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CA 2531172 A1 2005/07/21

(21) 2 531 172

(12) DEMANDE DE BREVET CANADIEN
CANADIAN PATENT APPLICATION

(13) A1

(86) Date de dépôt PCT/PCT Filing Date: 2004/11/25
(87) Date publication PCT/PCT Publication Date: 2005/07/21
(85) Entrée phase nationale/National Entry: 2006/01/03
(86) N° demande PCT/PCT Application No.: DE 2004/002615
(87) N° publication PCT/PCT Publication No.: 2005/065848
(30) Priorité/Priority: 2004/01/12 (10 2004 001 790.5) DE

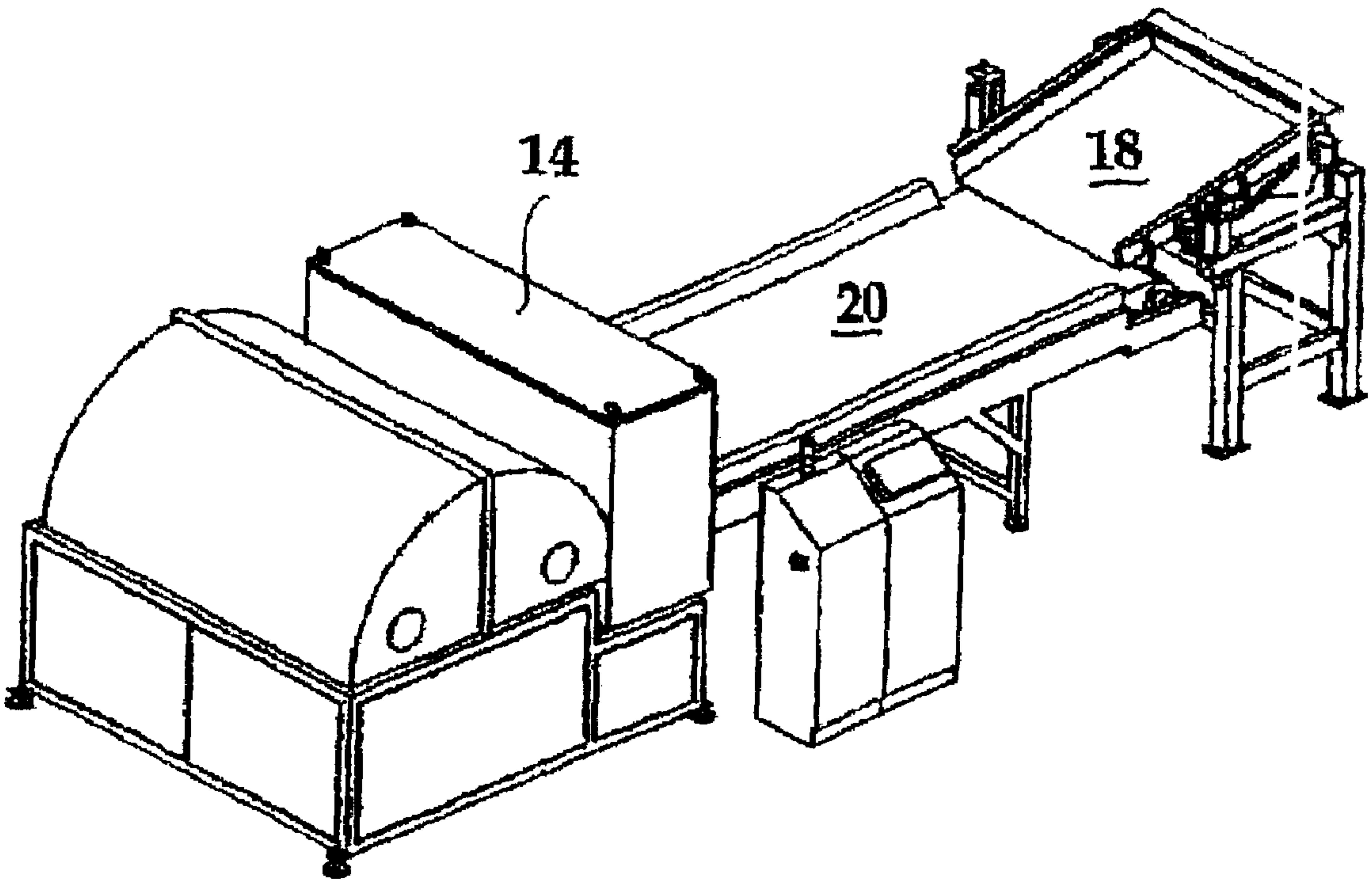
(51) Cl.Int./Int.Cl. *B07C 5/34* (2006.01), *G01N 23/04* (2006.01)

(71) Demandeur/Applicant:
COMMODAS DATEN-UND SYSTEMTECHNIK NACH MASS GMBH, DE

(72) Inventeurs/Inventors:
PETZOLD, GUENTHER, DE;
HARBECK, HARTMUT, DE;
REISCHMANN, GERD, DE

(74) Agent: BARRIGAR INTELLECTUAL PROPERTY LAW

(54) Titre : DISPOSITIF ET PROCEDE POUR SEPARER DES MATIERES EN VRAC
(54) Title: DEVICE AND METHOD FOR SEPARATING BULK MATERIALS



(57) Abrégé/Abstract:
The invention relates to a device and method for separating bulk materials with the aid of a blow-out device provided with blow-out nozzles arranged on a fall section which is disposed downstream from a conveyor belt (20). The blow-out nozzles are controlled by computer-assisted evaluation means according to sensor results of radiation which penetrates the flow of bulk goods on the conveyor belt, is emitted from an x-ray source and which is captured in sensor means (10). The x-ray radiation, which passes through the particles of the bulk materials, is filtered into at least two spectra of differing energy ranges before the radiation is captured with local resolution, with the aid of at least one sensor means (10), which is integrated within an energy range.

