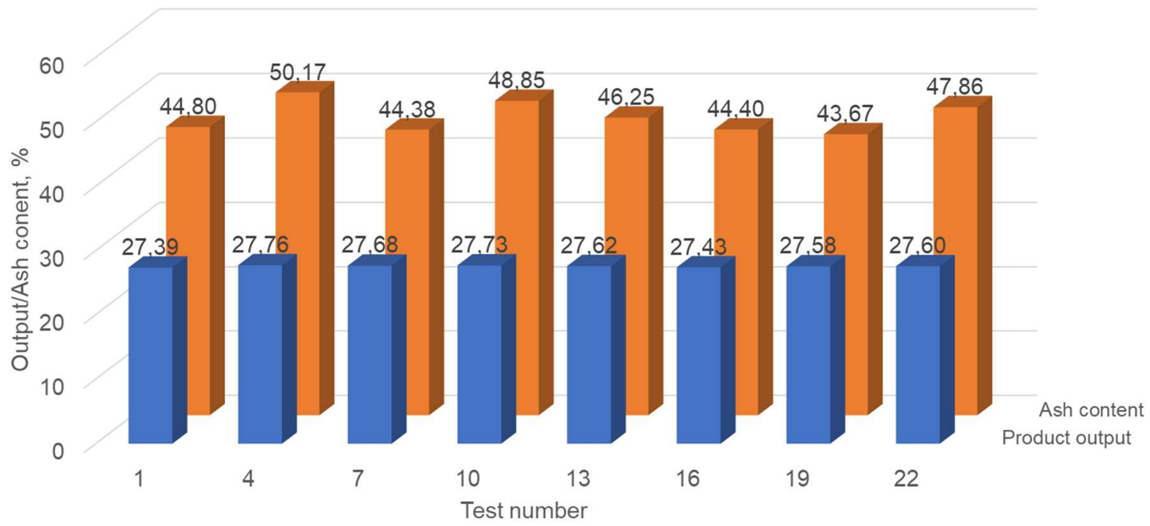

Fig. 6 Yield and ash content of the concentrate product - grain class 30-3 mm

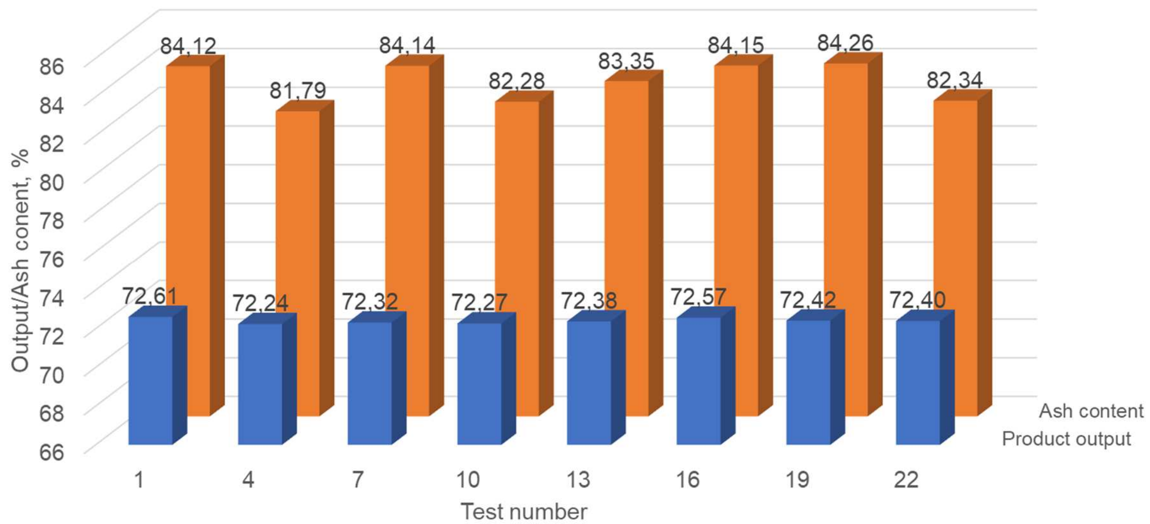

Fig. 7 Yield and ash content of the waste product - grain class 30-3 mm

Separation accuracy parameters

The results of the density separation of jigging beneficiation products enabled the calculation of indicators characteristic of the beneficiation process accuracy. Based on the shares of individual density fractions, separation numbers were determined, and separation curves for individual feeds were prepared according to the specified experimental parameters. The separation curves are presented in Figures 8 to 10 as trend lines approximated by a 3rd-degree polynomial. The values of the separation indicators are summarized in Tables 7 to 9.

The most favourable separation parameters for the grain size class 30-10 mm were obtained in the experiment where a pulsation frequency of 60 min^{-1} was used, along with a longer beneficiation time and a screen deck equipped with a slot screen with a slot size of 2.5 mm. For this case, the imperfection value was 0,205 and the probable error was equal to 0,235 g/cm^3.

Similarly favourable results were obtained in experiments conducted with a frequency of 40 min^{-1} on both tested screen decks (1.5 mm and 2.5 mm). For these experimental parameters, the imperfection was equal to: 0.217 and 0.231, and the probable error was 0.245 g/cm^3 and 0.258 g/cm^3.

The worst results were obtained for shorter beneficiation times (simulating increased load on the device), especially in the case of screen decks with a smaller slot size.

Table 7 Separation accuracy parameters – Grain class 30-10 mm

Parameter	Test number							
	1	4	7	10	13	16	19	22
Separation density D_{50}, g/cm^3	2.130	1.975	2.070	2.040	2.080	2.115	2.145	1.970
Probable error E_p, g/cm^3	0.245	0.498	0.273	0.535	0.365	0.258	0.235	0.453
Imperfection, I	0.217	0.510	0.255	0.514	0.338	0.231	0.205	0.466

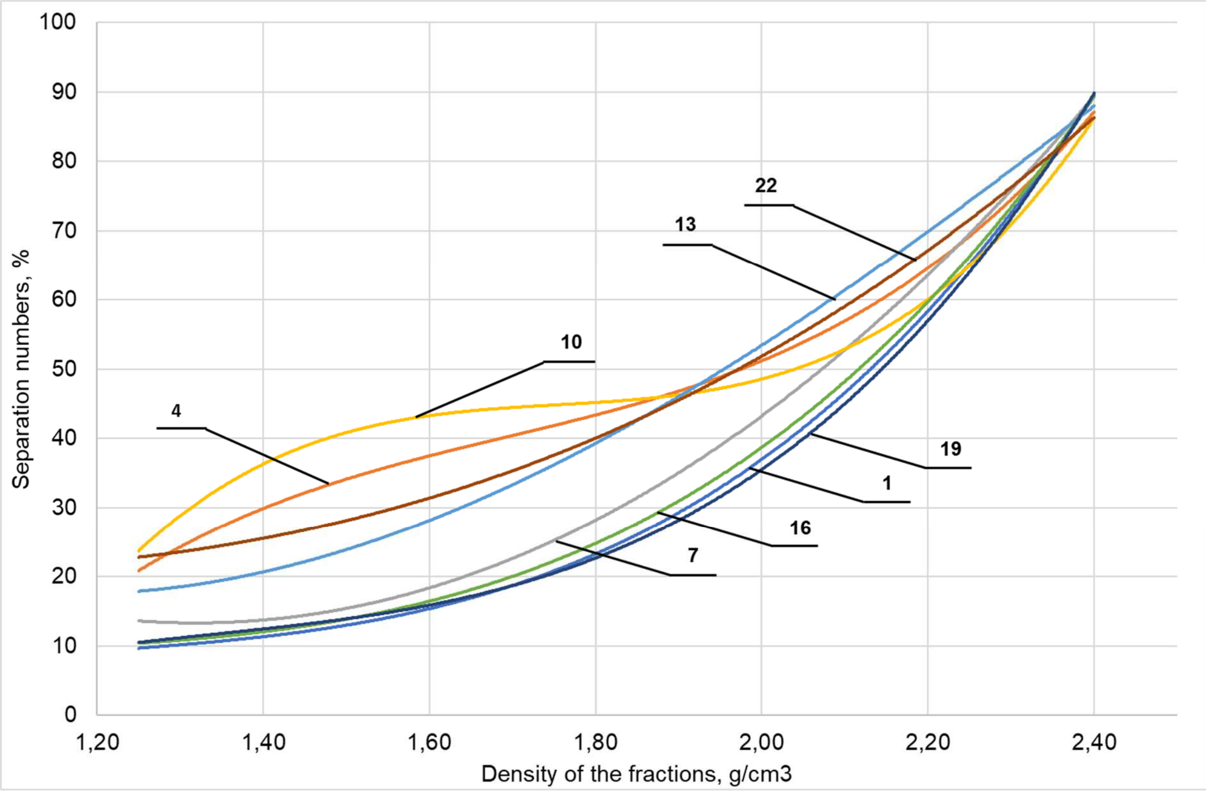

Fig. 8 Separation curves– Grain class 30-10 mm

In the case of the grain size class 10-3 mm, distinctly the most favourable separation parameters were obtained by using a screen deck with an increased slot size (2.5 mm). The best results were achieved with a pulsation frequency of 60 min^1, where the imperfection was 0.160 and the probable error was equal to 0.215 g/cm^3. A very similar separation accuracy was obtained at a frequency of 40 min^1, where the above-mentioned indicators were 0.178 and 0.215 g/cm^3.

Significantly (more than twice) worse results were obtained for the smaller slot size of the screen deck (1.5 mm) and shorter beneficiation times.

Table 8 Separation accuracy parameters – Grain class 10-3 mm

Parametr	Test number							
	2	5	8	11	14	17	20	23
Separation density D_{50}, g/cm^3	2.180	2.025	2.150	2.075	2.020	2.205	2.220	1.910
Probable error E_p, g/cm^3	0.255	0.515	0.273	0.510	0.340	0.215	0.195	0.493
Imperfection, I	0.216	0.502	0.237	0.474	0.333	0.178	0.160	0.541

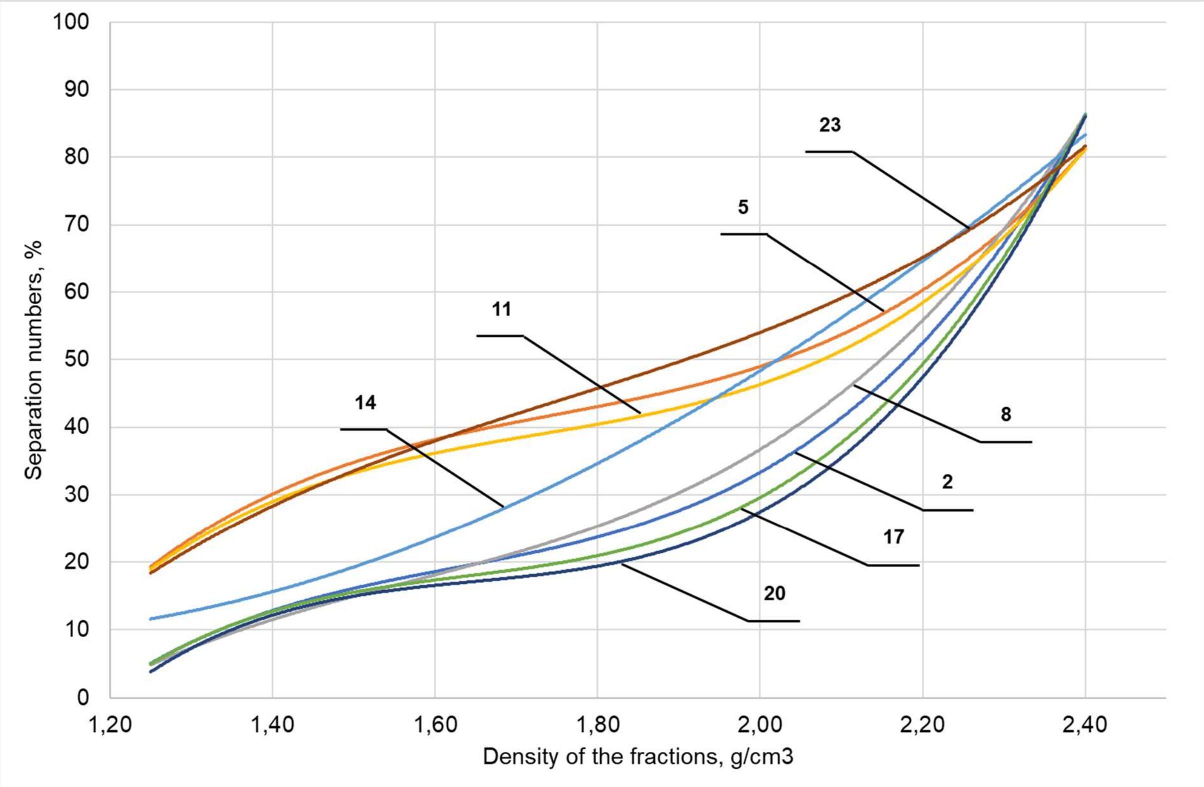

Fig. 9 Separation curves– Grain class 10-3 mm

Similarly, in the case of enriching material with a grain size of 30-3 mm, the most favourable results in terms of separation accuracy were obtained with a larger slot size of the screen deck and longer beneficiation times. Slightly better results were achieved with a pulsation frequency of 60 min^{-1} compared to a frequency of 40^{-1}. The lowest indicators were 0.131 and 0.160 g/cm^3 in the case of test number 20.

In the case of this grain size class and class 10-3 mm, fairly favourable separation results were also obtained for the highest of the tested frequencies, which was 80 min^{-1}.

