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(54) **Title**: SPOILAGE DETECTION USING ELECTROMAGNETIC SIGNAL AND MATHEMATICAL MODELING

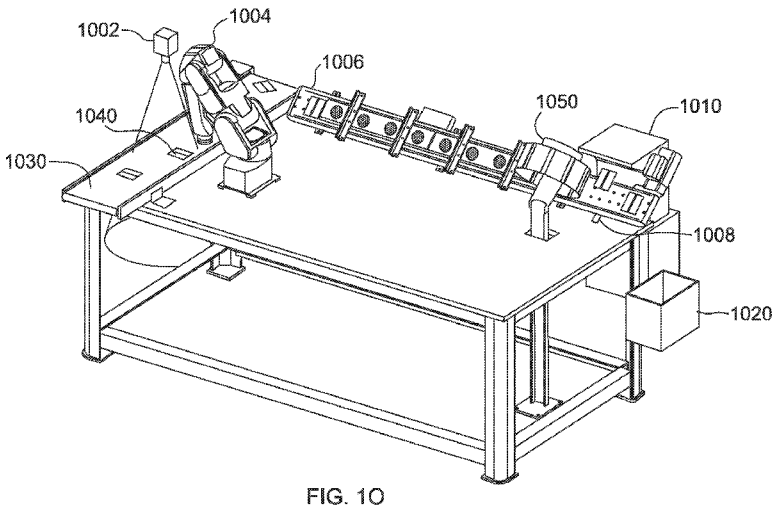

FIG. 1O

(57) **Abstract**: The present disclosure provides a system for inspecting a package (1040) having a substance subject to spoilage. An electromagnetic signal (e.g., a terahertz frequency signal) is directed to the package (1040), and an attenuated signal is received and sampled to generate a set of data points. A peak within the set of data points is detected, and the data points are shifted with respect to time to align the detected peak with a predetermined time. The set of shifted data points are compared to a mathematical model to determine whether the substance in the package (1040) is spoiled.

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SPOILAGE DETECTION USING ELECTROMAGNETIC SIGNAL AND MATHEMATICAL MODELING

[0001] This application claims priority to U.S. Provisional Application No. 61/428,637, filed December 30, 2010, the disclosure of which is herein incorporated by reference in its entirety.

FIELD OF THE INVENTION

[0002] The present disclosure relates to non-destructive inspection of packages for contaminants. More particularly, the present disclosure relates to the non-destructive inspection of packages for spoilage by analyzing electromagnetic signals from the packages.

BACKGROUND OF THE INVENTION

[0003] Packaged substances such as liquid products intended for human consumption are subject to spoilage (i.e., growth of undesirable bacteria or other microorganisms) in the packaging. Exemplary such liquid products include, without limitation, infant, toddler and adult nutritional formulas, fortifiers and dietary supplements. Such substances may be kept sterile from production through packaging (i.e., aseptic packaging) or may be sterilized after packaging (e.g., pasteurized). Sterilization after packaging may alter certain properties of the substance. For example, pasteurization may cause desirable proteins in a nutritional formula to break down, reducing the nutritional value of the formula.

[0004] One way of testing such packages for spoilage is to allow a relatively long incubation period before visually examining the package. Visual examination may fail to identify spoilage by certain bacteria or may fail to identify spoilage in a package having a relatively slow growing contaminant. Thus, a consumer could purchase and potentially use a package containing a spoiled substance. Further, visual examination on a commercial scale requires a substantial investment in training and man hours, and packages examined visually must be transparent and individually inspected (i.e., removed from a case containing a plurality of packages). This increases production costs and reduces flexibility in responding to changes in product demand.

[0005] Another way of inspecting packages containing a substance subject to spoiling is by destructive testing in which the package must be opened or otherwise rendered unusable such as pH analysis and culturing. Each method of destructive testing has its individual disadvantages such as not detecting early stage spoilage or not being sensitive to certain bacteria or contaminants. More importantly, however, destructive testing requires opening the package to sample the substance. The act of opening the package to sample the substance reintroduces the potential for contamination and spoilage. Thus, any test on the substance may not be valid for a given package going forward. Therefore, any packages tested are taken to be representative of a production lot and the sampled packages themselves are culled. This results in incomplete testing of a lot, excess product waste, and a significant expenditure of time which reduces flexibility in responding to changes in product demand.

SUMMARY OF THE DISCLOSURE

[0006] In one embodiment, an apparatus inspects a case of packages containing a substance subject to spoilage. The system includes an inspection system, a processor, and a labeling system. The inspection system includes an electromagnetic source, a plurality of electromagnetic scan systems, and a sampler. Each of the packages in the case has a corresponding electromagnetic scan system. The electromagnetic source generates an electromagnetic signal, and each of the plurality of electromagnetic scan systems directs the generated electromagnetic signal to a corresponding package in the case of packages. Each of the plurality of scan systems receives an attenuated electromagnetic signal from the corresponding package, and the sampler samples each of the received attenuated signals to generate a set of data points representative of an amplitude of the received attenuated signal over a predetermined period of time. The processor analyzes each set of data points by detecting a peak within the set of data points, shifting the data points with respect to time based on the detected peak, and determining whether the shifted data points correspond to a package containing a non-spoiled substance without generating an image from the set of data points. The labeling system marks any case having a package containing spoiled substance. Optionally, the apparatus includes robots for removing cases of packages from pallets for inspection and returning non-spoiled cases to a pallet after inspection. The apparatus may also include a culling system for removing packages

marked by the labeling system from an inspection system. The inspection system is more suitably a quality inspection system that may itself broadly define a production line comprises an inspection system. In one embodiment, the processor determines whether a package contains spoiled substance by comparing the shifted data points to at least one mathematical model.

[0007] In another embodiment, a mathematical model is generated for determining whether a substance in a package is spoiled. The substance is aseptically packaged in a plurality of packages, and a first group of the plurality of packages is inoculated with a first contaminant. A second group of the plurality of packages is maintained in an aseptic state. After an optional incubation period (e.g., 21 days), each of the plurality of packages is inspected. During inspection, an electromagnetic signal is directed at a package, an attenuated electromagnetic signal is received and sampled to generate a set of data points, a peak is detected within the set of data points, and the data points are shifted with respect to time to align the detected peak with a predetermined time. The set of shifted data points are analyzed to determine the mathematical model that maximizes discrimination between the sets of shifted data points corresponding to the packages of the first group and the sets of shifted data points corresponding to the packages of the second group. Optionally, after inspecting, each package of the second group of packages may be destructively tested to confirm the non-spoiled or aseptic state of the substance in the packages. In one embodiment, the mathematical model maximizing discrimination between the sets of data points of the two groups is determined by treating each data point in a set as an independent variable and performing an orthogonal partial least squares calculation. Optionally, additional variables may be added to each set of data points prior to determining the mathematical model. The additional variables are derived from the set of data points (e.g., a ratio of an amplitude of a first peak in the set of data points to an amplitude of a second peak in the set of data points).

[0008] Embodiments of the invention also provide systems and methods for determining a mathematical model for discriminating between a package containing spoiled substance and a package containing non-spoiled substance and an inspection system for inspecting for spoilage cases of packages of the substance using the mathematical model.

