



(51) International Patent Classification:

B07C 5/342 (2006.01)

B07C 5/346 (2006.01)

B07C 5/344 (2006.01)

(21) International Application Number:

PCT/EP2020/070995

(22) International Filing Date:

24 July 2020 (24.07.2020)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

1950907-4

29 July 2019 (29.07.2019)

SE

(71) Applicant: METSO SWEDEN AB [SE/SE]; Box 132, 231 22 TRELLEBORG (SE).

(72) Inventor: GRÖNVALL, Lars; Ängsnyckelvägen 11, 231 31 Trelleborg (SE).

(74) Agent: AWA SWEDEN AB; Box 665, 831 27 Östersund (SE).

(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, IT, JO, JP, KE, KG, KH, KN,

KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, WS, ZA, ZM, ZW.

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

- with international search report (Art. 21(3))
- before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))

(54) Title: BENEFICIATION ARRANGEMENT, METHOD AND USE OF THE ARRANGEMENT

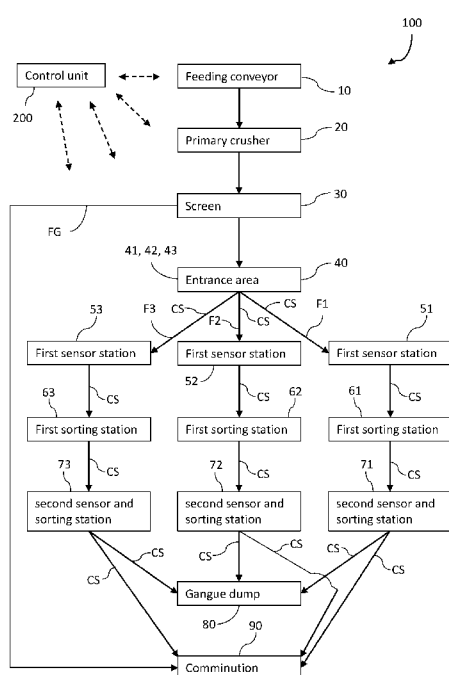


Fig. 1

(57) Abstract: Disclosed is a beneficiation arrangement for use with geological material, comprising an entrance area for the geological material, a first sensor station comprising at least one sensor for determining a property of the geological material, a first sorting station for sorting the geological material and an exit area where the geological material leaves the beneficiation arrangement. The beneficiation system further comprises a conveying system for transportation of the geological material extending between the entrance area and the exit area, wherein the first sensor station is arranged along the conveying system downstream of the entrance area and wherein the first sorting station is arranged along the conveying system downstream of the first sensor station and further wherein the operation of the first sorting station is based on information retrieved by the first sensor station. A corresponding method and use is also disclosed.

BENEFICIATION ARRANGEMENT, METHOD AND USE OF THE ARRANGEMENT

FIELD OF THE INVENTION

The present invention relates to a beneficiation arrangement, for example within the mining industry.

5

BACKGROUND OF THE INVENTION

When extracting minerals or other valuable materials from the earth, resource consumption, such as power and water, is coming more and more into focus. As the grade of the available global deposits is ever decreasing and most high-grade deposits are depleting quickly, more and more energy has to be invested in order to obtain a given amount of e.g. metal ore since processing and rejecting worthless material causes poor productivity. There are researches available indicating that well above 90 % of the energy consumed in the comminution process ends in heat and does not contribute to the liberation/benefication process which means that if it is possible to sort out worthless material as early as possible, substantial energy savings are possible. A solution is to apply coarse rejection technologies in order to be able to remove barren material as early in the process as possible. This will minimize the tonnage that has to be transported, comminuted and processed.

Different approaches to this dilemma have been presented throughout the years. For example, sensor based bulk ore sorting used to separate large volumes of gangue from more valuable ore volumes. Low-grade ore bodies generally contain a large proportion of liberated barren gangue, or, in other words, material of no worth which can be rejected from coarse feed which will increase the grade of the ore proceeding to the next stage of processing and avoids feeding the plant with material that only incur processing costs such that less tons of ore must be treated per ton of product, thus reducing the energy and water consumption per ton of product. Since gangue tends to be

10
15
20
25

high in silicates and typically harder than the minerals to be liberated, removal of this hard and barren material prior to comminution stages also has the potential to significantly reduce energy consumption and processing costs, and may also reduce ore transport requirements. This can be done by
5 separating large volumes of barren gangue from a fully loaded conveyor belt based on the grade as determined by sensor measurement. A variety of sensors are available, and commonly include photometric, electromagnetic, radiometric and x-ray. The sensors are normally applied to loaded truck boxes or a fully loaded conveyor belts such that bulk quantities of ore can be
10 evaluated.

Another approach is to control and perform blasting of the geological body to be mined such that a beneficiation is achieved. US-2014/0144342 describes a method for blasting which achieves that those parts of the
15 geological body to be mined having a higher grade have the finest fraction post-blasting whereas less valuable parts, such as gangue, have larger fractions. The more valuable, finer fractions can then be separated from the less valuable fractions by means of a screening device or other separation equipment.

20

Yet another known method is sensor based stream sorting. The concept as such is known from e.g. waste recycling and food processing and those systems have been adapted and modified to better suit the specific needs of the mining industry. However, throughput for these systems have
25 proven to be much too small to be of real relevance, often ~100 tons per hour whereas mining applications generally requires several or even many thousands of tons per hour.

SUMMARY OF THE INVENTION

30 An object of the invention is to overcome, or at least lessen the above mentioned problems, especially those related to sensor based stream sorting.

A particular object is to provide an arrangement for beneficiation for use with geological material. To better address this concern, in a first aspect of the invention there is provided a beneficiation arrangement for use with geological material comprising an entrance area for the geological material and a first sensor station comprising at least one sensor for determining a property of the geological material. It further comprises a first sorting station for sorting the geological material as well as an exit area where the geological material leaves the beneficiation arrangement. The beneficiation system further comprises a conveying system for transportation of the geological material. The conveying system extends between the entrance area and the exit area and the first sensor station is arranged along this conveying system, downstream of the entrance area. Further, the first sorting station is also arranged along the conveying system downstream of the first sensor station and the operation of the first sorting station is based on information retrieved by the first sensor station. This arrangement has the advantage that the sensor station can be used to obtain relevant parameters about the geological material, such as metal ore, and the data obtained at the sensor station is then used to control the downstream sorting station where the geological material can for example be sorted into one stream of more valuable material, which can be forwarded to further treatment and one stream of less valuable material which can be transported for disposal.

