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(54) **AUTOMATIC MATERIAL RECOGNITION SYSTEM**

(57) The present invention relates to an automatic recognition system (1) of materials (2) by tonal shock. It was exemplified and described applying it to the case of municipal solid waste (2). In this case, the system (1) is substantially provided with automatic recognition means of the waste (2) and an architecture (M), and also includes a reception device (5) of the acoustic waves (W_1), a detected data acquisition, processing and transfer device (19) provided with a computing card (20), within a microprocessor or microcontroller (27), and with a memory card (21) for periodically recording the selected waste in a database (22); a plurality of separation means (7, 9, 11) of the waste (2) itself, thus recognized (13, 14, 15), sorted, weighed, and stored in appropriately sized container means (23, 24, 25); energy consumption abatement means (26) to switch off the calculating card (20) of the microprocessor (27) through dedicated software when it is not in use.

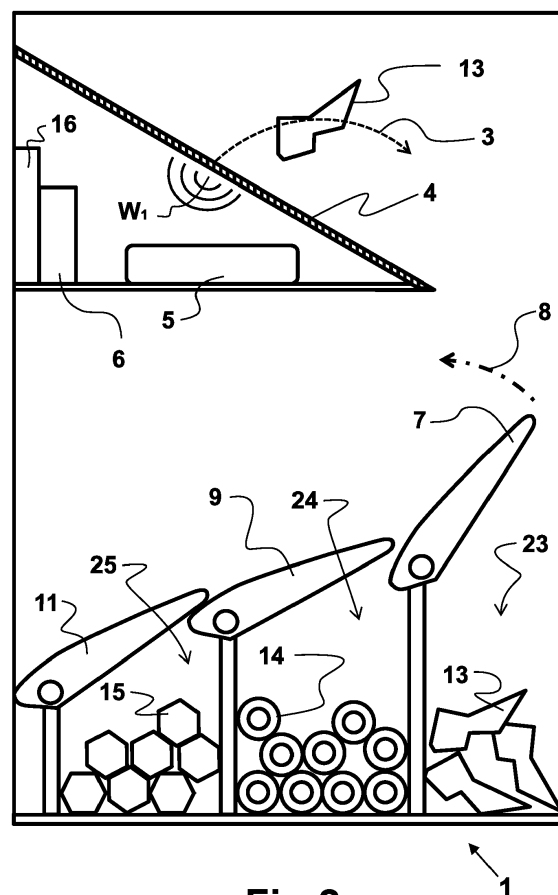


Fig.2

Description

[0001] The present invention relates to an automatic system for material recognition through tonal shock.

[0002] The present automatic material recognition system is entirely innovative and inventive because it emerges as an original technical solution to solve the problems which currently exist in the case illustrated by way of example related to the automatic recognition and separation of municipal solid waste, thereby minimizing the manufacturing and management costs of the automatic recognition systems themselves but which can be used equivalently and validly for the recognition of any material in general.

[0003] In the present description, reference will be made to a particular example of application related to municipal solid waste.

[0004] Various systems are known to date for the automatic recognition and separation of municipal solid waste, especially of the optical recognition type, through cameras or other electronic-computerized devices and the like.

[0005] To date, the systems adapted to automatically recognize and separate municipal solid waste provided with electronic-computerized devices have substantially displayed the following obvious disadvantages:

- a limited and low memory usage, usually correlated with the problem of not being able to offer anything other than small available spaces for their implementation;
- high and excessive energy consumption, which does not allow, even when necessary, powering the entire automatic waste recognition and separation system with simple batteries or in any case minimizing electricity consumption.

[0006] Therefore, it is the object of the present system to solve said problems and disadvantages of the prior art by designing and manufacturing an innovative automatic system for material recognition through tonal shock, in particular, in the example described below, for the recognition and separation of municipal solid waste.

[0007] It is a further object of the present system to use devices and components which have a minimized cost and a zero environmental impact index, and which are also possibly completely recyclable, the construction and functional features being the same.

[0008] Such objects are achieved by implementing an automatic system for material recognition through tonal shock, as claimed at the end of the present description and described below.

[0009] Such objects and the consequent advantages, as well as the features of the invention according to the present invention, will be more apparent from the following detailed description of a preferred solution, given by way of non-limiting example with reference to the accompanying drawings, in which:

➤ Fig. 1 is a two-dimensional, section view drawing of a first preferred but not limiting embodiment of an automatic material recognition system 1 through tonal shock, of material such as municipal solid waste 2, according to the present invention, from which the particular and innovative configuration of the system 1 itself can be inferred, which system substantially consists of a drum 4, of elastic type, adapted to emit a characteristic sound wave W_1 , when it is struck by a dropped piece of a waste 2 to be recognized, with said specific subscript "i" correlated with the particular type of waste to be recognized and separated, all through reception means 5 of the sound wave W_i , processing means 6 of the acoustic signal and automation means 16 of the movable elements (7, 9, 11), the latter being adapted to separate glass 13 from aluminum 14 and plastic 15, respectively, in the preferred but not limiting example shown;

➤ Fig. 2 is the same drawing as the automatic recognition system 1 of municipal solid waste 2 in Fig. 1, in which it is now possible to infer the drop point onto said drum 4 of the waste 2, which is instantly recognized as glass 13, with its rebound on the drum 4 itself along the drop trajectory 3 and the emission of a specific sound wave W_1 , activating said reception means 5, processing means 6 and automation means 16 of the corresponding movable element 7 to the container compartment 23 for glass 13, respectively;

➤ Fig. 3 is the same drawing as the automatic recognition system 1 of municipal solid waste 2 referred to in the preceding figures 1 and 2, in which it is now possible to infer the drop of the glass waste 13, previously recognized by the system 1, towards the container compartment 23 for glass 13, now accessible due to the complete opening of the movable element 7 which closed it;

Fig. 4 is a two-dimensional, section view showing a second preferred but not limiting embodiment of an automatic recognition system 1 of municipal solid waste 2 according to the present invention, from which the behavior of the system 1 itself can be inferred, if said drum 4 is struck by a piece of waste 2 different from the previous piece of waste recognized as glass 13, also to be recognized and separated;

Fig. 5 is the same drawing as the automatic recognition system 1 of municipal solid waste 2 in Fig. 4, in which it is now possible to infer the drop point onto said drum 4 of the waste 2, which is now instantly recognized as aluminum 14, with its rebound on the drum 4 itself along the drop trajectory 3 and the emission of a specific sound wave W_2 , activating said reception means 5, processing means 6 and automation means 16 of the corresponding movable element 9 to the container compartment 24 for alumi-

num 14, respectively;

Fig.6 is the same drawing as the automatic recognition system 1 of municipal solid waste 2 referred to in the preceding figures 4 and 5, in which it is now possible to infer the drop of the aluminum waste 14, previously recognized by the system 1, towards the container compartment 24 for aluminum 14, now accessible due to the complete opening of the movable element 9 which closed it;

Fig. 7 is a two-dimensional, section view showing a third preferred but not limiting embodiment of an automatic recognition system 1 of municipal solid waste 2 according to the present invention, from which the behavior of the system 1 itself can be inferred, if said drum 4 is struck by a piece of waste 2 different from the previous piece of waste recognized as glass 13 and aluminum 14, also to be recognized and separated;

Fig.8 is the same drawing as the automatic recognition system 1 of municipal solid waste 2 in Fig.7, in which it is now possible to infer the drop point onto said drum 4 of the waste 2, which is now instantly recognized as plastic material or plastic 15, with its rebound on the drum 4 itself along the drop trajectory 3 and the emission of a specific sound wave W_3 , activating said reception means 5, processing means 6 and automation means 16 of the corresponding movable element 11 to the container compartment 25 for plastic 15, respectively;

Fig. 9 is the same drawing as the automatic recognition system 1 of municipal solid waste 2 referred to in the preceding figures 7 and 8, in which it is now possible to infer the drop of the plastic waste 15, previously recognized by the system 1, towards the container compartment 25 for plastic 15, now accessible due to the complete opening of the movable element 11 that closed it;

Fig. 10 is a drawing illustrating the preferred architecture of the acquisition, processing and energy saving means M, in particular consisting in the preferred example, shown by way of non-limiting example by an acquisition device 19 of the detected input data of the selected waste 2, by means of a microphone 18 and a timer device 17, and interfaced with a computing card 20, with the latter connected, in turn, to a memory card 21, storing data 22 relating to the classification and collection of the waste 2, and additional saving energy means 26;

Fig.11 is a drawing showing the collected data reception and processing electronic circuit L, consisting of a microcontroller 27, a reader 28 and a receiver device 5 of the sound wave W_i (in this example with the subscript $i=1, 2$ and 3, relating to the three examined pieces of waste 2, i.e.: glass bottles 13 with the "glass bottle" rhombus symbol; aluminum cans 14 with the "aluminum can" circle symbol; and plastic bottles 15 with the "plastic bottle" four-pointed star symbol);

Fig.12 is a drawing showing the Fourier transforms at an assigned lambda wavelength (in the example, lambda equal to 0.1), the latter correlated with the particular feature of the shock wave $W_{i<\dots}$, said transform showing the level of the input signal power to the system 1 on the abscissa and the carrier peak frequency or most significant frequency level on the ordinate, to optimize the identification, selection and collection of individual pieces of waste 2;

Fig.13 is a block chart illustrating a first possible flow-chart F1 related to the operation of the management and control software of the designed system 1;

Fig.14 is another block chart illustrating a second possible flowchart F2 related to the operation of the management and control software of the designed system 1;

Fig.15 is a further block chart illustrating a third possible flowchart F3 related to the operation of the management and control software of the designed system 1.

[0010] As can be seen from the fifteen appended figures, which show a preferred but non-limiting solution of the present invention, the automatic recognition system 1 of municipal solid waste 2 firstly solves said problems still existing in the sector today, because we have devised an innovative and inventive automatic recognition means of waste 2, assisted by a timer device 17 and by an architecture M as well as:

- a reception device 5 of sound waves W_i , e.g. a microphone 18 possibly of passive type or another reception device 5 of the sound wave W_i (with index $i = 1, \dots, n$) emitted by yet another generic piece of waste 2 in the act of its dropping impact on a drum 4;
- a detected data acquisition, processing and transfer device 19 provided with a calculating card 20 within a microprocessor or microcontroller 27 (a microprocessor of the "Arduino Mega 2560 R3" type was adopted in the prototype made by way of non-limiting example only) and a memory card 21 for periodically recording the selected waste in a database 22;
- a plurality of separation means (7, 9, 11) of the waste 2 itself, thus recognized (13, 14, 15), sorted, weighed, and stored in appropriately sized container means (23, 24, 25);
- energy consumption abatement means 26 of the entire system (1), adapted to shut down the calculating card 20 of the microprocessor 27 when it is not in use, together with the necessary means for restarting the system 1 which restarts the system 1 only when necessary;
- and a storage device or memory card 21, adapted to store the information necessary for the classification of the progressively sorted quantities of municipal solid waste 2.

