allflux®

New technology for separation of coal slurry
in the size range 3 to 0,15 mm

Abstract

In processing coal, the low concentrate value, especially for steam coal, require high capacity production and sharp classification | separation techniques to reduce the specific production costs. The **allflux®** separator, a new process system introduced to the coal industry, meets these criteria in an economical way. Its two-stage process, a combination of rising current and fluidized bed technology, allows the treatment of extremely high massflows in a single unit. Using concepts that have proven successful in processing concrete sands for many years, testwork in iron ore, heavy minerals and pilot | half industrial scale applications for coal, look very promising.

General

Coal process circuits combine a number of process machinery used in different steps of desliming, classification, separation | beneficiation | enrichment, and dewatering of the desired products. The right choice of equipment has an impact on the technical and economical feasibility of today's and future projects. Not only the capital investment and operational costs but also the complexity of processing circuits relative to control equipment and the amount and quality of staff strongly influence project feasibility.

Not surprisingly the successful equipment suppliers to the coal processing industry constantly strive to develop equipment which combine features like high throughput and sharp separation | classification with ease of operation, a minimum of personnel, and less wear parts.

The **allflux®** separator meets these demands. Its design allows it to treat extremely high massflows in a single unit. The **allflux®** classifies a slurry feed into two size fractions, upgrades mineral contents by specific gravity, deslimes, and thickens the products before they enter following process steps. This has been proven by test and operation experience. In the past fluidized bed separators | hindered bed classifiers have occasionally been used for the benefication of fine coal.

The remarkable differences with use of the **allflux®** against other systems are that the unit does offer a two-step benefication on one hand and on the other hand that the products discharged from the two chambers are controlled with regards to a constant quality although the feed might vary.

Technical Description

The **allflux**® separator is a round, center feed process vessel that is sized according to hydraulic load. The process uses a unique combination of rising current and fluidized bed techniques and can be divided into three stages. The principle of an **allflux**® separator is schematically shown in Figure 1.