CA 02531172 2006-01-03

(12) NACH DEM VERTRAG ÜBER DIE INTERNATIONALE ZUSAMMENARBEIT AUF DEM GEBIET DES PATENTWESENS (PCT) VERÖFFENTLICHTE INTERNATIONALE ANMELDUNG

(19) Weltorganisation für geistiges Eigentum
Internationales Büro

(43) Internationales Veröffentlichungsdatum
21. Juli 2005 (21.07.2005)

PCT

(10) Internationale Veröffentlichungsnummer
WO 2005/065848 A1

(51) Internationale Patentklassifikation[7]: **B07C 5/34**, G01N 23/04

(21) Internationales Aktenzeichen: PCT/DE2004/002615

(22) Internationales Anmeldedatum: 25. November 2004 (25.11.2004)

(25) Einreichungssprache: Deutsch

(26) Veröffentlichungssprache: Deutsch

(30) Angaben zur Priorität:
10 2004 001 790.5 12. Januar 2004 (12.01.2004) DE

(71) Anmelder *(für alle Bestimmungsstaaten mit Ausnahme von US)*: **COMMODAS DATEN- UND SYSTEMTECHNIK NACH MASS GMBH** [DE/DE]; Rosengarten 10, 22880 Wedel (DE).

(72) Erfinder; und
(75) Erfinder/Anmelder *(nur für US)*: **PETZOLD, Guenther** [DE/DE]; Dorfstrasse 10, 25462 Rellingen (DE). **HARBECK, Hartmut** [DE/DE]; Op'n Klint 23, 22880 Wedel (DE). **REISCHMANN, Gerd** [DE/DE]; Bertha-von-Suttner-Ring 19, 25436 Tornesch (DE).

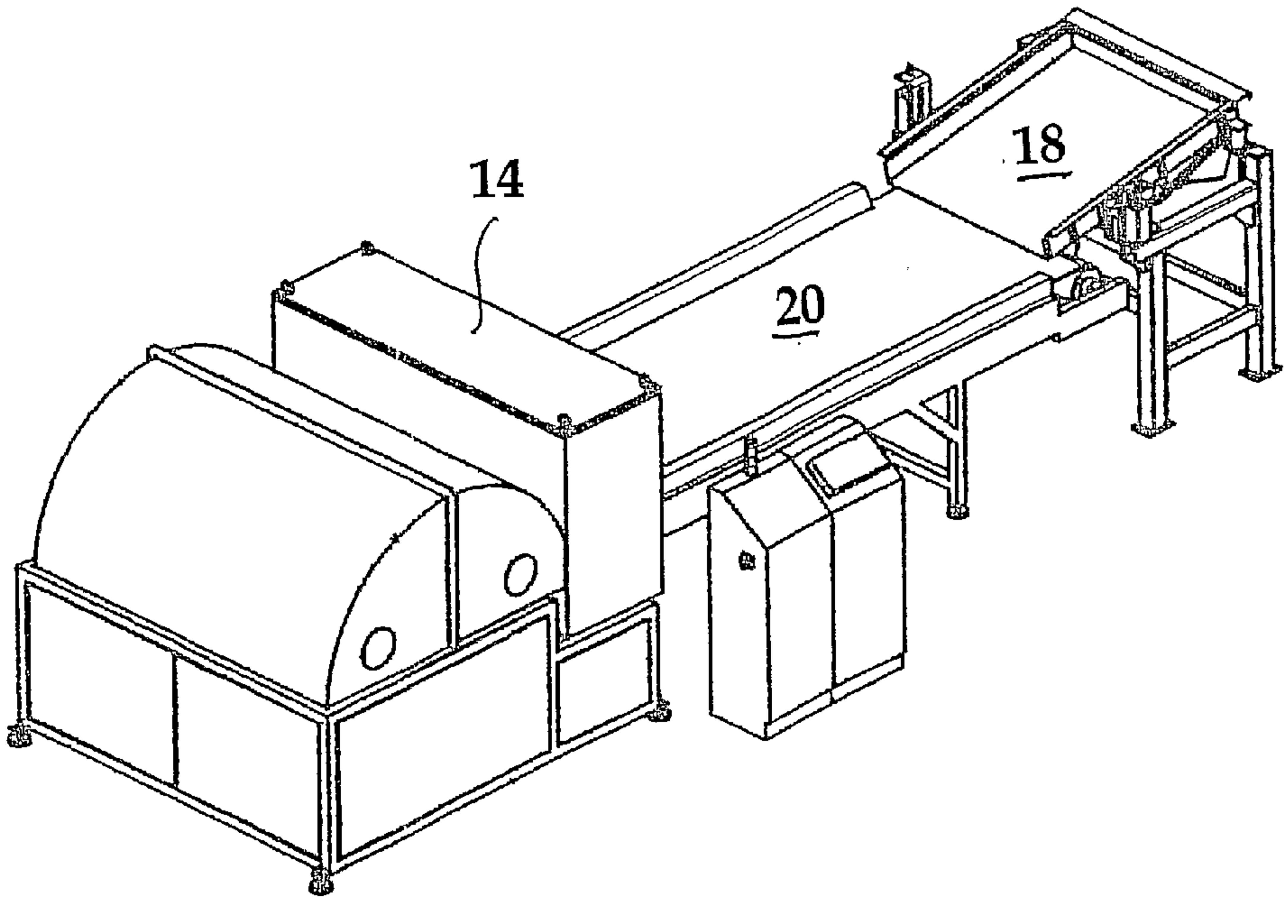
(74) Anwalt: BIEHL, Christian; Boehmert & Boehmert, Niemannsweg 133, 24105 Kiel (DE).

(81) Bestimmungsstaaten *(soweit nicht anders angegeben, für jede verfügbare nationale Schutzrechtsart)*: AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NA, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SY, TJ, TM,

[Fortsetzung auf der nächsten Seite]

(54) Title: DEVICE AND METHOD FOR SEPARATING BULK MATERIALS

(54) Bezeichnung: VORRICHTUNG UND VERFAHREN ZUR TRENNUNG VON SCHÜTTGÜTERN



(57) Abstract: The invention relates to a device and method for separating bulk materials with the aid of a blow-out device provided with blow-out nozzles arranged on a fall section which is disposed downstream from a conveyor belt (20). The blow-out nozzles are controlled by computer-assisted evaluation means according to sensor results of radiation which penetrates the flow of bulk goods on the conveyor belt, is emitted from an x-ray source and which is captured in sensor means (10). The x-ray radiation, which passes through the particles of the bulk materials, is filtered into at least two spectra of differing energy ranges before the radiation is captured with local resolution, with the aid of at least one sensor means (10), which is integrated within an energy range.