Table 9 Separation accuracy parameters – Grain class 30-3 mm

Parametr	Test number							
	2	5	8	11	14	17	20	23
Separation density D_{50}, g/cm^3	2.190	1.990	2.210	2.060	2.125	2.210	2.220	2.140
Probable error E_p, g/cm^3	0.193	0.300	0.173	0.305	0.258	0.173	0.160	0.268
Imperfection, I	0.162	0.303	0.143	0.288	0.229	0.143	0.131	0.235

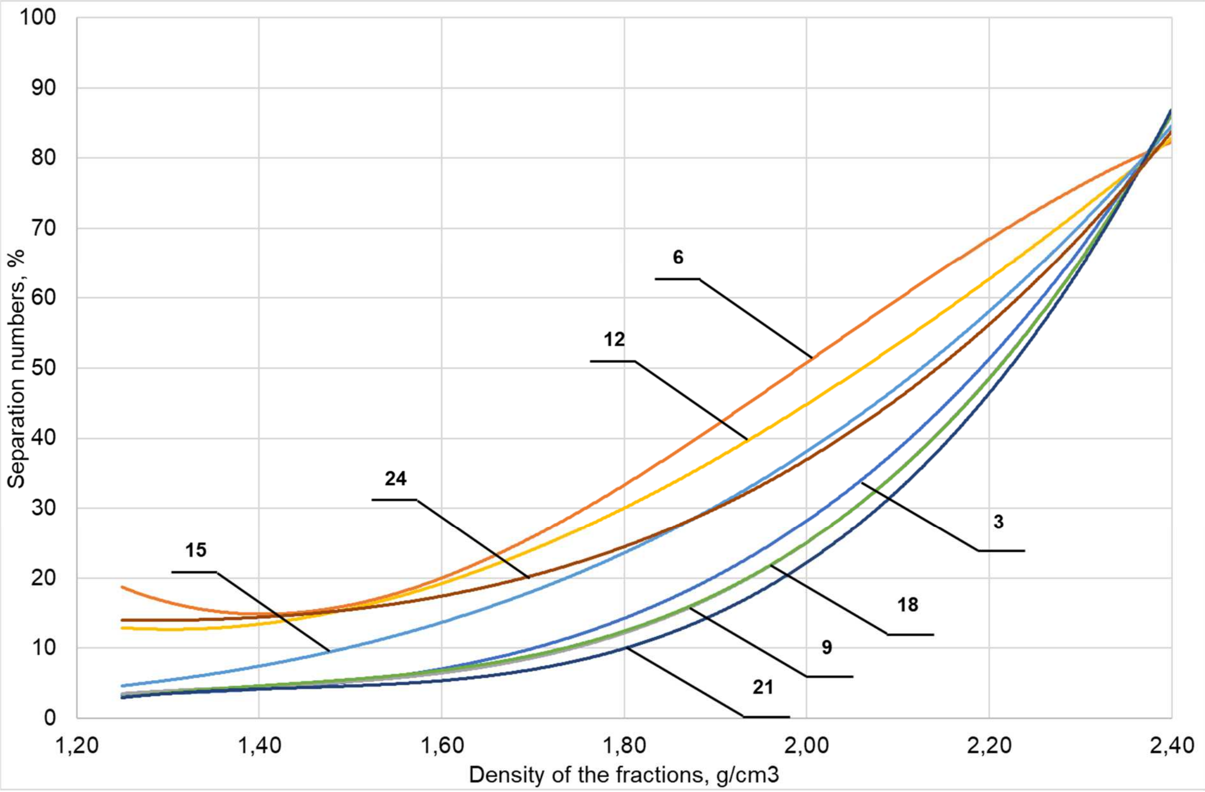

Fig. 10 Separation curves– Grain class 30-3 mm

5. Conclusions

As part of Task 3.1 „Laboratory tests of jig beneficiation” tests were conducted on the enrichment of mining waste using a laboratory jig unit. The goal was to determine the impact of selected technical-technological parameters and to make a preliminary selection of input data for designing a new device for the industrial separation of mining waste. The tests were carried out for three grain size ranges of waste material.

The variables in the experiments, in addition to the grain size ranges of the feed, included: pulsation frequency, enrichment time, and the size of the slot in the screen deck of the laboratory jig unit.

During the tests, the impact of selected experimental parameters on the effectiveness of separating individual grain size classes was analysed.

Based on the test results, a significant impact of the studied parameters on the enrichment efficiency and the quantitative and qualitative parameters of the separation products was demonstrated.

The most favourable results in terms of product quality and simultaneously the efficiency of separation for all the tested feeds were obtained at a pulsation frequency of 60 min^{-1}. Very similar and favourable separation results were achieved at a pulsation frequency of 40 min^{-1}. For grain classes with a large proportion of finer grains (<10 mm), acceptable results were obtained at a frequency of 80 min^{-1}.

The enrichment time, which corresponding to the load on the device, had a very significant impact – extending the enrichment time (that is, reducing the unit load) allowed for significantly more favourable results. The exact value of the unit load should be determined experimentally under industrial conditions, but it seems that, to maintain an acceptable efficiency in the separation of mining waste, it should not exceed 20-25 $t/h/m^2$.

The analysis of the results also showed that slightly better test results were obtained for a larger slot in the screen deck (s = 2.5 mm).

The results of the conducted tests were used for the preliminary selection of input data for the design needs planned in Task 3.3.

The implementation of an industrial device using the data obtained during these tests should enable significantly more favourable results and, consequently, homogeneous separation products:

- of low density, consisting mostly of grains of the combustible fraction,
- of high density, consisting mostly of grains of the mineral fraction.

High-quality density separation products will form the basis for the production of the project-designated products: geopolymer composites (from the mineral fraction) and hydrogen (from the grains of the combustible fraction).

6. Input data for the industrial device development

6.1. Pulsation valves

The essence of the operation of pulsating jigs lies in the loosening and separation of material under the influence of pulsation of the working fluid, usually water, in which the material is submerged. Based on the method of generating pulsation, jigs can be categorized into:

- jigs with piston or membrane pulsators,
- jigs with air pulsators,
- jigs with a movable working bed,
- jigs with bellows pulsators.

Jigs with piston pulsators were the first designs of pulsating jigs. In these, pulsation is mechanically generated through a piston or a flexible membrane that performs reciprocating movements, usually driven by an eccentric mechanism (Fig. 11). They are characterized by a complex structure due to the presence of the piston-eccentric mechanism and a limited range of pulsation parameter adjustment.

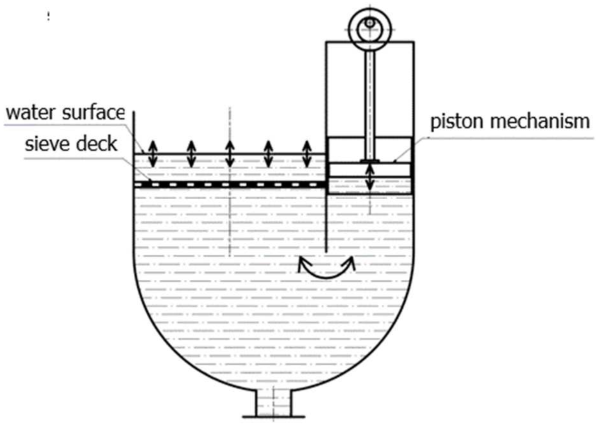

Fig. 11 Construction of an enrichment device with a piston pulsator [own work]

Over time, piston and membrane pulsators have been replaced by air pulsators. Jigs with air pulsating valves (Fig. 12) operate on the principle of cyclic introduction and removal of air into air chambers located beneath the sieve decks, on which the enriched material is placed. When air is introduced into the chamber, it displaces water, causing the water level to rise in the working trough and lifting the material, allowing the separation of particles with different densities. After the air is released from the chamber, the material settles, and the heavier particles fall to the bottom. This process is repeated cyclically, enabling the effective separation of the components of the mixture.

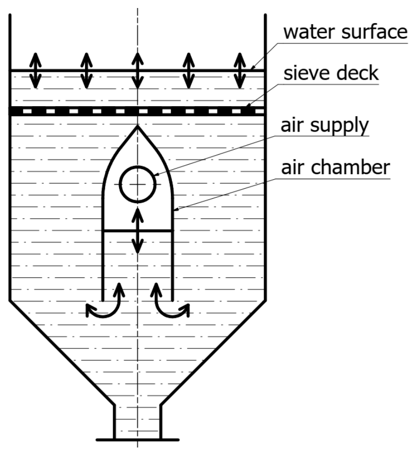

Fig. 12 Construction of an enrichment device with an air pulsator [own work]

In jigs with a movable working bed, the separation of material occurs as a result of vertical reciprocating movements of the sieve deck in a stationary water environment. On the other hand, bellows jigs have pulsators in the form of flexible bellows driven by actuators. The bellows are attached to the structure of the box, beneath the working deck. They are filled with water, and their movement, initiated by the actuators, causes pulsation of water in the working trough. Devices of both these types have not found widespread practical application.

Currently, the most commonly used are jigs with air pulsators. Their key components, which control the airflow and thus the pulsation cycles, are the air valves, also known as pulsators. These valves regulate the airflow, which determines the intensity of the pulsation, as well as the pulsation frequency and the duration of individual cycles, influencing the course and efficiency of the enrichment process. Based on their construction and operating principle, they are divided into:

- rotary pulsation valves,
- disc pulsation valves,
- membrane pulsation valves,
- piston pulsation valves,
- pendulum pulsation valves.

In practice, rotary and disc pulsation valves are the most widely used.

Rotary pulsation valves

In rotary pulsation valves, the flow of working air is achieved through the rotational movement of a rotor equipped with specially shaped air channels. During rotation, the rotor's channel system ensures the alternating opening and closing of holes in the cylindrical body of the valve, which are used to supply compressed working air to the working chamber and to discharge it into the atmosphere. In the basic version of the valve, the body is equipped with three ports (connections). These are: the supply port, which receives compressed air; the working port, connected to the air chamber of the jig; and the exhaust port, through which used air is released into the atmosphere.

One full rotation of the rotor corresponds to one pulsation cycle. During rotation, with changes in the angular position of the rotor, successive phases of the cycle occur. In the first phase, the supply port opens and connects with the working port. Compressed air flows into the jig's air chamber, causing the water level to rise in the working trough. Next, the supply port is closed, and the working port connects with the exhaust port. This is the exhaust phase, during which air from the air chamber is released into the atmosphere. In this phase, the water level in the working trough falls. After the exhaust port is closed, the operating cycle starts anew.

A seal is used between the valve rotor and the body, which must have a low coefficient of friction and high resistance to wear. The proportions of the duration of individual phases of the cycle can be adjusted to some extent by selecting the appropriate shape of the air channels in the rotor. The frequency of pulsation cycles is determined by selecting the appropriate rotational speed of the rotor.

To regulate the amount of air delivered to individual air chambers in order to adjust the pulsation parameters to the desired pulsation curve, a phase shift on individual valves is used (achieved by changing the coupling of the rotary valve shafts). Establishing the required shape of the pulsation curve must be done at the design stage of the rotary pulsation valve, and during operation, only limited possibilities for correcting work parameters are available, each of which requires physical intervention in the mechanical system of the valve assembly.

Disc pulsation valves

In disc pulsation valves, the flow of working air is controlled by a set of disc valves. Figure 13 shows a diagram of a disc pulsation valve in its simplest configuration, with two disc valves. Each such valve consists of a disc mounted on a spindle connected to a drive element (hydraulic, pneumatic, or electromagnetic actuator). The disc works with a valve seat, ensuring complete tightness. The valve body, which houses the seats and actuators, has three connection ports: the supply port, where compressed air is fed; the working port, connected to the air chamber of the jig; and the exhaust port, through which used air is released into the atmosphere.

The pulsation cycles are achieved by raising and lowering the spindles with the discs, ensuring the flow of air with the required intensity and duration. In the first phase of the cycle, the supply valve opens, allowing air to flow from the supply chamber to the working chamber and further into the air chamber of the jig, causing the water level to rise in the working trough. Next, the supply valve closes, and immediately or after a specified delay, the exhaust valve opens. This initiates the exhaust phase, during which air from the jig’s air chamber is released into the atmosphere through the working and exhaust chambers of the pulsation valve. In this phase, the water level in the working trough drops. After the exhaust valve closes, the working cycle starts again.

The regulation of pulsation parameters mainly involves controlling the operation of the actuators, offering almost unlimited possibilities for shaping the required pulsation curve and adjusting the frequency, which can be done from the jig's control system.

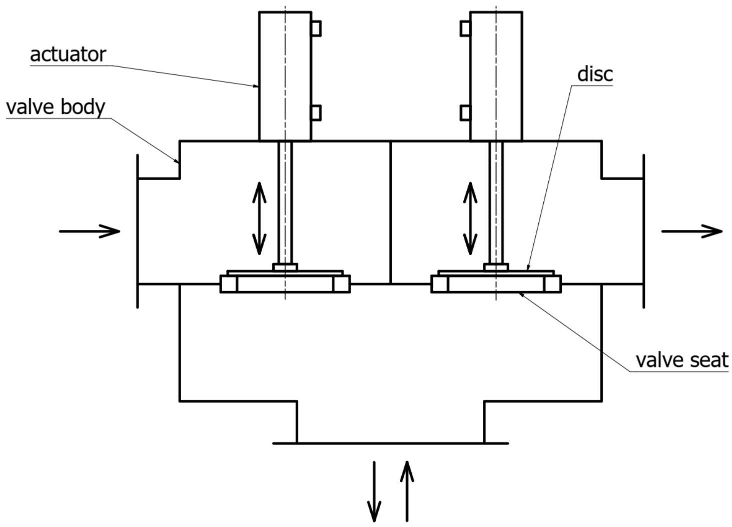

Fig. 13 Schematic of a plate pulsation valve [own work]

Comparison of the most commonly used pulsators and selection of the most optimal solution for the designed jig

The fundamental aspects of implementing pulsation cycles in pulsating jigs have been presented above, along with the most commonly used pulsator solutions and a brief description of their operation. Based on the analysis, it can be concluded that air pulsators are currently the most widely used. Among this group, rotary and disc pulsation valves have found the most practical applications. These are the most commonly used pulsators in enrichment devices designed by companies such as Allmineral, Bateman, and KOMAG.

As part of the project, laboratory tests on the enrichability of coal waste were conducted, which are described in detail in section 4. By using a laboratory pulsating jig equipped with an air pulsator, offering a very wide range of possibilities for shaping the pulsation curve, it was possible to carry out tests for a series of different parameters. The results clearly showed that the shape of the pulsation curve and frequency have a very significant impact on the efficiency of the enrichment process.

For this reason, a disc pulsation valve was selected for use in the newly designed jig. This type of pulsator allows easy shaping of the pulsation curve and frequency adjustment during operation. Moreover, the regulation and adjustment of parameters can be performed without the need for physical intervention in the valve's structure, as is required with rotary valves. All settings can be changed from the control panel or even remotely, provided that the control system is equipped with an appropriate wireless communication module.

The new jig will feature an advanced version of the disc pulsation valve, equipped with four disc valves and two working chambers that independently supply working air to the front and rear parts of the working deck. This will provide even greater possibilities for shaping the jig's pulsation parameters.

6.2. Stone discharge system

In the process of enriching coal waste in the designed pulsating jig, one of the main operations that determines the effectiveness of the process is the removal of the separated material from the working area of the trough. In such devices, the removal of the stone fraction is performed by control systems that simultaneously serve to automatically regulate the material layer level in the jig's working trough. To achieve the lowest possible enrichment process costs, as well as high reliability and efficiency, the chosen technical solution for the discharge system must ensure:

- the ability to adjust the throughput (discharge rate) over a wide range,
- minimal water outflow through the stone product discharge opening,
- stable product discharge,
- long operational life,
- simple and quick maintenance procedures.

Among the known product discharge systems, the following can be mentioned:

- overflow discharge system,
- rotary cell discharge system,
- vibratory discharge system,
- slide gate,
- tilting bed,
- outlet (discharge) valve

In practice, the most commonly used discharge systems in pulsating jigs available on the market are the overflow, rotary cell, and vibratory discharge systems.