FIGURES AND DRAWINGS

[0009] The foregoing objects, features and advantages of the present disclosure will become more apparent from a reading of the following description in connection with the accompanying drawings in which:

[0010] FIG. 1 is an example of a plot of magnitude versus time for an attenuated electromagnetic signal received from a package containing a substance subject to spoilage.

[0011] FIG. 2 is an example of a plot of magnitude versus time for a plurality of attenuated electromagnetic signals received from a plurality of packages.

[0012] FIG. 3 is a magnified section of the plot of FIG. 2.

[0013] FIG. 4 is the magnified section of the plot of FIG. 2 as shown in FIG. 3 after aligning the attenuated electromagnetic signals with respect to time based on a peak of each of the attenuated electromagnetic signals.

[0014] FIG. 5 is a flow chart showing a method of generating a mathematical model in accordance with the present disclosure.

[0015] FIG. 6 is a plot of selected variables which maximize discrimination between vectors corresponding to packages containing an aseptic substance and packages containing a spoiled substance.

[0016] FIG. 7 is a perspective view of an inspection system for inspecting cases of packages containing a substance subject to spoiling.

[0017] FIG. 8 is a top view of the inspection system of FIG. 7.

[0018] FIG. 9 is a side view of the inspection system of FIGS. 7 and 8.

[0019] FIG. 10 is a perspective view of an inspection system for handling individual pouches containing a substance subject to spoiling.

DESCRIPTION OF EMBODIMENTS

[0020] For the purposes of promoting an understanding of the principles of the present disclosure, reference will now be made to embodiments and specific language will be used to describe the same. It will nevertheless be understood that no limitation of the scope of the claims is thereby intended, such alteration and further modifications of the readings of the disclosure as illustrated herein, being contemplated as would normally occur to one skilled in the art to which the disclosure relates.

[0021] Articles "a" and "an" are used herein to refer to one or to more than one (*i.e.* at least one) of the grammatical object of the article. By way of example, "an element" means at least one element and can include more than one element.

[0022] Unless otherwise defined, all technical terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this disclosure belongs.

[0023] The present disclosure provides systems and methods for rapid discrimination between packages containing a spoiled substance and packages containing non-spoiled substance. As used herein the term "substance" refers to a liquid product and more suitably a liquid intended for human consumption. The term "liquid product" means a product that is a flowable non-solid product including, for example but not limited to, aqueous solutions, solutions having a determinable viscosity, emulsions, colloids, pastes, gels, dispersions and other flowable non-solid products so as to exclude solid products such as bars and particulate products, such as powders.

[0024] Generally, a package containing such a substance is scanned when an electromagnetic signal from an electromagnetic source is directed at the package via an electromagnetic scan system and an attenuated electromagnetic signal is received by the electromagnetic scan system and sampled to generate a set of data points. In one embodiment, the electromagnetic scan system comprises a scan head that transmits the electromagnetic signal and receives a reflection of the electromagnetic signal which is the attenuated signal. In another embodiment, the electromagnetic scan system comprises a transmitter and corresponding receiver wherein the transmitter is located on a first side of the package, and the corresponding receiver is located on a second side of the package

opposite the first side such that the attenuated signal is the electromagnetic signal after having passed through the package and substance. The data points from the scan are aligned with respect to time based on a peak detected within the set of data points and a predetermined time, and a determination of whether the package contains spoiled substance is made based on the set of aligned data points without generating an image from the set of data points. In one embodiment, the electromagnetic signal has a frequency in the range of about 0.02 terahertz to about 3.5 terahertz and a wavelength between about 0.3mm and 3mm, and the set of data points includes 4096 data points sampled over a predetermined time period of 320 picoseconds.

[0025] The packaging containing the inspected substance may be generally any suitable packaging for containing substances that are subject to spoilage including, without limitation, glass or plastic bottles, plastic containers, bags or pouches constructed of films or other plastics, and other suitable packaging. In a more suitable embodiment, the package is substantially transparent with respect to at least one frequency or wavelength of the electromagnetic signal. As one non-limiting example, one such package may comprise a pouch formed from any suitable material including woven material, non-woven material, films, laminates, or a combination thereof. More particularly, a suitable pouch may comprises a two layered laminate having an inner layer and an outer layer, with the inner layer formed from a co-extrusion of linear low density polyethylene (LLDPE) and ethylene vinyl alcohol (EVOH), and the outer layer formed from barrier coated polyethylene terephthalate (PET). In another embodiment, a pouch may comprise a three layered laminate having an inner layer, an outer layer, and an intermediate layer, with the inner layer 50 formed from a co-extrusion of linear low density polyethylene (LLDPE) and ethylene vinyl alcohol (EVOH), the outer layer formed from barrier coated polyethylene terephthalate (PET), and the intermediate layer formed from aluminum oxide coated PET, or ethylene vinyl alcohol. Other suitable materials from which such a pouch may be constructed such as silicone dioxide and high density polyethylene are contemplated to be within the scope of this invention. It is also contemplated that in some embodiments a plurality of packages, each containing a substance that is subject to spoilage, are collectively packaged in an outer packaging or case (e.g., a cardboard box, plastic wrap or other suitable casing).

[0026] Referring to FIG. 1, one example of an electromagnetic signal attenuated by a package containing a substance is shown. In this example, the attenuated electromagnetic signal is reflected from the package containing the substance. In the plot of FIG. 1, the y-axis (i.e., the vertical axis) is magnitude, amplitude, or intensity, and the x-axis (i.e., the horizontal axis) is sample number or time. A first peak 102, a second peak 104, and a third peak 106 indicate a first boundary between the package and the substance contained in the package. A fourth peak 108 indicates a second boundary between the substance and the package. The second boundary is opposite the first boundary. For example, the first boundary is at a bottom of the package while the second boundary is at a top of the package, or the first boundary is a first side of the package while the second boundary is a second side of the package opposite the first side.

[0027] Referring to FIG. 2, sets of data points generated from scanning a plurality of packages are plotted on common axes. As in FIG. 1, the y-axis is magnitude, amplitude, or intensity, and the x-axis is sample number or time. Even though care is taken to maintain a predetermined spacing and alignment between the scan head and each package, spatial variation may still occur and presents itself in the plot as temporal variation. The fourth peak 108 of the sets of data points in FIG. 2 is shown magnified in FIG. 3. A processor uses a mathematical algorithm to identify a peak (e.g., the first peak 102 or the fourth peak 108) within each set of data points, and the temporal location of each of the data points in the data set is shifted such that the peak aligns with a predetermined time or sample number. Thus, misalignment of attenuated electromagnetic signals with respect to time as is eliminated as a variable when comparing sets of data points. FIG. 4 shows the fourth peak 108 of the sets of data points of FIG. 3 after alignment of the data points. In one embodiment, the peak for aligning or shifting the set of data points is detected by determining the data point in the set of data points having the greatest magnitude or intensity. In another embodiment, the peak is detected by determining the average for a predetermined number of adjacent data points and determining that the peak is centered at the data point in the center of the group of adjacent data points having the highest average. Other mathematical peak finding algorithms are contemplated within the scope of this disclosure. In one embodiment, MATLAB is used to detect peaks within the set of data points and shift the data points. MATLAB is available from and a registered trademark of The MathWorks, Inc.