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WO 2005/065848 A1

WO 2005/065848 A1

TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.

(84) Bestimmungsstaaten *(soweit nicht anders angegeben, für jede verfügbare regionale Schutzrechtsart)***:** ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), eurasisches (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), europäisches (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IS, IT, LU, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

Veröffentlicht:
— *mit internationalem Recherchenbericht*

Zur Erklärung der Zweibuchstaben-Codes und der anderen Abkürzungen wird auf die Erklärungen ("Guidance Notes on Codes and Abbreviations") am Anfang jeder regulären Ausgabe der PCT-Gazette verwiesen.

(57) Zusammenfassung: Vorrichtung und Verfahren zur Trennung von Schüttgütern mit Hilfe einer Ausblaseinrichtung mit an einer einem Förderband (20) nachgeordneten Fallstrecke angeordneten Ausblasdüsen, wobei die Ausblasdüsen von rechnergestützten Auswertemitteln in Abhängigkeit von Sensorergebnissen einer, den Schüttgutstrom auf dem Förderband durchdringenden, aus einer Röntgenquelle emittierten und in Sensormitteln (10) aufgefangenen Strahlung gesteuert werden, wobei mit Filtern eine Filterung der die Schüttgutteilchen passierten Röntgenstrahlung in wenigstens zwei Spektren unterschiedlicher Energiebereiche erfolgt, bevor mit wenigstens einen Sensormittel (10) die Strahlung ortsaufgelöst auf dem Sensormittel (10) integriert über Energiebereichs aufgefangen wird.

DEVICE AND METHOD FOR SEPARATING BULK MATERIALS

The invention relates to a device and a method for separating or sorting bulk materials according to the preamble of the main claim.

Devices for separating bulk materials require a large number of sensors, particularly optical and electromagnetic sensors, such as is described in the applicant's EP B1-1 253 981.

Besides such sensors it is also advantageous to use X-radiation for the non-destructive testing of material characteristics of all possible objects which are not readily detectable on the surface.

In this connection US 6,122,343 only provides the information given in the introductory part of claim 1 and only the reference that superimposed arrays can be used as sensor means indicate the possible appearance of the filters on the detectors. No further details are given of data processing and instead merely an increased contrast image constitutes the sought result.

Particularly through the observation of a high resolution image whilst observing two X-radiation energy levels and the mathematical evaluation of a resulting differential image make it possible to obtain information on the constituents of individual bulk material particles, but no teaching in this direction is provided by US 6,122,343.

This is e.g. of interest when separating ores, where the decision as to whether a particle is or is not discarded decisively depends on whether and possibly which material is present in a specific bulk material particle. The method can also be used in the separation of waste particles.

In hitherto known devices where X-ray sources were used, as a result of the not inconsiderable spatial dimensions of the X-ray sources and also the detectors, as well as the necessary screening or shielding, spatial demands have arisen making it impossible or only possible with considerable difficulty to bring about a place-precise evaluation, such as is required for the control of blow-out nozzles for blowing out smaller bulk material particles.

The problem of the invention is to provide a safe saving arrangement with which it is not only reliably possible to detect small metal parts such as screws and nuts, but permitting the reliable separation thereof from the remaining bulk material flow through blow-out nozzles directly following the observation location.

According to the invention this problem is solved by the features of the main claim and using two X-ray filters for different energy levels, which are in each case brought in front of the sensors, different informations concerning the bulk material particles can be obtained. Alternatively the filters can directly follow the X-ray source, or use can be made of X-ray sources with different emitted energies.

The spatial arrangement of the filters can be fixed, so that by moving the bulk material particles it is possible to bring about a suitable filter-following reflection of the x-radiation e.g. by crystals onto a detector line or row in the case of an association of two measured results recorded at different times for the bulk material particles advancing on the bulk material conveyor belt.

However, in another variant of the device it is also possible to work with two sensors, which follow one another transversely to the conveyor belt extension and are e.g. located below the same. Through suitable mathematical delay loops it is then possible to associate the successively obtained image informations with individual bulk material particles and, following mathematical evaluation, use the same for controlling the blow-out nozzles.

Through the upstream placing of filters, it is also possible to restrict the X-radiation to a specific energy level with respect to an X-ray source emitting in a broader spectrum prior to the same striking the bulk material particle. No further filter is then required between the bulk material particles and a downstream sensor.

It is also proposed that the device be equipped with a shield, which is obviously provided around the X-ray source and the irradiation location of the bulk material particles and the actual sensors in a X-ray-tight manner, but which also extends on the bulk material conveyor belt surface up to a filling device filling the conveyor belt via a sloping chute. This ensures that operating personnel can remain around the sorting and separating device. Covers must be secured in such a way that on removal the device cannot be operated.

The inventive method for separating bulk materials with the aid of a blow-out device operates with blow-out nozzles located on a fall section downstream of a conveyor belt, the blow-out nozzles being controlled by a computer-assisted evaluating means as a function of the sensor results of radiation penetrating the bulk material flow on the conveyor belt, which is emitted by an X-ray source and is captured in sensor means.

Filtering of the X-radiation which has traversed bulk material particles takes place in at least two different spectra for the place-resolved capturing of the X-radiation which has traversed the bulk material particles integrated in at least one line sensor over a predetermined energy range. This can take place when using a sensor means (a long line formed from numerous individual detectors) by passing through different filters and successive capturing of the transmitted radiation, or preferably by two sensor lines with in each case a different filter, the filters permitting the passage of different spectra, which on the one hand tend to have a soft and on the other a hard character.

A Z-classification and standardization of image areas takes place for determining the atomic density class on the basis of the sensor signals of the X-ray photons of different energy spectra captured in the at least two sensor lines.

Finally the objective can advantageously be achieved by a segmentation of the characteristic class formation for controlling the blow-out nozzles on the basis of both the detected average transmission of the bulk material particles in the different X-ray energy spectra captured by the at least two sensor lines and also the density information obtained by Z-standardization.

Further advantages and features of the invention can be gathered from the following description of a preferred embodiment with reference to the attached drawings, wherein show:

Fig. 1 The device according to the invention in a diagrammatic side view.

Fig. 2 The device according to the invention in a perspective view with removed radiation protection above the conveyor belt.

Fig. 3 A diagrammatic view of the X-ray sensor means structure.