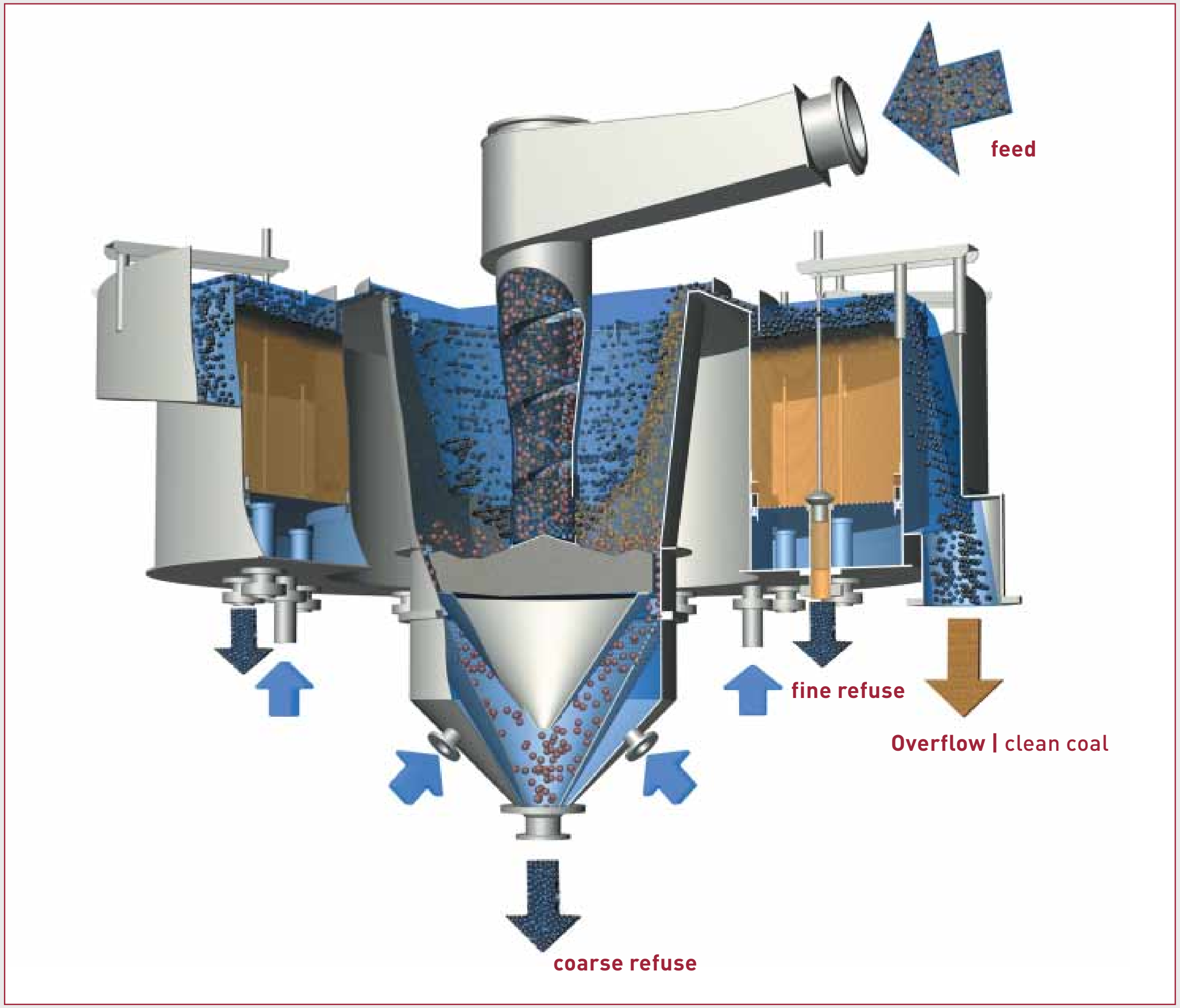

Fig. 1: schematic drawing of the **allflux**® separator

Coarse Section

The typical feed to an **allflux®** is either a screen underflow or a hydrocyclone underflow allowing up to 2.000 m^3|h in a single unit with solid contents between 10 % and 60 %. Maximum feed sizes range up to 4 mm depending on the operation.

The feed slurry enters the coarse section via a specially designed inlet pipe. Volumetric load and adjustable upstream water allow only the coarse and specific heavier particles to settle in the central hopper for discharge. Geometry and upstream water flow are selected in a way, that all light particles together with the fines flow into the secondary processing stage, the peripheral ring or fine section.

feed to the coarse section

In a classification only process, the cutpoint between coarse and fine can be independently adjusted. If a separation, as e. g. for the coal | refuse separation, or concentration of particles with different specific gravities is also demanded, the overlay of settling velocities between coarse light particles and fine heavy particles define the classification cutpoint. In order to clean concrete sand (= 2.650 kg | m^3) from lignite impurities (= 1.400 kg | m^3), this means that lignite up to a top feed size of 4 mm will be separated while the sand classification ranges between 0.5 mm and 1 mm according to the particle shape [1]. Also, the buildup of an autogenous dense media in the coarse sand section enlarges the sortable size range | specific gravity. Practically, the separation density in the coarse section is as high as 1.800 kg | m^3 and sometimes even higher due to this concept. This phenomenon, known as the equal-falling law, is the base for all up-current sorting processes.

Figure 2 shows the density distribution through the coarse section of an **allflux**®-separator at a sand plant in northwestern Germany. These numbers are guaranteeing that no light particles can enter the coarse clean sand discharge hopper.

Further, the average density inside the separation room which is approximately 1.300 kg | m^3 also is adjustable. Using these numbers in the equal falling law as the liquid density confirms the practical proven number of a separating density of 1.800 kg | m^3 [2].

The discharge of coarse material out of the central hopper is automatically controlled by a density probe and a pinch valve.

It is obvious that especially these separation densities are suitable for the adjustable cut between coal, middlings and for refuse.