[0011] Said automatic recognition means of the waste

2, thus designed, is adapted to recognize the elastic shock sound wave W_i generated by every single piece of waste 2, when the latter interacts with the drum 4, through said acoustic sensor 5 and an automatic management program of the plurality of separation means (7, 9, 11) of the waste 2 itself.

[0012] Said identification means, according to an illustrative but non-limiting aspect of the invention, shown by example in Figures 1-9, consist of movable elements (7, 9, 11), hinged at one end and rotating about it in so that the other free end can describe a curvilinear trajectory (8, 10, 12) adapted to correspondingly allow the opening of the container underneath (23, 24, 25), corresponding to the waste identified (13, 14, 15) and thus selected.

[0013] According to another aspect of the invention, said microphone 18, in particular, is replaceable by any other acoustic type sensor 5, provided that the latter is validly supported by an automatic management program of a plurality of separation means (7, 9, 11) of the waste 2 itself thus correspondingly recognized (13, 14, 15), selected and weighed by the system 1 itself.

[0014] Said reception device 5 of the acoustic waves W_i is, therefore, in a preferred but non-limiting solution, a microphone 18, provided with an acoustic processor connected either remotely or not to a microprocessor 27, the latter in turn instantaneously activating the corresponding movable element (7, 9, 11) of the respective container (23, 24, 25) upon recognition of the particular selected waste (13, 14, 15), through an automation device 16.

[0015] A system 1 thus made is designed so that, after having been started and having checked that each of its components is working, it can enter a dormant state, waiting for specific input from the user. Such an input consists of closing a switch, which thus sends a low signal to one of the pins of the calculating card 20, indicating that the next acquisition is on its way. A threshold, at this point, is processed based on the average " W_i " signal and, as soon as it is exceeded, this indicates to the software that an object 2 has just struck the drum 4 used for the acquisition. The signal is recorded at this point with a sampling frequency of 3,333 Hz. This choice is coherent with a previous analysis of the sound frequencies related to the impacts, which are in any case lower than 1,800 Hz, and therefore which can be correctly or almost correctly analyzed through such a sampling rapidity. Sample after sample, the signal is saved in on a micro-SD card 21 in a text file in "csv" (comma-separated value) format. Such a file, once the acquisitions have been completed, is used through a script in "R" language for analysis to extract the features and thresholds to be used in the final classifier.

[0016] When input into the classification software, the data are cleaned, removing any failed acquisitions and corrupted data, to obtain a sample which is as true to reality as possible. It is worth noting that the need to do this also indicates the need to improve the robustness of the acquisition system to prevent similar phenomena

from occurring with the data to be classified, once the classifier thresholds have been established (Figure 12).

[0017] In the preferred but non-limiting example, shown in the diagram in Fig.12, reference was made to only three typical materials present in municipal solid waste 2 (glass 13, aluminum 14 and plastic 15) and the typical characteristic shock waves (W_1 , W_2 , W_3 , respectively), emitted on drum 4, when they are dropped onto the latter.

[0018] The features are extracted at this point. The latter are analyzed using simple linear regression, using the strategy known as "One Vs All", to establish the probability that the concerned object belongs to each type of material considered. This stratagem is appropriate to the intrinsic capabilities of system 1 because it allow establishing, in relation to its performance in terms of memory and computational power, the levels of potentiality and reliability of the system 1 itself, thus generating a model which must be simply acquired by default in the specifically designed system to allow a quick classification of the input signal, related to the particular types of waste 2 to be selected.

[0019] According to an aspect of the invention, the present system 1, fundamentally designed for the automatic recognition and separation of municipal solid waste 2 could very well be applied in other areas, such as, for example, but not limited to, the recognition and separation of waste in the agriculture field or other specific sectors of special industrial waste.

[0020] Said features considered in particular with this system 1 are:

- signal power;
- the most significant carrier frequency (excluding the first);
- the product of bandwidth and carrier power;
- the signal damping rate, obtained by an approximation averaging the ratios of the various signal samples, grouped in bins.

[0021] The frequencies are acquired by applying the "Welch Method" (Fig.12), a procedure which acquires overlapping signal windows and applies the Fourier transform (in our case, with "fft" algorithm) along the whole signal, adding the results together, which results in a lower frequency resolution but in a spectrum which is more readable and easier to analyze for the learning system.

[0022] Each of said frequencies is calculated on a signal which shows only the first impact of the object on the drum 4, the average of which is then reduced to zero. The following combinations of features have been tested for achieving the case illustrated by way of non-limiting example of the present system 1:

- The combination of signal power and the most significant carrier frequency, which gives a classification accuracy of about 97%, with a lambda adjust-

ment of 0.1 (Fig.12);

- The combination of signal power and the product of bandwidth and carrier power, which gives an accuracy of about 94%, with a lambda adjustment of 0.2;
- The combination of signal power and signal damping speed, which gives an accuracy of about 96%, with a lambda adjustment of 0.1.

[0023] For each combination, the lambda adjustment is calculated empirically, making various tests for its various values. In any case, it is worth noting that the adjustment process is essential to prevent the addition of polynomial features to the system, in order to model decision-making boundaries with greater freedom and avoid overfitting phenomena, which can cause an excessive adaptation to the training sample.

[0024] The features are coupled to prevent the explosion of the number of polynomial features (and therefore of thresholds to be stored), which is substantially due to the high number of combinations of polynomial features which would already be created, in general, with just one tuple of features.

[0025] Instead, by attempting to combine a trio of features and accepting the trade-off of slightly reducing the number of polynomial features (i.e. reducing the degree of the polynomial) input into the learning system, one goes from a sixth-degree polynomial to a fourth-degree polynomial. The experimental results in the case illustrated by way of non-limiting example of the present system 1 are:

- the triple combination of signal power, most significant carrier frequency and signal damping speed, which give an accuracy of about 97%, with a lambda adjustment of 0.1;
- the triple combination of signal power, most significant carrier frequency and the product of bandwidth and carrier power, which give an accuracy of about 92%, with a lambda adjustment of 0.1.

[0026] The preferred architecture of the acquisition, processing and energy saving means M for the system 1 (Fig.10) consists by way of non-limiting example in: a detected input data acquisition device 19 of the selected waste 2, by means of a microphone 18 and a timer device 17; the data acquisition device 19 is also interfaced with a computing card 20, with the latter, in turn, connected to a memory card 21, storing the data 22 relating to the classification and collection of the waste 2, and further saving energy means 26.

[0027] The reception and processing electronic circuit L of the collected data (Fig.11) in the preferred example of the system 1 (Fig.10), by way of non-limiting example only substantially consists of a microcontroller 27, a reader 28 and an acoustic sensor 5 (i.e. a microphone 18), operating as described and illustrated above.

[0028] A first possible flow chart F1 is shown in Fig.13: This relates to the operation of the management and con-

trol software of the designed system 1 and is characterized precisely for the step of sending to sleep 30 of the system 1 started after the step of starting or start S and setting-up 29 of the system, with the following step of querying 31 on the wake-up signal, which is repeated in case of negative response. If the latter is confirmed, the actual step of waking-up 32 starts, with the subsequent step of checking of the input signal 33 (which step is repeated in case of negative response), which followed, in the affirmative case, by the step of sampling 34 of the waste 2, which is thus determined and selected by the automatic recognition means using the microprocessor 27. At the affirmative response to the new query of the successive step of signal ended 35, the system 1 returns to the step of sending to sleep 30, thus repeating the mentioned cycle; otherwise, in case of negative response, the system goes to the step of querying 36 of the actual completion of the waste sampling period and, in the affirmative case, repeats a new step of sampling 34; otherwise, it repeats the step of querying 36 again, with saving to SD card 37.

[0029] A second possible flow chart F2 is shown in Fig.14: This differs from the previous one F1 for the step of setting-up and threshold reading 38 which is input (IN) to the system 1, as well as the steps after sampling 34, i.e. the step of signal power extracting 39, the subsequent step of converting in the frequency domain 40 with the Welch method, the following step of peak frequency extracting 41, with the further steps of normalizing 42 and data re-processing 43, the successive step of regularized logistic regression 44, with the successive outputting of the classification label (OUT) before the said characterizing step of sending to sleep 30 of the system 1 itself.

[0030] A third possible and final flow chart F3 is shown in Fig.15: This differs from the previous ones F1 and F2 for the step present immediately after the step of data setting-up 29, related to data acquisition 46 (signal power), which is very similar, however, to the previous step of signal power extracting 39, as well as the step of saving the normalization coefficients 47 of the output data (OUT) and the steps of saving of the output (OUT) threshold values 48 and of respective validating 49, with the following end of process signal E.

[0031] Advantageously according to the invention, the system 1 may be made to allow any sorting, recognition, and selection of a great plurality of types of waste, because it can be applied to any type of waste, even special types.

[0032] The advantages provided by this system are apparent because the system solves all said problems of the prior art providing the following obvious advantages:

- where necessary, even a limited and minimized use of memory, fully solving the problem usually related to the impossibility of having nothing else but small spaces available for its implementation;
- low levels of electrical power necessary for the op-

eration of the system and related minimized energy consumption, fully solving the problem usually related to the need for high power supplies, even allowing, if necessary, to power the entire system with batteries charged, in turn, by photovoltaic systems or, in any case, without negative impacts due to high consumption of electricity, which would partially affect the benefits obtained from the application of the same automatic system of recognition of municipal solid waste referred to in this invention.

[0033] The further advantages provided by this system are capable to be found in that it is also applicable to other types of automatic material recognition and separation systems, in general.

[0034] The additional, no less important advantages are the low manufacturing and installation costs of this system, as well as its ease of installation for both small and large installations.

[0035] It is also apparent that many adjustments, adaptations, additions, variants and replacements of elements with others which are functionally equivalent can be made to the exemplary embodiment described above by way of non-limiting example, without however departing from the scope of protection of the following claims.