Fig. 4 A diagrammatic representation of the X-ray signal processing structure.

Fig. 1 diagrammatically shows how by means of a flat detector 10 positioned below the conveyor belt 20 and a X-ray source 12 above the same by means of downstream blow-out nozzles 24 in two different product chambers it is possible to separate a rejection product from a pass-through product in the bulk material flow. A wedge-like separating element 26 between the two product flows can have its slope adjusted, so that it is easily possible to adapt to products of different heaviness with different flight characteristics, without the blow-out air pressure having to be subsequently adjusted.

As with most of the metallic parts which have to be blown out there are considerable demands regarding a uniform air supply, but in part considerable air quantities have to be simultaneously delivered, it is proposed to intermediately store a larger compressed air volume using an intermediate storage means 28 and said volume is connected to the blow-out nozzles. A continuously operating compressed air pump is used for the subsequent delivery of compressed air to said volume.

Fig. 1 also shows how, above the conveyor belt 20, there is a cover 16 for preventing X-radiation reflected against the product delivery direction passing out to the separating device. On the filling side there is a seal of the conveyor belt box 16 through a sloping material delivery chute 18 on conveyor belt 20, so that radiation cannot pass out counter to the conveying direction parallel to the conveyor belt.

The device for separating bulk materials with the aid of a blow-out device with blow-out nozzles 24 located on a fall section downstream of a conveyor belt 20 consequently largely comprises computer-assisted evaluating means which can be controlled as a function of sensor results of two captured X-ray transmitted light images penetrating the bulk material flow on the conveyor belt, emitted by an X-ray source 12 and captured in sensor means 10. There are also two not shown filter devices for passing on X-radiation in relation to mutually different energies placed upstream of the at least one sensor means, said sensor means being 10 line sensors with a plurality of individual pixels positioned transversely to the conveyor belt 20. In particular, there can be one sensor line for each filter.

A sensor line corresponding to the conveyor belt width is formed by lined up photodiode arrays, whose active surface is covered with a fluorescent paper. The filters are preferably metal foils through which X-radiation of different energy levels is transmitted. However, the filters can also be formed by crystals, which reflect X-radiation to mutually differing energy levels, particularly X-radiation in different energy ranges in different solid angles.

There can also be more than two filters for the use of more than two energy levels. Advantageously the filters are located below the conveyor belt 20 upstream of the sensor means 10 and above the conveyor belt 20 is located an X-ray tube 12 producing a bremsspektrum.

The device is equipped with a shielding box 14, 16 above the conveyor belt and which surrounds the latter and the blow-out section 22 and as cover 16 covers the conveyor belt in a section upstream of the X-ray source and at the beginning of the belt there is a sloping chute 18 covering the entrance cross-section (shown perspectively in fig. 2). In the device shown inter alia glass ceramic is separated from bottle glass. However, also the different glass types, which in part have much higher melting points than "normal glass" and used in display screen tubes and which have hitherto constituted a material difficult to separate in the recycling of broken glass can now for the first time be separated using the device according to the invention.

For the better understanding of the separating procedure a technical description will now be given of X-ray signal processing by means of two X-ray transmission spectra and a segmentation into characteristic classes. A suitable coverage is to be ensured within the framework of X-ray sensor means and this is achieved by a filter technique having spectral resolution.

Through a suitable filtering of the X-radiation upstream of the particular sensor of the two-channel system, there is firstly a spectral selectivity The arrangement of the sensor lines then permits an independent filtering so that the optimum selectivity for a given separating function can be achieved.

Generally a higher energy spectrum and a lower energy spectrum is covered For this for the former a high pass filter is used which greatly attenuates the lower frequencies with a lower energy content. The high frequencies are transmitted with limited attenuation. For this purpose it is possible to use a metal foil of a metal with a higher density class, such as e.g. a 0.45 mm thick copper foil.

For the lower energy spectrum the filter is used upstream of the given sensor as an absorption filter which suppresses a specific higher energy wave range. It is designed in such a way that the absorption is in the close proximity to the higher density elements. For this purpose it is in particular possible to use a metal foil of a lower density class metal such as e.g. a 0.45 mm thick aluminium foil.

Each of the two sensor lines S1.i and S2.i (i e.g. from n times 1 to n times 64 for all the lined up arrays over the conveying width) comprises a plurality of photodiode arrays equipped with a scintillator for converting X-rediation into visible light.

A typical array has 64 pixels (in one row) with either 0.4 or 0.8 mm pixel rasters. As diagrammatically shown in fig. 3, by means of analog amplifiers and analog/digital converters 32, the intensity is digitized with 14 bit dynamics and read out in line-synchronous manner using FIFO (First In/First Out) memories and a serial interface 36. The line first cut from the sorting product as a result of the material conveying direction is delayed until the data are quasi-simultaneously available with those of the subsequently cut line (with the other energy spectrum).

The thus time-correlated data are converted by multiplexer 38 into a byte-serial data stream and transmitted via the standard interface Camera Link 40 over a distance of several metres to the evaluation electronics.

By lining up electronic modules, which in each case cover a 300 mm conveying width, it is possible to build up in two-channel form maximum conveying widths of 1800 mm. For this purpose on each module the necessary operating voltages are generated anew and the clock signals are prepared anew.

The X-ray signal processing takes place on the data stream transmitted via Camera Link 40 (shown diagrammatically in fig. 4) and undergoes separation into two sensor channels again using demultiplexer 42.

For each channel separately a black/white correction is carried out in an electronic unit 44. On measuring this correction stage, for each pixel determination takes place of the black value in the absence of radiation and the white value for 100% radiation and an adjustment or compensation table is used. In normal operation the untreated data are corrected with the aid of said table. For suppressing signal noise (module 46), separately and for each channel by the buffer storage of a number of following lines temporarily an image is built up and is smoothed by a mean value filter, whose size in rows and columns can be adjusted. This significantly reduces noise.

Z-transformation (module 50) produces from the intensities of two channels of different spectral imaging n classes of average atomic density (abbreviated to Z), whose association is largely independent of the X-ray transmission and therefore the material thickness.

A standardization of the values to an average atomic density of one or more selected representative materials makes it possible to differently classify image areas on either side of the standard curve. A calibration in which over the captured spectrum the context is produced in non-linear manner enables the "fading out" of equipment effects.