[0028] Referring to FIG. 5, a method of generating a mathematical model for determining whether a substance in a package is spoiled begins at 502. At 502, a substance subject to spoilage is aseptically packaged in a plurality of packages. It is contemplated that the packages may be sterilized by means other than aseptic packaging such as by pasteurization or other suitable sterilization technique. At 504, a first group of the plurality of packages is inoculated with a first contaminant (i.e., the substance contained therein is intentionally subjected to spoilage). In one embodiment, the first contaminant is at least one of B. Subtilis, S. Epidermidis, L. Casei, E. Cloacae, Saccharomyces Cerevisiae, and/or C. Sporogenes. A second group of the plurality of packages is maintained in an aseptic or sterile (i.e., non-inoculated) state. In one embodiment at 504, a third group of the plurality of packages is inoculated with a second contaminant. Optionally, an incubation period (e.g., 21 days) follows 504. At 506, each package of the plurality of packages is inspected or scanned (i.e., a set of data points is collected from each package). Inspecting each package includes generating an electromagnetic signal at an electromagnetic source, directing the electromagnetic signal at the package, receiving an attenuated electromagnetic signal, sampling the attenuated electromagnetic signal to generate a set of data points, detecting a peak within the set of data points, and shifting the data points based on the detected peak. The data points are shifted such that the detected peak is aligned with a predetermined time. Following inspection at 506, the second group of the plurality of packages may be tested by any means including destructive testing in order to ensure that the substance contained therein has not spoiled.

[0029] At 508, the sets of data points generated from inspecting the plurality of packages is analyzed to determine a mathematical model that maximizes discrimination between the second group and any other groups of the plurality of packages (i.e., any groups of the plurality of packages inoculated with a contaminant such that the substance contained by the package is spoiled). In one embodiment, the mathematical model is derived by treating each data point within a set of data points as an independent variable and performing a matrix or multi-dimensional (e.g., 20 dimensions) vector analysis based on all of the variables. In one embodiment, the analysis includes an orthogonal partial least squares analysis to determine the mathematical model that provides the greatest discrimination between sets of data corresponding to spoiled substance and sets of data corresponding to non-spoiled substance. SIMCA P^+ is a software package developed by

and available from Umetrics/MKS Systems which may be used to determine the relationship between variables maximizing discrimination. In one embodiment, independent variables are added to the sets of data points including an amplitude of the first peak 102, an amplitude of the second peak 104, an amplitude of the third peak 106, a ratio of the amplitude of the first peak 102 to the amplitude of the second peak 104, a ratio of the amplitude of the third peak 106 to the amplitude of the second peak 104, a ratio of the amplitude of the first peak 102 to the amplitude of the third peak 106, a position of the second peak 104, a distance between the second peak 104 and the first peak 102, a distance between the third peak 106 and the second peak 104, and a width of a peak.

[0030] Referring now to FIG. 6, a 2 dimensional graphic representation of the multi-dimensional vectors representing the sets of data points gathered in the method of FIG. 5 shows the clustering and discrimination between packages containing spoiled substance and packages containing non-spoiled substance. The four axes shown are arbitrary due to the multi-dimensional (e.g., 20 dimensions) nature of the analyzed vectors or matrices. In FIG. 6, BS corresponds to a package inoculated with B. Subtilis, SE corresponds to a package inoculated with S. Epidermidis, LC corresponds to a package inoculated with L. Casei, CS corresponds to a package inoculated with C. Sporogenes, and CONTROL corresponds to a package maintained in an aseptic or non-spoiled state (i.e., a test control).

[0031] Referring now to FIGS. 7-9, various views of a an inspection system for inspecting a packaging case having a plurality of packages each containing a substance subject to spoilage are shown according to one embodiment of the disclosure. Corresponding reference characters indicate corresponding parts throughout FIGS. 7-9. In one embodiment, the cases may be inspected at least 21 days after being manufactured to ensure that any contaminants and thus spoilage is detected by the apparatus. A first robot 702 removes cases of packages from a first pallet 704 and places the cases on a conveyor belt 706. The conveyor belt 706 transfers each case in turn to a first inversion system 708 for inverting each case. An inspection system robot 710 having a plurality of scan heads scans each case, and a labeling system on the inspection system robot 710 marks any cases determined to have packages containing a spoiled substance.

[0032] In one embodiment, the scan heads each receive an electromagnetic signal from one common electromagnetic source and serially scan the packages, and in another embodiment, the scan heads each have a corresponding electromagnetic source generating the electromagnetic signal. Not shown is a processor for analyzing sets of data points obtained by the inspection system robot 710 to determine whether and which packages in a case contain spoiled substance without generating an image from the sets of data points. In one embodiment, the labeling system marks a case by identifying the case in a database, and in another embodiment, the labeling system marks a case by placing ultraviolet reactive print on the case. A culling system 712 comprises redundant systems for identifying marked cases by querying the database or by exposing the cases to ultraviolet light and detecting ultraviolet reactive print on the case. The culling system 712 removes cases that it identifies as marked from the inspection system. A second inversion system 714 rights the cases that are not removed from the inspection system by the culling system 712, and a second robot 716 places the righted cases on a second pallet 718. It is contemplated that one robot may perform the function of both the first robot 702 and the second robot 716 within the scope of this disclosure.

[0033] The inspection system robot 710 has a head that includes both a plurality of scan heads, and the labeling system. In one embodiment, the number of scan heads matches the number of packages in a case. In another embodiment, the inspection system robot 710 has 8 scan heads while the cases may each contain 6 or 8 packages, and the inspection system robot 710 has a throughput of 72 cases per minute. In one embodiment, each case is allowed to settle for at least 20 seconds after inversion by the first inversion system 708 before inspection, and the inspection system robot 710 and area of the conveyor belt 706 where the cases are inspected are isolated for vibration.

[0034] Referring to FIG. 10, one embodiment of an inspection system for inspecting pouches containing a substance subject to spoiling includes a camera 1002 and handling arm 1004. When the camera 1002 detects a pouch 1040 on a conveyor belt 1030, the handling arm 1004 is guided to the pouch 1040 by the camera 1002, and the handling arm 1004 places the pouch 1040 on a vacuum conveyor belt 1006. The pouch 1040 is passed between the vacuum conveyor belt 1006 and a scan head 1050 mounted on a rotating assembly. The rotating assembly presses against the pouch 1040 to flatten the

pouch 1040 and control the distance between the scan head 1050 and the pouch in order to improve measurement precision. If the pouch 1040 is determined not to be spoiled, an air nozzle 1008 blows the pouch into a first bin 1010, and if the pouch 1040 is determined to be spoiled, the pouch 1040 is dropped into a second bin 1020.

[0035] As used herein, a processor refers to any computing device capable of executing computer executable instructions to accomplish the function of the processor described herein. Examples of a processor are a personal computer, a server, a distributed computing environment, a computing device, and an application specific integrated circuit.

[0036] From the foregoing description, it will be apparent that an improved spoilage detection system and methods have been provided. Variations and modifications of the herein described systems, apparatuses, methods and other applications will undoubtedly suggest themselves to those skilled in the art. Accordingly, the foregoing description should be taken as illustrative and not in a limiting sense.