In accordance with an embodiment of the beneficiation arrangement, the entrance area comprises a separation arrangement for dividing the geological material in a plurality of material flows before reaching the conveying system. This has the advantage that each part-flow can be treated optimally in the beneficiation arrangement.

In accordance with an embodiment of the beneficiation arrangement, the conveying system comprises separate tracks for each of the material

flows. By providing separate tracks it is possible to convey and sort the material in parallel flows.

In accordance with an embodiment of the beneficiation arrangement, a track bypasses the first sensor station and the first sorting station. Sometimes, if other, previous pre-concentration means have been sufficiently successful, it is possible to guide a part of the geological material past the sensor station and sorting station and directly to subsequent treatment facilities, such as a downstream comminution line. The purpose of beneficiation is to only treat those parts of the flow of geological material that requires treatment. Usually, what is meant by treatment in this field is comminution but if a parts of the material has already been determined to have a sufficient grade, there is no point in having it pass the sensors and sorting station. This would only consume beneficiation capacity that could be better used for other parts of the flow, or you could even argue that it would cause increased energy needed with no benefit.

In accordance with an embodiment of the beneficiation arrangement, the plurality of material flows are divided by means of a screening arrangement dividing the flow of materials based on particle size. This has a number of advantages. Often, particle size post blasting can be used to estimate grade. As discussed in US-2014/0144342, the teachings and content of which is incorporated by reference herein, more valuable parts of the ore body will have finer fraction whereas less valuable, barren material, gangue, will break into coarser fractions. One possibility is for example to have the finest particles, or particles in a finer range, bypass the sensor station and sorting station and continue directly to further comminution.

In accordance with an embodiment of the beneficiation arrangement, the first sensor station comprises a plurality of sensors. By using multiple sensors, measurement accuracy can be improved.

In accordance with an embodiment of the beneficiation arrangement, the plurality of sensors comprises different sensor types. By measuring different properties of the geological material, measurement accuracy can be further improved and the sorting station can be fed with information of higher
5 quality.

In accordance with an embodiment of the beneficiation arrangement, the plurality of sensors comprises sensor types selected from a group comprising but not limited to: laser sensor; camera; color sensor; photometric
10 sensor; magnetic resonance sensor; radiometric sensor; near-infrared sensor; Lidar; Radar; x-ray; gamma ray spectrometers; weight sensor. These are all applicable and the type of sensors could be selected depending on which geological material is to be evaluated. Different sensors have different benefits in the evaluation process, some measure based on outside
15 parameters, like laser scanner and cameras, some screen the internal parameters, like x-ray sensors.

In accordance with an embodiment of the beneficiation arrangement, at least a first sensor of a first type and a second sensor of a second type are
20 arranged in series within the first sensor station.

In accordance with an embodiment of the beneficiation arrangement, a plurality of sensors is arranged in series within the first sensor station, in particular 2-10 sensors, more particularly 2-7 sensors, even more particularly
25 3-6 sensors.

In accordance with an embodiment of the beneficiation arrangement, a first sensor is arranged upstream of a second sensor and wherein the second sensor is activated depending on information retrieved by the first sensor.
30 This has several advantages. The application of sensors will always imply certain power requirements. By arranging the sensors in way that the

outcome of a first, upstream sensor is used to determine if a second, downstream sensor should be applied at all and if so, to what extent it must be used. If the first sensor can determine with a probability that exceeds a given threshold value that a particle of geological material has a certain
5 property, for example that it is of no value, then any downstream sensors need not to be applied and thereby energy requirements is reduced and available computational capacity can be used for better purposes.

In accordance with an embodiment of the beneficiation arrangement,
10 the sensors are serially arranged in an upstream-downstream arrangement and wherein a downstream sensor is activated depending on information retrieved by one or more of upstream sensor/s.

In accordance with an embodiment of the beneficiation arrangement,
15 the sensors comprise sensors of different types.

In accordance with an embodiment of the beneficiation arrangement, at least two of the sensors are arranged in parallel with each other. In some situations, it can be advantageous to have two or more sensors perform their
20 measurements simultaneously, for example to enhance measurement accuracy.

In accordance with an embodiment of the beneficiation arrangement, the at least two sensors arranged in parallel with each other are arranged in
25 series with at least one further sensor.

In accordance with an embodiment of the beneficiation arrangement, the output data of the sensors is arranged to be combined in a fusion process. Each of the sensors used has certain advantages and
30 disadvantages. The aim of sensor fusion is to use the advantages of the individual sensor to precisely understand the environment.

In accordance with an embodiment of the beneficiation arrangement, the fusion process is done as direct fusion.

5 In accordance with an embodiment of the beneficiation arrangement, the direct fusion is done by using sensor data from heterogeneous and/or homogeneous sensors and/or soft sensors and/or history values of sensor data.

10 In accordance with an embodiment of the beneficiation arrangement, the fusion process is done as indirect fusion.

15 In accordance with an embodiment of the beneficiation arrangement, the indirect fusion is done using previous knowledge about the environment and/or human input.

In accordance with an embodiment of the beneficiation arrangement, the fusion process is done as a combination of direct fusion and indirect fusion.

20 In accordance with an embodiment of the beneficiation arrangement, the fusion process is done in a centralized manner. In this embodiment, the sensors forward their output data to a central computational unit which takes care of the correlating and fusing of the data as well as any decision making based on the outcome.

25

In accordance with an embodiment of the beneficiation arrangement, the fusion process is done in a decentralized manner. In this embodiment, the sensors do not simply forward their output data to a central computational unit. Instead, each or at least some of the units handle correlation and fusing themselves and has a certain amount of autonomy when it comes to how the
30 outcome is used and what decisions to make based thereon.