The atomic density class generated during the standardization to a specific Z (atomic number of an element, or more generally average atomic density of the material) forms the typical density of the participating materials. In parallel to this in module 48 a further channel is calculated providing the resulting, average transmission over the entire spectrum.

By computer-assisted combination of the atomic density class with a transmission interval (T_{min}-, T_{max}) to the pixels can be allocated a characteristic class in module 52 which, following morphological filter 54, can be used for material differentiation in module 56.

Here again in temporary manner an image of a few lines height is built up in order to suppress interfering informations with a bidimensional filter. It is e.g. possible for undesired misinformations to be suppressed at the edge of particles by cut pixels.

The data stream of characteristic classes is treated as image material. The "machine idling" characteristic class describes the state when the X-ray source is switched on without sorting material in the measurement section. All characteristic pixels diverging from machine idling are processed as foreground and combined by segmentation to line segments and finally to surfaces. The characteristic distribution over these surfaces is described by object data sets. In addition, said data sets also contain informations regarding the position, shape and size of the linked characteristic surfaces.

In the evaluation quantity relations of the characteristic pixels, as well as the shape and size per object are compared with learned parameters per material. On this basis the object is associated with a specific material class.

CLAIMS

1. Device for separating bulk materials with the aid of a blow-out device with blow-out nozzles located on a fall section downstream of a conveyor belt (20), with a X-ray source, computer-controlled evaluating means and sensor means (10), the blow-out nozzles being controllable by the computer-assisted evaluating means as a function of sensor signals, which result from the radiation penetrating the bulk material flow on the conveyor belt, emitted by the X-ray source and captured in the sensor means, characterized by at least two filter devices for permitting the passage of X-radiation in relation to mutually different energy spectra positioned upstream of the at least one sensor means (10) and line sensors with a plurality of individual pixels positioned transversely to the conveyor belt (20) as sensor means.

2. Device according to claim 1, characterized in that there is a sensor line for each filter.

3. Device according to one of the preceding claims, characterized in that a sensor line corresponding to the conveyor belt width is formed by lined up photodiode arrays, whose active surface is covered with a fluorescent paper.

4. Device according to one of the preceding claims, characterized in that the filters are metal foils through which X-radiation of mutually different energy levels is transmitted.

5. Device according to one of the preceding claims, characterized in that the filters below the conveyor belt (20) are positioned upstream of the sensors and a X-ray tube (12) producing a bremsspektrum is positioned above the conveyor belt (20).

6. Device according to one of the preceding claims, characterized in that the device is provided with a shielding box (14) essentially above the conveyor belt (20), which surrounds the latter and the blow-out section (22), as a covering (16) covers the conveyor belt in a section upstream of the X-ray source and at the start of the belt a sloping chute (18) covers the entrance cross-section.

7. Device according to one of the preceding claims, characterized in that there are more than two filters for using more than two energy levels.

8. Method for separating bulk materials with the aid of a blow-out device with blow-out nozzles located on a fall section downstream of a conveyor belt (20), the blow-out nozzles are controlled by computer-assisted evaluating means as a function of the sensor results of radiation penetrating the bulk material flow on the conveyor belt, emitted by an X-ray source and captured in

the sensor means, characterized by filtering the X-radiation which has traversed the bulk material particles into at least two different spectra for the location-resolved capturing of the X-radiation which has traversed the bulk material particles integrated in at least one line sensor over a predetermined energy range.

9. Device according to claim 8, characterized in that there is a Z-classification and standardization of image areas for determining the atomic density class on the basis of the sensor signals of the X-ray photons of different energy spectra captured in the at least two sensor lines.

10. Device according to claim 8 or 9, characterized in that there is a segmentation of the characteristic class formation for controlling the blow-out nozzle on the basis of both the detected average transmission of the bulk material particles in the different X-ray energy spectra captured by the at least two sensor lines and also the density information obtained by Z-standardization.