Overflow discharge system

The overflow discharge system has a fixed, horizontal threshold with an edge that has a flexible seal and is in contact with a movable, rotating shutter of the discharge opening. The position of the cylindrical shutter is adjusted using a shaft connected to a bidirectional gear motor, based on changes detected by a float sensor that measures the material layer level in the jig's working trough. The cross-section size of the discharge opening with a fixed width increases from top to bottom, up to the level of the edge of the fixed threshold. It is located at the end of the working trough, behind the overflow threshold and below the level of its overflow edge. Thanks to this positioning, under the influence of the pulsating water movement, the grains of the product, along with a portion of the process water, are discharged over the "overflow" above the top edge of the movable shutter.

The water pulsation stroke in the jig trough can reach up to 120 mm. The size of the grains discharged in this way ranges from 32 to 0 mm, with an allowable maximum grain size of 42 mm and a content of grains in the 2-0 mm range in the feed up to 50%. The overflow discharge system is characterized by limited leakage of process water and a moderate degree of discharge rate (product collection rate) adjustment accuracy. It also has a simple construction.

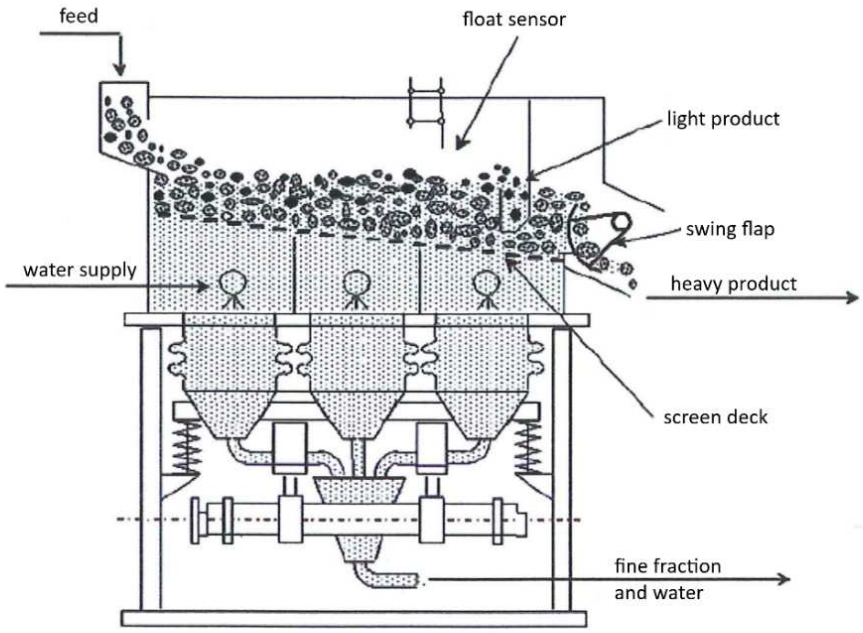

Fig. 14 Pulsating enrichener with an overflow receiver [1]

Rotary cell discharge system

The rotary cell discharge system (Fig. 15) consists of a rotor equipped with six scooping blades inclined in the opposite direction to the rotation. The length of the rotor's working section is equal to the width of the working trough. The rotor is mounted in a cylindrical housing with two openings cut along the entire working length—an inlet opening from above and an outlet opening from below. The spaces between the rotor blades form working chambers that transport the collected material between the inlet and outlet openings.

The rotor blades are equipped with steel, sliding wear-resistant covers, which allow for adjusting the gap between the rotor and the housing. The rotor shafts extend outside the housing through side covers. The seal between the rotating shafts and the covers is ensured by gland seals. The shafts that protrude outward are supported by two bearings mounted on the side covers, with appropriate offsets to protect the bearings from contamination due to potential leaks.

The discharge system is located below the level of the screen deck, which is connected to it via an inclined receiving box. The discharge rate of the stone product, dependent on the material level in the jig trough, is regulated by automatically adjusting the appropriate rotational speed of the discharge system. The direction of rotation ensures gravitational transport of the material, assisted by the partial outflow of process water.

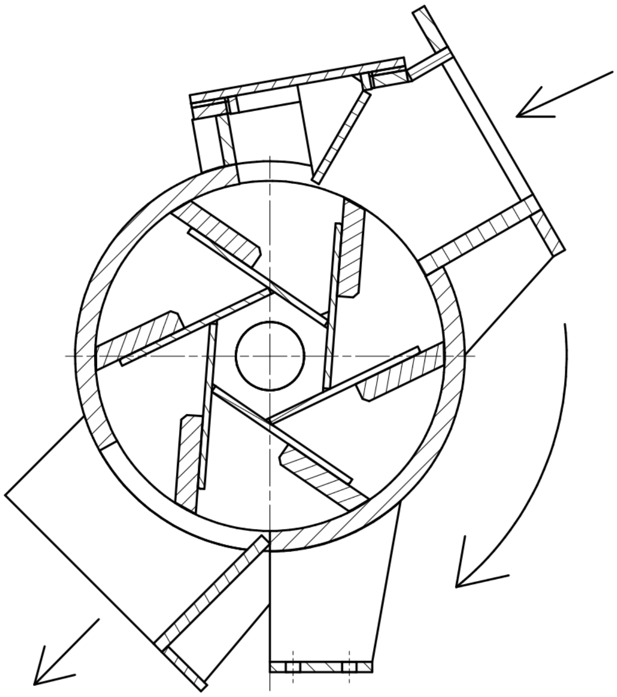

Fig. 15 Rotary cell receiver [own work]

The described type of receiver enables the transport of material in the grain size class of 16-0 mm, with a maximum grain size of 32 mm. Its primary advantage is the ability to very precisely adjust the throughput (product retrieval rate), which translates into good efficiency in the enrichment process. It also ensures very minimal leakage of process water. The drawback of this solution is the possibility of material grains becoming jammed between the body and the blades. For this reason, it is necessary to use overload sensors and provide the possibility of reverse movement. The wear-resistant linings on the scrapers are subject to natural wear and require periodic replacement.

Vibratory receiver

The vibratory receiver consists of a stationary receiving box, a feeder transfer box, and a feeder with a vibratory drive. The receiving box, mounted at the outlet of the enrichment device, has a vertical opening through which the stone material from the surface of the screen deck is discharged. Positioned beneath the outlet opening of the receiving box is the feeder transfer box, which is open from the top. This box is equipped with a sloped chute centrally located beneath the outlet opening of the receiving box to reduce the load on the working surface of the feeder. From this chute, the stone product is directed onto the vibratory feeder through a vertical transfer channel, with the discharge opening placed above the feeder's working surface.

An electronic system is used to control the amount of material retrieved from the enrichment device. Signals from a float layer sensor are processed and used to regulate the efficiency of the vibratory feeder that transports the material. The vibratory feeder is driven by one or two electrovibrators. The feeder's efficiency is adjusted by changing the rotational speed of the electrovibrators, which has a crucial impact on the vibration frequency and the resulting force generated by the vibratory receiver.

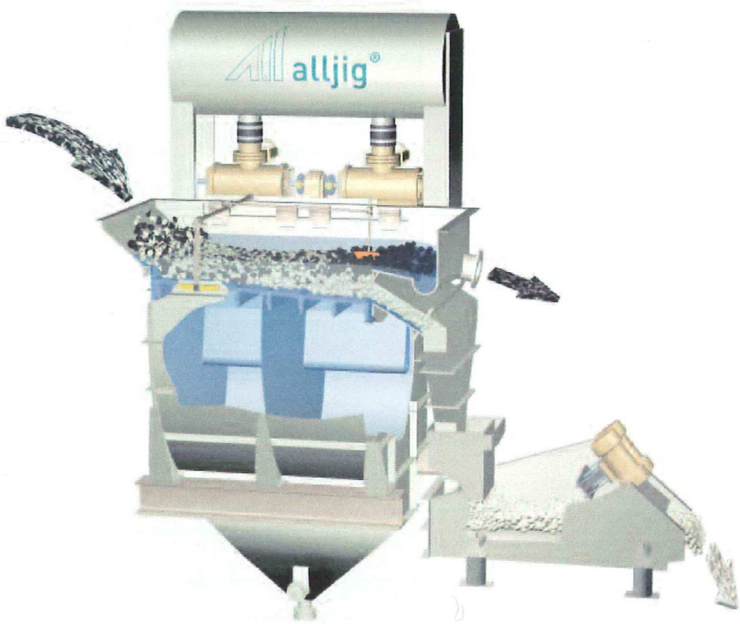

Fig. 16 Pulsating enrichener with a vibrating receiver [2]

The vibratory receiver can handle materials with a grain size of up to 100 mm and is characterized by high throughput. It is often used in metal ore enrichment devices due to the high hardness of the material. Its main drawback is the significant outflow of process water, especially when there is no feed. Due to the lack of flow restrictions, starting up the enrichment device can be problematic, as forming a stable layer of material on the working deck is challenging. Therefore, additional systems are needed to dampen the flow of feed water.

Comparison of the most common receiver solutions and selection of the most optimal one for the new enrichment device

Each device used for the pulsating enrichment of mineral materials must have parameters tailored to the material being processed. This also applies to the material receivers used in them. The examples of solutions described above are among the most commonly applied and have proven effective in practice.

For the designed enrichment device, a rotary cell receiver will be used. This choice was primarily driven by its capability for precise throughput control, which significantly influences the efficiency of the enrichment process. None of the other solutions offer such capabilities. Additionally, a major advantage of this solution is the minimal outflow of process water.

In the new device, the scraping rotor will be modified. The rotor blades will be equipped with flexible polyurethane linings. These linings will take the form of polyurethane strips with a steel reinforcing insert. A sliding mounting with bolt connections is planned, allowing for the adjustment of the gap between the rotor and the body. The use of flexible linings will reduce the tendency of grains to jam between the body and the rotor. This will enable the collection of material in the grain size range of 30 – 3 mm, with individual oversized grains up to 40 mm. It is also anticipated that the use of a rotor with flexible blades will increase the durability of both the rotor and the body.

The rotor's bearing and sealing assemblies will also be modified. An additional sealing and flushing system with clean water will be applied to the areas directly adjacent to the seals, between the side surfaces of the rotor and the side covers. This will prevent material buildup in these areas and reduce wear on both the rotor components and the seals.

6.3. Screen deck

The main component of the pulse jig is the working trough with a screen deck, where the enrichment process takes place. It is a box-like structure with a bottom in the form of a screen deck. In its front and rear sections, there are appropriately shaped openings – the inlet for feeding the material and the outlet for collecting the separated products. The working trough, along with the screen deck, is mounted on the central chamber, where the pulsation of the process fluid is carried out. Depending on technological requirements, the deck can be positioned horizontally or with a slight incline towards the outlet. In current practice, steel grating screens, perforated steel sheets, and flexible polyurethane screens are most commonly used as screen decks.

In the newly designed pulse jig, a working trough with a screen deck 2000 mm in width and 2000 mm in length, inclined towards the outlet at an angle of approximately 5.8° (Figure 17), is planned. The dimensions of the deck were chosen based on the results of tests conducted on a laboratory jig, as optimal for the required throughput of 100 Mg/h. The deck consists of modular screens with a steel load-bearing structure and an elastic screen surface made of polyurethane vulcanized onto it. The planned slot size in the screens is 2.5 mm, a value also determined based on laboratory tests. Trials on the laboratory jig were carried out for two screen decks with different slot sizes – 1.5 mm and 2.5 mm. Significantly better results were achieved using screens with a slot size of 2.5 mm. The larger slot provides a greater clearance of the screen deck and thus a higher pulsation intensity. This ensures better loosening of the enriched material and greater accuracy in separating materials of different densities. Simultaneously, with the lower grain size limit of the feed being 3 mm, the chosen slot size ensures only a small amount of fine material passing through the screen deck.

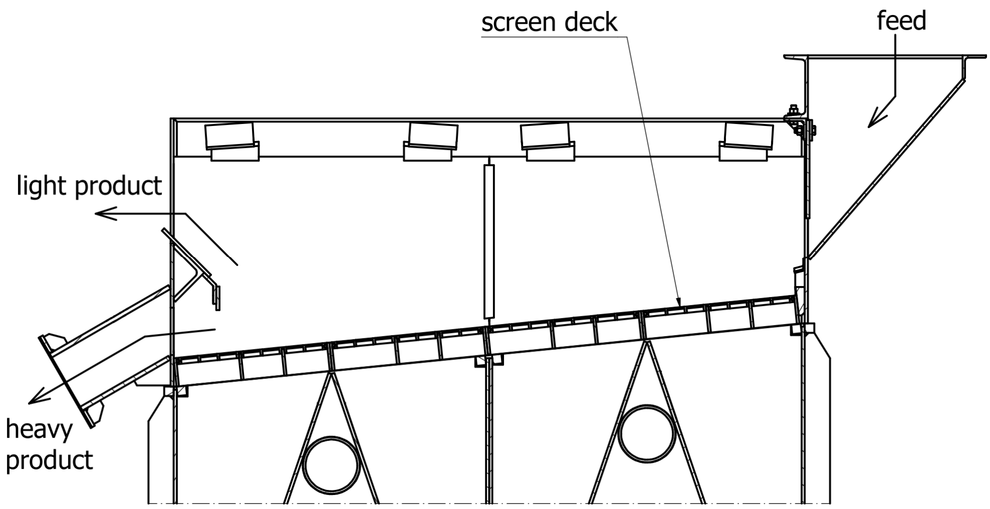

Fig. 17 Concept of the working trough with a screen deck of the designed pulse jig [own work]

The modular screens of the working deck are mounted using a set of clamping strips and wooden wedges. Under such heavy working conditions, this ensures a reliable connection, allowing for easy and quick disassembly and replacement of the screens.

7. Preparation of samples for testing in T3.2

The objective of the study was to obtain separation products from materials deposited in mining dumps, which will be used for analysis in T3.2. The products were obtained as a result of separating materials from selected dumps at the laboratory jig stand.

In accordance with internal agreements based on the previous tests results, three materials utilized and analysed in T2.2 were selected for study in T3.2: Haldex 1, Haldex 2, and Karvina 2. Each of these materials was separated in the laboratory jig into two products: a concentrate primarily composed of coal grains and a waste product largely consisting of mineral grains.

The procedure for preparing, starting, and stopping the laboratory jig was the same as for the tests conducted to gather input data for designing the industrial device. The difference lay in the technique of introducing material into the jig and the duration of material beneficiation.

After starting the jig filled only with water, the device was gradually filled with material. A single trial lasted approximately 5 minutes, and the mass of the introduced and separated material was about 40 kg. The test parameters are shown in Table 10.