In accordance with an embodiment of the beneficiation arrangement, some of the sensors are arranged in a competitive configuration. This can for example be used to detect sensors not working correctly. For example, a sensor station may comprise more than one sensor capable of determining the size of a particle of geological material, e.g. a laser scanner and a camera. It is then possible to have these two sensors work in a competitive configuration to see if they deliver comparable results. If not, error correction could be considered. It is thus not necessary or even required that the sensors work in a competitive configuration at all time.

10

In accordance with an embodiment of the beneficiation arrangement, at least some of the sensors are arranged in a complementary configuration. In a complementary configuration, a plurality of sensors supply different information about the same geological material. During continuous operation, this is often more energy efficient than the competitive configuration.

15

In accordance with an embodiment of the beneficiation arrangement, sensors are arranged in a manner such that less energy requiring sensors are arranged upstream of more energy requiring sensors.

20

In accordance with an embodiment of the beneficiation arrangement, a more energy requiring sensors is activated in dependence of information retrieved by a less energy requiring sensor. This arrangement makes considerable energy-saving possible. Some sensor types are extremely energy intensive, for example x-ray, and if those sensors should be applied to the entire flow of material, which can exceed 3500 tons per hour, sometimes more than 6000 tons per hour and in certain applications even more than 15000 tons per hour, enormous amounts of energy would be required. Thus, even if x-ray is a good way of improving measurement accuracy, the energy consumption makes it impossible to apply continuously. The present invention instead makes it possible to apply sensors with high energy consumptions

25
30

only in cases where previous, upstream and less energy intense sensors have not been able to establish the characteristics of a geological particle with a sufficiently high probability. Only when the data of previous sensors is not enough to determine if a particle is valuable or not, more energy intense
5 sensors, such as x-ray, should be applied. This brings about considerable energy savings while maintaining excellent measurement accuracy.

In accordance with an embodiment of the beneficiation arrangement, the first sorting station comprises at least one robot arranged to sort
10 geological material being transported by the conveying system.

In accordance with an embodiment of the beneficiation arrangement, the first sorting station comprises a group of robots.

15 In accordance with an embodiment of the beneficiation arrangement, the robots of the first sorting station comprise deflectors. Sometimes, deflectors are better suited to divert particles into the correct stream.

In accordance with an embodiment of the beneficiation arrangement,
20 the group of robots are arranged in an upstream-downstream arrangement along the track of the conveying system.

In accordance with an embodiment of the beneficiation arrangement, separate tracks of the conveying system comprise separate first sorting
25 stations. Since different tracks will convey geological material having different properties, e.g. particles of different size, it is advantageous to have separate robot sorting stations for each track. Smaller particles will probably require less powerful robots but instead speed is more relevant to be able to handle more particles per hour.

In accordance with an embodiment of the beneficiation arrangement, the at least one robot arranged to sort geological material comprises gripping means for picking and placing geological material.

- 5 In accordance with an embodiment of the beneficiation arrangement, the at least one robot arranged to sort geological material comprises vacuum suction means for picking and placing geological material.

- 10 In accordance with an embodiment of the beneficiation arrangement, the at least one robot arranged to sort geological material comprises pushing means for moving geological material during sorting thereof.

- 15 In accordance with an embodiment of the beneficiation arrangement, the entrance area comprises openings having pre-defined width and/or height.

- 20 In accordance with an embodiment of the beneficiation arrangement, the width and/or height of the openings are adapted to a particle size of the respective tracks such the particles can only pass through the openings one at the time. The information of the sensors will be much more reliable if they can perform their measurements on individual particles. The solution with openings having predetermined opening size will prevent particles of geological material from entering the conveying system in groups. Instead, the particles will enter one by one such that the system can differentiate
25 between the individual particles.

- 30 In accordance with an embodiment of the beneficiation arrangement, the conveying system comprises one or more conveyor belts per track. Conveyor belts are convenient way of transporting geological material, such as ore.

In accordance with an embodiment of the beneficiation arrangement, at least one of the tracks comprises more than one conveyor belt and wherein the conveyor belts are arranged to be operated at different speeds.

5 In accordance with an embodiment of the beneficiation arrangement, a conveyor belt of the tracks is operated at a speed exceeding the feed rate of geological material. This will ensure that the adjacent particles will become distanced from each other such that the system will be able to evaluate each particle individually. If the sensors are allowed to measure one particle at
10 them time, measurement accuracy will be greatly improved.

 In accordance with an embodiment of the beneficiation arrangement, the conveying system comprises one or more conveyor belts per track. Using two or more conveyor belts per track makes it possible to provide continuous
15 sorting of material. A first conveyor belt can for example transport the particles that have been considered valuable towards further comminution. A second conveyor belt can transport the particles that have been considered to have little or no value towards gangue dumps or similar.

20 In accordance with an embodiment of the beneficiation arrangement, a further sensor station and/or sorting station is arranged between the first sorting station and the exit area.

 In accordance with an embodiment of the beneficiation arrangement, a
25 further sensor station and a further sorting station are arranged between the first sorting station and the exit area.

 In accordance with an embodiment of the beneficiation arrangement, the beneficiation arrangement is arranged to use information retrieved by at
30 least the further sensor station for system optimization. The further sensor station can be used as quality assurance and can operate continuously as a

last stage sensor and sorting station or can be applied at regular intervals as a control stage to determine if the system with the first sensor station and first sorting station is operating as intended.

- 5 In accordance with an embodiment of the beneficiation arrangement, the information retrieved by at least the further sensor station is relayed back into the system for quality check purposes.

- 10 In accordance with an embodiment of the beneficiation arrangement, a control unit is provided. The control unit is arranged to obtain information from all other parts of the beneficiation arrangement and to process the information and send out instructions to the parts of the beneficiation arrangement based on that information.

- 15 According to a second aspect of the invention, there is provided a method for beneficiation of geological material, comprising the following steps:

- feeding the geological material through an entrance area;
- transporting the geological material from the entrance area to a
- 20 first sensor station comprising at least one sensor by means of a conveying system;
- determining a property of the geological material by means of the at least one sensor;
- transporting the geological material from the first sensor station
- 25 to a first sorting station by means of the conveying system;
- sorting the geological material; and
- transporting the geological material from the first sorting station to an exit area where the geological material leaves the beneficiation arrangement,
- 30 wherein the operation of the first sorting station is based on information retrieved by said first sensor station.