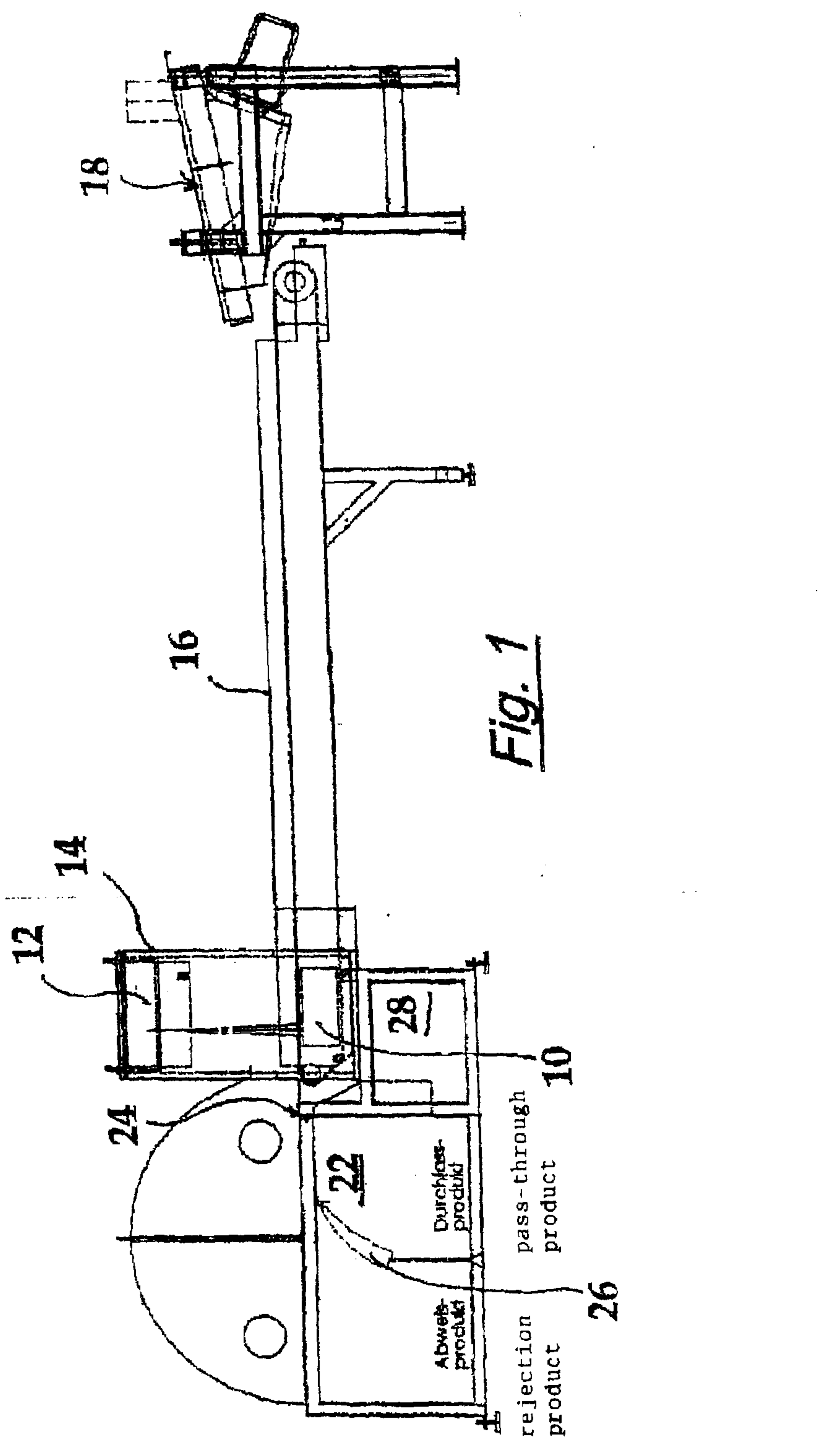

18
16
14
12
10
24
22
28
26
Durchlass-produkt
Abweis-produkt
pass-through product
rejection product