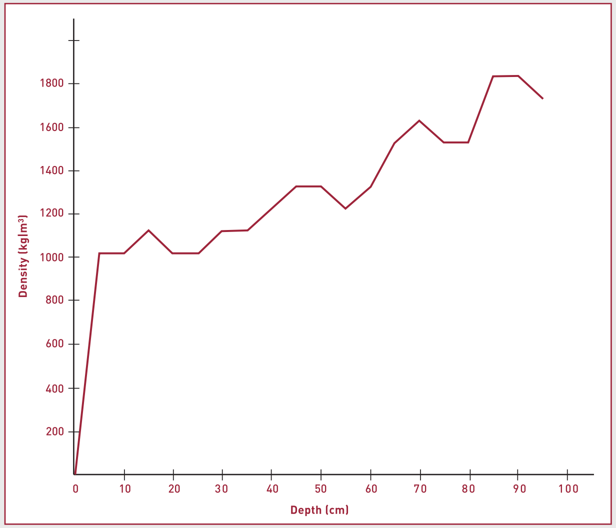

Fig. 2: Density Distribution through Coarse Section using Quartz Sand (= 2.650 kg | m^3)

Fine Section

The fines and all lighter particles enter the peripheral ring called the fine section. The fine section utilizes fluidized bed techniques in order to classify and|or separate particles. In the lower part of the fine sand section, water is added through a specially designed screen plate, which distributes the water-flow. By that upstream a hindered settling of the fines is achieved and a fluidized bed produced [1].

The fluidization of particles is dependent mainly on the particle size and the specific gravity of the particle. The **allflux®** therefore uses different amounts of upstream water. In order to guarantee a homogenous fluidization, the pressure drop across the screen plate also has to be adjusted. For this reason, different screen plates are available to fit different material characteristics. Of special advantage for creation and maintenance of a fluidized bed is the elimination of coarse heavy particles, which settle quickly and destroy the homogenous bed. In the **allflux®**, these particles are separated in the coarse section. The apparent density of the fluidized bed is dependent on the particle size and density of the material that create the fluidized bed. Quartz sand (= 2.650 kg|m^3) produces bed densities of 1.800 kg|m^3 when fluidized in water, hematite (= 5.200 kg|m^3) of up to 3.170 kg|m^3. Usual refuse material out of hard coal can create densities of up to 1.700 kg|m^3.

Fig. 3: Organic Impurities on Top of the Autogenous Fluidized Bed in a Sand Cleaning Application.

Particles of a lower specific gravity than the fluidized bed will remain above the fluidized bed, as shown in **Figure 3**, and are discharged along with most of the water over a weir. The cut point at the overflow weir can be influenced by the hydraulic load fed through the unit, the amount of upstream water, and the height of the fluidized bed. The concentrated fine heavy product is discharged through automatically controlled cone valves in the screen plate with solid contents between 40 % and 60 %.

Overflow Chute

Ultrafine and all lighter particles (i. e. coal concentrates) will overflow with most of the process water to the overflow chute. The overflow product can be pre-dewatered in hydrocyclones and afterwards fed to a dewatering stage.

Operational Data and Test Results

Concrete Sand – The Classic Application

The **allflux®** was first introduced to the mineral processing industry in 1991 in Germany. It was invented due to the increasing demands for high quality concrete and industrial sands in a market with deteriorating reserve quality. Primary sand contaminants were light impurities such as lignite and roots and varying size distributions in natural sand deposits. Design criteria for the **allflux®** were

- a system that is based on specific gravity separation
- high capacity, reaching 2.000 m^3|h
- consistent high product quality
- automatic operation of discharge systems and water feeds
- high solids content of discharged sand (40 % - 60 %)
- low wear
- low energy consumption

Today, more than 50 industrial units are operating worldwide. Some units treat up to 500 t|h of sand 4 – 0 mm. The process steps in these units include

- feed from a dredge at 1.200 m^3|h
- classification and deligniting of clean coarse sand 4 - 1 mm
- classification and deligniting of clean fine sand 1 – 0.15 mm
- desliming and thickening of both products
- remixing of coarse and fine sand into a customized product

Table I shows the size distribution of the individual products and the corresponding percentage of organic impurities. The overflow from the **allflux®** is discarded to a pond [1].