In accordance with an embodiment of the method, the method further comprises the step of separating the geological material in a plurality of material flows at or near the entrance area before reaching the conveying system.

5

In accordance with an embodiment of the method, the method further comprises the step of having at least one of the material flows bypassing the first sensor station and the first sorting station.

10

In accordance with an embodiment of the method, the method further comprises the step of using a screening arrangement for dividing the flows of materials based on particle size.

15

In accordance with an embodiment of the method, the method further comprises the step of applying a plurality of sensors in the first sensor station.

In accordance with an embodiment of the method, the method further comprises the step of applying different sensor types.

20

In accordance with an embodiment of the method, the method further comprises the step of selecting type of sensors from a group comprising: laser sensor; camera; color sensor; photometric sensor; magnetic resonance sensor; radiometric sensor; near-infrared sensor; Lidar; Radar; x-ray; weight sensor.

25

In accordance with an embodiment of the method, the method further comprises the step of arranging at least a first sensor of a first type and a second sensor of a second type in series within the first sensor station.

30

In accordance with an embodiment of the method, the method further comprises the step of arranging a plurality of sensors in series within the first

sensor station, in particular 2-10 sensors, more particularly 2-7 sensors, even more particularly 3-6 sensors.

In accordance with an embodiment of the method, the method further
5 comprises the step of arranging a first sensor upstream of a second sensor and such that the second sensor is activated depending on information retrieved by the first sensor.

In accordance with an embodiment of the method, the method further
10 comprises the step of arranging the sensors serially in an upstream-downstream arrangement and such that a downstream sensor is activated depending on information retrieved by one or more of upstream sensor/s.

In accordance with an embodiment of the method, the method further
15 comprises the step of applying sensors of different types.

In accordance with an embodiment of the method, the method further comprises the step of arranging at least two of the sensors in parallel with each other.
20

In accordance with an embodiment of the method, the method further comprises the step of arranging the at least two sensors arranged in parallel with each other in series with at least one further sensor.

25 In accordance with an embodiment of the method, the method further comprises the step of combining the output data of the sensors in a fusion process.

In accordance with an embodiment of the method, the method further
30 comprises the step of performing the fusion process in a centralized manner.

In accordance with an embodiment of the method, the method further comprises the step of performing the fusion process in a centralized manner.

5 In accordance with an embodiment of the method, the method further comprises the step of arranging at least some of the sensors in a competitive configuration.

In accordance with an embodiment of the method, the method further comprises the step of arranging at least some of the sensors in a
10 complementary configuration.

In accordance with an embodiment of the method, the method further comprises the step of arranging sensors in a manner such that less energy requiring sensors are arranged upstream of more energy requiring sensors.
15

In accordance with an embodiment of the method, the method further comprises the step of arranging sensors such that a more energy requiring sensor is activated in dependence of information retrieved by a less energy requiring sensor.
20

In accordance with an embodiment of the method, the method further comprises the step of arranging at least one robot arranged to sort geological material being transported by the conveying system at the first sorting station.

25 In accordance with an embodiment of the method, the method further comprises the step of arranging a group of robots at the first sorting station.

In accordance with an embodiment of the method, the method further comprises the step of arranging the group of robots in an upstream-
30 downstream arrangement along the track of the conveying system.

In accordance with an embodiment of the method, the method further comprises the step of arranging separate first sorting stations at the separate tracks of the conveying system.

- 5 In accordance with an embodiment of the method, the at least one robot arranged to sort geological material comprises gripping means for picking and placing geological material.

- 10 In accordance with an embodiment of the method, the at least one robot arranged to sort geological material comprises vacuum suction means for picking and placing geological material.

- 15 In accordance with an embodiment of the method, the at least one robot arranged to sort geological material comprises pushing means for moving geological material during sorting thereof.

In accordance with an embodiment of the method, the conveying system comprises separate tracks for each of the material flows

- 20 In accordance with an embodiment of the method, the entrance area comprises openings having pre-defined width and/or height.

- 25 In accordance with an embodiment of the method, the width and/or height of the openings are adapted to a particle size of the respective tracks such the particles can only pass through the openings one at the time.

In accordance with an embodiment of the method, the conveying system comprises one or more conveyor belts per track.

In accordance with an embodiment of the method, at least one of the tracks comprises more than one conveyor belt and wherein the conveyor belts are arranged to be operated at different speeds.

- 5 In accordance with an embodiment of the method, a conveyor belt of the tracks is operated at a speed exceeding the feed rate of geological material

- 10 In accordance with an embodiment of the method, a further sensor station and/or sorting station is arranged between the first sorting station and the exit area.

- 15 In accordance with an embodiment of the method, a further sensor station and a further sorting station are arranged between the first sorting station and the exit area.

- 20 In accordance with an embodiment of the method, the beneficiation arrangement is arranged to use information retrieved by at least the further sensor station for system optimization.

- In accordance with an embodiment of the method, the information retrieved by at least the further sensor station is relayed back into the system for quality check purposes

25 .

 Similarly, and correspondingly to the arrangement disclosed above, the embodiment of this method in accordance with this second aspect will provide substantial advantages over prior art solutions.

- 30 Other objectives, features and advantages of the present invention will appear from the following detailed disclosure, from the attached claims, as

well as from the drawings. It is noted that the invention relates to all possible combinations of features.

Generally, all terms used in the claims are to be interpreted according to their ordinary meaning in the technical field, unless explicitly defined
5 otherwise herein. All references to “a/an/the [element, device, component, means, step, etc.]” are to be interpreted openly as referring to at least one instance of said element, device, component, means, step, etc., unless explicitly stated otherwise.

As used herein, the term “comprising” and variations of that term are
10 not intended to exclude other additives, components, integers or steps.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be described in more detail and with reference to the appended drawings in which:

15 Fig. 1 shows a schematic structure of the beneficiation arrangement in accordance with a first embodiment of the invention.