Table 10 Tests parameters

Parameter	Unit	Value
Pulsation frequency	min^{-1}	60
Inlet	ms	230
Interval	ms	250
Outlet	ms	230
Interval	ms	290
Process water supply flow rate	m^3/h	4,5

After completing a single trial and emptying the jig of water, the upper layer (concentrate product - coal grains) was first manually removed, followed by the rest of the material (waste product - mineral grains).

Each of the products was mixed to ensure its homogeneity, divided into four equal parts, and delivered to partners who planned to conduct laboratory tests on these materials as part of T3.2 (ITPE, GIG, USTARCH, KOMAG).

8. Bibliography

1. https://www.ffag.ch/en/conveyor-technique/detail/pulsator-jig.html
2. https://www.allmineral.com/en/

Appendix

Complete density and quality composition

Table I Test 1 Grain class 30-10 mm

Density fraction	Share	Moisture content, W^a	Ash content, A^a	Sulphur content, S^a	Heat of combustion, Q_s^a	Calorific value, Q_i^a
g/cm^3	%	%	%	%	kJ/kg	kJ/kg
Concentrate product						
<1.3	1.89	1.35	3.33	0.72	33077	31919
1.3-1.4	2.20	1.16	7.82	0.96	30657	29555
1.4-1.5	1.16	1.14	18.73	0.99	26172	25198
1.5-1.6	1.27	1.28	30.45	0.95	22572	21735
1.6-1.7	1.43	1.37	36.75	0.59	19128	18364
1.7-1.8	1.65	1.36	44.80	0.67	16027	15358
1.8-2.2	2.07	0.92	51.03	0.58	13589	13000
>2.2	8.72	0.72	78.50	0.30	3432	3169
Sum	20.39					
Average		1.00	49.07	0.57	14755	14142
Waste product						
<1.3	0.26	1.32	3.50	0.62	33441	32285
1.3-1.4	0.22	1.92	6.88	0.84	31345	30222
1.4-1.5	0.12	1.75	16.73	0.81	27101	26096
1.5-1.6	0.13	1.58	25.66	0.95	23210	22313
1.6-1.7	0.42	1.37	34.26	1.44	19915	19122
1.7-1.8	0.61	1.44	44.21	0.90	16181	15504
1.8-2.2	0.95	1.13	52.15	0.52	13828	13249
>2.2	76.90	0.99	85.04	0.29	1363	1174
Sum	79.61					
Average		1.00	83.38	0.31	1985	1777
Feed (calculated)						
<1.3	2.15	1.35	3.35	0.71	33121	31963
1.3-1.4	2.42	1.23	7.74	0.95	30719	29614
1.4-1.5	1.28	1.20	18.54	0.97	26261	25284
1.5-1.6	1.40	1.31	29.99	0.95	22632	21790
1.6-1.7	1.85	1.37	36.19	0.78	19306	18536
1.7-1.8	2.26	1.38	44.64	0.73	16068	15398
1.8-2.2	3.02	0.99	51.38	0.56	13664	13078
>2.2	85.62	0.96	84.37	0.29	1574	1377
Sum	100.00					
Average		1.00	76.39	0.36	4589	4298

Table II Test 2 Grain class 10-3 mm

Density fraction	Share	Moisture content, W^a	Ash content, A^a	Sulphur content, S^a	Heat of combustion, Q_s^a	Calorific value, Q_i^a
g/cm³	%	%	%	%	kJ/kg	kJ/kg
Concentrate product						
<1.3	4.39	1.54	3.64	0.73	32411	31254
1.3-1.4	4.96	1.54	9.80	0.76	30154	29070
1.4-1.5	2.32	1.56	21.40	0.76	25943	24995
1.5-1.6	1.62	1.71	30.62	0.75	21740	20899
1.6-1.7	1.31	1.76	37.67	0.85	19187	18429
1.7-1.8	1.99	1.60	47.14	0.66	15880	15236
1.8-2.2	2.35	1.52	51.99	0.52	13265	12679
>2.2	10.44	1.01	73.21	0.31	5365	5036
Sum	29.36					
Average		1.37	40.63	0.57	18078	17360
Waste product						
<1.3	0.32	1.70	3.43	0.74	32532	31371
1.3-1.4	0.53	1.43	8.62	0.82	30561	29465
1.4-1.5	0.29	1.88	21.48	0.81	26252	25301
1.5-1.6	0.36	1.59	27.85	0.76	22983	22112
1.6-1.7	0.35	1.47	31.45	0.56	20798	19971
1.7-1.8	0.72	1.44	43.50	0.85	16428	15743
1.8-2.2	0.74	1.32	50.28	0.60	14485	13882
>2.2	67.33	1.18	82.22	0.32	2435	2210
Sum	70.64					
Average		1.19	79.81	0.34	3343	3090
Feed (calculated)						
<1.3	4.71	1.55	3.63	0.73	32419	31262
1.3-1.4	5.49	1.53	9.69	0.77	30194	29108
1.4-1.5	2.60	1.60	21.41	0.77	25976	25029
1.5-1.6	1.97	1.69	30.12	0.75	21964	21118
1.6-1.7	1.65	1.70	36.36	0.79	19525	18752
1.7-1.8	2.71	1.56	46.17	0.71	16026	15371
1.8-2.2	3.09	1.47	51.58	0.54	13557	12967
>2.2	77.77	1.16	81.01	0.32	2828	2590
Sum	100.00					
Average		1.25	68.30	0.41	7669	7280

Table III Test 3 Grain class 30-3 mm

Density fraction	Share	Moisture content, W^a	Ash content, A^a	Sulphur content, S^a	Heat of combustion, Q_s^a	Calorific value, Q_i^a
g/cm³	%	%	%	%	kJ/kg	kJ/kg
Concentrate product						
<1.3	3.22	1.46	3.30	0.74	32770	31610
1.3-1.4	4.07	1.24	9.93	0.83	29952	28873
1.4-1.5	2.07	1.48	18.99	0.80	26250	25275
1.5-1.6	1.75	1.45	30.00	0.79	22184	21340
1.6-1.7	1.29	1.56	37.30	0.75	19011	18251
1.7-1.8	1.94	1.54	44.91	0.88	15952	15282
1.8-2.2	2.01	1.23	49.98	0.62	13958	13352
>2.2	11.04	1.02	76.85	0.34	4015	3729
Sum	27.39					
Average		1.24	44.80	0.60	16372	15705
Waste product						
<1.3	0.13	1.70	4.50	0.80	31724	30576
1.3-1.4	0.17	1.44	8.55	0.78	30686	29588
1.4-1.5	0.09	1.65	15.13	0.79	28031	27009
1.5-1.6	0.06	1.76	24.94	0.72	23320	22412
1.6-1.7	0.09	1.64	31.68	0.60	21219	20392
1.7-1.8	0.44	1.56	42.96	0.65	16419	15726
1.8-2.2	0.69	1.28	49.65	0.42	14768	14158
>2.2	70.94	1.15	85.24	0.28	1263	1074
Sum	72.61					
Average		1.16	84.12	0.29	1683	1481
Feed (calculated)						
<1.3	3.35	1.47	3.35	0.74	32729	31570
1.3-1.4	4.24	1.25	9.88	0.83	29981	28902
1.4-1.5	2.16	1.49	18.82	0.80	26327	25350
1.5-1.6	1.81	1.46	29.83	0.79	22222	21375
1.6-1.7	1.38	1.57	36.93	0.74	19155	18391
1.7-1.8	2.38	1.54	44.55	0.84	16037	15364
1.8-2.2	2.70	1.24	49.90	0.57	14165	13558
>2.2	81.98	1.13	84.11	0.29	1634	1432
Sum	100.00					
Average		1.18	73.35	0.37	5706	5377

Table IV Test 4 Grain class 30-10 mm

Density fraction	Share	Moisture content, W^a	Ash content, A^a	Sulphur content, S^a	Heat of combustion, Q_s^a	Calorific value, Q_i^a
g/cm³	%	%	%	%	kJ/kg	kJ/kg
Concentrate product						
<1.3	1.45	1.35	3.33	0.72	33077	31919
1.3-1.4	1.69	1.16	7.82	0.96	30657	29555
1.4-1.5	0.89	1.14	18.73	0.99	26172	25198
1.5-1.6	0.82	1.28	30.45	0.95	22572	21735
1.6-1.7	0.64	1.37	36.75	0.59	19128	18364
1.7-1.8	1.30	1.36	44.80	0.67	16027	15358
1.8-2.2	2.85	0.92	51.03	0.58	13589	13000
>2.2	10.58	0.72	78.50	0.30	3432	3169
Sum	20.22					
Average		0.93	49.07	0.51	12353	11813
Waste product						
<1.3	0.45	1.32	3.50	0.62	33441	32285
1.3-1.4	0.58	1.92	6.88	0.84	31345	30222
1.4-1.5	0.36	1.75	16.73	0.81	27101	26096
1.5-1.6	0.35	1.58	25.66	0.95	23210	22313
1.6-1.7	0.58	1.37	34.26	1.44	19915	19122
1.7-1.8	1.20	1.44	44.21	0.90	16181	15504
1.8-2.2	1.92	1.13	52.15	0.52	13828	13249
>2.2	74.34	0.99	85.04	0.29	1363	1174
Sum	79.78					
Average		1.02	83.38	0.32	2631	2402
Feed (calculated)						
<1.3	1.90	1.35	3.35	0.71	33121	31963
1.3-1.4	2.27	1.23	7.74	0.95	30719	29614
1.4-1.5	1.25	1.20	18.54	0.97	26261	25284
1.5-1.6	1.17	1.31	29.99	0.95	22632	21790
1.6-1.7	1.22	1.37	36.19	0.78	19306	18536
1.7-1.8	2.50	1.38	44.64	0.73	16068	15398
1.8-2.2	4.77	0.99	51.38	0.56	13664	13078
>2.2	84.92	0.96	84.37	0.29	1574	1377
Sum	100.00					
Average		1.00	76.39	0.36	4597	4305

Table V Test 5 Grain class 10-3 mm

Density fraction	Share	Moisture content, W^a	Ash content, A^a	Sulphur content, S^a	Heat of combustion, Q_s^a	Calorific value, Q_i^a
g/cm³	%	%	%	%	kJ/kg	kJ/kg
Concentrate product						
<1.3	3.63	1.54	3.64	0.73	32411	31254
1.3-1.4	4.10	1.54	9.80	0.76	30154	29070
1.4-1.5	1.92	1.56	21.40	0.76	25943	24995
1.5-1.6	1.20	1.71	30.62	0.75	21740	20899
1.6-1.7	0.97	1.76	37.67	0.85	19187	18429
1.7-1.8	1.48	1.60	47.14	0.66	15880	15236
1.8-2.2	1.85	1.52	51.99	0.52	13265	12679
>2.2	14.39	1.01	73.21	0.31	5365	5036
Sum	29.54					
Average		1.30	46.96	0.52	15608	14965
Waste product						
<1.3	0.92	1.70	3.43	0.74	32532	31371
1.3-1.4	1.54	1.43	8.62	0.82	30561	29465
1.4-1.5	0.82	1.88	21.48	0.81	26252	25301
1.5-1.6	0.66	1.59	27.85	0.76	22983	22112
1.6-1.7	0.64	1.47	31.45	0.56	20798	19971
1.7-1.8	1.34	1.44	43.50	0.85	16428	15743
1.8-2.2	1.33	1.32	50.28	0.60	14485	13882
>2.2	63.20	1.18	82.22	0.32	2435	2210
Sum	70.46					
Average		1.21	76.56	0.36	4575	4283
Feed (calculated)						
<1.3	4.55	1.55	3.63	0.73	32419	31262
1.3-1.4	5.64	1.53	9.69	0.77	30194	29108
1.4-1.5	2.74	1.60	21.41	0.77	25976	25029
1.5-1.6	1.86	1.69	30.12	0.75	21964	21118
1.6-1.7	1.61	1.70	36.36	0.79	19525	18752
1.7-1.8	2.82	1.56	46.17	0.71	16026	15371
1.8-2.2	3.18	1.47	51.58	0.54	13557	12967
>2.2	77.59	1.16	81.01	0.32	2828	2590
Sum	100.00					
Average		1.24	67.82	0.41	7834	7439

Table VI Test 6 Grain class 30-3 mm

Density fraction	Share	Moisture content, W^a	Ash content, A^a	Sulphur content, S^a	Heat of combustion, Q_s^a	Calorific value, Q_i^a
g/cm³	%	%	%	%	kJ/kg	kJ/kg
Concentrate product						
<1.3	2.80	1.46	3.30	0.74	32770	31610
1.3-1.4	3.53	1.24	9.93	0.83	29952	28873
1.4-1.5	1.80	1.48	18.99	0.80	26250	25275
1.5-1.6	1.39	1.45	30.00	0.79	22184	21340
1.6-1.7	1.02	1.56	37.30	0.75	19011	18251
1.7-1.8	1.54	1.54	44.91	0.88	15952	15282
1.8-2.2	1.48	1.23	49.98	0.62	13958	13352
>2.2	14.20	1.02	76.85	0.34	4015	3729
Sum	27.76					
Average		1.20	50.17	0.55	14308	13705
Waste product						
<1.3	0.59	1.70	4.50	0.80	31724	30576
1.3-1.4	0.76	1.44	8.55	0.78	30686	29588
1.4-1.5	0.42	1.65	15.13	0.79	28031	27009
1.5-1.6	0.15	1.76	24.94	0.72	23320	22412
1.6-1.7	0.22	1.64	31.68	0.60	21219	20392
1.7-1.8	1.05	1.56	42.96	0.65	16419	15726
1.8-2.2	1.34	1.28	49.65	0.42	14768	14158
>2.2	67.70	1.15	85.24	0.28	1263	1074
Sum	72.24					
Average		1.17	81.79	0.30	2558	2328
Feed (calculated)						
<1.3	3.39	1.47	3.35	0.74	32729	31570
1.3-1.4	4.30	1.25	9.88	0.83	29981	28902
1.4-1.5	2.22	1.49	18.82	0.80	26327	25350
1.5-1.6	1.53	1.46	29.83	0.79	22222	21375
1.6-1.7	1.24	1.57	36.93	0.74	19155	18391
1.7-1.8	2.60	1.54	44.55	0.84	16037	15364
1.8-2.2	2.82	1.24	49.90	0.57	14165	13558
>2.2	84.72	1.13	84.11	0.29	1634	1432
Sum	100.00					
Average		1.18	73.01	0.37	5820	5486