[0037] Any patents or publications referenced in this specification are indicative of the levels of those skilled in the art to which the invention pertains. These patents and publications are herein incorporated by reference to the same extent as if each individual publication was specifically and individually indicated to be incorporated by reference.

WHAT IS CLAIMED IS:

1. An apparatus for determining whether a substance in a package is spoiled, said apparatus comprising:

an electromagnetic source for generating an electromagnetic signal;

an electromagnetic scan system for receiving the generated electromagnetic signal, directing the received signal at the package, and receiving an attenuated electromagnetic signal; and

a processor for determining whether the package contains spoiled substance as a function of the received attenuated electromagnetic signal.

2. The apparatus of claim 1 further comprising a sampler for sampling the received attenuated signal and generating a set of data points representative of an amplitude of the received attenuated signal over a predetermined period of time; and wherein the processor analyzes the set of data points, wherein the processor:

detects a peak within the set of data points,

shifts the data points with respect to time based on the detected peak, and

compares the set of shifted data points to at least one mathematical model to determine whether the package contains spoiled substance.

3. The apparatus of claim 1 wherein the substance is a biological fluid and is aseptically packaged, and wherein the package is substantially transparent with respect to a frequency of the electromagnetic signal and comprises at least one of linear low density polyethylene (LLDPE), barrier coated polyethylene terephthalate (PET), aluminum oxide coated PET, ethylene vinyl alcohol (EVOH), Silicone Oxide (SiOx), and High Density Polyethylene (HDPE).

4. The apparatus of claim 1 wherein the electromagnetic scan system comprises a transmitter located on a first side of the package and a receiver located on a second side of the package such that the attenuated signal is the electromagnetic signal after having passed through the package and substance.

5. The apparatus of claim 1 wherein the electromagnetic scan system comprises a scan head for directing the received signal at the package and for receiving a reflected signal, wherein the attenuated signal is the reflected signal.

6. The apparatus of claim 1 wherein the processor determines whether the substance in the package is spoiled by determining that the substance in the package comprises at least one of B. Subtilis, S. Epidermidis, L. Casei, E. Cloacae, Saccharomyces Cerevisiae, or C. Sporogenes.

7. The apparatus of claim 2 wherein the electromagnetic signal is in the range of about 0.02 terahertz to about 3.5 terahertz and the at least one mathematical model corresponds to a package containing unspoiled substance, and wherein the processor shifts the set of data points with respect to time in order to align the detected peak with a predetermined time.

8. A method for determining whether a substance in a package is spoiled, said method comprising:

generating an electromagnetic signal;

directing the generated electromagnetic signal at the package;

receiving an attenuated electromagnetic signal; and

determining, as a function of the received attenuated electromagnetic signal, whether the substance in the package is spoiled.

9. The method of claim 8 further comprising:

sampling the received attenuated signal to generate a set of data points representative of an amplitude of the received attenuated signal over a predetermined period of time;

detecting a peak within the set of data points;

shifting the data points with respect to time based on the detected peak; and

comparing the set of shifted data points to at least one mathematical model, wherein determining whether the substance in the package is spoiled as a function of the received attenuated electromagnetic signal comprises determining whether the substance in the

package is spoiled as a function of the comparison of the set of shifted data points to the at least one mathematical model.

10. The method of claim 9 wherein the electromagnetic signal is in the range of about 0.02 terahertz to about 3.5 terahertz.

11. The method of claim 8 wherein the substance is aseptically packaged into the package.

12. The method of claim 9 wherein the at least one mathematical model corresponding to a package containing unspoiled substance is determined by analyzing a matrix of sets of data points, said sets of data points generated by inspecting a plurality of packages containing the substance wherein a portion of the plurality of packages are known to contain spoiled substance and the remainder of the plurality of packages are known to contain unspoiled substance, and determining a set of variables maximizing discrimination between the packages containing spoiled substance and the packages containing unspoiled substance, wherein each shifted data point is treated as a variable when analyzing the matrix, and wherein said analyzing comprises orthogonal partial least squares analysis.

13. An apparatus for determining whether a substance in a package is spoiled, said apparatus comprising:

an electromagnetic source for generating an electromagnetic signal;

an electromagnetic scan system for receiving the generated electromagnetic signal, directing the received signal at the package, and receiving an attenuated electromagnetic signal;

a sampler for sampling the received attenuated signal and generating a set of data points representative of an amplitude of the received attenuated signal over a predetermined period of time; and

a processor for analyzing the set of data points, wherein the processor:

detects a peak within the set of data points,

shifts the data points with respect to time based on the detected peak, and

compares the set of shifted data points to at least one mathematical model to determine whether the package contains spoiled substance.

14. A method for determining whether a substance in a package is spoiled, said method comprising:

generating an electromagnetic signal;

directing the generated electromagnetic signal at the package;

receiving an attenuated electromagnetic signal;

sampling the received attenuated signal to generate a set of data points representative of an amplitude of the received attenuated signal over a predetermined period of time;

detecting a peak within the set of data points;

shifting the data points with respect to time based on the detected peak;

comparing the set of shifted data points to at least one mathematical model; and

determining whether substance in the package is spoiled as a function of said comparing.

15. A method of generating a mathematical model for determining whether a substance in a package is spoiled, said method comprising:

aseptically packaging the substance in a plurality of packages;

inoculating a first group of the plurality of packages with a first contaminant;

maintaining a second group of the plurality of packages in an aseptic state;

inspecting each of the plurality of packages, said inspecting comprising:

directing an electromagnetic signal at a package;

receiving an attenuated electromagnetic signal;

sampling the received attenuated electromagnetic signal to generate a set of data points representative of an amplitude of the received attenuated signal over a predetermined period of time;

detecting a peak within the set of data points; and

shifting the data points with respect to time based on the detected peak;

analyzing the shifted data points to determine the mathematical model that maximizes discrimination between the sets of shifted data points corresponding to the packages of the first group and the sets of shifted data points corresponding to the packages of the second group.