KEY

[0036]

1. Automatic material recognition system (by way of example only, for municipal solid waste)
2. Municipal solid waste or other materials in general to be recognized
3. Trajectory of the solid waste 2 drop onto the drum 4
4. Drum or means adapted to emit a characteristic shock wave W_i following the impact of a piece of solid waste 2 onto it
5. Device for receiving the sound wave W_i emitted by the drum
6. Received data processing device
7. Movable element of the first container, e.g. glass
8. Opening angle of the movable element 7
9. Movable element of the second container, e.g. aluminum
10. Opening angle of the movable element 9
11. Movable element of the third container, e.g. plastic
12. Opening angle of the movable element 11
13. Glass
14. Aluminum
15. Plastic
16. Automation device for movable elements 7, 9 and 11
17. Timer device
18. Microphone
19. Data acquisition and transfer device

20. Calculating device or spreadsheet
21. Storage device or memory card
22. Received database related to waste classification and collection 2
23. Glass container means
24. Aluminum container means
25. Plastic container means
26. Energy consumption abatement means
27. Microprocessor or microcontroller
28. Micro-SD card reader
29. Step of setting-up of the system 1 in flowchart F
30. Step of sending to sleep of the system 1
31. Step of querying through wake-up signal
32. Step of waking-up of the system 1
33. Step of querying by the input signal to start sampling
34. Step of sampling of the system 1
35. Step of signal ended querying
36. Step of querying of the sampling period completion
37. Saving to SD card
38. Setup and input reading thresholds (IN)
39. Signal power extraction
40. Frequency domain conversion with the Welch method
41. Peak frequency extraction
42. Data normalization
43. Polynomial data processing
44. Regularized logistic regression
45. Output classification label (OUT)
46. Data acquisition (signal power)
47. Saving of normalization coefficients
48. Saving of threshold values
49. Validation
- E End
- F_i Operation flow charts of the system 1 ($i=1, 2, 3$)
- L Waste data acquisition means electronic circuit diagram
- M Acquisition, processing and energy saving means architecture
- S Start of flow chart
- W_i Characteristic sound wave ($i=1, 2$ and 3 , thus, W_1, W_2, W_3) of the impact on the drum 4 of the generic municipal waste 2.

Claims

1. A system (1) for the automatic recognition of a material (2), **characterized in that** it comprises:
 - automatic recognition means of a material (2) by impact,
 - a timing device (17), cooperating with said automatic recognition means, and
 - an architecture (M), said architecture (M) comprising:
 - a reception device (5) of acoustic waves (W_i),

adapted to receive a sound wave (W_i with index $i = 1, \dots, n$) emitted by a material (2) at a respective dropping impact on elastic means or drum (4);

- a device (19) for acquiring, processing and transferring information relating to one or more materials (2), recognized by said recognition means, said device (19) being provided with a computing card (20), within a microprocessor or microcontroller (27), and with a memory card (21) for periodically recording such information relating to one or more materials (2) which are recognized (13, 14, 15) in a database (22);

- a plurality of separation means (7, 9, 11), controlled by dedicated software means, for mutually separating the different materials (2), which was previously recognized (13, 14, 15), selected, weighted, and stored in specific containment means (23, 24, 25);

- means (26) for abating the energy consumption of the entire system (1), provided with dedicated software means to determine the shutdown of the calculating card (20) of the microprocessor (27) when it is not in use, as well as the automatic reactivation thereof following input by a user, and

- means (21) adapted to store information necessary for classifying the quantities of material (2) progressively selected.

2. A system (1) for the automatic recognition of a material (2), according to the preceding claim, **characterized in that** said reception device (5) of the acoustic waves (W_i) is an acoustic sensor or microphone (18), provided with an acoustic processor, and operationally connected to said microprocessor (27), configured for the actuation of said separation means (7, 9, 11) at the same time as the recognition of a selected material (13, 14, 15), through an automation device (16).

3. A system (1) for the automatic recognition of a material (2), according to one or more of the preceding claims, **characterized in that** said system (1) comprises management and control software means configured to:

- determine the automatic activation of a system stand-by mode (1) following the completion of a step of system setting-up (1), comprising start-up operations of the system (1) and the operational control of respective hardware components, and
- restore an operative condition of the system (1) upon a specific input from the user,
- said specific input being determined through the operation of switch means which determine the sending of a control signal to one of the pins

of the calculating card (20).

4. A system (1) for the automatic recognition of a material (2), according to one or more of the preceding claims, **characterized in that** said microprocessor (27) is a microprocessor of the "Arduino Mega 2560 R3" type.

5. A system (1) for the automatic recognition of a material (2), according to one or more of the preceding claims, **characterized in that** said separation means (7, 9, 11) comprise movable elements (7, 9, 11) having two ends, said movable elements (7, 9, 11) being hinged to one of said ends and rotating around it so that the other free end describes a curvilinear trajectory (8, 10, 12) adapted to allow the opening of one of said container means (23, 24, 25) corresponding to the specifically identified material (13, 14, 15).

6. A system (1) for the automatic recognition of a material (2), according to one or more of the preceding claims, **characterized in that** said system (1) is configured to recognize and separate solid municipal waste, agricultural waste or industrial waste.

7. A system (1) for the automatic recognition of a material (2), according to one or more of the preceding claims, **characterized in that** it comprises software means configured to:

- record, for each material (2) subjected to acquisition, a respective signal detected at the impact moment of the material (2) on said elastic means or drum (4), with a sampling rate of 3,333 Hz, and
- save said signals related to each material (2), subjected to acquisition, on a micro-SID card (21) in "comma-separated value" (csv) text file format,
- said file being used, after completion of the acquisitions, for determining the thresholds and features to be used to establish a possibility of belonging of a given material (2) to a given predetermined type through a specific script,

said features comprising:

- signal power;
- most significant carrier frequency;
- product of bandwidth and carrier power;
- signal damping rate, obtained by an approximation averaging the ratios between the various signal samples, grouped in bins.

8. A system (1) for the automatic recognition of a material (2), according to claim 7, **characterized in that** said frequencies are acquired by the Welch Method.

9. A system (1) for the automatic recognition of a material (2), according to claims 7 or 8, **characterized in that** that said features comprise the following combinations of:

- most significant signal power and carrier frequency;
- signal power and the product of bandwidth and carrier power;
- signal power and signal damping rate.

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in case of negative response to said step of signal ended (35), said management and control software means are configured to:

- execute a step of querying (36) on the actual completion of the material sampling period (2) ed,
- in case of a negative response, repeat said step of querying (36), with corresponding saving to SD card (37).

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10. A system (1) for the automatic recognition of a material (2) according to claim 3, **characterized in that** such management and control software means are configured to:

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- perform a step of querying (31) a wake-up signal during said stand-by condition (30) of the system (1), which step of querying is repeated in case of a negative response;
- in the case of affirmative response, perform a step of waking-up (32),
- after the step of waking-up (32), execute a step of input signal verifying (33), which step is repeated in case of negative response,
- in the case of affirmative response, executing a successive step of sampling (34) of the material (2), which is thus selected by said automatic recognition means, through the microprocessor (27).

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11. A system (1) for the automatic recognition of a material (2) according to claim 10, **characterized in that** such management and control software means are also configured to execute a step of signal ended (35) after said step of sampling (34).

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12. A system (1) for the automatic recognition of a material (2) according to claim 11, **characterized in that**, in the case of an affirmative response to said step of signal ended (35), said management and controlling software means are configured to reactivate said stand-by mode (30) of the system (1).

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13. A system (1) for the automatic recognition of a material (2) according to claim 11, **characterized in that** in case of negative response to said step of signal ended (35), said management and control software means are configured to:

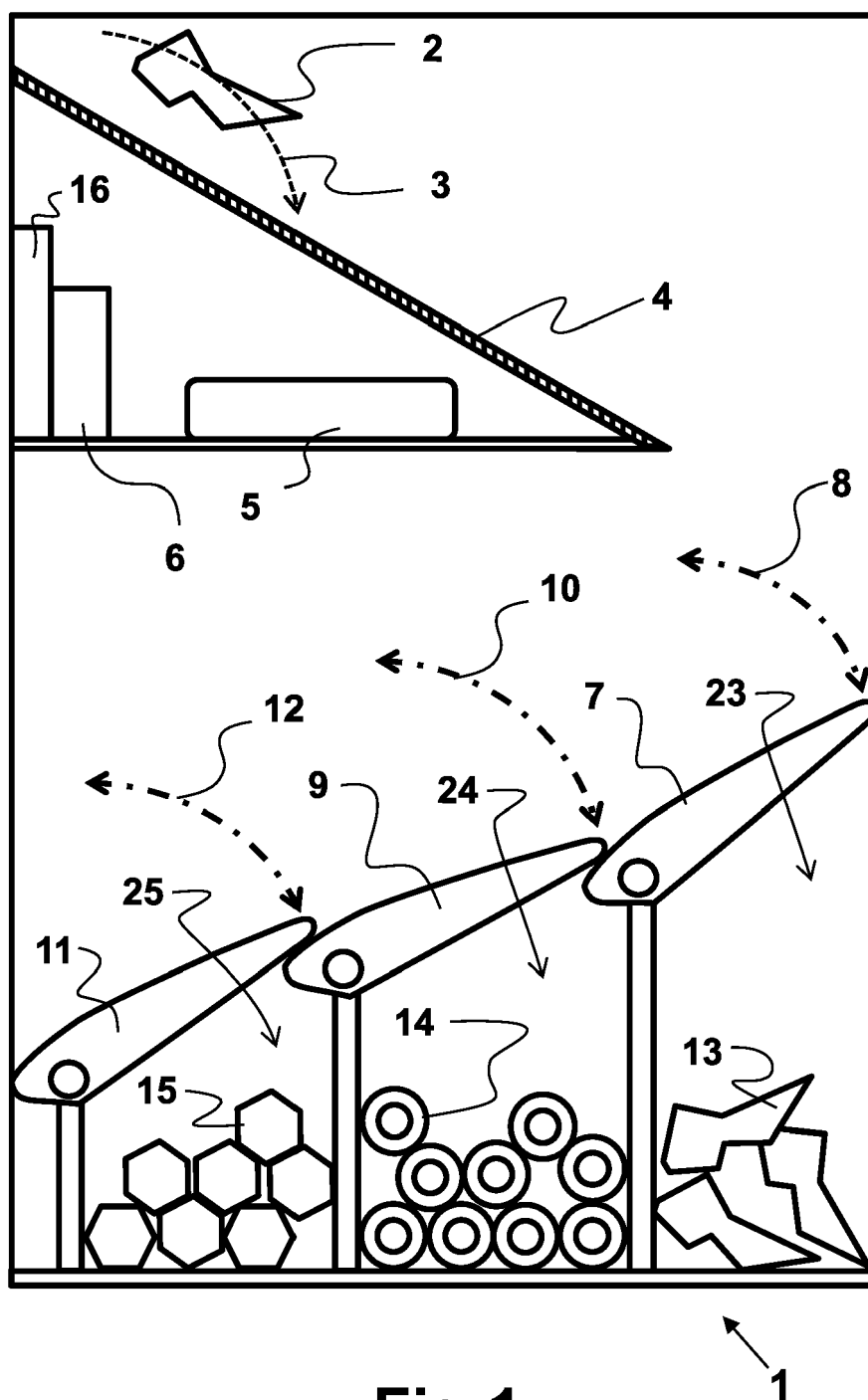
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- execute a step of querying (36) on the actual completion of the material sampling period (2) ed,
- in the case of affirmative response, execute a further step of sampling (34).