It is interesting to note that the gradation curves indicate a cutpoint of about 1 mm in the coarse sand section and about 0.15 mm in the fine sand section. The curve for the customized concrete sand 0|2a corresponds with the average of the last two years' production.

The analyses of organic impurities in the clean sands compared to the feed sand prove high separation efficiencies, independent of the contamination level in the feed. Sink|Float tests show misplaced material at a specific gravity of 1.800 kg|m^3 typically in the range of less than 0.001 %.

Grain Size	Feed	Coars Sand	Fine Sand	Passing, m% Overflow	2/4	0/2a
4 mm	9.55	7.26	100.00	--	93.80	100.00
2 mm	90.19	51.86	97.44	100.00	13.70	95.67
1 mm	79.98	9.34	93.11	9.88	1.19	84.57
0.5 mm	51.67	2.07	56.84	99.70	--	50.97
0.25 mm	17.96	0.11	14.06	83.53	--	12.54
0.125 mm	0.43	--	0.24	2.80	--	0.22
m% Yield	100.00	16.40	74.70	8.90	7.10	84.00
Organic Impurities $<1.8 g/cm^3$	0.181	0.0017	0.0007	2.025	0.0015	0.0008

Table I: Size Distribution and Organic Impurities of **allflux**® Products [1]

Operational Data and Test Results

Hard Coal

After years of successful use in different quartz-based sand operations, the coal industry, after various proven pilot tests, is on the verge of introducing the **allflux**® to its first industrial-sized plant. The **allflux**® finds its most economic use in fine coal recovery from old settling ponds or retrofit, in plant fines circuits.

Hard coal applications are different from those in concrete sand. Here, the light particles are the valuable product and the heavier stones are the »contaminate« for the further use of the coal product. Nevertheless, the **allflux**® works in the same manner as in the concrete sand. Rising current and fluidized bed techniques are used for a float a low ash coal product over the weir of the overflow chute. Fine rock particles, contained naturally in the feed, are used as an autogenous heavy medium to build up high bed densities.

Coal lighter than the rocks will stay on top of the fluidized bed and be discharged into the overflow chute.

The fluidized bed built up by refuse out of coal indicates possible bed densities of up to 1.700 k|m3. Thus, it is possible to separate a clean coal product out of a slurried feed of 20 to 70 % ash.

Operational Data and Test Results

Pilot plant testing

Figure 4 shows the general layout of a typical **allflux®** pilot plant, type AFX P 100, including pump sump and feed pump.

This unit usually handles up to 30 t|h of fine coal 3 - 0 mm with a hydraulic load of 40 to 80 m3|h.

Tests have been performed in Raton|New Mexico (USA) with ROM-fine coal as well as with old dumped refuse material in order to recover the remaining coal.

Furthermore southern hemisphere coal with a high content of near gravity material from New-castle|Kwazulu Natal (RSA) has been tested.