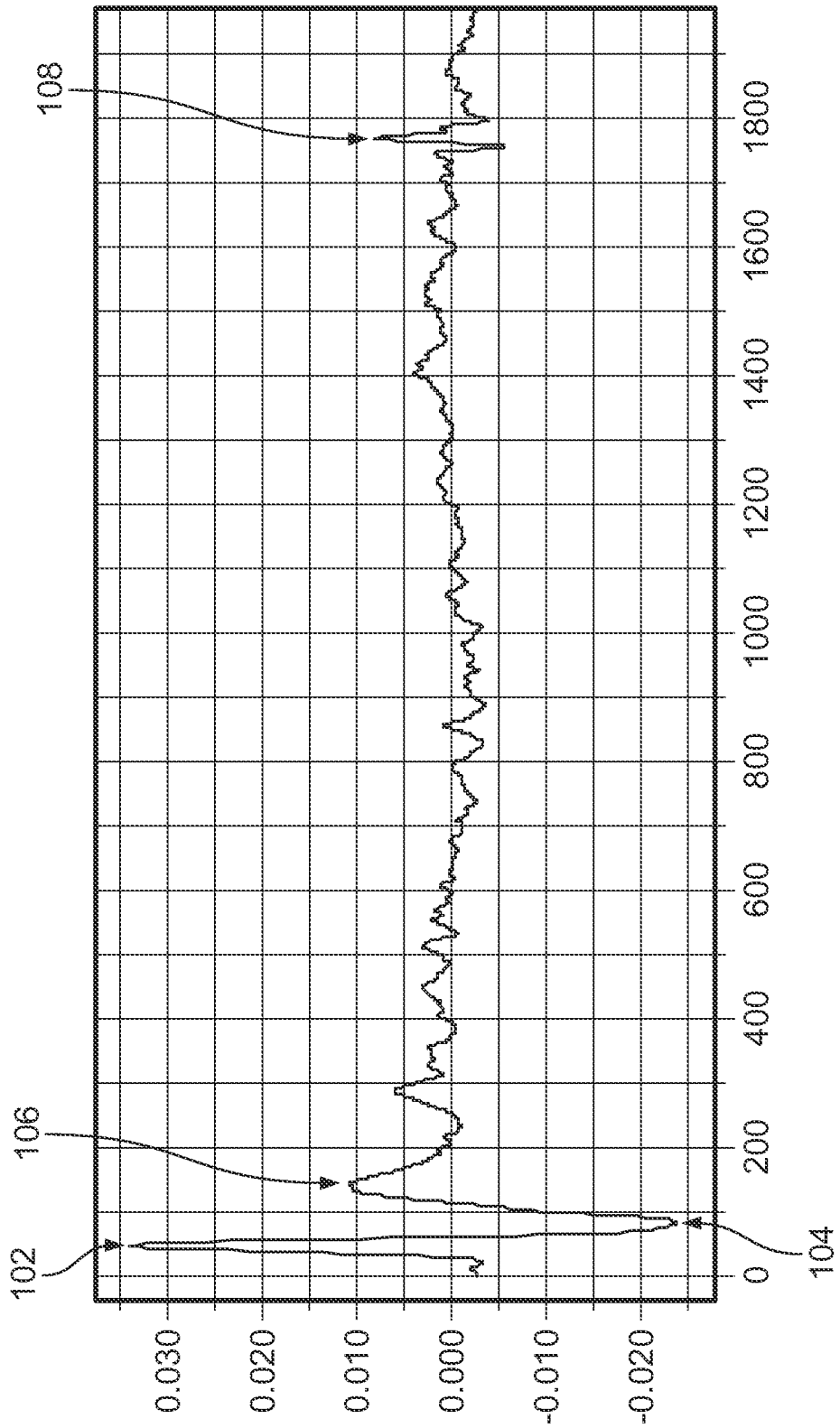
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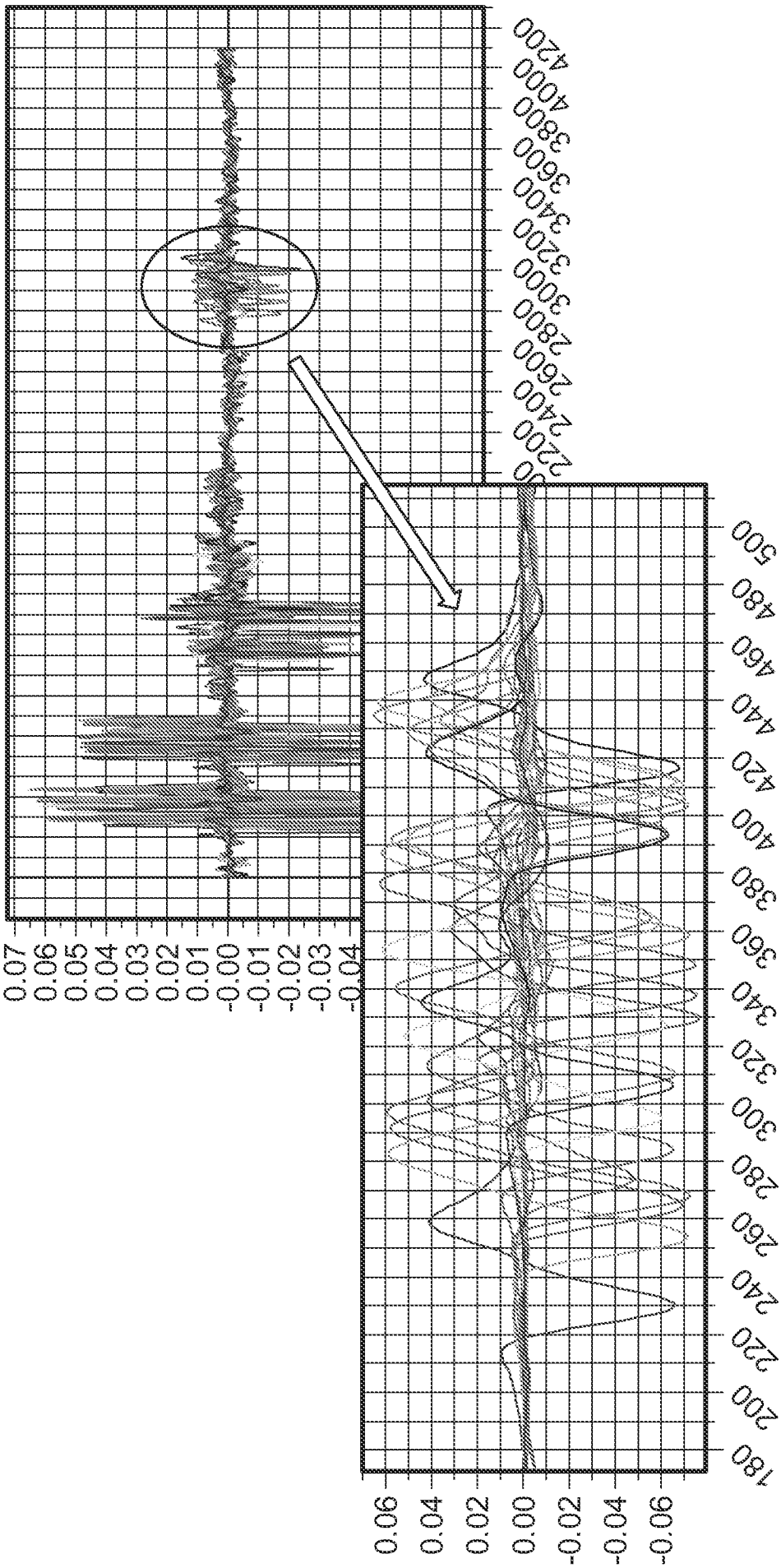
FIG. 1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0.00
-0.01
-0.02
-0.03
-0.04
2200
2400
2600
2800
3000
3200
3400
3600
3800
4000
4200
0.06
0.04
0.02
0.00
-0.02
-0.04
-0.06
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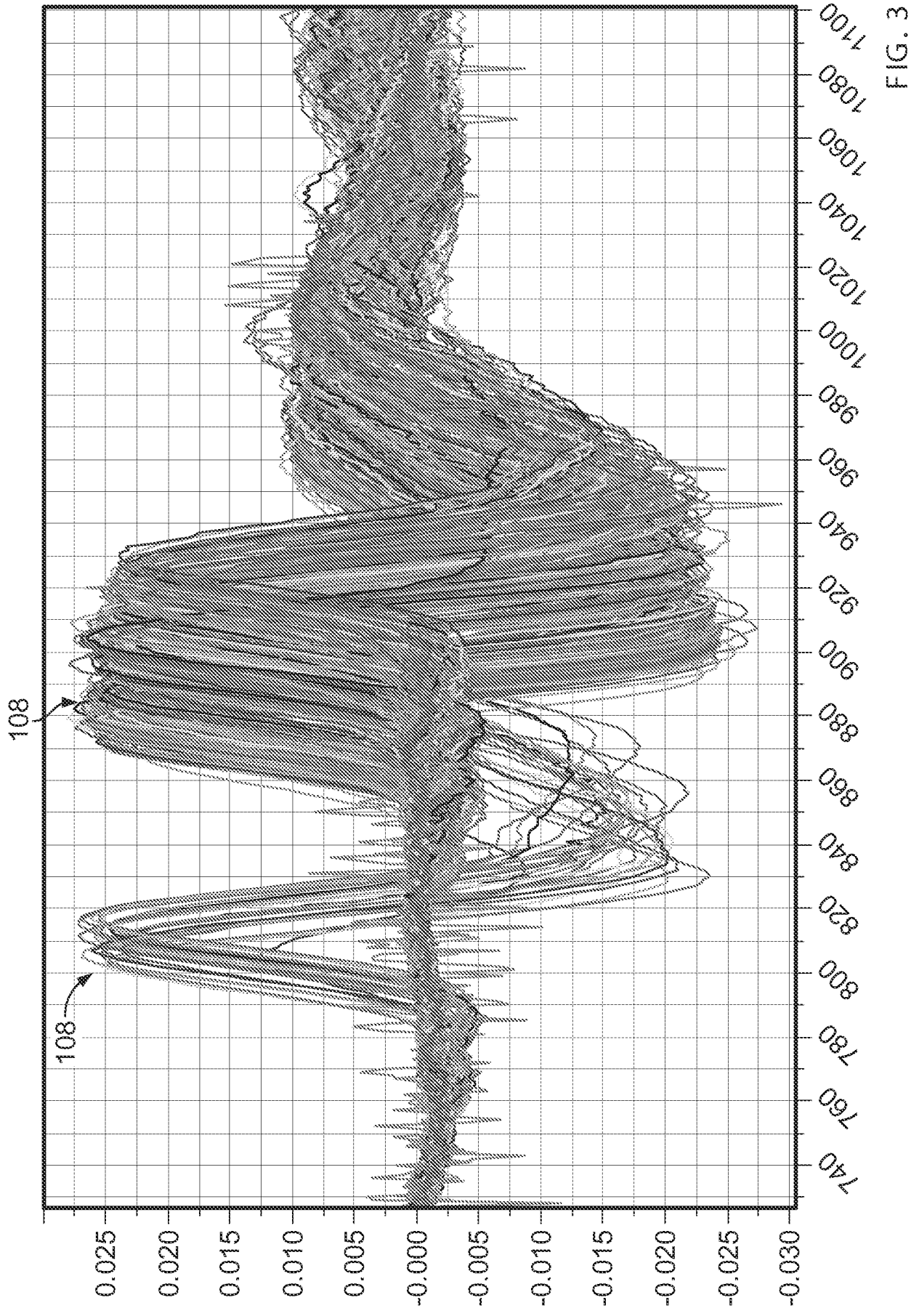
200
220
240
260
280
300
320
340
360
380
400
420
440
460
480
500