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14. A system (1) for the automatic recognition of materials (2) according to claim 11, **characterized in that**



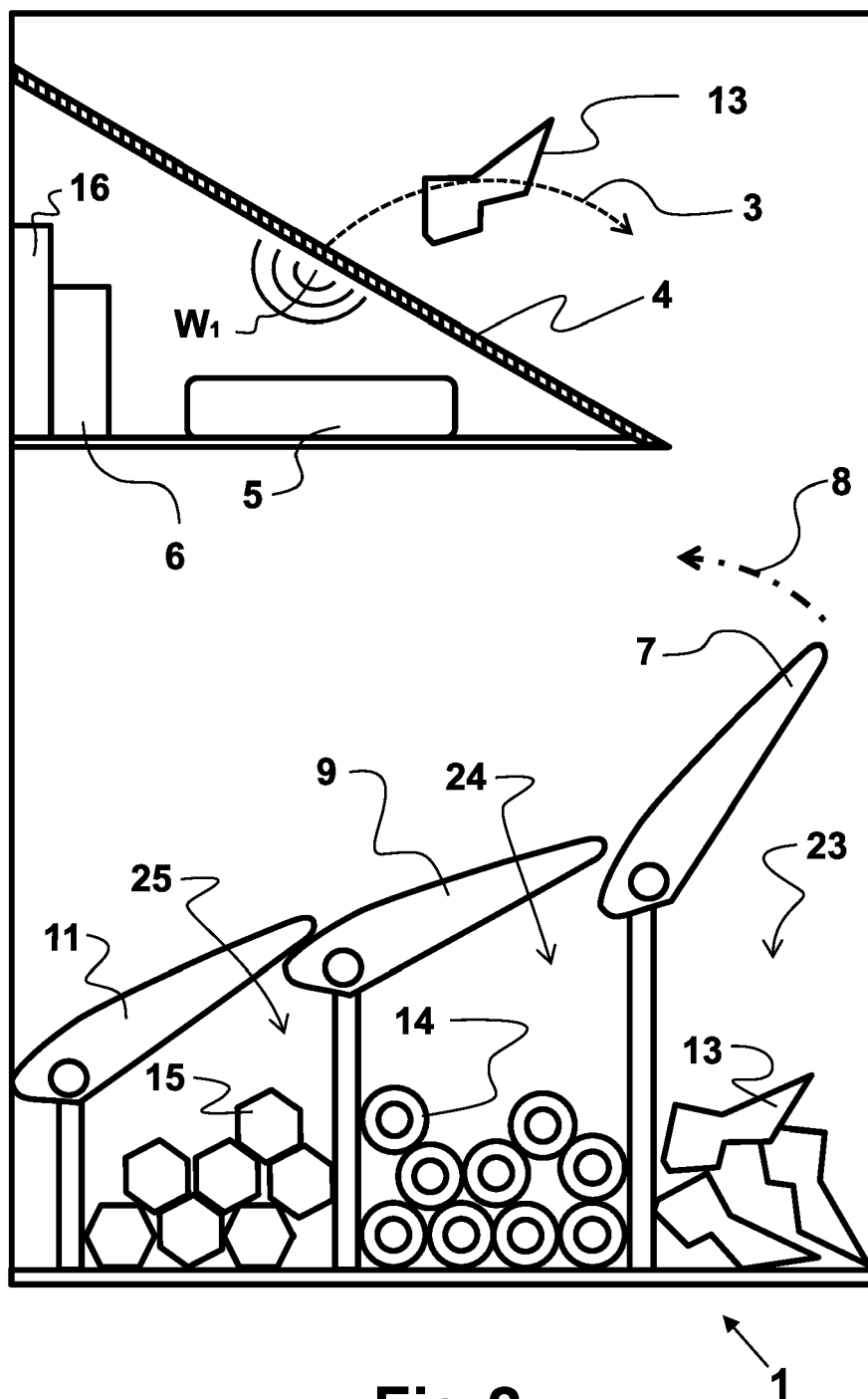


Fig.2

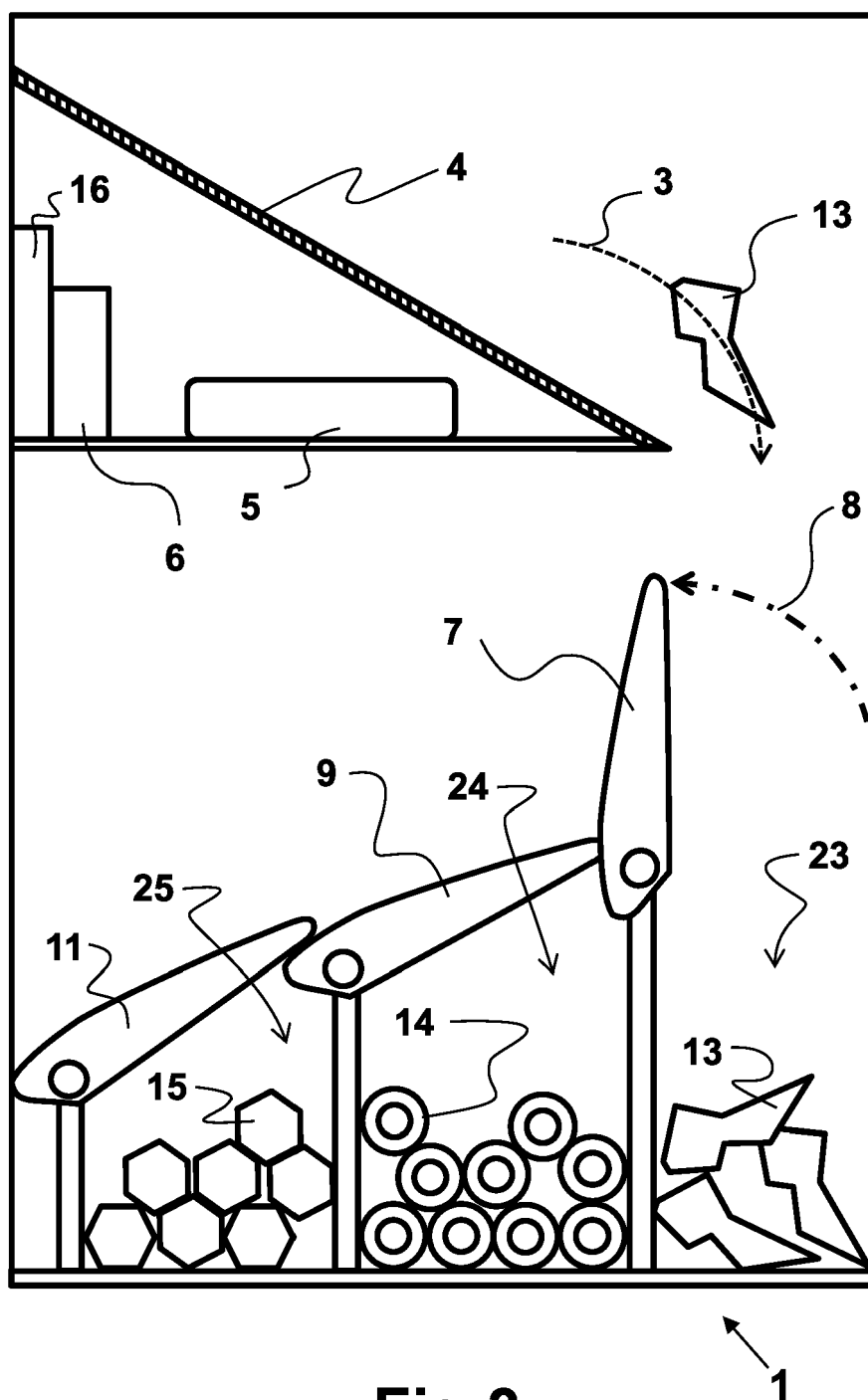


Fig.3

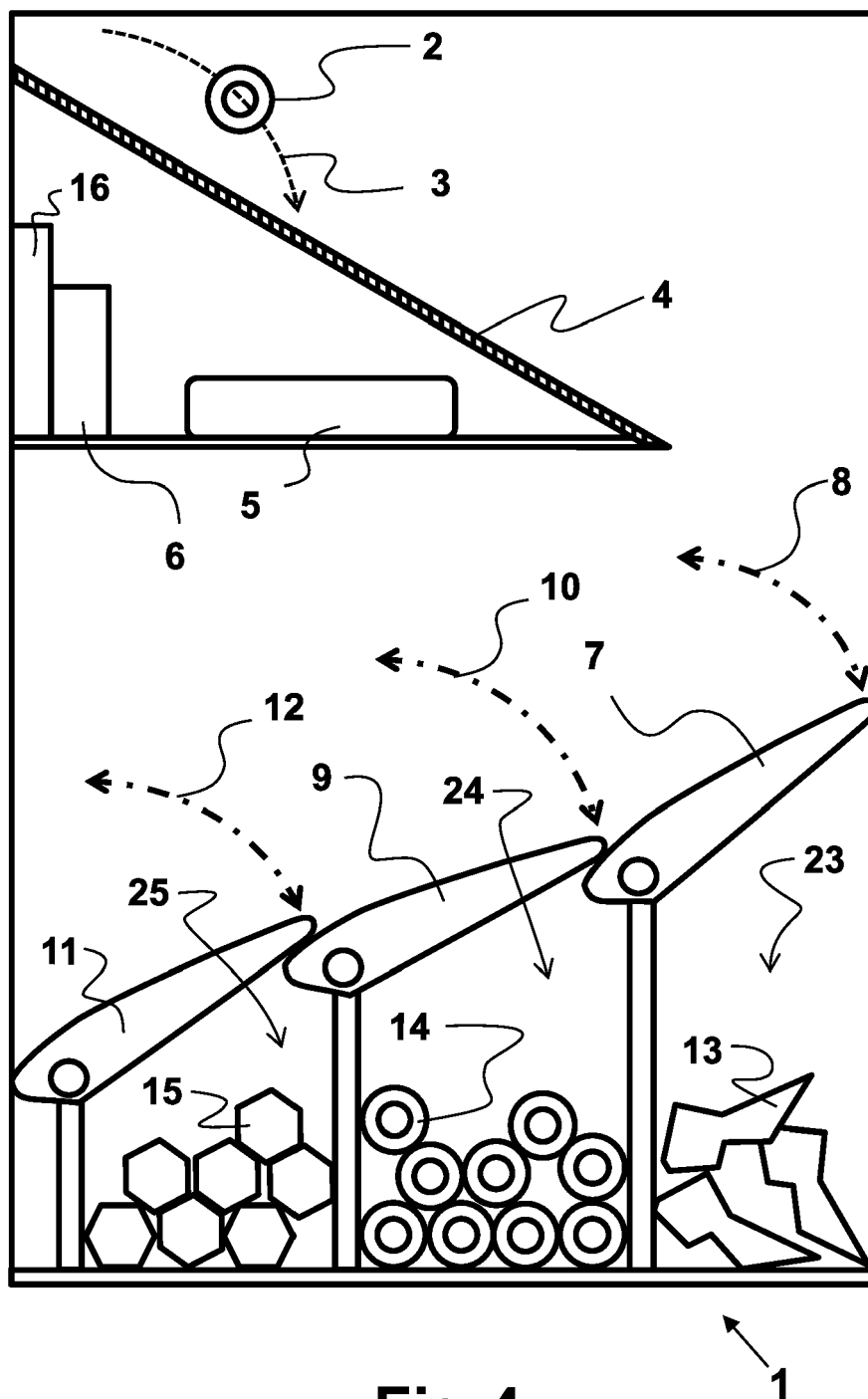


Fig.4

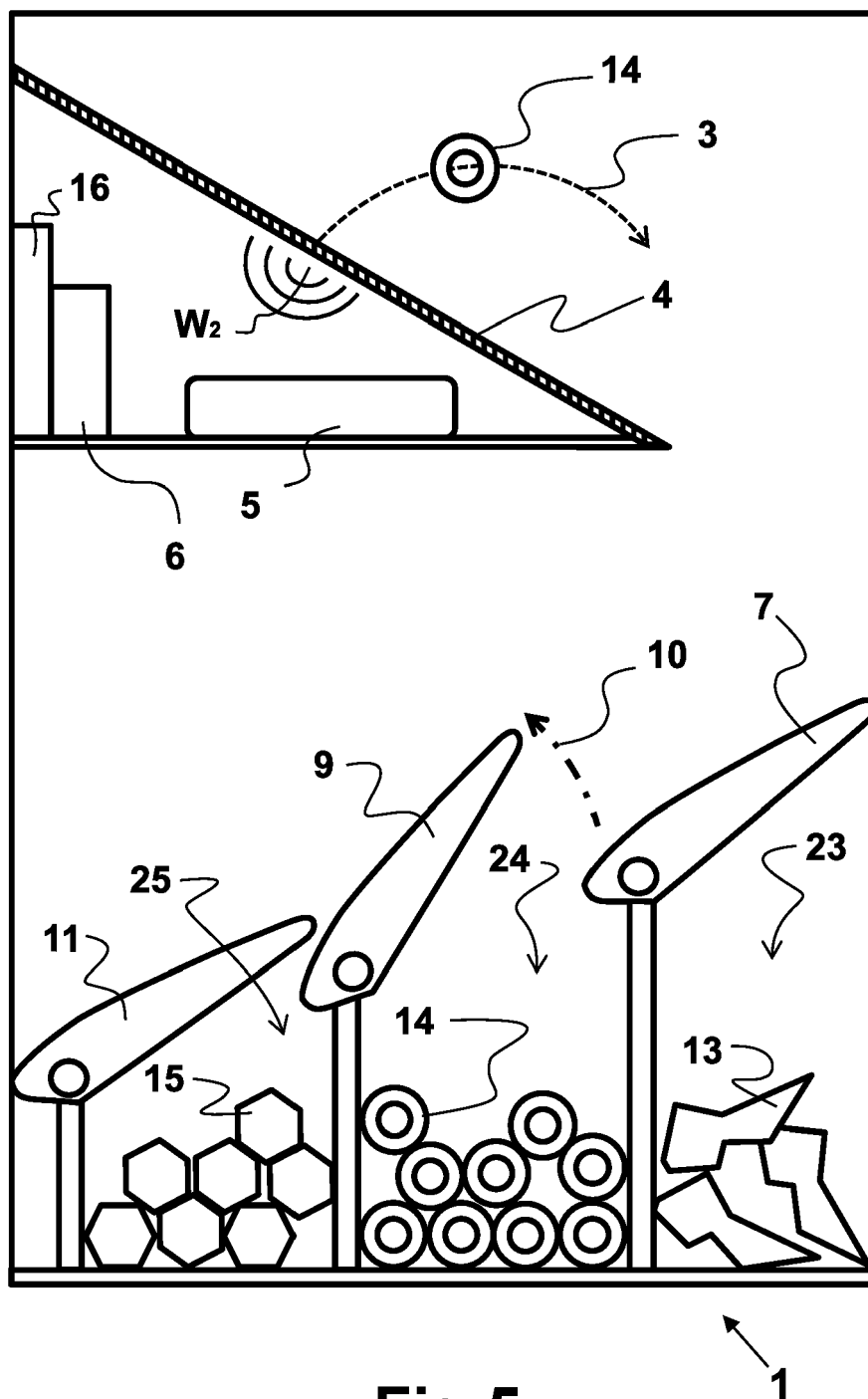


Fig.5