Fig. 1

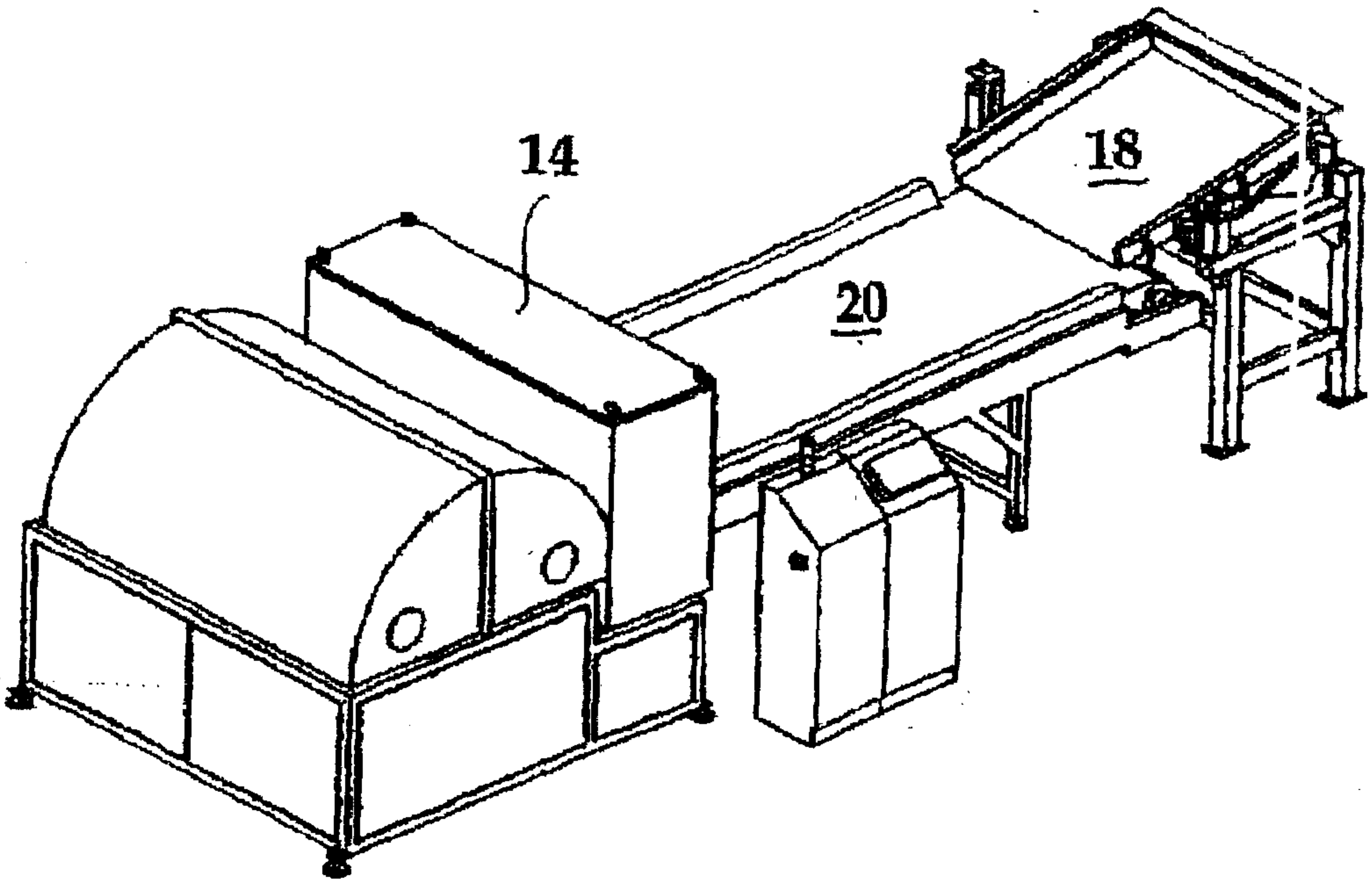


Fig. 2

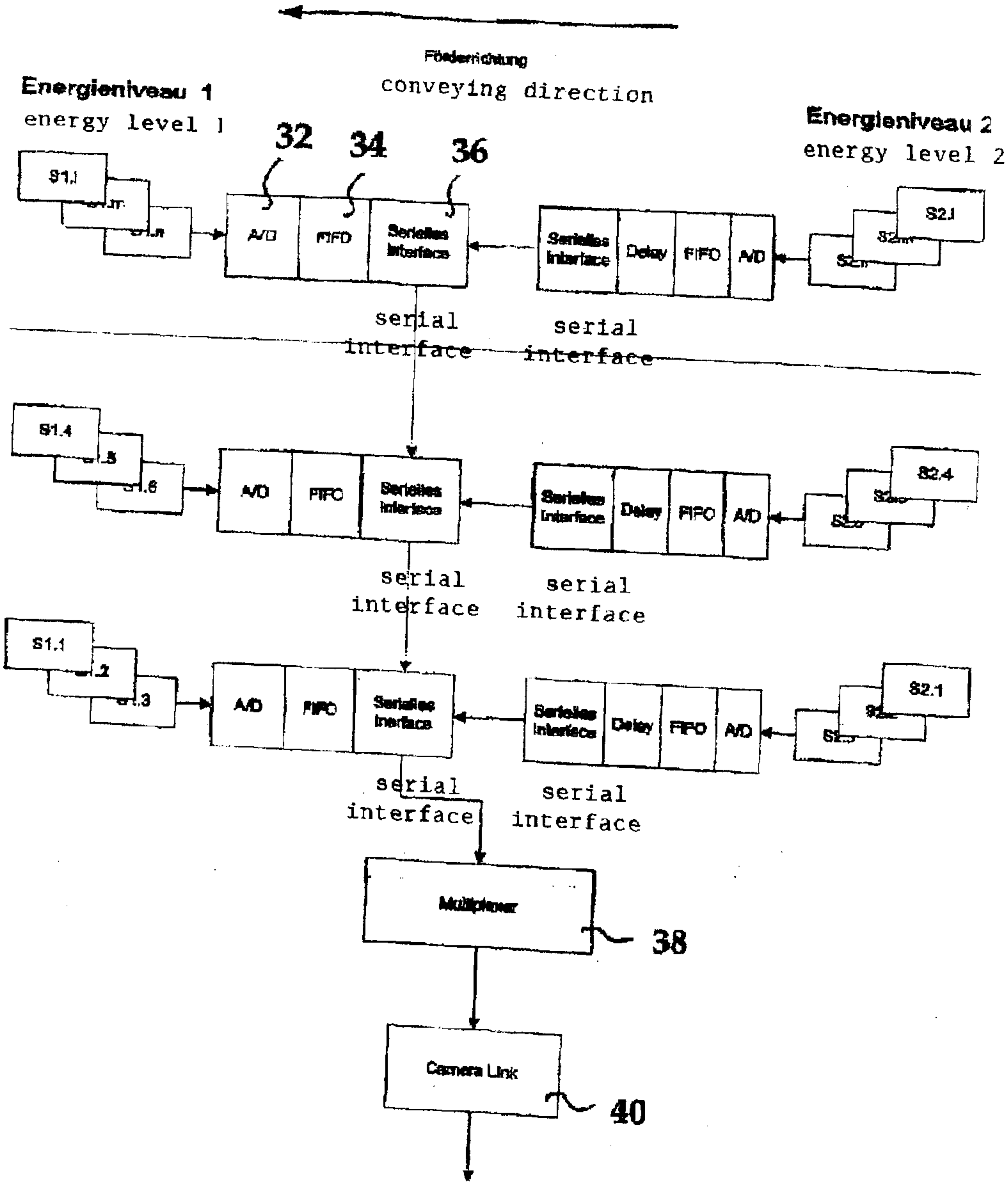

Föderrichtung
conveying direction
Energieniveau 1
energy level 1
Energieniveau 2
energy level 2
32
34
36
S1.i
A/D
FIFO
Serielles Interface
Serielles Interface
Delay
FIFO
A/D
S2.i
serial interface
serial interface
S1.4
A/D
FIFO
Serielles Interface
Serielles Interface
Delay
FIFO
A/D
S2.4
serial interface
serial interface
S1.1
A/D
FIFO
Serielles Interface
Serielles Interface
Delay
FIFO
A/D
S2.1
serial interface
serial interface
Multiplexer
38
Camera Link
40