DESCRIPTION OF EMBODIMENTS

The present invention will now be described more fully hereinafter with
20 reference to the accompanying drawings, in which exemplifying embodiments of the invention are shown. The present invention may, however, be embodied in many different forms and should not be construed as limited to the embodiments set forth herein; rather, these embodiments are provided for thoroughness and completeness, and to fully convey the scope of the
25 invention to the skilled addressee. Like reference characters refer to like elements throughout.

Referring now to figure 1, it can be seen that the beneficiation arrangement 100 may start with a feeding arrangement, such as a feeding
30 conveyor 10 which feeds geological material, such as ore or other geological material which may benefit from the invention. The feeding conveyor 10 may

obtain the material from an intermediate storage of material, directly from dump trucks or in any other suitable manner. The material is typically run of mine ore coming directly from blasting and no previous crushing or similar has yet been performed. However, to avoid damage to the equipment, some
5 type of size check is required. This could be done by using a so-called grizzly feeder. The feeding conveyor 10 may then, if necessary, transport the material to a primary crusher 20, such as a jaw crusher or gyratory crusher which reduces the particle size prior to further processing. Typically, a primary crusher reduces particle size to <250mm, often to a size between 100-
10 200mm. After the primary crusher 20, the material arrives at a screening arrangement 30 which splits the flow of material into for example three different material flows F1, F2 and F3. The difference between these material flows being the size of the particles. In one embodiment, F1 may comprise particles having a size between 150-250mm; F2 may comprise particles
15 having a size between 100-150mm and; F3 may comprise particles having a size between 75-100mm. However, it should be noted that these particle sizes are only exemplary and large variations may occur depending on the geological material to be treated, blasting methods and equipment used. Further, the invention is by no means limited to three flows of material. In
20 some situations, a single flow will suffice whereas in other cases more than three will be necessary. Further, in accordance with a further embodiment of the invention, an additional flow of material FG is provided. As discussed earlier, it is possible to use other pre-concentrations technologies in combination with the beneficiation arrangement of the invention. One
25 example is to use an optimized blasting method, as described in e.g. US2014/0144342, which will cause higher grade parts of the ore body to break into relatively fine fractions whereas parts of the ore body having lower grade will typically break into coarser fractions. This can be utilized such that the finest fractions will be extracted in the screening process at 30 and
30 immediately transported towards further comminution. If it is confirmed that the pre-concentration, for example by applying suitable blasting methods, is

successful, there is no need for this material to be further beneficiated, it can be fed directly into a comminution step. This saves energy consumption and/or makes it possible to increase throughput per hour. The flows of material F1, F2, F3 enters an entrance area 40. This entrance area 40
5 comprises three entrances 41, 42, 43, one for each material flow F1, F2, F3, each entrance being fed by a corresponding output from the screening arrangement 30. Each of these entrances 41, 42, 43 comprises an opening having a pre-defined width and/or height. The width and/or height of these openings are adapted to the particle size of the respective material flow F1,
10 F2, F3 such that the particles can only pass through the openings one at the time. This is advantageous in that it ensures that particles don't leave the entrances 41, 42, 43 lying on top of each other or in heaps. Instead they will leave the entrance area 40 and enter a respective first conveyor belt of the conveying system CS one by one. The openings of the entrances 41, 42, 43
15 can be provided in the form of comb-shaped elements, i.e. pipes or similar extending in a generally vertical plane keeping the particles laterally spaced apart. After leaving the entrance area 40, the particles will be transported by the conveying system CS comprising one track per flow of material F1, F2, F3. The conveying system CS typically comprises several conveyor belts, at
20 least one conveyor belt per track. The conveyor belts are preferably arranged to operate at a speed which is higher than the feeding rate through the respective entrances 41, 42, 43. This means that the particles will become laterally separated by the openings of the entrances 41, 42, 43 and longitudinally separated by means of the higher speed of the conveyor belt.
25 Together, these arrangements make sure that the particles are kept separated. In a next step, the particles enter the first sensor station 50, 51, 52. Note that in this embodiment, there are three first sensor stations 50, 51, 52. One for each flow of material F1, F2, F3, i.e. one for each particle size range. The first sensor stations 50, 51, 52 each comprises a number of
30 different sensors arranged to determine the content of the particles, i.e. to determine the amount of valuable material, such as iron, gold, copper, or

other material, present in each particle. The sensors are typically arranged in upstream-downstream arrangement and are arranged such that the application of a downstream sensor is made dependent on the outcome of one or more upstream sensors. It may be the case that some sensors are
5 very accurate when it comes to determining the content of a particle but will have substantial energy requirements. One such sensor type is x-ray sensors. X-ray can determine the content to a high degree and could, if used to every particle, deliver very reliable output. But the drawback is that it requires large amounts of electricity. Other sensors, such as laser scanners
10 or cameras are less energy intensive but also less reliable in some situations. In accordance with the present invention, sensors using less energy are applied first and if they can deliver results, with a pre-defined level of certainty, the use of downstream, more energy intensive sensors need not be used. For example, if an upstream, sensor, such as a laser scanner, can
15 establish that a given particle is comprises valuable material in an amount above a pre-defined limit and that this information is at a level of certainty above a given threshold, there is no need to apply downstream sensors, such as x-ray sensors. Thereby, energy can be saved. However, if upstream sensor/s are not capable to determine the amount of valuable material in a
20 particle, downstream sensors are applied one after the other until a decision can be made. It is, however, also possible to apply the sensors in more intricate manners. For example, if a first sensor determines that a particle seems to have a specific set of properties, it may, based on the outcome of previous measurements, be determined that this particle is best evaluated by
25 a specific sensor or specific set of sensors of the sensor station. For example, a sensor arranged at a most upstream position, i.e. closest to the entrance area 40, determines that a particle seems to have properties identical or at least similar to previously sensed particles which properties in the end were best determined by a specific sensor, such as an x-ray, or specific set of
30 sensors, the system can activate that or those sensors immediately and avoid using sensors that previously have proven to be unsuccessful. It should also

be noted in this respect, that the sensors applied in the sensor station need not all be actual, physical sensors. In addition, so-called soft sensors or virtual sensing means can be applied. These use information available from other measurements and process parameters to calculate an estimate of the

5 quantity of interest and may be used to provide feasible and economical alternatives to costly or impractical physical measurement instruments. The sensors can be arranged in a sensor fusion process. In accordance with one embodiment, direct fusion may be applied. Direct fusion is the fusion of data from a set of sensors, soft sensors, and history values of sensor data. In

10 accordance with one embodiment, indirect fusion may be applied which also uses information sources like a priori knowledge about the environment and also human input.