Table VII Test 7 Grain class 30-10 mm

Density fraction	Share	Moisture content, W^a	Ash content, A^a	Sulphur content, S^a	Heat of combustion, Q_s^a	Calorific value, Q_i^a
g/cm³	%	%	%	%	kJ/kg	kJ/kg
Concentrate product						
<1.3	1.85	1.35	3.33	0.72	33077	31919
1.3-1.4	2.15	1.16	7.82	0.96	30657	29555
1.4-1.5	1.13	1.14	18.73	0.99	26172	25198
1.5-1.6	1.29	1.28	30.45	0.95	22572	21735
1.6-1.7	1.02	1.37	36.75	0.59	19128	18364
1.7-1.8	1.89	1.36	44.80	0.67	16027	15358
1.8-2.2	2.09	0.92	51.03	0.58	13589	13000
>2.2	8.77	0.72	78.50	0.30	3432	3169
Sum	20.19					
Average		1.00	49.55	0.57	14575	13967
Waste product						
<1.3	0.35	1.32	3.50	0.62	33441	32285
1.3-1.4	0.29	1.92	6.88	0.84	31345	30222
1.4-1.5	0.16	1.75	16.73	0.81	27101	26096
1.5-1.6	0.15	1.58	25.66	0.95	23210	22313
1.6-1.7	0.46	1.37	34.26	1.44	19915	19122
1.7-1.8	0.66	1.44	44.21	0.90	16181	15504
1.8-2.2	0.65	1.13	52.15	0.52	13828	13249
>2.2	77.10	0.99	85.04	0.29	1363	1174
Sum	79.81					
Average		1.00	83.26	0.31	2034	1824
Feed (calculated)						
<1.3	2.20	1.35	3.35	0.71	33121	31963
1.3-1.4	2.44	1.23	7.74	0.95	30719	29614
1.4-1.5	1.29	1.20	18.54	0.97	26261	25284
1.5-1.6	1.44	1.31	29.99	0.95	22632	21790
1.6-1.7	1.47	1.37	36.19	0.78	19306	18536
1.7-1.8	2.55	1.38	44.64	0.73	16068	15398
1.8-2.2	2.74	0.99	51.38	0.56	13664	13078
>2.2	85.87	0.96	84.37	0.29	1574	1377
Sum	100.00					
Average		1.00	76.45	0.36	4566	4276

Table VIII Test 8 Grain class 10-3 mm

Density fraction	Share	Moisture content, W^a	Ash content, A^a	Sulphur content, S^a	Heat of combustion, Q_s^a	Calorific value, Q_i^a
g/cm³	%	%	%	%	kJ/kg	kJ/kg
Concentrate product						
<1.3	4.43	1.54	3.64	0.73	32411	31254
1.3-1.4	5.01	1.54	9.80	0.76	30154	29070
1.4-1.5	2.34	1.56	21.40	0.76	25943	24995
1.5-1.6	1.56	1.71	30.62	0.75	21740	20899
1.6-1.7	1.26	1.76	37.67	0.85	19187	18429
1.7-1.8	1.92	1.60	47.14	0.66	15880	15236
1.8-2.2	2.12	1.52	51.99	0.52	13265	12679
>2.2	10.66	1.01	73.21	0.31	5365	5036
Sum	29.31					
Average		1.37	40.66	0.57	18068	17351
Waste product						
<1.3	0.29	1.70	3.43	0.74	32532	31371
1.3-1.4	0.49	1.43	8.62	0.82	30561	29465
1.4-1.5	0.26	1.88	21.48	0.81	26252	25301
1.5-1.6	0.34	1.59	27.85	0.76	22983	22112
1.6-1.7	0.33	1.47	31.45	0.56	20798	19971
1.7-1.8	0.68	1.44	43.50	0.85	16428	15743
1.8-2.2	0.81	1.32	50.28	0.60	14485	13882
>2.2	67.49	1.18	82.22	0.32	2435	2210
Sum	70.69					
Average		1.19	79.93	0.34	3297	3045
Feed (calculated)						
<1.3	4.73	1.55	3.63	0.73	32419	31262
1.3-1.4	5.50	1.53	9.69	0.77	30194	29108
1.4-1.5	2.61	1.60	21.41	0.77	25976	25029
1.5-1.6	1.90	1.69	30.12	0.75	21964	21118
1.6-1.7	1.59	1.70	36.36	0.79	19525	18752
1.7-1.8	2.60	1.56	46.17	0.71	16026	15371
1.8-2.2	2.93	1.47	51.58	0.54	13557	12967
>2.2	78.15	1.16	81.01	0.32	2828	2590
Sum	100.00					
Average		1.25	68.42	0.41	7626	7238

Table IX Test 9 Grain class 30-3 mm

Density fraction	Share	Moisture content, W^a	Ash content, A^a	Sulphur content, S^a	Heat of combustion, Q_s^a	Calorific value, Q_i^a
g/cm³	%	%	%	%	kJ/kg	kJ/kg
Concentrate product						
<1.3	3.29	1.46	3.30	0.74	32770	31610
1.3-1.4	4.15	1.24	9.93	0.83	29952	28873
1.4-1.5	2.11	1.48	18.99	0.80	26250	25275
1.5-1.6	1.76	1.45	30.00	0.79	22184	21340
1.6-1.7	1.30	1.56	37.30	0.75	19011	18251
1.7-1.8	1.96	1.54	44.91	0.88	15952	15282
1.8-2.2	2.25	1.23	49.98	0.62	13958	13352
>2.2	10.86	1.02	76.85	0.34	4015	3729
Sum	27.68					
Average		1.25	44.38	0.60	16529	15857
Waste product						
<1.3	0.14	1.70	4.50	0.80	31724	30576
1.3-1.4	0.18	1.44	8.55	0.78	30686	29588
1.4-1.5	0.10	1.65	15.13	0.79	28031	27009
1.5-1.6	0.05	1.76	24.94	0.72	23320	22412
1.6-1.7	0.08	1.64	31.68	0.60	21219	20392
1.7-1.8	0.39	1.56	42.96	0.65	16419	15726
1.8-2.2	0.65	1.28	49.65	0.42	14768	14158
>2.2	70.72	1.15	85.24	0.28	1263	1074
Sum	72.32					
Average		1.16	84.14	0.29	1677	1475
Feed (calculated)						
<1.3	3.43	1.47	3.35	0.74	32729	31570
1.3-1.4	4.34	1.25	9.88	0.83	29981	28902
1.4-1.5	2.21	1.49	18.82	0.80	26327	25350
1.5-1.6	1.81	1.46	29.83	0.79	22222	21375
1.6-1.7	1.38	1.57	36.93	0.74	19155	18391
1.7-1.8	2.35	1.54	44.55	0.84	16037	15364
1.8-2.2	2.90	1.24	49.90	0.57	14165	13558
>2.2	81.58	1.13	84.11	0.29	1634	1432
Sum	100.00					
Average		1.18	73.13	0.37	5788	5456

Table X Test 10 Grain class 30-10 mm

Density fraction	Share	Moisture content, W^a	Ash content, A^a	Sulphur content, S^a	Heat of combustion, Q_s^a	Calorific value, Q_i^a
g/cm³	%	%	%	%	kJ/kg	kJ/kg
Concentrate product						
<1.3	1.42	1.35	3.33	0.72	33077	31919
1.3-1.4	1.65	1.16	7.82	0.96	30657	29555
1.4-1.5	0.87	1.14	18.73	0.99	26172	25198
1.5-1.6	0.79	1.28	30.45	0.95	22572	21735
1.6-1.7	0.62	1.37	36.75	0.59	19128	18364
1.7-1.8	1.15	1.36	44.80	0.67	16027	15358
1.8-2.2	2.53	0.92	51.03	0.58	13589	13000
>2.2	11.30	0.72	78.50	0.30	3432	3169
Sum	20.31					
Average		0.92	56.52	0.50	11872	11347
Waste product						
<1.3	0.50	1.32	3.50	0.62	33441	32285
1.3-1.4	0.80	1.92	6.88	0.84	31345	30222
1.4-1.5	0.46	1.75	16.73	0.81	27101	26096
1.5-1.6	0.40	1.58	25.66	0.95	23210	22313
1.6-1.7	0.83	1.37	34.26	1.44	19915	19122
1.7-1.8	1.05	1.44	44.21	0.90	16181	15504
1.8-2.2	1.71	1.13	52.15	0.52	13828	13249
>2.2	73.94	0.99	85.04	0.29	1363	1174
Sum	79.69					
Average		1.02	81.28	0.33	2779	2546
Feed (calculated)						
<1.3	1.92	1.35	3.35	0.71	33121	31963
1.3-1.4	2.45	1.23	7.74	0.95	30719	29614
1.4-1.5	1.33	1.20	18.54	0.97	26261	25284
1.5-1.6	1.19	1.31	29.99	0.95	22632	21790
1.6-1.7	1.45	1.37	36.19	0.78	19306	18536
1.7-1.8	2.20	1.38	44.64	0.73	16068	15398
1.8-2.2	4.24	0.99	51.38	0.56	13664	13078
>2.2	85.24	0.96	84.37	0.29	1574	1377
Sum	100.00					
Average		1.00	76.25	0.36	4626	4333

Table XI Test 11 Grain class 10-3 mm

Density fraction	Share	Moisture content, W^a	Ash content, A^a	Sulphur content, S^a	Heat of combustion, Q_s^a	Calorific value, Q_i^a
g/cm³	%	%	%	%	kJ/kg	kJ/kg
Concentrate product						
<1.3	3.70	1.54	3.64	0.73	32411	31254
1.3-1.4	4.18	1.54	9.80	0.76	30154	29070
1.4-1.5	1.96	1.56	21.40	0.76	25943	24995
1.5-1.6	1.27	1.71	30.62	0.75	21740	20899
1.6-1.7	1.02	1.76	37.67	0.85	19187	18429
1.7-1.8	1.56	1.60	47.14	0.66	15880	15236
1.8-2.2	1.73	1.52	51.99	0.52	13265	12679
>2.2	14.26	1.01	73.21	0.31	5365	5036
Sum	29.69					
Average		1.31	46.53	0.53	15777	15129
Waste product						
<1.3	0.91	1.70	3.43	0.74	32532	31371
1.3-1.4	1.52	1.43	8.62	0.82	30561	29465
1.4-1.5	0.81	1.88	21.48	0.81	26252	25301
1.5-1.6	0.62	1.59	27.85	0.76	22983	22112
1.6-1.7	0.60	1.47	31.45	0.56	20798	19971
1.7-1.8	1.26	1.44	43.50	0.85	16428	15743
1.8-2.2	1.34	1.32	50.28	0.60	14485	13882
>2.2	63.25	1.18	82.22	0.32	2435	2210
Sum	70.31					
Average		1.21	76.69	0.36	4526	4235
Feed (calculated)						
<1.3	4.61	1.55	3.63	0.73	32419	31262
1.3-1.4	5.70	1.53	9.69	0.77	30194	29108
1.4-1.5	2.77	1.60	21.41	0.77	25976	25029
1.5-1.6	1.89	1.69	30.12	0.75	21964	21118
1.6-1.7	1.63	1.70	36.36	0.79	19525	18752
1.7-1.8	2.82	1.56	46.17	0.71	16026	15371
1.8-2.2	3.07	1.47	51.58	0.54	13557	12967
>2.2	77.51	1.16	81.01	0.32	2828	2590
Sum	100.00					
Average		1.24	67.74	0.41	7866	7469

Table XII Test 12 Grain class 30-3 mm

Density fraction	Share	Moisture content, W^a	Ash content, A^a	Sulphur content, S^a	Heat of combustion, Q_s^a	Calorific value, Q_i^a
g/cm³	%	%	%	%	kJ/kg	kJ/kg
Concentrate product						
<1.3	2.94	1.46	3.30	0.74	32770	31610
1.3-1.4	3.72	1.24	9.93	0.83	29952	28873
1.4-1.5	1.89	1.48	18.99	0.80	26250	25275
1.5-1.6	1.37	1.45	30.00	0.79	22184	21340
1.6-1.7	1.01	1.56	37.30	0.75	19011	18251
1.7-1.8	1.52	1.54	44.91	0.88	15952	15282
1.8-2.2	1.83	1.23	49.98	0.62	13958	13352
>2.2	13.45	1.02	76.85	0.34	4015	3729
Sum	27.73					
Average		1.21	48.85	0.56	14813	14194
Waste product						
<1.3	0.46	1.70	4.50	0.80	31724	30576
1.3-1.4	0.60	1.44	8.55	0.78	30686	29588
1.4-1.5	0.33	1.65	15.13	0.79	28031	27009
1.5-1.6	0.15	1.76	24.94	0.72	23320	22412
1.6-1.7	0.22	1.64	31.68	0.60	21219	20392
1.7-1.8	1.05	1.56	42.96	0.65	16419	15726
1.8-2.2	1.18	1.28	49.65	0.42	14768	14158
>2.2	68.28	1.15	85.24	0.28	1263	1074
Sum	72.27					
Average		1.17	82.28	0.30	2371	2148
Feed (calculated)						
<1.3	3.41	1.47	3.35	0.74	32729	31570
1.3-1.4	4.31	1.25	9.88	0.83	29981	28902
1.4-1.5	2.22	1.49	18.82	0.80	26327	25350
1.5-1.6	1.51	1.46	29.83	0.79	22222	21375
1.6-1.7	1.23	1.57	36.93	0.74	19155	18391
1.7-1.8	2.57	1.54	44.55	0.84	16037	15364
1.8-2.2	3.01	1.24	49.90	0.57	14165	13558
>2.2	81.73	1.13	84.11	0.29	1634	1432
Sum	100.00					
Average		1.18	73.01	0.37	5821	5488

Table XIII Test 13 Grain class 30-10 mm

Density fraction	Share	Moisture content, W^a	Ash content, A^a	Sulphur content, S^a	Heat of combustion, Q_s^a	Calorific value, Q_i^a
g/cm³	%	%	%	%	kJ/kg	kJ/kg
Concentrate product						
<1.3	1.72	1.35	3.33	0.72	33077	31919
1.3-1.4	1.99	1.16	7.82	0.96	30657	29555
1.4-1.5	1.05	1.14	18.73	0.99	26172	25198
1.5-1.6	1.04	1.28	30.45	0.95	22572	21735
1.6-1.7	0.82	1.37	36.75	0.59	19128	18364
1.7-1.8	1.52	1.36	44.80	0.67	16027	15358
1.8-2.2	2.21	0.92	51.03	0.58	13589	13000
>2.2	9.70	0.72	78.50	0.30	3432	3169
Sum	20.05					
Average		0.97	52.12	0.54	13578	13001
Waste product						
<1.3	0.48	1.32	3.50	0.62	33441	32285
1.3-1.4	0.40	1.92	6.88	0.84	31345	30222
1.4-1.5	0.23	1.75	16.73	0.81	27101	26096
1.5-1.6	0.23	1.58	25.66	0.95	23210	22313
1.6-1.7	0.62	1.37	34.26	1.44	19915	19122
1.7-1.8	1.14	1.44	44.21	0.90	16181	15504
1.8-2.2	1.34	1.13	52.15	0.52	13828	13249
>2.2	75.52	0.99	85.04	0.29	1363	1174
Sum	79.95					
Average		1.01	82.27	0.32	2404	2182
Feed (calculated)						
<1.3	2.20	1.35	3.35	0.71	33121	31963
1.3-1.4	2.39	1.23	7.74	0.95	30719	29614
1.4-1.5	1.28	1.20	18.54	0.97	26261	25284
1.5-1.6	1.27	1.31	29.99	0.95	22632	21790
1.6-1.7	1.44	1.37	36.19	0.78	19306	18536
1.7-1.8	2.66	1.38	44.64	0.73	16068	15398
1.8-2.2	3.55	0.99	51.38	0.56	13664	13078
>2.2	85.22	0.96	84.37	0.29	1574	1377
Sum	100.00					
Average		1.00	76.23	0.36	4645	4352