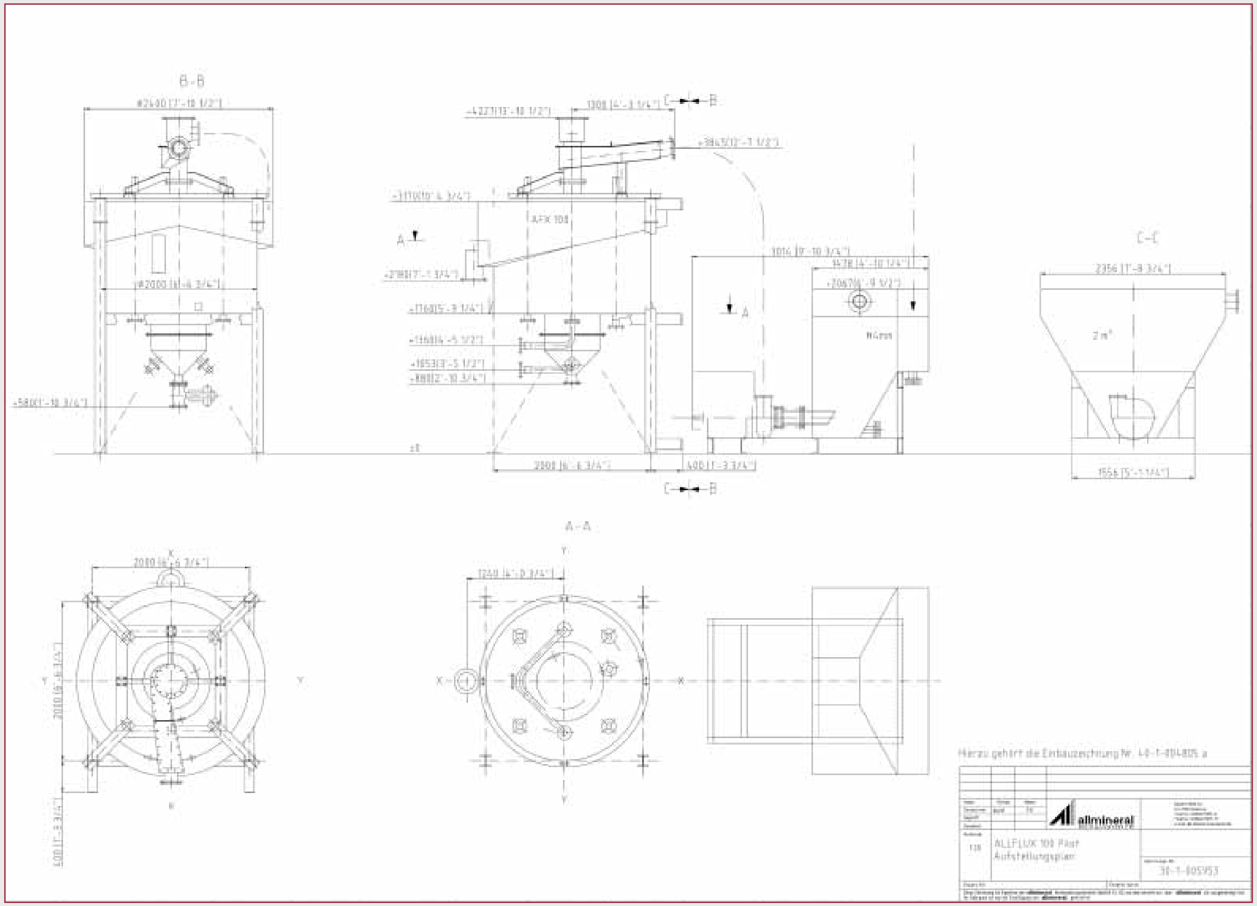

Fig. 4: shows the general layout of a typical **allflux®** pilot plant

Operational Data and Test Results

Raton, ROM - coal

The typical feed material is characterised as sumerized in table II.

During the pilot phase, which lasted over 2 months continuous sampling of the products was performed.

The typical results form the **allflux**® -separator can be summarised as follows:

coarse discharge (refuse)	80 to 88 % ash
fine discharge (refuse)	58 to 68 % ash
overflow (product)	10 to 12 % ash
after desliming by hydrocyclones:	7,5 to 8,5 % ash

The pilot separator has been fed with about 40 m^3/h of pulp at a feed rate of 20 to 25 tph of deslimed raw fine coal.