After leaving the first sensor station 50, 51, 52, the first conveyor belt of the

15 conveying system CS further transports the particles to first sorting stations 60, 61, 62 comprising one or more sorting robots. It is advantageous if these conveyor belts have a certain minimum length. This will give the system enough time to process the data obtained at the first sensor stations 50, 51, 52 and decide on what action is required. Based on the data from the

20 sensors, the system will send instructions to the first sorting stations 60, 61, 62. At or near these first sorting stations 60, 61, 62, the conveying system CS comprises an additional conveyor belt running in parallel with the first conveyor belt. The robots of the first sorting stations 60, 61, 62 will receive instructions to either leave a given particle on the first conveyor belt or to

25 move this particle to the additional conveyor belt. Each of the first and additional conveyor belts are assigned to either particles deemed valuable enough for further comminution or to particles which are deemed less valuable and which will therefore be transported to a gangue dump or similar. The different first sorting stations 60, 61, 62 each comprises one or more

30 robots capable of sorting particles of the sizes of the respective material flows F1, F2, F3. Thus, the robots of a first sorting station 60, 61, 62 may be

arranged to handle larger particles than the robots of another first sorting station 60, 61, 62. Generally, but not necessarily, the first sorting stations 60, 61, 62 handling particles of smaller sizes, must be able to handle larger number of particles per time unit than the first sorting stations 60, 61, 62
5 handling particles of larger sizes. The robots may work in accordance with principle of pick and place by lifting the particle using any of a gripping means; a vacuum means; a magnetic means or any other suitable means or they may work as a deflector, guiding, or knocking the particles to a correct position on the first or additional conveyor belt. By arranging a plurality of
10 robots in an upstream-downstream arrangement along the conveying system, the system can be dimensioned to handle high volumes of material. And since the invention allows the use of conveyor belts having also substantial lengths, there will be space enough for high number of robots arranged in series, one after the other. Obviously, robots can be arranged on both sides
15 of the conveyor belts as well.

After leaving the first sorting stations 60, 61, 62, the particles continue to move along the first or the additional conveyor belt, towards a second sensing and sorting station 70, 71, 72. This second sensing and sorting station 70, 71,
20 72 may comprise a sensor station having for example an x-ray sensor and a sorting station having a sorting robot. This second sensing and sorting arrangement may be in constant use evaluating the particles deemed to be of less value and if the system, based on the data from the second sensor station, indicates that a particle is indeed of interest for further comminution,
25 the second sorting station may move the particle back to the conveyor belt for valuable particles. The data obtained in this second sensing and sorting station 70, 71, 72 may be used for quality check of the first sensor stations 50, 51, 52 and first sorting stations 60, 61, 62 and the results may be looped back into the system such that function will improve over time. It is also
30 possible to use this second sensing and sorting station 70, 71, 72 in an intermittent manner, e.g. for regular quality checks or when processing

geological material where the system has little or no previous experience and where the knowledge needs to be gathered in order to run-in the system properly. It can also be applied when new types of sensors are applied in the first sensor stations 50, 51, 52 which need to be fine-tuned. When leaving the
5 second sensing and sorting station 70, 71, 72, the particles of less value are transported to a gangue dump or similar and the valuable particles are transported for further beneficiation and comminution.

A control unit 100 is arranged to receive information from all other parts
10 of the beneficiation arrangement, such as sensor data, robot sorting statistics, conveyor belt speed, feeding rate from primary crusher, flow ratio between the different material flow F1, F2, F3 etc. Based on this input, the control unit decides on which actions are to be taken, i.e. instructions to the robots of the sorting stations; required conveyor belts speeds; which sensors are to be
15 applied and in which order, etc.

The skilled person realizes that a number of modifications of the embodiments described herein are possible without departing from the scope of the invention, which is defined in the appended claims. For example, the
20 skilled person realizes that the arrangement may not necessarily be connected to a central control unit which processes all the information and takes all the decisions in a centralized manner. Instead, the parts of the arrangement, such as the sensors, may themselves be responsible for processing the information obtained thereby, or even by other parts of the
25 arrangement, and take actions for correlating and fusing the data and may have a certain autonomy in decision making in a decentralized manner. Combinations of the centralized and decentralized systems may also be applied.

CLAIMS

1. A beneficiation arrangement for use with geological material,
comprising an entrance area for the geological material, a first sensor
station comprising at least one sensor for determining a property of the
5 geological material, a first sorting station for sorting the geological
material and an exit area where the geological material leaves the
beneficiation arrangement, wherein the beneficiation system further
comprises a conveying system for transportation of the geological
material extending between the entrance area and the exit area,
10 wherein said first sensor station is arranged along said conveying
system downstream of said entrance area and wherein said first
sorting station is arranged along said conveying system downstream of
said first sensor station and further wherein the operation of said first
sorting station is based on information retrieved by said first sensor
15 station.
2. A beneficiation arrangement in accordance with claim 1, wherein the
entrance area comprises a separation arrangement for dividing the
geological material in a plurality of material flows before reaching the
20 conveying system.
3. A beneficiation arrangement in accordance with claim 2, wherein the
conveying system comprises separate tracks for each of the material
flows.
25
4. A beneficiation arrangement in accordance with claim 3, wherein a
track bypasses the first sensor station and the first sorting station.