FIG. 2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108
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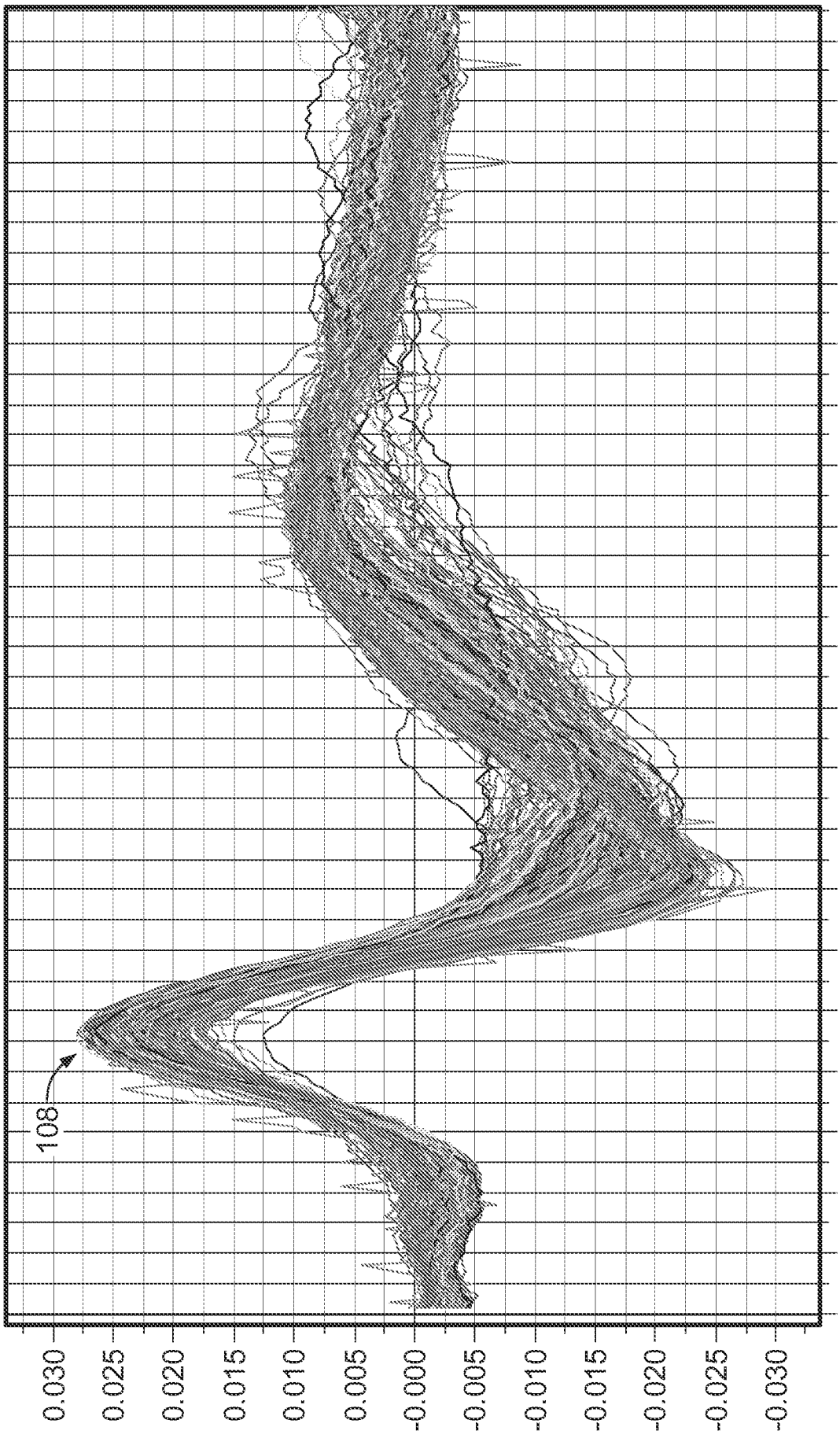
0.020
0.015
0.010
0.005
-0.000
-0.005
-0.010
-0.015
-0.020
-0.025
-0.030
740
760
780
800
820
840
860
880
900
920
940
960
980
1000
1020
1040
1060
1080
1100