Table XIV Test 14 Grain class 10-3 mm

Density fraction	Share	Moisture content, W^a	Ash content, A^a	Sulphur content, S^a	Heat of combustion, Q_s^a	Calorific value, Q_i^a
g/cm³	%	%	%	%	kJ/kg	kJ/kg
Concentrate product						
<1.3	3.98	1.54	3.64	0.73	32411	31254
1.3-1.4	4.78	1.54	9.80	0.76	30154	29070
1.4-1.5	2.26	1.56	21.40	0.76	25943	24995
1.5-1.6	1.80	1.71	30.62	0.75	21740	20899
1.6-1.7	1.26	1.76	37.67	0.85	19187	18429
1.7-1.8	1.24	1.60	47.14	0.66	15880	15236
1.8-2.2	2.13	1.52	51.99	0.52	13265	12679
>2.2	12.08	1.01	73.21	0.31	5365	5036
Sum	29.53					
Average		1.35	42.87	0.56	17713	16621
Waste product						
<1.3	0.62	1.70	3.43	0.74	32532	31371
1.3-1.4	0.80	1.43	8.62	0.82	30561	29465
1.4-1.5	0.44	1.88	21.48	0.81	26252	25301
1.5-1.6	0.30	1.59	27.85	0.76	22983	22112
1.6-1.7	0.32	1.47	31.45	0.56	20798	19971
1.7-1.8	1.26	1.44	43.50	0.85	16428	15743
1.8-2.2	1.45	1.32	50.28	0.60	14485	13882
>2.2	65.28	1.18	82.22	0.32	2435	2210
Sum	70.47					
Average		1.20	78.50	0.35	3826	3558
Feed (calculated)						
<1.3	4.60	1.55	3.63	0.73	32419	31262
1.3-1.4	5.58	1.53	9.69	0.77	30194	29108
1.4-1.5	2.70	1.60	21.41	0.77	25976	25029
1.5-1.6	2.10	1.69	30.12	0.75	21964	21118
1.6-1.7	1.58	1.70	36.36	0.79	19525	18752
1.7-1.8	2.50	1.56	46.17	0.71	16026	15371
1.8-2.2	3.58	1.47	51.58	0.54	13557	12967
>2.2	77.36	1.16	81.01	0.32	2828	2590
Sum	100.00					
Average		1.24	67.98	0.41	7782	7389

Table XV Test 15 Grain class 30-3 mm

Density fraction	Share	Moisture content, W^a	Ash content, A^a	Sulphur content, S^a	Heat of combustion, Q_s^a	Calorific value, Q_i^a
g/cm³	%	%	%	%	kJ/kg	kJ/kg
Concentrate product						
<1.3	3.14	1.46	3.30	0.74	32770	31610
1.3-1.4	3.97	1.24	9.93	0.83	29952	28873
1.4-1.5	2.02	1.48	18.99	0.80	26250	25275
1.5-1.6	1.58	1.45	30.00	0.79	22184	21340
1.6-1.7	1.17	1.56	37.30	0.75	19011	18251
1.7-1.8	1.76	1.54	44.91	0.88	15952	15282
1.8-2.2	2.05	1.23	49.98	0.62	13958	13352
>2.2	11.93	1.02	76.85	0.34	4015	3729
Sum	27.62					
Average		1.23	46.25	0.59	15812	15162
Waste product						
<1.3	0.21	1.70	4.50	0.80	31724	30576
1.3-1.4	0.27	1.44	8.55	0.78	30686	29588
1.4-1.5	0.15	1.65	15.13	0.79	28031	27009
1.5-1.6	0.12	1.76	24.94	0.72	23320	22412
1.6-1.7	0.18	1.64	31.68	0.60	21219	20392
1.7-1.8	0.86	1.56	42.96	0.65	16419	15726
1.8-2.2	0.99	1.28	49.65	0.42	14768	14158
>2.2	69.60	1.15	85.24	0.28	1263	1074
Sum	72.38					
Average		1.16	83.35	0.29	1968	1757
Feed (calculated)						
<1.3	3.35	1.47	3.35	0.74	32729	31570
1.3-1.4	4.24	1.25	9.88	0.83	29981	28902
1.4-1.5	2.17	1.49	18.82	0.80	26327	25350
1.5-1.6	1.70	1.46	29.83	0.79	22222	21375
1.6-1.7	1.35	1.57	36.93	0.74	19155	18391
1.7-1.8	2.62	1.54	44.55	0.84	16037	15364
1.8-2.2	3.04	1.24	49.90	0.57	14165	13558
>2.2	81.53	1.13	84.11	0.29	1634	1432
Sum	100.00					
Average		1.18	73.10	0.37	5792	5459

Table XVI Test 16 Grain class 30-10 mm

Density fraction	Share	Moisture content, W^a	Ash content, A^a	Sulphur content, S^a	Heat of combustion, Q_s^a	Calorific value, Q_i^a
g/cm³	%	%	%	%	kJ/kg	kJ/kg
Concentrate product						
<1.3	1.91	1.35	3.33	0.72	33077	31919
1.3-1.4	2.22	1.16	7.82	0.96	30657	29555
1.4-1.5	1.17	1.14	18.73	0.99	26172	25198
1.5-1.6	1.32	1.28	30.45	0.95	22572	21735
1.6-1.7	1.04	1.37	36.75	0.59	19128	18364
1.7-1.8	1.93	1.36	44.80	0.67	16027	15358
1.8-2.2	1.99	0.92	51.03	0.58	13589	13000
>2.2	8.73	0.72	78.50	0.30	3432	3169
Sum	20.30					
Average		1.00	49.11	0.57	14744	14131
Waste product						
<1.3	0.28	1.32	3.50	0.62	33441	32285
1.3-1.4	0.23	1.92	6.88	0.84	31345	30222
1.4-1.5	0.13	1.75	16.73	0.81	27101	26096
1.5-1.6	0.13	1.58	25.66	0.95	23210	22313
1.6-1.7	0.42	1.37	34.26	1.44	19915	19122
1.7-1.8	0.60	1.44	44.21	0.90	16181	15504
1.8-2.2	0.72	1.13	52.15	0.52	13828	13249
>2.2	77.18	0.99	85.04	0.29	1363	1174
Sum	79.70					
Average		1.00	83.44	0.31	1965	1757
Feed (calculated)						
<1.3	2.19	1.35	3.35	0.71	33121	31963
1.3-1.4	2.46	1.23	7.74	0.95	30719	29614
1.4-1.5	1.30	1.20	18.54	0.97	26261	25284
1.5-1.6	1.45	1.31	29.99	0.95	22632	21790
1.6-1.7	1.45	1.37	36.19	0.78	19306	18536
1.7-1.8	2.53	1.38	44.64	0.73	16068	15398
1.8-2.2	2.71	0.99	51.38	0.56	13664	13078
>2.2	85.91	0.96	84.37	0.29	1574	1377
Sum	100.00					
Average		1.00	76.47	0.36	4560	4269

Table XVII Test 17 Grain class 10-3 mm

Density fraction	Share	Moisture content, W^a	Ash content, A^a	Sulphur content, S^a	Heat of combustion, Q_s^a	Calorific value, Q_i^a
g/cm^3	%	%	%	%	kJ/kg	kJ/kg
Concentrate product						
<1.3	4.38	1.54	3.64	0.73	32411	31254
1.3-1.4	4.95	1.54	9.80	0.76	30154	29070
1.4-1.5	2.32	1.56	21.40	0.76	25943	24995
1.5-1.6	1.65	1.71	30.62	0.75	21740	20899
1.6-1.7	1.33	1.76	37.67	0.85	19187	18429
1.7-1.8	2.03	1.60	47.14	0.66	15880	15236
1.8-2.2	2.45	1.52	51.99	0.52	13265	12679
>2.2	10.34	1.01	73.21	0.31	5365	5036
Sum	29.45					
Average		1.38	40.57	0.57	18099	17381
Waste product						
<1.3	0.32	1.70	3.43	0.74	32532	31371
1.3-1.4	0.53	1.43	8.62	0.82	30561	29465
1.4-1.5	0.29	1.88	21.48	0.81	26252	25301
1.5-1.6	0.32	1.59	27.85	0.76	22983	22112
1.6-1.7	0.31	1.47	31.45	0.56	20798	19971
1.7-1.8	0.65	1.44	43.50	0.85	16428	15743
1.8-2.2	0.89	1.32	50.28	0.60	14485	13882
>2.2	67.24	1.18	82.22	0.32	2435	2210
Sum	70.55					
Average		1.19	79.83	0.34	3336	3083
Feed (calculated)						
<1.3	4.70	1.55	3.63	0.73	32419	31262
1.3-1.4	5.49	1.53	9.69	0.77	30194	29108
1.4-1.5	2.60	1.60	21.41	0.77	25976	25029
1.5-1.6	1.97	1.69	30.12	0.75	21964	21118
1.6-1.7	1.64	1.70	36.36	0.79	19525	18752
1.7-1.8	2.68	1.56	46.17	0.71	16026	15371
1.8-2.2	3.34	1.47	51.58	0.54	13557	12967
>2.2	77.58	1.16	81.01	0.32	2828	2590
Sum	100.00					
Average		1.25	68.27	0.41	7684	7293

Table XVIII Test 18 Grain class 30-3 mm

Density fraction	Share	Moisture content, W^a	Ash content, A^a	Sulphur content, S^a	Heat of combustion, Q_s^a	Calorific value, Q_i^a
g/cm³	%	%	%	%	kJ/kg	kJ/kg
Concentrate product						
<1.3	3.25	1.46	3.30	0.74	32770	31610
1.3-1.4	4.11	1.24	9.93	0.83	29952	28873
1.4-1.5	2.09	1.48	18.99	0.80	26250	25275
1.5-1.6	1.72	1.45	30.00	0.79	22184	21340
1.6-1.7	1.27	1.56	37.30	0.75	19011	18251
1.7-1.8	1.91	1.54	44.91	0.88	15952	15282
1.8-2.2	2.35	1.23	49.98	0.62	13958	13352
>2.2	10.73	1.02	76.85	0.34	4015	3729
Sum	27.43					
Average		1.25	44.40	0.60	16519	15847
Waste product						
<1.3	0.13	1.70	4.50	0.80	31724	30576
1.3-1.4	0.17	1.44	8.55	0.78	30686	29588
1.4-1.5	0.10	1.65	15.13	0.79	28031	27009
1.5-1.6	0.06	1.76	24.94	0.72	23320	22412
1.6-1.7	0.08	1.64	31.68	0.60	21219	20392
1.7-1.8	0.41	1.56	42.96	0.65	16419	15726
1.8-2.2	0.66	1.28	49.65	0.42	14768	14158
>2.2	70.96	1.15	85.24	0.28	1263	1074
Sum	72.57					
Average		1.16	84.15	0.29	1672	1471
Feed (calculated)						
<1.3	3.39	1.47	3.35	0.74	32729	31570
1.3-1.4	4.28	1.25	9.88	0.83	29981	28902
1.4-1.5	2.18	1.49	18.82	0.80	26327	25350
1.5-1.6	1.77	1.46	29.83	0.79	22222	21375
1.6-1.7	1.35	1.57	36.93	0.74	19155	18391
1.7-1.8	2.32	1.54	44.55	0.84	16037	15364
1.8-2.2	3.01	1.24	49.90	0.57	14165	13558
>2.2	81.69	1.13	84.11	0.29	1634	1432
Sum	100.00					
Average		1.18	73.25	0.37	5745	5414

Table XIX Test 19 Grain class 30-10 mm

Density fraction	Share	Moisture content, W^a	Ash content, A^a	Sulphur content, S^a	Heat of combustion, Q_s^a	Calorific value, Q_i^a
g/cm³	%	%	%	%	kJ/kg	kJ/kg
Concentrate product						
<1.3	1.92	1.35	3.33	0.72	33077	31919
1.3-1.4	2.23	1.16	7.82	0.96	30657	29555
1.4-1.5	1.17	1.14	18.73	0.99	26172	25198
1.5-1.6	1.37	1.28	30.45	0.95	22572	21735
1.6-1.7	1.07	1.37	36.75	0.59	19128	18364
1.7-1.8	1.99	1.36	44.80	0.67	16027	15358
1.8-2.2	2.04	0.92	51.03	0.58	13589	13000
>2.2	8.39	0.72	78.50	0.30	3432	3169
Sum	20.18					
Average		1.01	48.50	0.58	14978	14357
Waste product						
<1.3	0.29	1.32	3.50	0.62	33441	32285
1.3-1.4	0.24	1.92	6.88	0.84	31345	30222
1.4-1.5	0.14	1.75	16.73	0.81	27101	26096
1.5-1.6	0.13	1.58	25.66	0.95	23210	22313
1.6-1.7	0.41	1.37	34.26	1.44	19915	19122
1.7-1.8	0.59	1.44	44.21	0.90	16181	15504
1.8-2.2	0.62	1.13	52.15	0.52	13828	13249
>2.2	77.40	0.99	85.04	0.29	1363	1174
Sum	79.82					
Average		1.00	83.47	0.31	1952	1744
Feed (calculated)						
<1.3	2.21	1.35	3.35	0.71	33121	31963
1.3-1.4	2.47	1.23	7.74	0.95	30719	29614
1.4-1.5	1.31	1.20	18.54	0.97	26261	25284
1.5-1.6	1.50	1.31	29.99	0.95	22632	21790
1.6-1.7	1.48	1.37	36.19	0.78	19306	18536
1.7-1.8	2.58	1.38	44.64	0.73	16068	15398
1.8-2.2	2.66	0.99	51.38	0.56	13664	13078
>2.2	85.79	0.96	84.37	0.29	1574	1377
Sum	100.00					
Average		1.00	76.42	0.36	4581	4290