5. A beneficiation arrangement in accordance with claim 2, wherein the plurality of material flows are divided by means of a screening arrangement dividing the flow of materials based on particle size.
- 5 6. A beneficiation arrangement in accordance with claim 2, wherein the plurality of material flows are divided based on the structure of the geological material.
- 10 7. A beneficiation arrangement in accordance with claim 1, wherein the first sensor station comprises a plurality of sensors.
8. A beneficiation arrangement in accordance with claim 7, wherein the plurality of sensors comprises different sensor types.
- 15 9. A beneficiation arrangement in accordance with claim 8, wherein the plurality of sensors comprises sensor types selected from a group comprising: laser sensor; camera; color sensor; photometric sensor; magnetic resonance sensor; radiometric sensor; near-infrared sensor; Lidar; Radar; x-ray; weight sensor.
- 20 10. A beneficiation arrangement in accordance with claim 7, wherein at least a first sensor of a first type and a second sensor of a second type are arranged in series within the first sensor station.
- 25 11. A beneficiation arrangement in accordance with claim 7, wherein a plurality of sensors is arranged in series within the first sensor station, in particular 2-10 sensors, more particularly 2-7 sensors, even more particularly 3-6 sensors.

12. A beneficiation arrangement in accordance with claim 7, wherein a first sensor is arranged upstream of a second sensor and wherein the second sensor is activated depending on information retrieved by the first sensor.
- 5
13. A beneficiation arrangement in accordance with claim 11, wherein the sensors are serially arranged in an upstream-downstream arrangement and wherein a downstream sensor is activated depending on information retrieved by one or more of upstream sensor/s.
- 10
14. A beneficiation arrangement in accordance with claim 11, wherein the sensors comprise sensors of different types.
- 15
15. A beneficiation arrangement in accordance with claim 7, wherein at least two of the sensors are arranged in parallel with each other.
- 20
16. A beneficiation arrangement in accordance with claim 15, wherein in the at least two sensors arranged in parallel with each other are arranged in series with at least one further sensor.
- 25
17. A beneficiation arrangement in accordance with claim 7, wherein the output data of the sensors is arranged to be combined in a fusion process.
- 30
18. A beneficiation arrangement in accordance with claim 17, wherein the fusion process is done in a centralized manner.
19. A beneficiation arrangement in accordance with claim 17, wherein the fusion process is done in a decentralized manner.

20. A beneficiation arrangement in accordance with claim 7, wherein some of the sensors are arranged in a competitive configuration.
- 5 21. A beneficiation arrangement in accordance with claim 7, wherein some of the sensors are arranged in a complementary configuration.
22. A beneficiation arrangement in accordance with claim 7, wherein sensors are arranged in a manner such that less energy requiring sensors are arranged upstream of more energy requiring sensors.
- 10 23. A beneficiation arrangement in accordance with claim 22, wherein a more energy requiring sensors is activated in dependence of information retrieved by a less energy requiring sensor.
- 15 24. A beneficiation arrangement in accordance with claim 1, wherein the first sorting station comprises at least one robot arranged to sort geological material being transported by the conveying system.
- 20 25. A beneficiation arrangement in accordance with claim 24, wherein the first sorting station comprises a group of robots.
26. A beneficiation arrangement in accordance with claim 25, wherein the group of robots are arranged in an upstream-downstream arrangement along the track of the conveying system.
- 25 27. A beneficiation arrangement in accordance with claim 24, wherein separate tracks of the conveying system comprise separate first sorting stations.

28. A beneficiation arrangement in accordance with claim 24, wherein the at least one robot arranged to sort geological material comprises gripping means for picking and placing geological material.
- 5 29. A beneficiation arrangement in accordance with claim 24, wherein the at least one robot arranged to sort geological material comprises vacuum suction means for picking and placing geological material.
- 10 30. A beneficiation arrangement in accordance with claim 24, wherein the at least one robot arranged to sort geological material comprises pushing means for moving geological material during sorting thereof.
- 15 31. A beneficiation arrangement in accordance with claim 3, wherein the entrance area comprises openings having pre-defined width and/or height.
- 20 32. A beneficiation arrangement in accordance with claim 3, wherein the width and/or height of the openings are adapted to a particle size of the respective tracks such the particles can only pass through the openings one at the time.
33. A beneficiation arrangement in accordance with claim 3, wherein the conveying system comprises one or more conveyor belts per track.
- 25 34. A beneficiation arrangement in accordance with claim 33, wherein at least one of the tracks comprises more than one conveyor belt and wherein the conveyor belts are arranged to be operated at different speeds.

35. A beneficiation arrangement in accordance with claim 33, wherein the conveying system comprises one or more conveyor belts per track.
- 5 36. A beneficiation arrangement in accordance with claim 1, wherein a further sensor station and/or sorting station is arranged between the first sorting station and the exit area.
- 10 37. A beneficiation arrangement in accordance with claim 1, wherein a further sensor station and a further sorting station are arranged between the first sorting station and the exit area and wherein the beneficiation arrangement is arranged to use information retrieved by at least the further sensor station for system optimization.
- 15 38. A beneficiation arrangement in accordance with claim 37, wherein the information retrieved by at least the further sensor station is relayed back into the system for quality check purposes.
- 20 39. A beneficiation arrangement in accordance with claim 1, wherein a control unit is provided for receiving information from at least the first sensor station.
40. Method for beneficiation of geological material, comprising the following steps:
- 25 - feeding the geological material through an entrance area;
- transporting the geological material from the entrance area to a first sensor station comprising at least one sensor by means of a conveying system;
- 30 - determining a property of the geological material by means of said at least one sensor;

- transporting the geological material from the first sensor station to a first sorting station by means of the conveying system;
 - sorting the geological material; and
 - transporting the geological material from the first sorting station to an exit area where the geological material leaves the beneficiation arrangement,
- 5
- wherein the operation of said first sorting station is based on information retrieved by said first sensor station.

10 41. Use of a beneficiation arrangement in accordance with any of claims 1 to 39.