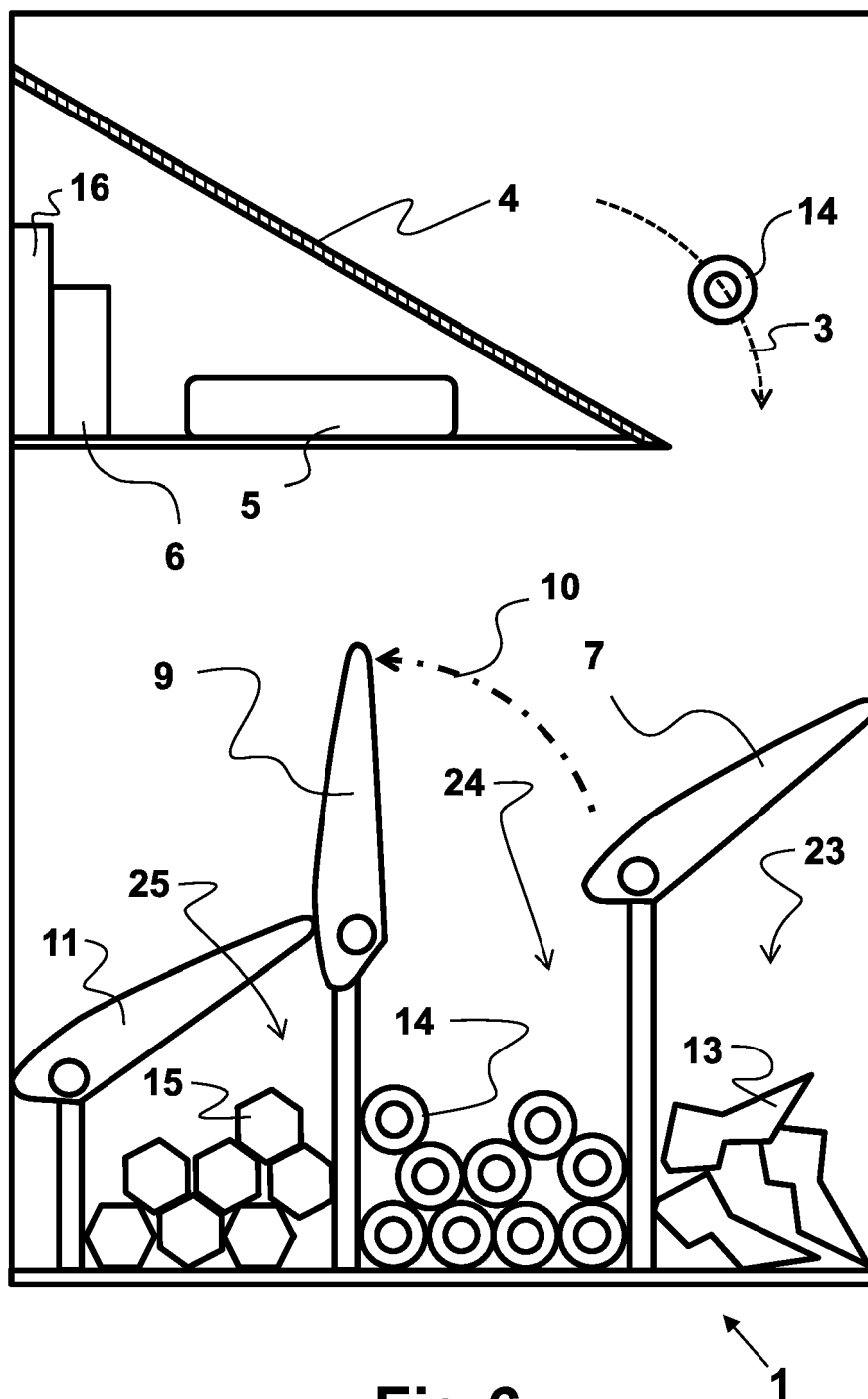


Fig.6

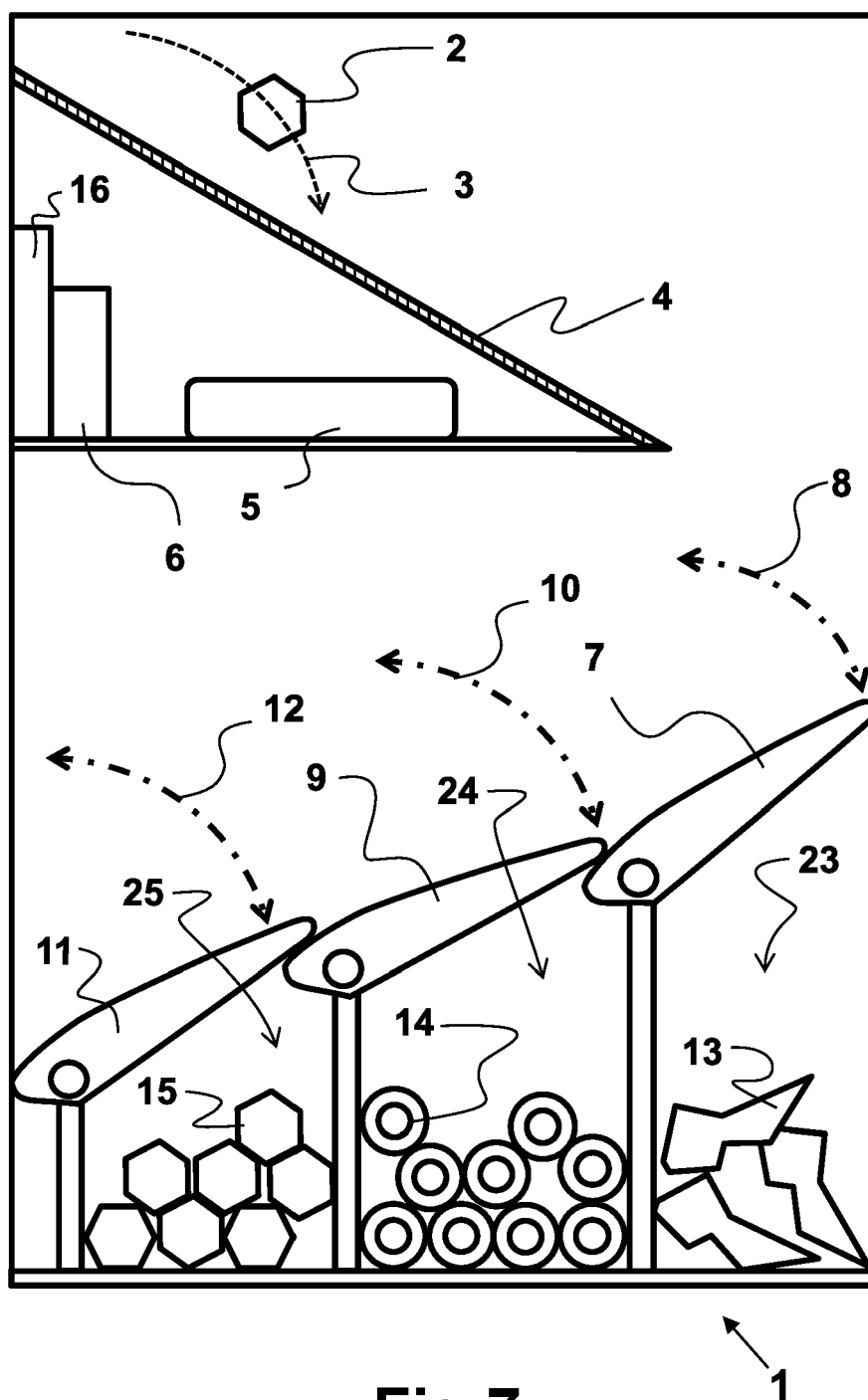


Fig.7

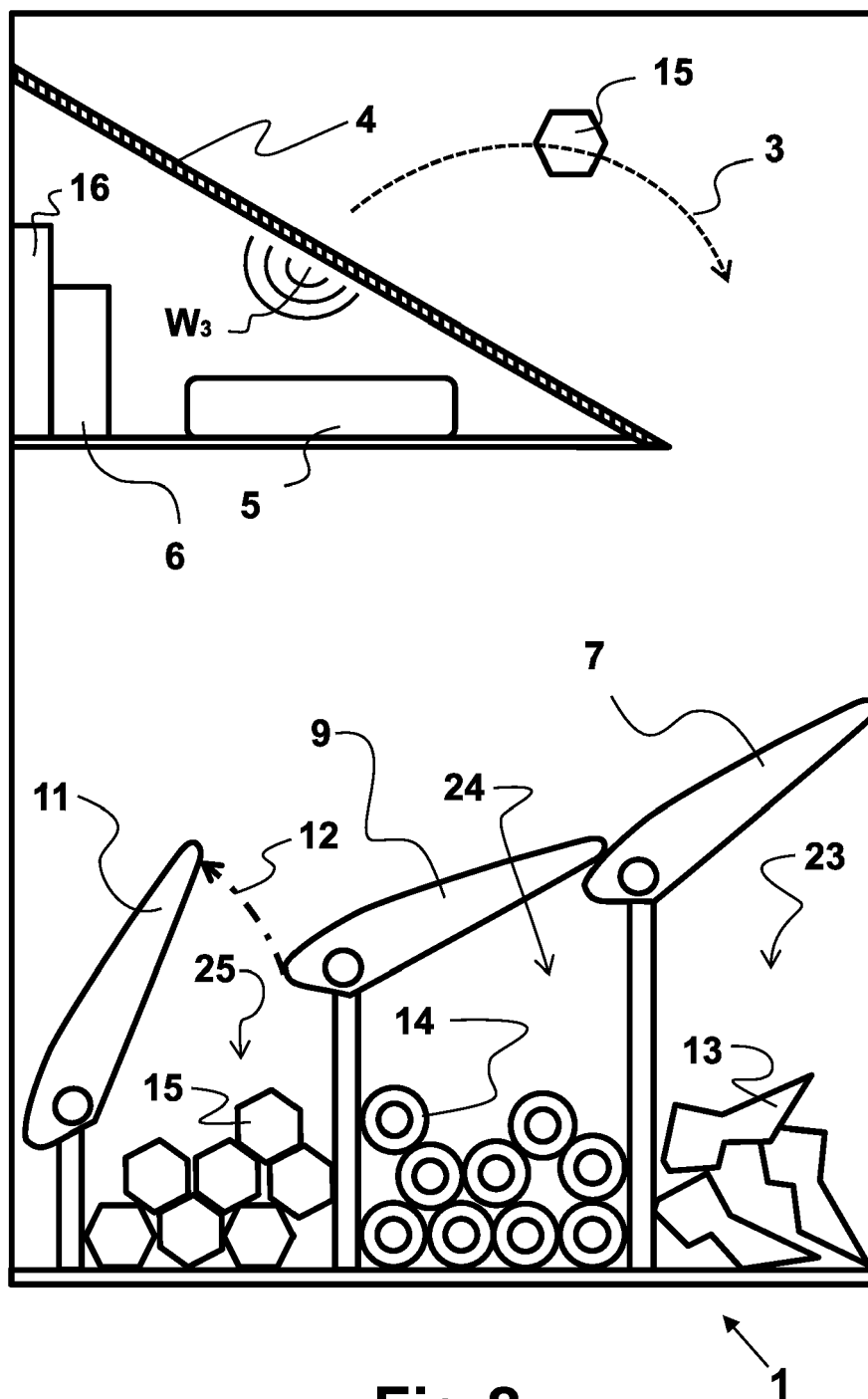
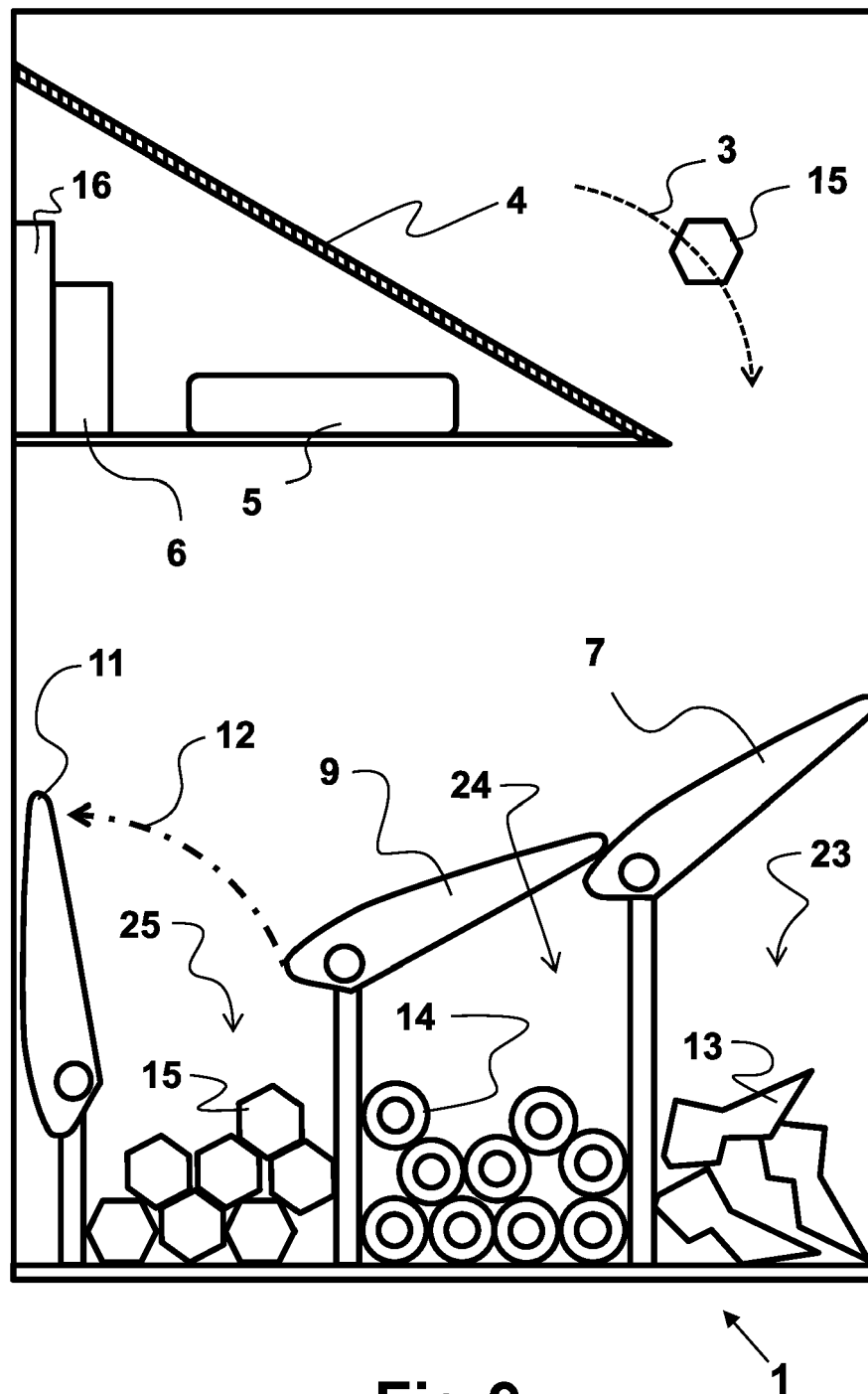