Table XX Test 20 Grain class 10-3 mm

Density fraction	Share	Moisture content, W^a	Ash content, A^a	Sulphur content, S^a	Heat of combustion, Q_s^a	Calorific value, Q_i^a
g/cm^3	%	%	%	%	kJ/kg	kJ/kg
Concentrate product						
<1.3	4.48	1.54	3.64	0.73	32411	31254
1.3-1.4	5.07	1.54	9.80	0.76	30154	29070
1.4-1.5	2.37	1.56	21.40	0.76	25943	24995
1.5-1.6	1.60	1.71	30.62	0.75	21740	20899
1.6-1.7	1.29	1.76	37.67	0.85	19187	18429
1.7-1.8	1.97	1.60	47.14	0.66	15880	15236
1.8-2.2	2.28	1.52	51.99	0.52	13265	12679
>2.2	10.48	1.01	73.21	0.31	5365	5036
Sum	29.54					
Average		1.37	40.38	0.57	18174	17453
Waste product						
<1.3	0.29	1.70	3.43	0.74	32532	31371
1.3-1.4	0.48	1.43	8.62	0.82	30561	29465
1.4-1.5	0.26	1.88	21.48	0.81	26252	25301
1.5-1.6	0.30	1.59	27.85	0.76	22983	22112
1.6-1.7	0.29	1.47	31.45	0.56	20798	19971
1.7-1.8	0.60	1.44	43.50	0.85	16428	15743
1.8-2.2	0.72	1.32	50.28	0.60	14485	13882
>2.2	67.52	1.18	82.22	0.32	2435	2210
Sum	70.46					
Average		1.19	80.07	0.34	3244	2993
Feed (calculated)						
<1.3	4.77	1.55	3.63	0.73	32419	31262
1.3-1.4	5.55	1.53	9.69	0.77	30194	29108
1.4-1.5	2.63	1.60	21.41	0.77	25976	25029
1.5-1.6	1.90	1.69	30.12	0.75	21964	21118
1.6-1.7	1.58	1.70	36.36	0.79	19525	18752
1.7-1.8	2.57	1.56	46.17	0.71	16026	15371
1.8-2.2	3.00	1.47	51.58	0.54	13557	12967
>2.2	78.00	1.16	81.01	0.32	2828	2590
Sum	100.00					
Average		1.25	68.35	0.41	7654	7265

Table XXI Test 21 Grain class 30-3 mm

Density fraction	Share	Moisture content, W^a	Ash content, A^a	Sulphur content, S^a	Heat of combustion, Q_s^a	Calorific value, Q_i^a
g/cm³	%	%	%	%	kJ/kg	kJ/kg
Concentrate product						
<1.3	3.32	1.46	3.30	0.74	32770	31610
1.3-1.4	4.20	1.24	9.93	0.83	29952	28873
1.4-1.5	2.13	1.48	18.99	0.80	26250	25275
1.5-1.6	1.78	1.45	30.00	0.79	22184	21340
1.6-1.7	1.32	1.56	37.30	0.75	19011	18251
1.7-1.8	1.98	1.54	44.91	0.88	15952	15282
1.8-2.2	2.52	1.23	49.98	0.62	13958	13352
>2.2	10.33	1.02	76.85	0.34	4015	3729
Sum	27.58					
Average		1.25	43.67	0.61	16799	16118
Waste product						
<1.3	0.13	1.70	4.50	0.80	31724	30576
1.3-1.4	0.16	1.44	8.55	0.78	30686	29588
1.4-1.5	0.09	1.65	15.13	0.79	28031	27009
1.5-1.6	0.04	1.76	24.94	0.72	23320	22412
1.6-1.7	0.07	1.64	31.68	0.60	21219	20392
1.7-1.8	0.32	1.56	42.96	0.65	16419	15726
1.8-2.2	0.62	1.28	49.65	0.42	14768	14158
>2.2	70.99	1.15	85.24	0.28	1263	1074
Sum	72.42					
Average		1.16	84.26	0.29	1630	1430
Feed (calculated)						
<1.3	3.45	1.47	3.35	0.74	32729	31570
1.3-1.4	4.36	1.25	9.88	0.83	29981	28902
1.4-1.5	2.22	1.49	18.82	0.80	26327	25350
1.5-1.6	1.83	1.46	29.83	0.79	22222	21375
1.6-1.7	1.38	1.57	36.93	0.74	19155	18391
1.7-1.8	2.30	1.54	44.55	0.84	16037	15364
1.8-2.2	3.14	1.24	49.90	0.57	14165	13558
>2.2	81.32	1.13	84.11	0.29	1634	1432
Sum	100.00					
Average		1.18	73.07	0.38	5814	5481

Table XXII Test 22 Grain class 30-10 mm

Density fraction	Share	Moisture content, W^a	Ash content, A^a	Sulphur content, S^a	Heat of combustion, Q_s^a	Calorific value, Q_i^a
g/cm³	%	%	%	%	kJ/kg	kJ/kg
Concentrate product						
<1.3	1.53	1.35	3.33	0.72	33077	31919
1.3-1.4	1.78	1.16	7.82	0.96	30657	29555
1.4-1.5	0.94	1.14	18.73	0.99	26172	25198
1.5-1.6	0.99	1.28	30.45	0.95	22572	21735
1.6-1.7	0.78	1.37	36.75	0.59	19128	18364
1.7-1.8	1.44	1.36	44.80	0.67	16027	15358
1.8-2.2	1.92	0.92	51.03	0.58	13589	13000
>2.2	11.16	0.72	78.50	0.30	3432	3169
Sum	20.54					
Average		0.94	55.22	0.51	12385	11845
Waste product						
<1.3	0.57	1.32	3.50	0.62	33441	32285
1.3-1.4	0.48	1.92	6.88	0.84	31345	30222
1.4-1.5	0.27	1.75	16.73	0.81	27101	26096
1.5-1.6	0.24	1.58	25.66	0.95	23210	22313
1.6-1.7	0.76	1.37	34.26	1.44	19915	19122
1.7-1.8	1.09	1.44	44.21	0.90	16181	15504
1.8-2.2	1.12	1.13	52.15	0.52	13828	13249
>2.2	74.93	0.99	85.04	0.29	1363	1174
Sum	79.46					
Average		1.01	82.06	0.32	2484	2260
Feed (calculated)						
<1.3	2.10	1.35	3.35	0.71	33121	31963
1.3-1.4	2.26	1.23	7.74	0.95	30719	29614
1.4-1.5	1.21	1.20	18.54	0.97	26261	25284
1.5-1.6	1.23	1.31	29.99	0.95	22632	21790
1.6-1.7	1.53	1.37	36.19	0.78	19306	18536
1.7-1.8	2.54	1.38	44.64	0.73	16068	15398
1.8-2.2	3.04	0.99	51.38	0.56	13664	13078
>2.2	86.09	0.96	84.37	0.29	1574	1377
Sum	100.00					
Average		1.00	76.55	0.36	4518	4228

Table XXIII Test 23 Grain class 10-3 mm

Density fraction	Share	Moisture content, W^a	Ash content, A^a	Sulphur content, S^a	Heat of combustion, Q_s^a	Calorific value, Q_i^a
g/cm³	%	%	%	%	kJ/kg	kJ/kg
Concentrate product						
<1.3	3.77	1.54	3.64	0.73	32411	31254
1.3-1.4	4.26	1.54	9.80	0.76	30154	29070
1.4-1.5	1.99	1.56	21.40	0.76	25943	24995
1.5-1.6	1.17	1.71	30.62	0.75	21740	20899
1.6-1.7	0.94	1.76	37.67	0.85	19187	18429
1.7-1.8	1.43	1.60	47.14	0.66	15880	15236
1.8-2.2	1.68	1.52	51.99	0.52	13265	12679
>2.2	13.95	1.01	73.21	0.31	5365	5036
Sum	29.19					
Average		1.30	46.09	0.52	15946	15294
Waste product						
<1.3	0.89	1.70	3.43	0.74	32532	31371
1.3-1.4	1.48	1.43	8.62	0.82	30561	29465
1.4-1.5	0.79	1.88	21.48	0.81	26252	25301
1.5-1.6	0.64	1.59	27.85	0.76	22983	22112
1.6-1.7	0.62	1.47	31.45	0.56	20798	19971
1.7-1.8	1.30	1.44	43.50	0.85	16428	15743
1.8-2.2	1.82	1.32	50.28	0.60	14485	13882
>2.2	63.27	1.18	82.22	0.32	2435	2210
Sum	70.81					
Average		1.22	76.55	0.36	4580	4288
Feed (calculated)						
<1.3	4.65	1.55	3.63	0.73	32419	31262
1.3-1.4	5.74	1.53	9.69	0.77	30194	29108
1.4-1.5	2.78	1.60	21.41	0.77	25976	25029
1.5-1.6	1.81	1.69	30.12	0.75	21964	21118
1.6-1.7	1.56	1.70	36.36	0.79	19525	18752
1.7-1.8	2.73	1.56	46.17	0.71	16026	15371
1.8-2.2	3.50	1.47	51.58	0.54	13557	12967
>2.2	77.22	1.16	81.01	0.32	2828	2590
Sum	100.00					
Average		1.25	67.66	0.41	7898	7501

Table XXIV Test 24 Grain class 30-3 mm

Density fraction	Share	Moisture content, W^a	Ash content, A^a	Sulphur content, S^a	Heat of combustion, Q_s^a	Calorific value, Q_i^a
g/cm³	%	%	%	%	kJ/kg	kJ/kg
Concentrate product						
<1.3	2.94	1.46	3.30	0.74	32770	31610
1.3-1.4	3.71	1.24	9.93	0.83	29952	28873
1.4-1.5	1.89	1.48	18.99	0.80	26250	25275
1.5-1.6	1.49	1.45	30.00	0.79	22184	21340
1.6-1.7	1.10	1.56	37.30	0.75	19011	18251
1.7-1.8	1.66	1.54	44.91	0.88	15952	15282
1.8-2.2	2.23	1.23	49.98	0.62	13958	13352
>2.2	12.58	1.02	76.85	0.34	4015	3729
Sum	27.60					
Average		1.22	47.86	0.58	15187	14557
Waste product						
<1.3	0.50	1.70	4.50	0.80	31724	30576
1.3-1.4	0.65	1.44	8.55	0.78	30686	29588
1.4-1.5	0.36	1.65	15.13	0.79	28031	27009
1.5-1.6	0.14	1.76	24.94	0.72	23320	22412
1.6-1.7	0.21	1.64	31.68	0.60	21219	20392
1.7-1.8	0.89	1.56	42.96	0.65	16419	15726
1.8-2.2	1.04	1.28	49.65	0.42	14768	14158
>2.2	68.61	1.15	85.24	0.28	1263	1074
Sum	72.40					
Average		1.17	82.34	0.30	2351	2128
Feed (calculated)						
<1.3	3.44	1.47	3.35	0.74	32729	31570
1.3-1.4	4.36	1.25	9.88	0.83	29981	28902
1.4-1.5	2.25	1.49	18.82	0.80	26327	25350
1.5-1.6	1.63	1.46	29.83	0.79	22222	21375
1.6-1.7	1.31	1.57	36.93	0.74	19155	18391
1.7-1.8	2.55	1.54	44.55	0.84	16037	15364
1.8-2.2	3.27	1.24	49.90	0.57	14165	13558
>2.2	81.19	1.13	84.11	0.29	1634	1432
Sum	100.00					
Average		1.18	72.83	0.38	5894	5558

Abbreviated density and quality composition

Table XXV Test 1 Grain class 30-10 mm

Density fraction	Share	Ash Content, A^a	Calorific value, Q_i^a	Share	Ash Content, A^a	Calorific value. Q_i^a
	Concentrate product			Waste product		
g/cm³	%	%	kJ/kg	%	%	kJ/kg
<1.5	5.25	8.61	29446	0.60	7.43	30272
1.5-1.8	4.35	37.96	18208	1.16	38.47	17598
>1.8	10.79	73.23	5055	77.85	84.64	1321
Sum	20.39			79.61		
Average		49.07	14142		83.38	1777

Table XXVI Test 2 Grain class 10-3 mm

Density fraction	Share	Ash Content, A^a	Calorific value, Q_i^a	Share	Ash Content, A^a	Calorific value. Q_i^a
	Concentrate product			Waste product		
g/cm³	%	%	kJ/kg	%	%	kJ/kg
<1.5	11.66	9.79	29081	1.14	10.39	28955
1.5-1.8	4.91	39.18	17950	1.43	36.66	18362
>1.8	12.79	69.31	6440	68.07	81.87	2337
Sum	29.36			70.64		
Average		40.63	17360		79.81	3090

Table XXVII Test 3 Grain class 30-3 mm

Density fraction	Share	Ash Content, A^a	Calorific value, Q_i^a	Share	Ash Content, A^a	Calorific value. Q_i^a
	Concentrate product			Waste product		
g/cm³	%	%	kJ/kg	%	%	kJ/kg
<1.5	9.36	9.65	29020	0.39	8.77	29303
1.5-1.8	4.98	37.71	18176	0.59	39.37	17134
>1.8	13.05	72.71	5211	71.63	84.90	1200
Sum	27.39			72.61		
Average		44.80	15705		84.12	1481

Table XXVIII Test 4 Grain class 30-10 mm

Density fraction	Share	Ash Content, A^a	Calorific value, Q_i^a	Share	Ash Content, A^a	Calorific value. Q_i^a
	Concentrate product			Waste product		
g/cm³	%	%	kJ/kg	%	%	kJ/kg
<1.5	4.03	8.61	29446	1.39	8.33	29826
1.5-1.8	2.76	38.67	17951	2.13	38.45	17608
>1.8	13.43	72.67	5255	76.26	84.21	1478
Sum	20.22			79.78		
Average		55.26	11813		81.67	2402

Table XXIX Test 5 Grain class 10-3 mm

Density fraction	Share	Ash Content, A^a	Calorific value, Q_i^a	Share	Ash Content, A^a	Calorific value. Q_i^a
	Concentrate product			Waste product		
g/cm³	%	%	kJ/kg	%	%	kJ/kg
<1.5	9.65	9.79	29081	3.28	10.39	28955
1.5-1.8	3.65	39.18	17950	2.65	36.66	18362
>1.8	16.24	70.79	5907	64.53	81.56	2451
Sum	29.54			70.46		
Average		46.96	14965		76.56	4283

Table XXX Test 6 Grain class 30-3 mm

Density fraction	Share	Ash Content, A^a	Calorific value, Q_i^a	Share	Ash Content, A^a	Calorific value. Q_i^a
	Concentrate product			Waste product		
g/cm³	%	%	kJ/kg	%	%	kJ/kg
<1.5	8.13	9.65	29020	1.78	8.77	29303
1.5-1.8	3.95	37.71	18176	1.42	39.37	17134
>1.8	15.68	74.31	4637	69.04	84.55	1328
Sum	27.76			72.24		
Average		50.17	13705		81.79	2328

Table XXXI Test 7 Grain class 30-10 mm

Density fraction	Share	Ash Content, A^a	Calorific value, Q_i^a	Share	Ash Content, A^a	Calorific value. Q_i^a
	Concentrate product			Waste product		
g/cm³	%	%	kJ/kg	%	%	kJ/kg
<1.5	5.14	8.61	29446	0.80	7.43	30272
1.5-1.8	4.20	38.43	18051	1.27	38.47	17598
>1.8	10.86	73.21	5061	77.75	84.77	1275
Sum	20.19			79.81		
Average		49.55	13967		83.26	1824