1/1

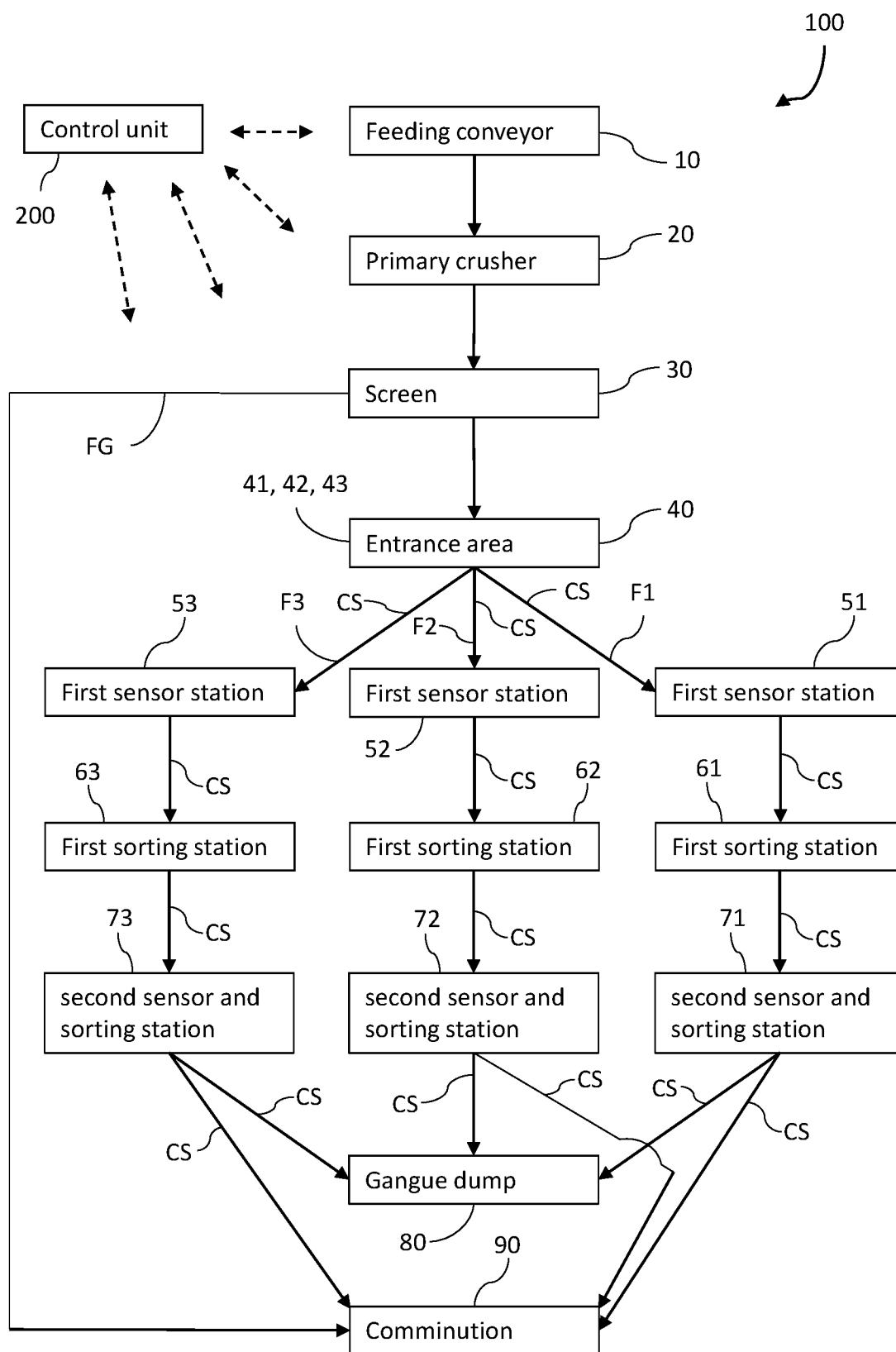


Fig. 1

INTERNATIONAL SEARCH REPORT

International application No.
PCT/EP2020/070995

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

1-6, 31-35, 40, 41

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2020/070995

A. CLASSIFICATION OF SUBJECT MATTER INV. B07C5/342 B07C5/344 B07C5/346 ADD.		
According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) B07C		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) EPO-Internal, WPI Data		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2013/292307 A1 (BAMBER ANDREW SHERLIKER [CA] ET AL) 7 November 2013 (2013-11-07) figures	1-6, 31-35, 40,41
X	US 2016/016203 A1 (BAMBER ANDREW SHERLIKER [CA] ET AL) 21 January 2016 (2016-01-21) figures	1-3
☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.		
* Special categories of cited documents : "A" document defining the general state of the art which is not considered to be of particular relevance "E" earlier application or patent but published on or after the international filing date "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified) "O" document referring to an oral disclosure, use, exhibition or other means "P" document published prior to the international filing date but later than the priority date claimed "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art "&" document member of the same patent family		
Date of the actual completion of the international search 24 September 2020		Date of mailing of the international search report 30/11/2020
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016		Authorized officer Wich, Roland

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2020/070995

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2013292307	A1	07-11-2013	
		AU 2013255051 A1	13-11-2014
		AU 2016216528 A1	08-09-2016
		AU 2018203576 A1	14-06-2018
		CA 2871632 A1	07-11-2013
		CL 2014002925 A1	10-07-2015
		DK 2844403 T3	17-09-2018
		EP 2844403 A1	11-03-2015
		EP 3369488 A1	05-09-2018
		PL 2844403 T3	31-01-2019
		US 2013292307 A1	07-11-2013
		US 2016193630 A1	07-07-2016
		US 2019134671 A1	09-05-2019
		WO 2013163759 A1	07-11-2013

US 2016016203	A1	21-01-2016	
		AU 2015292228 A1	02-02-2017
		AU 2018204838 A1	26-07-2018
		AU 2020202849 A1	21-05-2020
		CA 2955636 A1	28-01-2016
		CL 2017000150 A1	11-08-2017
		CN 106999989 A	01-08-2017
		CN 110090812 A	06-08-2019
		EP 3171989 A1	31-05-2017
		US 2016016203 A1	21-01-2016
		US 2019001374 A1	03-01-2019
		US 2020139406 A1	07-05-2020
		WO 2016011551 A1	28-01-2016

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-6, 31-35, 40, 41

Separation

2. claims: 7-23, 38(completely); 36, 37(partially)

Sensors

3. claims: 24-30(completely); 36, 37(partially)

Robot, sorting arrangement

4. claim: 39

Control unit