Fig.8



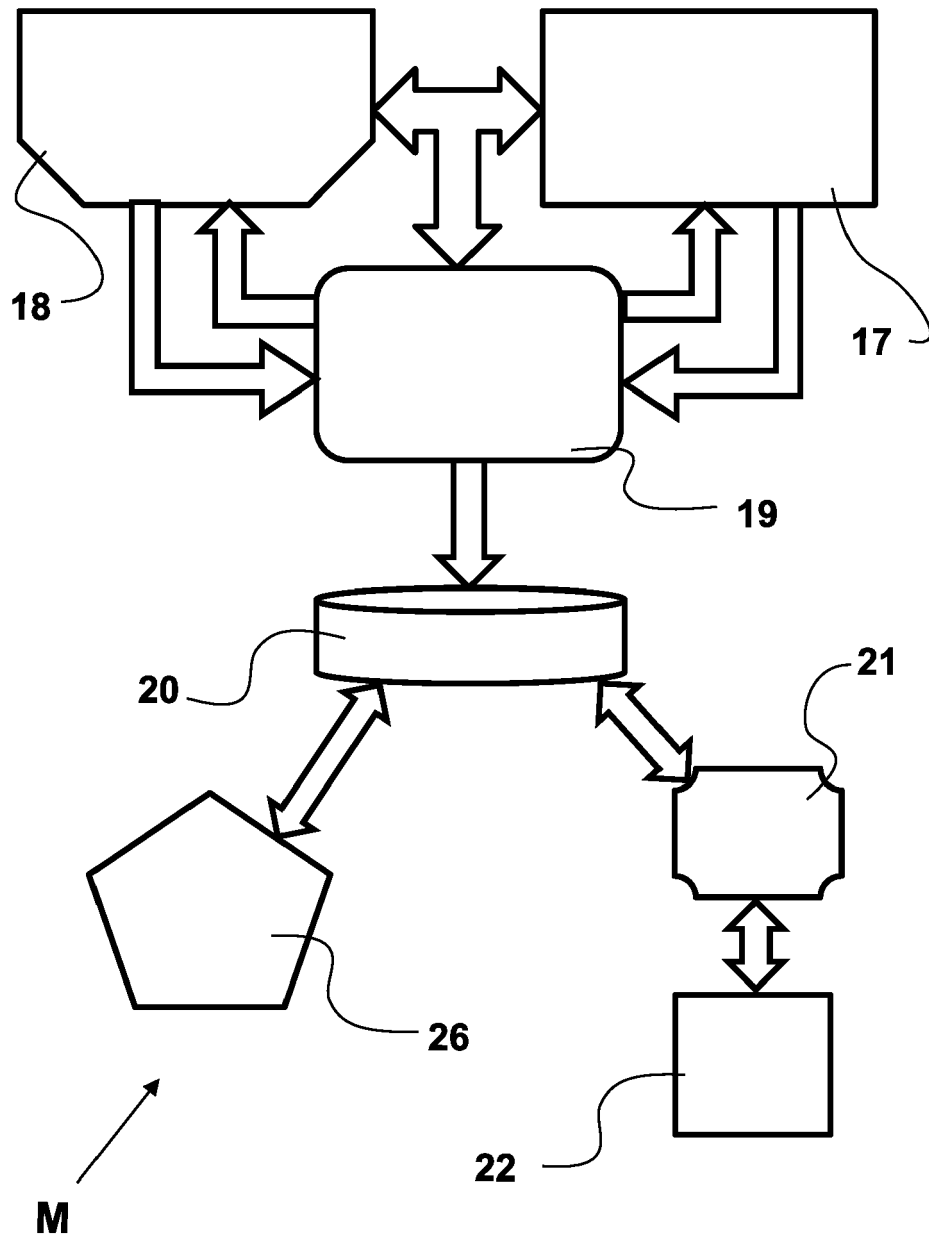


Fig.10

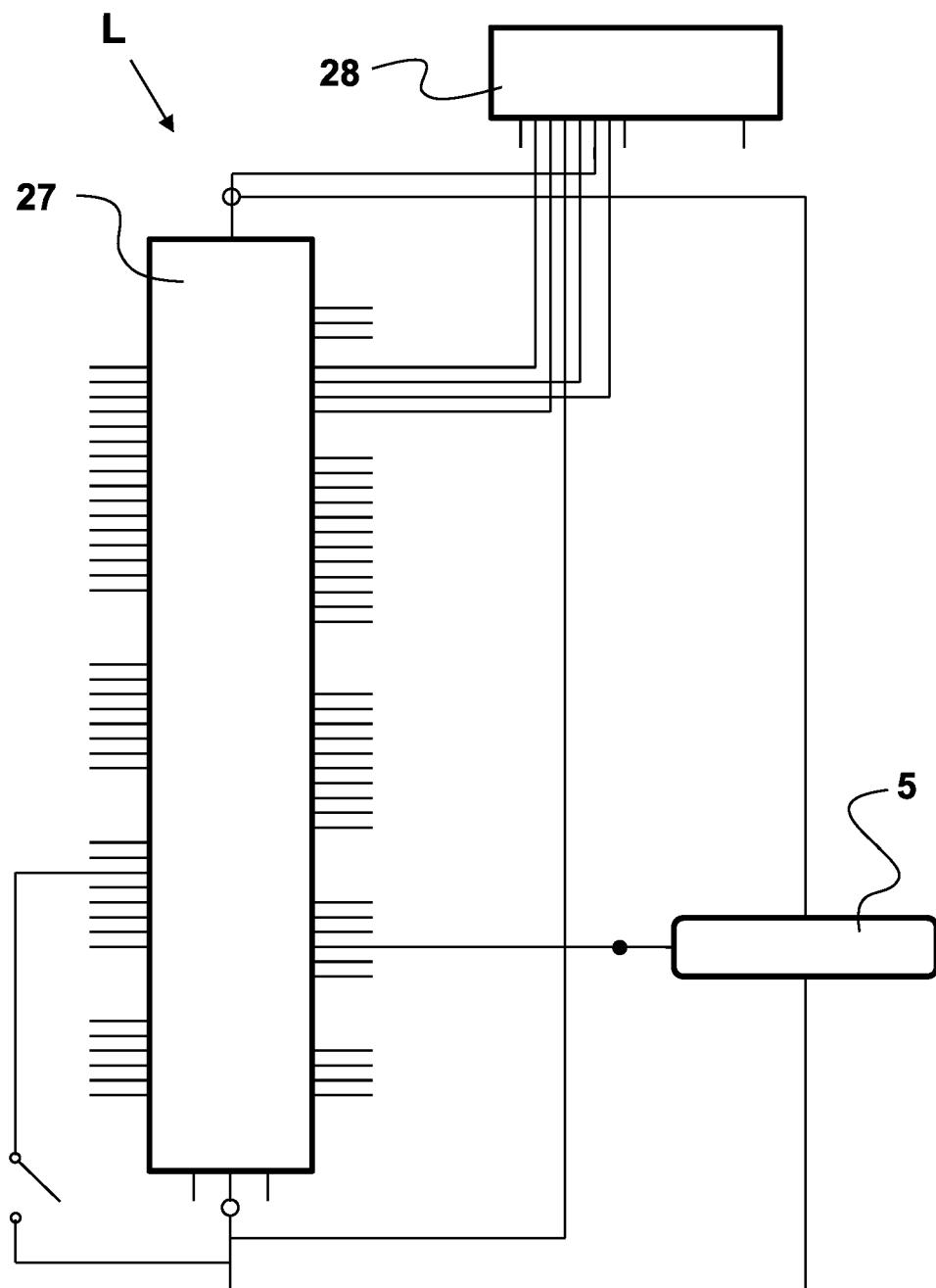


Fig.11

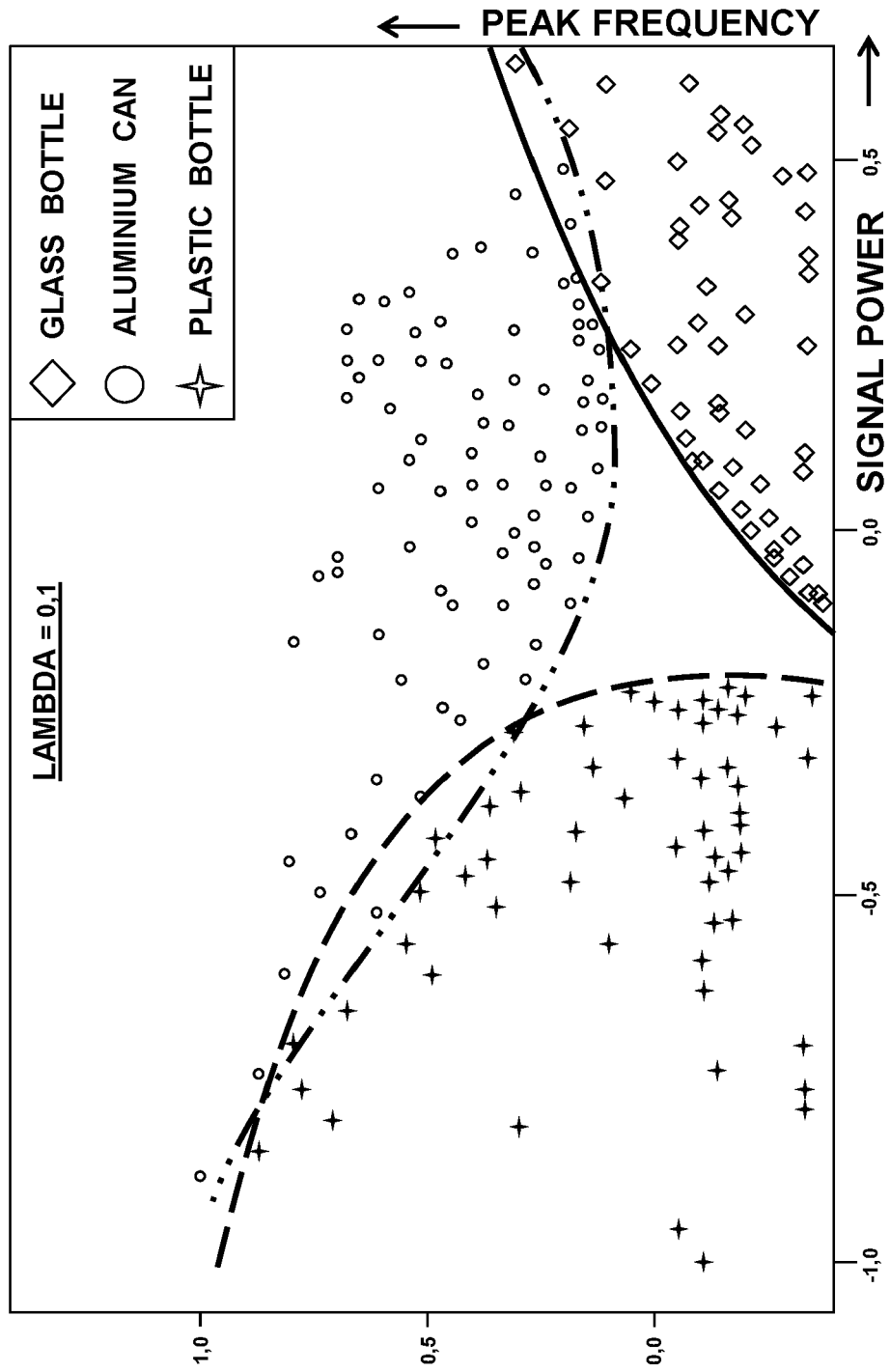


Fig.12

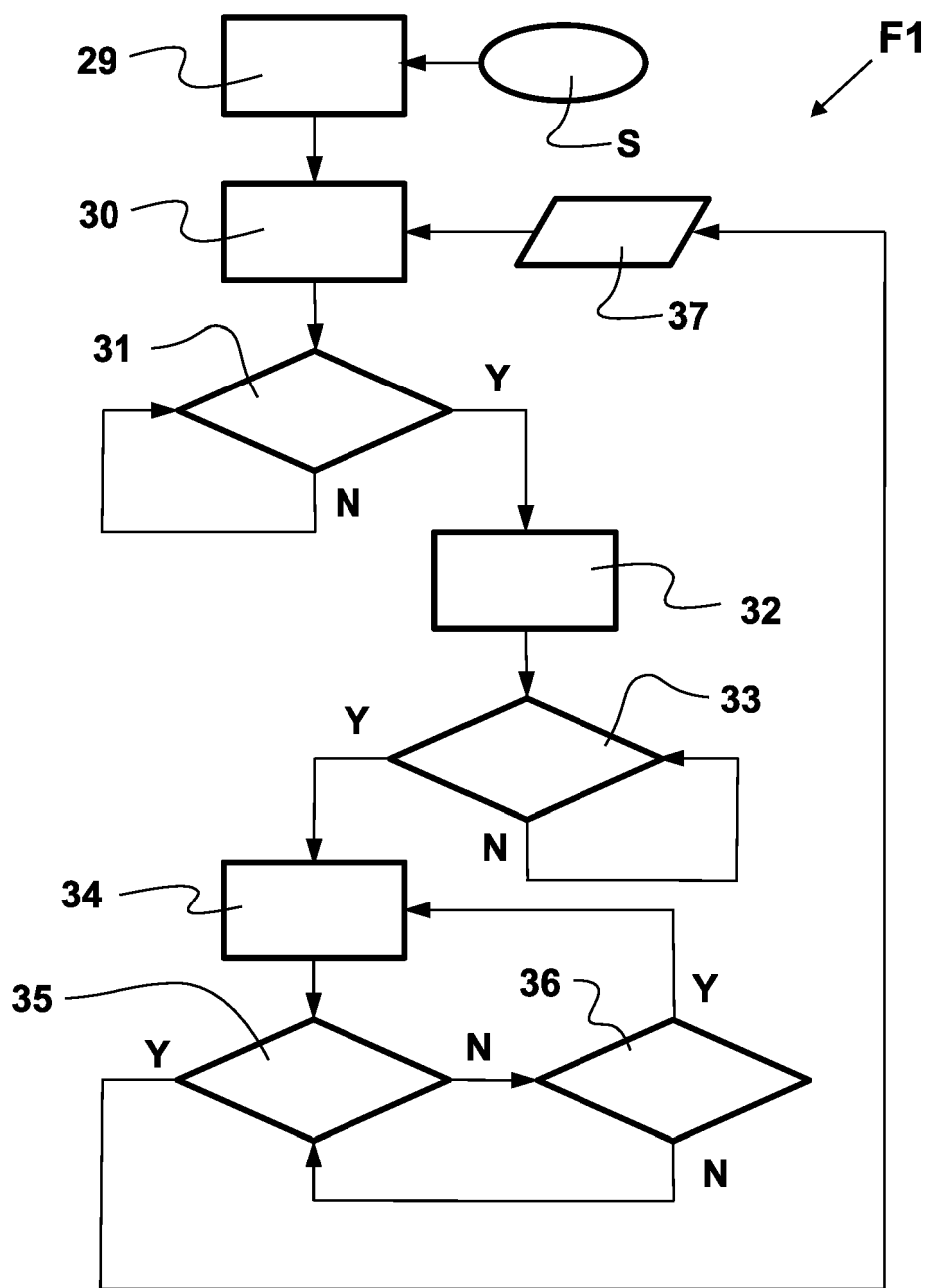


Fig.13

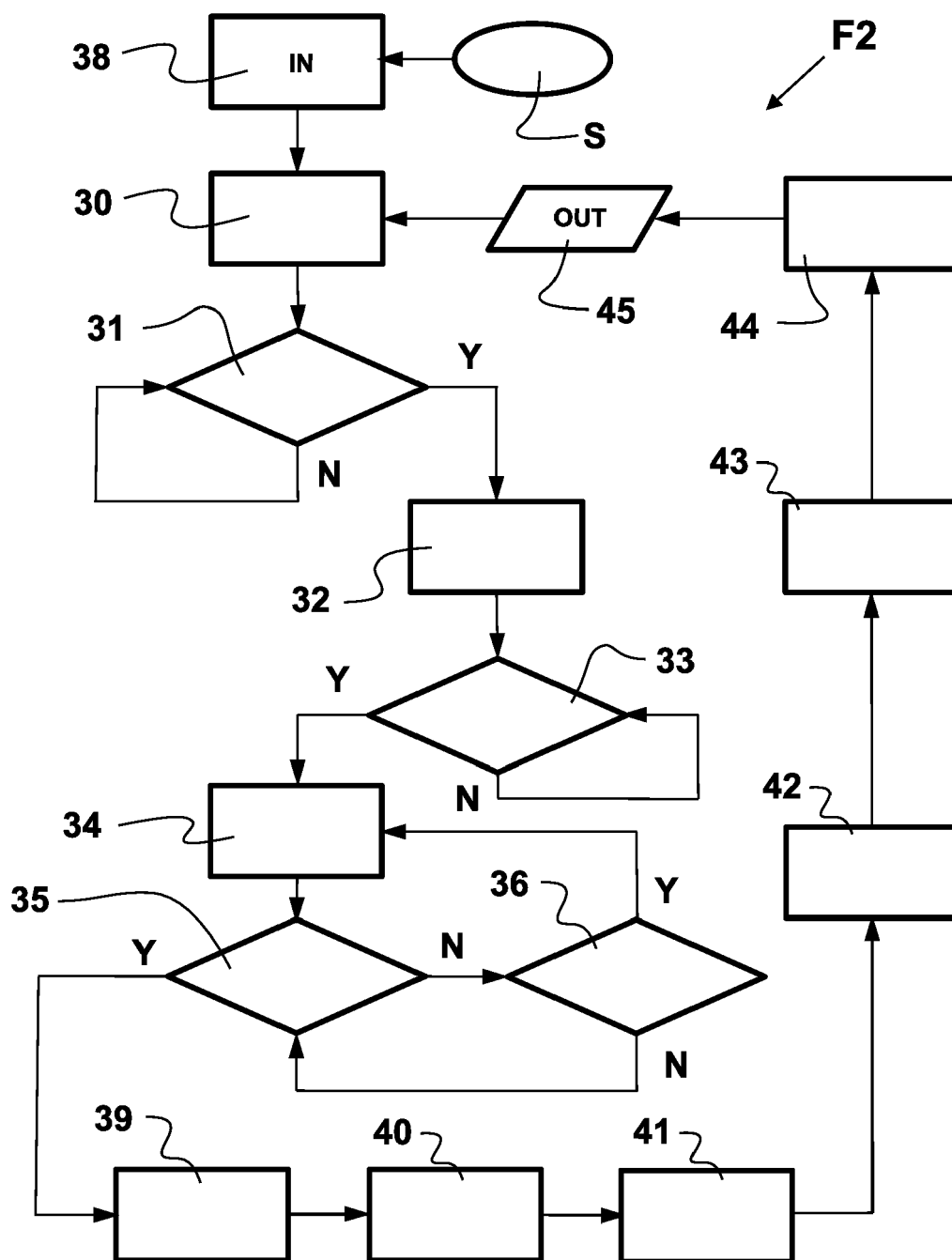


Fig.14

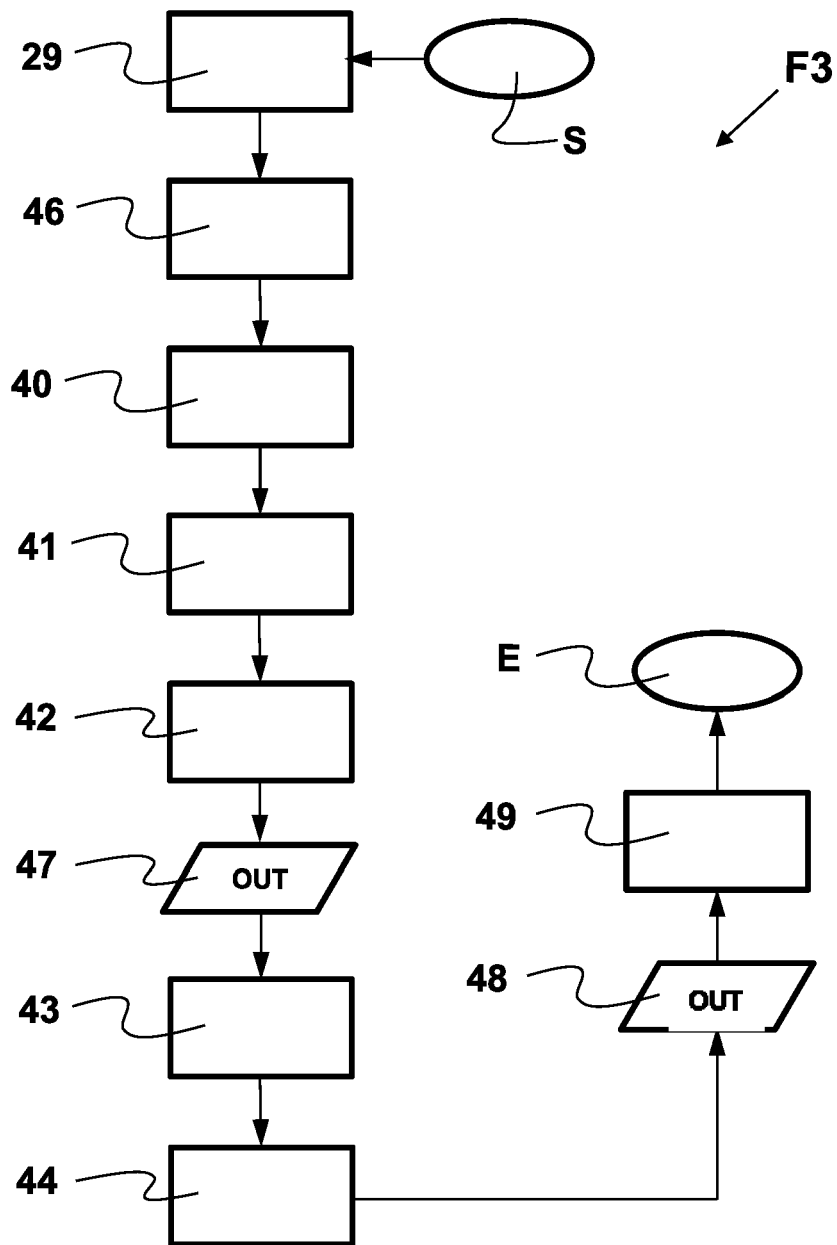


Fig.15



EUROPEAN SEARCH REPORT

Application Number
EP 20 16 1572

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DOCUMENTS CONSIDERED TO BE RELEVANT			
Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
A	WO 2017/089145 A1 (PRIMETALS TECHNOLOGIES AUSTRIA GMBH [AT]) 1 June 2017 (2017-06-01) * figures * -----	1-14	INV. B07C5/34 B07C5/36
			TECHNICAL FIELDS SEARCHED (IPC)
			B07C
The present search report has been drawn up for all claims			
Place of search Munich		Date of completion of the search 9 July 2020	Examiner Wich, Roland
CATEGORY OF CITED DOCUMENTS X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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ON EUROPEAN PATENT APPLICATION NO.

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The members are as contained in the European Patent Office EDP file on
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09-07-2020

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WO 2017089145 A1	01-06-2017	AT 518043 A1	15-06-2017
		WO 2017089145 A1	01-06-2017

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