Table XXXII Test 8 Grain class 10-3 mm

Density fraction	Share	Ash Content, A^a	Calorific value, Q_i^a	Share	Ash Content, A^a	Calorific value. Q_i^a
	Concentrate product			Waste product		
g/cm³	%	%	kJ/kg	%	%	kJ/kg
<1.5	11.79	9.79	29081	1.04	10.39	28955
1.5-1.8	4.74	39.18	17950	1.35	36.66	18362
>1.8	12.78	69.69	6304	68.30	81.84	2349
Sum	29.31			70.69		
Average		40.66	17351		79.93	3045

Table XXXIII Test 9 Grain class 30-3 mm

Density fraction	Share	Ash Content, A^a	Calorific value, Q_i^a	Share	Ash Content, A^a	Calorific value. Q_i^a
	Concentrate product			Waste product		
g/cm³	%	%	kJ/kg	%	%	kJ/kg
<1.5	9.55	9.65	29020	0.43	8.77	29303
1.5-1.8	5.02	37.71	18176	0.52	39.37	17134
>1.8	13.11	72.24	5381	71.37	84.92	1193
Sum	27.68			72.32		
Average		44.38	15857		84.14	1475

Table XXXIV Test 10 Grain class 30-10 mm

Density fraction	Share	Ash Content, A^a	Calorific value, Q_i^a	Share	Ash Content, A^a	Calorific value. Q_i^a
	Concentrate product			Waste product		
g/cm³	%	%	kJ/kg	%	%	kJ/kg
<1.5	3.93	8.61	29446	1.76	8.49	29730
1.5-1.8	2.55	38.43	18051	2.28	37.33	18016
>1.8	13.83	73.47	4968	75.65	84.30	1447
Sum	20.31			79.69		
Average		56.52	11347		81.28	2546

Table XXXV Test 11 Grain class 10-3 mm

Density fraction	Share	Ash Content, A^a	Calorific value, Q_i^a	Share	Ash Content, A^a	Calorific value. Q_i^a
	Concentrate product			Waste product		
g/cm³	%	%	kJ/kg	%	%	kJ/kg
<1.5	9.84	9.79	29081	3.24	10.39	28955
1.5-1.8	3.86	39.18	17950	2.48	36.66	18362
>1.8	15.99	70.91	5863	64.59	81.56	2452
Sum	29.69			70.31		
Average		46.53	15129		76.69	4235

Table XXXVI Test 12 Grain class 30-3 mm

Density fraction	Share	Ash Content, A^a	Calorific value, Q_i^a	Share	Ash Content, A^a	Calorific value. Q_i^a
	Concentrate product			Waste product		
g/cm³	%	%	kJ/kg	%	%	kJ/kg
<1.5	8.55	9.65	29020	1.39	8.77	29303
1.5-1.8	3.90	37.71	18176	1.42	39.37	17134
>1.8	15.28	73.63	4881	69.46	84.64	1297
Sum	27.73			72.27		
Average		48.85	14194		82.28	2148

Table XXXVII Test 13 Grain class 30-10 mm

Density fraction	Share	Ash Content, A^a	Calorific value, Q_i^a	Share	Ash Content, A^a	Calorific value. Q_i^a
	Concentrate product			Waste product		
g/cm³	%	%	kJ/kg	%	%	kJ/kg
<1.5	4.76	8.61	4993	1.10	7.43	30272
1.5-1.8	3.38	38.43	4993	1.99	38.98	17415
>1.8	11.91	73.40	4993	76.86	84.47	1384
Sum	20.05			79.95		
Average		52.12	13001		82.27	2182

Table XXXVIII Test 14 Grain class 10-3 mm

Density fraction	Share	Ash Content, A^a	Calorific value, Q_i^a	Share	Ash Content, A^a	Calorific value. Q_i^a
	Concentrate product			Waste product		
g/cm³	%	%	kJ/kg	%	%	kJ/kg
<1.5	11.02	9.95	29023	1.86	9.93	29115
1.5-1.8	4.30	37.45	18542	1.88	38.95	17479
>1.8	14.21	70.03	6182	66.73	81.53	2464
Sum	29.53			70.47		
Average		42.87	16621		78.50	3558

Table XXXIX Test 15 Grain class 30-3 mm

Density fraction	Share	Ash Content, A^a	Calorific value, Q_i^a	Share	Ash Content, A^a	Calorific value. Q_i^a
	Concentrate product			Waste product		
g/cm³	%	%	kJ/kg	%	%	kJ/kg
<1.5	9.13	9.65	29020	0.63	8.77	29303
1.5-1.8	4.51	37.71	18176	1.16	39.37	17134
>1.8	13.98	72.91	5140	70.59	84.74	1258
Sum	27.62			72.38		
Average		46.25	15162		83.35	1757

Table XLTest 16 Grain class 30-10 mm

Density fraction	Share	Ash Content, A^a	Calorific value, Q_i^a	Share	Ash Content, A^a	Calorific value. Q_i^a
	Concentrate product			Waste product		
g/cm³	%	%	kJ/kg	%	%	kJ/kg
<1.5	5.30	8.61	29446	0.65	7.43	30272
1.5-1.8	4.28	38.43	18051	1.15	38.47	17598
>1.8	10.72	73.40	4994	77.90	84.74	1286
Sum	20.30			79.70		
Average		49.11	14131		83.44	1757

Table XLI Test 17 Grain class 10-3 mm

Density fraction	Share	Ash Content, A^a	Calorific value, Q_i^a	Share	Ash Content, A^a	Calorific value. Q_i^a
	Concentrate product			Waste product		
g/cm³	%	%	kJ/kg	%	%	kJ/kg
<1.5	11.65	9.79	29081	1.14	10.39	28955
1.5-1.8	5.01	39.18	17950	1.28	36.66	18362
>1.8	12.79	69.15	6500	68.13	81.80	2363
Sum	29.45			70.55		
Average		40.57	17381		79.83	3083

Table XLII Test 18 Grain class 30-3 mm

Density fraction	Share	Ash Content, A^a	Calorific value, Q_i^a	Share	Ash Content, A^a	Calorific value. Q_i^a
	Concentrate product			Waste product		
g/cm³	%	%	kJ/kg	%	%	kJ/kg
<1.5	9.45	9.65	29020	0.40	8.77	29303
1.5-1.8	4.90	37.71	18176	0.55	39.37	17134
>1.8	13.08	72.02	5458	71.62	84.91	1195
Sum	27.43			72.57		
Average		44.40	15847		84.15	1471

Table XLIII Test 19 Grain class 30-10 mm

Density fraction	Share	Ash Content, A^a	Calorific value, Q_i^a	Share	Ash Content, A^a	Calorific value. Q_i^a
	Concentrate product			Waste product		
g/cm³	%	%	kJ/kg	%	%	kJ/kg
<1.5	5.32	8.61	29446	0.67	7.43	30272
1.5-1.8	4.43	38.43	18051	1.13	38.47	17598
>1.8	10.43	73.13	5092	78.02	84.78	1270
Sum	20.18			79.82		
Average		48.50	14357		83.47	1744

Table XLIV Test 20 Grain class 10-3 mm

Density fraction	Share	Ash Content, A^a	Calorific value, Q_i^a	Share	Ash Content, A^a	Calorific value. Q_i^a
	Concentrate product			Waste product		
g/cm³	%	%	kJ/kg	%	%	kJ/kg
<1.5	11.92	9.79	29081	1.03	10.39	28955
1.5-1.8	4.86	39.18	17950	1.19	36.66	18362
>1.8	12.76	69.42	6402	68.24	81.88	2333
Sum	29.54			70.46		
Average		40.38	17453		80.07	2993

Table XLV Test 21 Grain class 30-3 mm

Density fraction	Share	Ash Content, A^a	Calorific value, Q_i^a	Share	Ash Content, A^a	Calorific value. Q_i^a
	Concentrate product			Waste product		
g/cm³	%	%	kJ/kg	%	%	kJ/kg
<1.5	9.65	9.65	29020	0.38	8.77	29303
1.5-1.8	5.08	37.71	18176	0.43	39.37	17134
>1.8	12.85	71.58	5616	71.61	84.93	1188
Sum	27.58			72.42		
Average		43.67	16118		84.26	1430

Table XLVI Test 22 Grain class 30-10 mm

Density fraction	Share	Ash Content, A^a	Calorific value, Q_i^a	Share	Ash Content, A^a	Calorific value. Q_i^a
	Concentrate product			Waste product		
g/cm³	%	%	kJ/kg	%	%	kJ/kg
<1.5	4.25	8.61	29446	1.32	7.43	30272
1.5-1.8	3.21	38.43	18051	2.09	38.47	17598
>1.8	13.08	74.47	4612	76.05	84.56	1352
Sum	20.54			79.46		
Average		55.22	11845		82.06	2260

Table XLVII Test 23 Grain class 10-3 mm

Density fraction	Share	Ash Content, A^a	Calorific value, Q_i^a	Share	Ash Content, A^a	Calorific value. Q_i^a
	Concentrate product			Waste product		
g/cm³	%	%	kJ/kg	%	%	kJ/kg
<1.5	10.02	9.79	29081	3.16	10.39	28955
1.5-1.8	3.54	39.18	17950	2.56	36.66	18362
>1.8	15.63	70.93	5858	65.09	81.33	2536
Sum	29.19			70.81		
Average		46.09	15294		76.55	4288

Table XLVIII Test 24 Grain class 30-3 mm

Density fraction	Share	Ash Content, A^a	Calorific value, Q_i^a	Share	Ash Content, A^a	Calorific value. Q_i^a
	Concentrate product			Waste product		
g/cm³	%	%	kJ/kg	%	%	kJ/kg
<1.5	8.54	9.65	29020	1.51	8.77	29303
1.5-1.8	4.25	37.71	18176	1.24	39.04	17262
>1.8	14.81	72.80	5178	69.65	84.71	1270
Sum	27.60			72.40		
Average		47.86	14557		82.34	2128

Grain size analysis

Table XLIX Test 1-3

Grain class. mm	Feed 30-10 mm		Feed 10-3 mm		Feed 30-3 mm	
	Concentrate product	Waste product	Concentrate product	Waste product	Concentrate product	Waste product
	share, %	share, %	share, %	share, %	share, %	share, %
30-20	36.76	44.15			7.35	24.02
20-16	20.24	16.97			5.88	8.85
20-10	43.00	38.88			16.10	23.55
10-6			61.32	65.01	40.96	28.83
6-3			38.68	34.99	29.71	14.75
Sum	100.00	100.00	100.00	100.00	100.00	100.00

Table L Test 4-6

Grain class. mm	Feed 30-10 mm		Feed 10-3 mm		Feed 30-3 mm	
	Concentrate product	Waste product	Concentrate product	Waste product	Concentrate product	Waste product
	share, %	share, %	share, %	share, %	share, %	share, %
30-20	35.76	43.89			7.12	24.36
20-16	19.88	17.25			6.18	8.63
20-10	44.36	38.86			15.98	23.97
10-6			60.45	65.61	40.58	28.43
6-3			39.55	34.39	30.14	14.61
Sum	100.00	100.00	100.00	100.00	100.00	100.00

Table LI Test 7-9

Grain class. mm	Feed 30-10 mm		Feed 10-3 mm		Feed 30-3 mm	
	Concentrate product	Waste product	Concentrate product	Waste product	Concentrate product	Waste product
	share, %	share, %	share, %	share, %	share, %	share, %
30-20	37.38	44.74			7.25	24.16
20-16	19.56	16.95			6.01	9.27
20-10	43.06	38.31			15.82	22.56
10-6			60.80	64.15	40.66	28.26
6-3			39.20	35.85	30.26	15.75
Sum	100.00	100.00	100.00	100.00	100.00	100.00

Table LII Test 10-12

Grain class. mm	Feed 30-10 mm		Feed 10-3 mm		Feed 30-3 mm	
	Concentrate product	Waste product	Concentrate product	Waste product	Concentrate product	Waste product
	share, %	share, %	share, %	share, %	share, %	share, %
30-20	35.92	43.25			7.73	25.12
20-16	20.87	16.95			5.70	8.71
20-10	43.21	39.80			16.27	22.81
10-6			61.05	63.81	41.28	28.05
6-3			38.95	36.19	29.02	15.31
Sum	100.00	100.00	100.00	100.00	100.00	100.00

Table LIII Test 13-15

Grain class. mm	Feed 30-10 mm		Feed 10-3 mm		Feed 30-3 mm	
	Concentrate product	Waste product	Concentrate product	Waste product	Concentrate product	Waste product
	share, %	share, %	share, %	share, %	share, %	share, %
30-20	37.36	42.99			8.06	23.99
20-16	20.05	17.65			5.62	9.01
20-10	42.59	39.36			15.73	22.35
10-6			61.13	63.85	41.12	29.37
6-3			38.87	36.15	29.47	15.28
Sum	100.00	100.00	100.00	100.00	100.00	100.00

Table LIV Test 16-18

Grain class. mm	Feed 30-10 mm		Feed 10-3 mm		Feed 30-3 mm	
	Concentrate product	Waste product	Concentrate product	Waste product	Concentrate product	Waste product
	share, %	share, %	share, %	share, %	share, %	share, %
30-20	36.88	43.08			7.56	24.12
20-16	20.62	18.02			5.82	9.32
20-10	42.50	38.9			16.03	22.14
10-6			62.11	64.12	41.33	29.03
6-3			37.89	35.88	29.26	15.39
Sum	100.00	100.00	100.00	100.00	100.00	100.00

Table LV Test 19-21

Grain class. mm	Feed 30-10 mm		Feed 10-3 mm		Feed 30-3 mm	
	Concentrate product	Waste product	Concentrate product	Waste product	Concentrate product	Waste product
	share, %	share, %	share, %	share, %	share, %	share, %
30-20	38.11	43.16			8.25	24.28
20-16	19.09	17.12			5.76	8.88
20-10	42.80	39.72			15.82	22.44
10-6			62.48	65.57	40.84	29.85
6-3			37.52	34.43	29.33	14.55
Sum	100.00	100.00	100.00	100.00	100.00	100.00

Table LVI Test 22-24

Grain class. mm	Feed 30-10 mm		Feed 10-3 mm		Feed 30-3 mm	
	Concentrate product	Waste product	Concentrate product	Waste product	Concentrate product	Waste product
	share, %	share, %	share, %	share, %	share, %	share, %
30-20	36.31	43.05			7.98	25.14
20-16	20.39	17.22			6.02	8.58
20-10	43.30	39.73			16.22	21.76
10-6			60.28	63.97	41.64	28.99
6-3			39.72	36.03	28.14	15.53
Sum	100.00	100.00	100.00	100.00	100.00	100.00