The calculated imperfection values are varying between 0,1 and 0,18 depending on the size and on the cut point.

density (g | cm3)	+ 1,4 mm		1,4 - 0,5 mm		0,5 - 0,15 mm	
	m %	ash %	m %	ash %	m %	ash %
- 1,3	65,8	5,3	69,9	7,2	33,0	7,4
1,3 - 1,4	10,0	20,7	0,1	7,9	20,6	10,6
1,4 - 1,5	1,1	24,1	0,2	22,2	0,6	13,1
1,5 - 1,6	0,9	34,6	0,2	33,4	0,5	35,
1,6 - 1,65	0,6	42,0	1,0	38,8	0,4	44,1
1,65 - 1,7	0,5	45,5	0,4	44,9	0,7	50,8
1,7 - 1,8	1,0	54,1	1,0	50,9	0,8	56,7
1,8 - 2,0	2,1	63,2	2,9	73,3	0,4	65,6
+ 2,0	18,0	86,4	24,3	85,5	43,0	76,6
total	100,0	24,0	100,0	29,1	100,0	39,1

Table II: Size and Density Distribution of ROM - Coal Fines at Raton | New Mexico (USA)

mm	m %	ash %
+ 2,4	1,9	24,0
2,4 - 1,4	8,9	
1,4 - 1,0	20,2	29,1
1,0 - 0,5	25,5	
0,5 - 0,25	18,2	39,1
0,25 - 0,15	10,6	
- 0,15	14,7	47,9
total	100,0	34,2

Operational Data and Test Results

Newcastle, ROM-coal

In early 1998 pilot testing of a deslimed fine coal material with relatively high near gravity positions has been tested.
The typical raw fine coal which comes in this case from a thickening | desliming BAUM-tower, is characterised by the data summarised in table III.

Comparing the sink and float analysis of the american and the south african coal it is obvious that separation of the »Gondwana coal« must be more complicated.
There people usually use spiral separators, which are well known to have a good performance below 0,3 mm.
Thus for this application with a lot of good material + 0,5 mm where cut points of about 1,5 to 1,6 g|cm^3 are required the application of spirals can not be the optimum.

Within the plant flowsheet the spiral concentrators take the underflow from the Baumtower and send the coal concentrates to sieve bends in order to reclean the coal by desliming | classifying at 0,3 mm.

The plant goal for the concentrate was an ash value of ± 12 %.
The pilot testing has been done by feeding the unit with up to 30 tph at a pulp flow rate of 60 to 75 m^3|h. The rising current water, which was added at the coarse and fine section amounted to 30 m^3|h, total.

The typical results have been

coarse product (refuse)	68,1 - 74,5 % ash
fine product (refuse)	60,5 - 64,4 % ash
overflow (concentrate)	11,2 - 12,8 % ash

density (g | cm3)	fraction + 0,3	
	m %	ash %
- 1,35	26,3	9,0
1,35 - 1,40	12,3	12,1
1,40 - 1,45	9,4	15,6
1,45 - 1,50	7,2	19,5
1,50 - 1,55	12,0	25,1
1,55 - 1,60	6,5	40,6
+ 1,60	26,3	61,7
total	100,0	28,6

mm	m %	ash %
+ 1,0	8,7	30,6
1,0 - 0,5	31,8	23,7
0,5 - 0,3	21,8	34,2
0,3 - 1,50	21,5	43,6
- 0,15	16,2	48,2
	100,0	33,7

Table III: Size and Density Distribution of Deslimed ROM Coal Fines at Newcastle | Kwazulu Natal (RSA)

Plant concept

For the fine coal separation a typical plant concept for the minus 1|8" (3 mm) has been developed.

The flowsheet is shown in figure 5 and is based on the recovery of fine coal from pond material. The plant will be built in that way that the feed alternatively will come from the pond by using a dredge or from the stripmining out of the preparation plant from a thickening cyclone.

The illustrated concept combines an **allflux**® separator for the 3 - 0 mm (150 tph) and a one step flotation plant, type **allflot**® for about 50 tph retreating the fines from the overflow of the hydrocyclones.

The total investment of such a plant amounts to approx. 3,5 Mio. USD.