FIG. 3


108
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0.025
0.020
0.015
0.010
0.005
-0.000
-0.005
-0.010
-0.015
-0.020
-0.025
-0.030
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180
190
200
210

FIG. 4

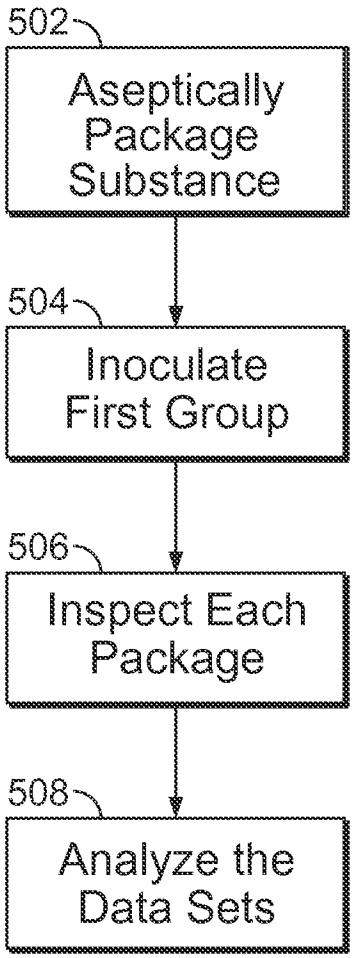
502
Aseptically Package Substance
504
Inoculate First Group
506
Inspect Each Package
508
Analyze the Data Sets

FIG. 5

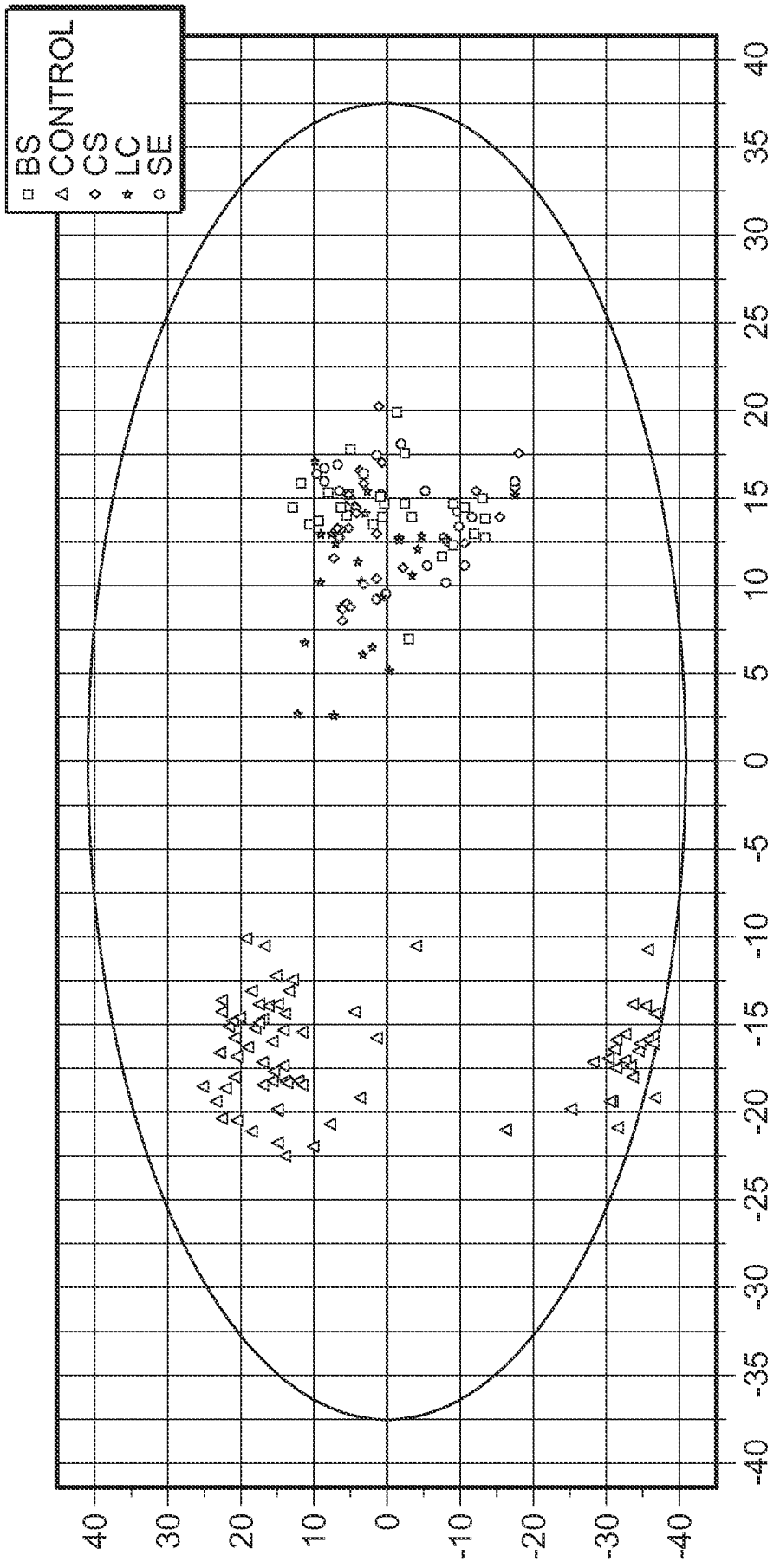
BS
CONTROL
CS
LC
SE
40
35
30
25
20
15
10
5
0
-5
-10
-15
-20
-25
-30
-35
-40
40
30
20
10
0
-10
-20
-30
-40