Fig. 3

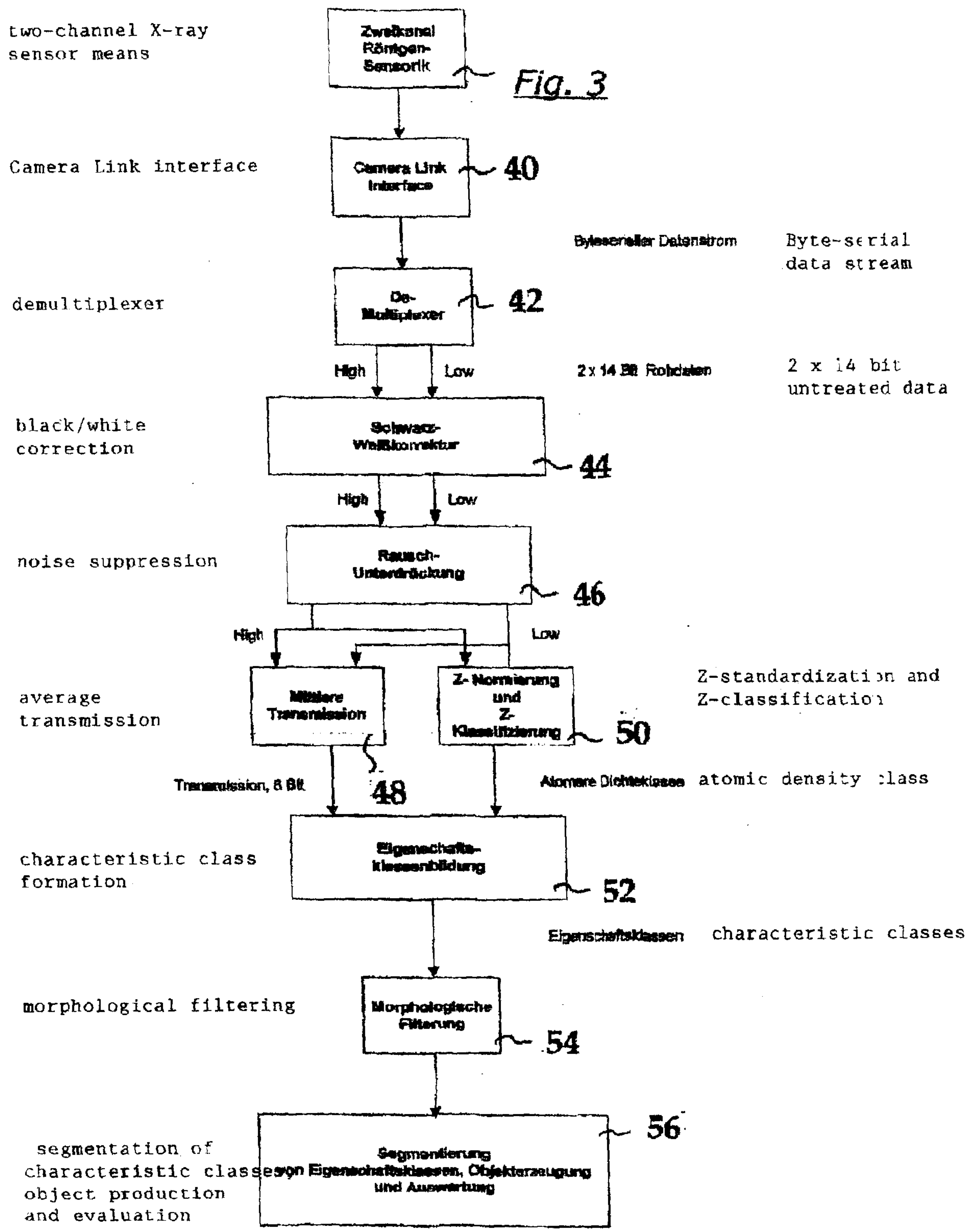
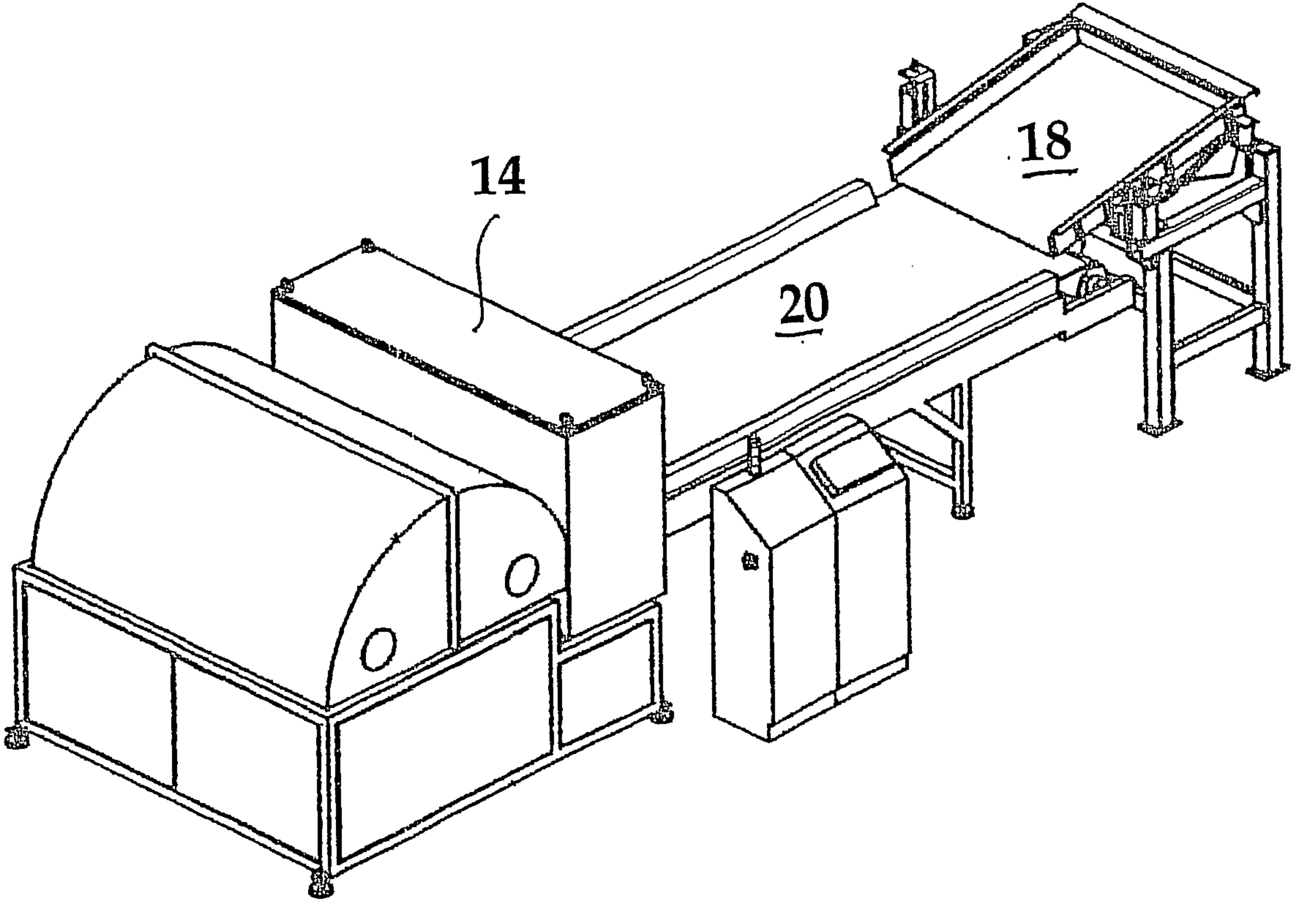

two-channel X-ray sensor means
Zweikanal Röntgen-Sensorik
Fig. 3
Camera Link interface
Camera Link Interface
40
Byteserieller Datenstrom
Byte-serial data stream
demultiplexer
De-Multiplexer
42
High
Low
2 x 14 Bit Rohdaten
2 x 14 bit untreated data
black/white correction
Schwarz-Weißkorrektur
44
High
Low
noise suppression
Rausch-Unterdrückung
46
High
Low
average transmission
Mittlere Transmission
48
Z-Normierung und Z-Klassifizierung
50
Z-standardization and Z-classification
Transmission, 8 Bit
Atomare Dichteklasse
atomic density class
characteristic class formation
Eigenschafts-klassenbildung
52
Eigenschaftsklassen
characteristic classes
morphological filtering
Morphologische Filterung
54
segmentation of characteristic classes object production and evaluation
Segmentierung von Eigenschaftsklassen, Objekterzeugung und Auswertung
56

Fig. 4


14
18
20