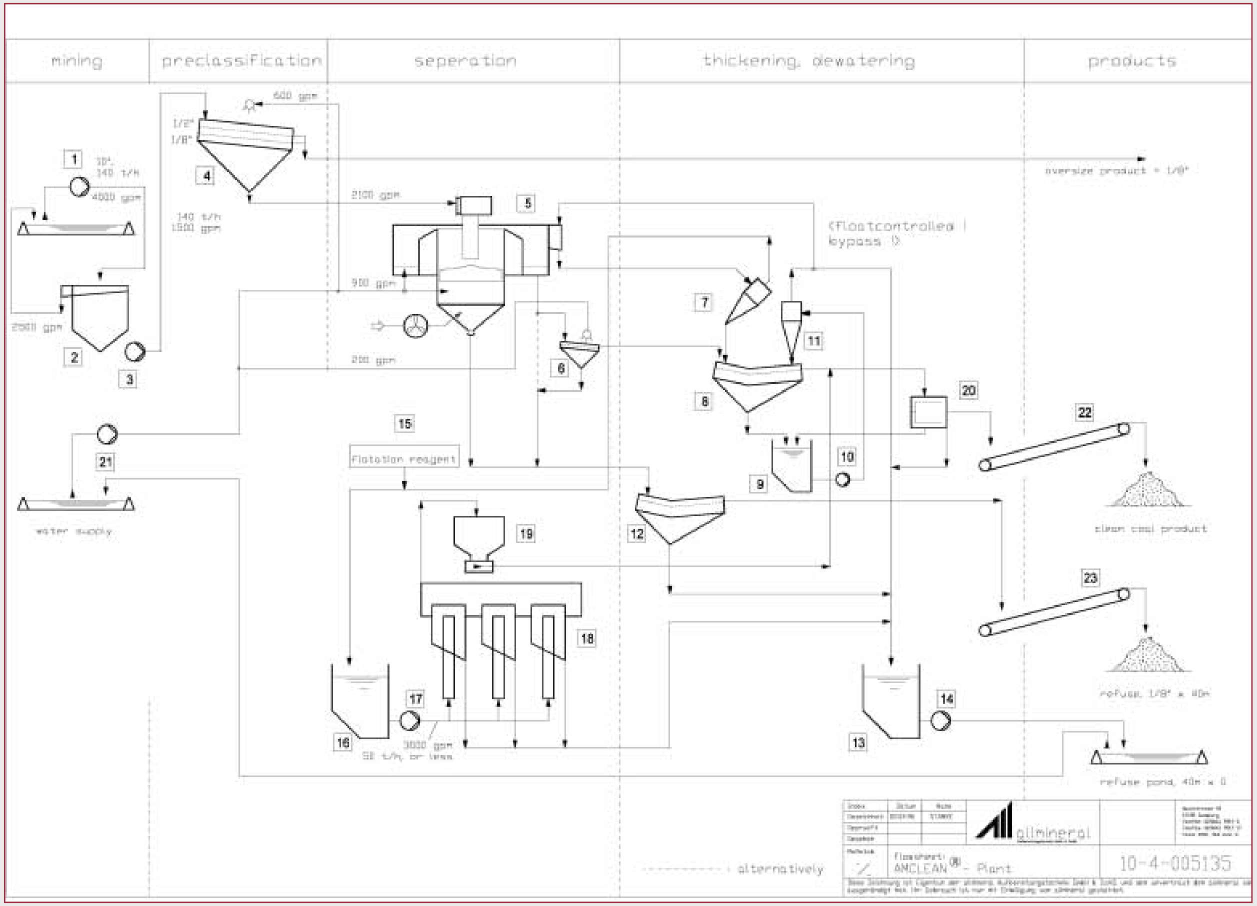

Fig. 5: shows the **allflux**® separator and a one step flotation plant.

Futur Outlook

Operation and test data of the **allflux**® separator have proven it to be a successful and efficient alternative in mineral processing. The unique combination of long proven mineral processing techniques enable this machine to do jobs others cannot do or can do only in multiple steps.

Thus, the **allflux**® comprises technical process advantages as well as a high economical efficiency by combining multiple process steps in one unit. Since the unit operates completely automatic and without moving parts, it will cut down maintenance cost and save expensive downtime losses

References

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[4] Grotjohann P., Snoby R. J., 1998, »**allflux**®-Separator/A New Way to Process Your Heavy Minerals«, pp. 1-7.

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