FIG. 6

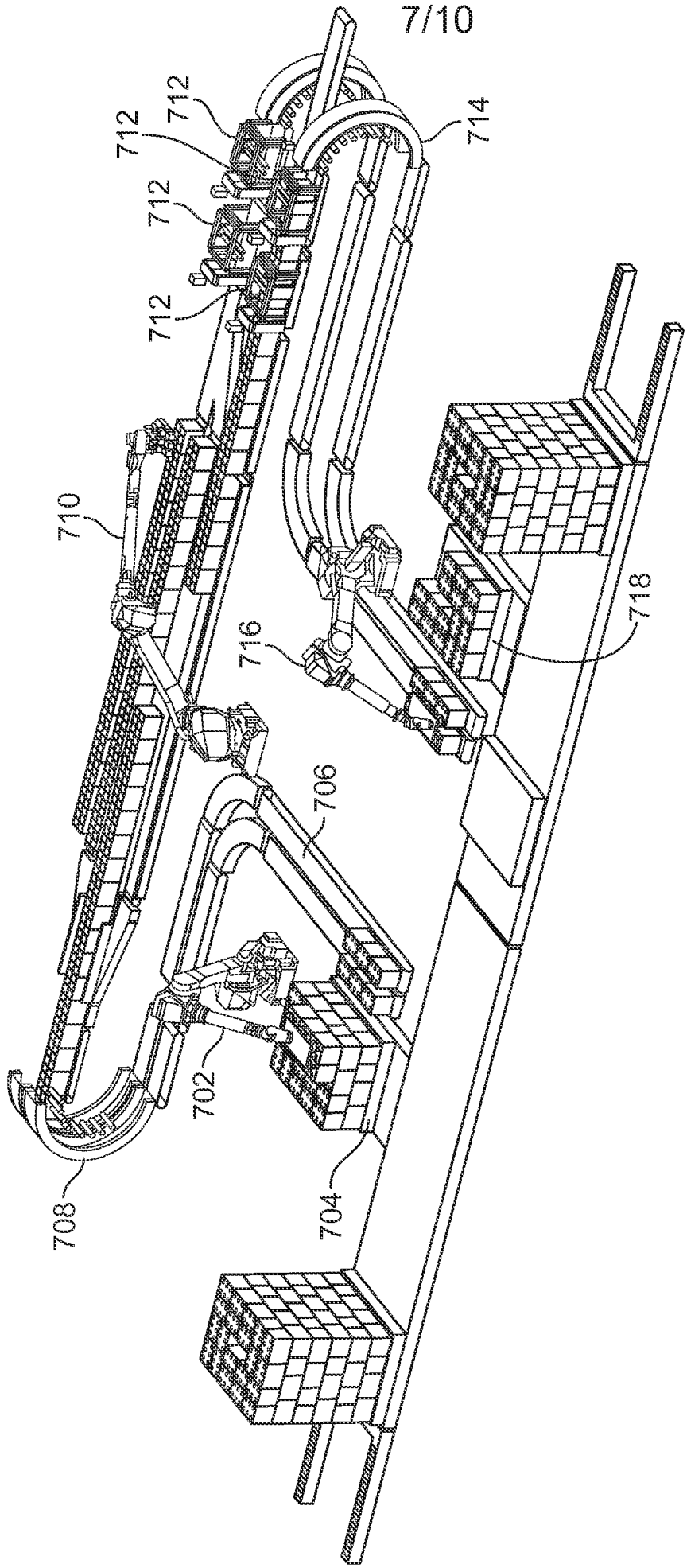

FIG. 7

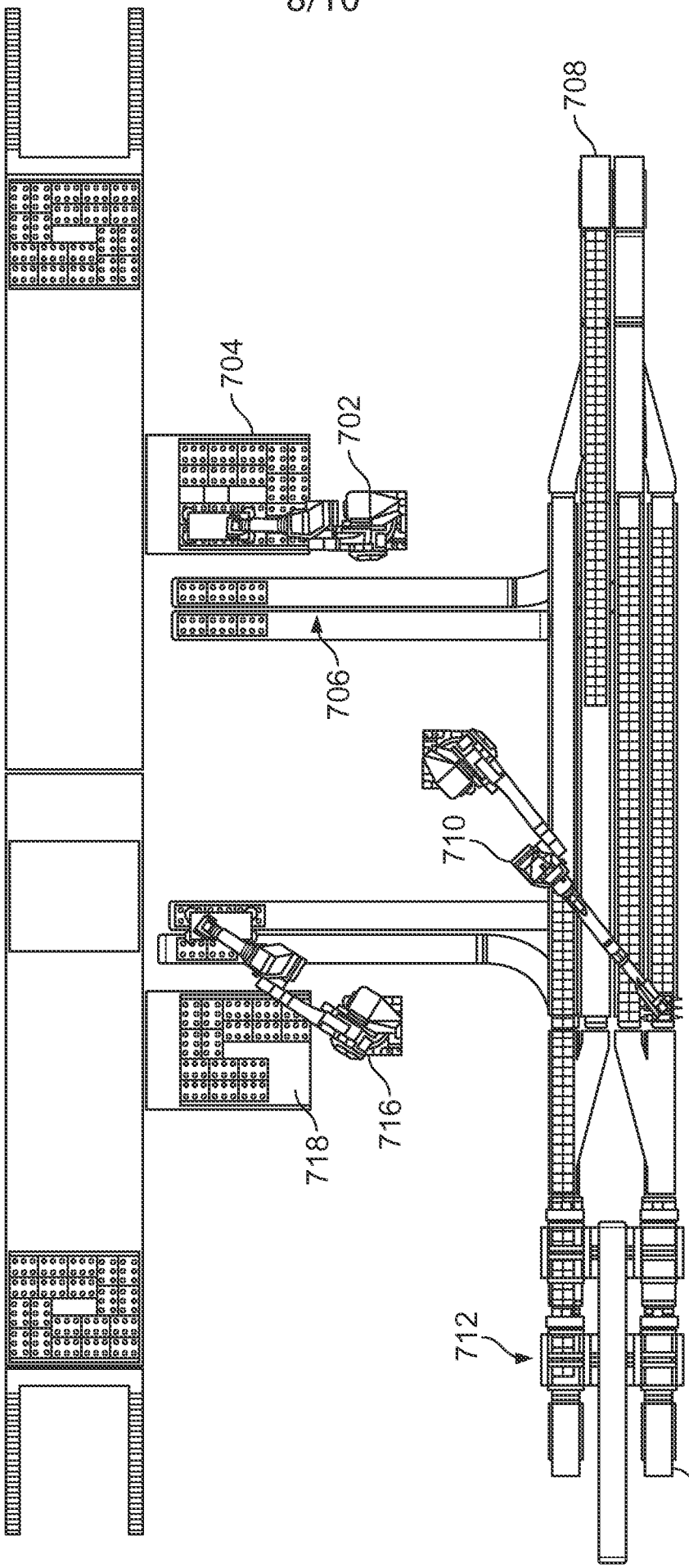

FIG. 8

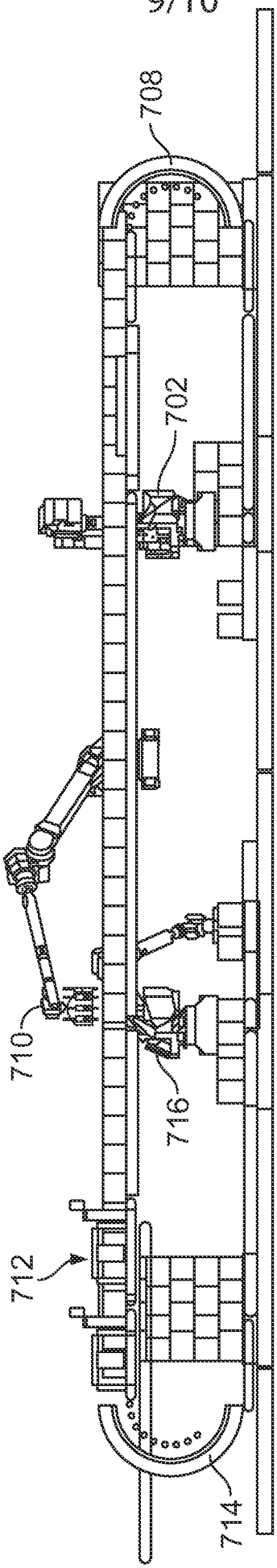

FIG. 9

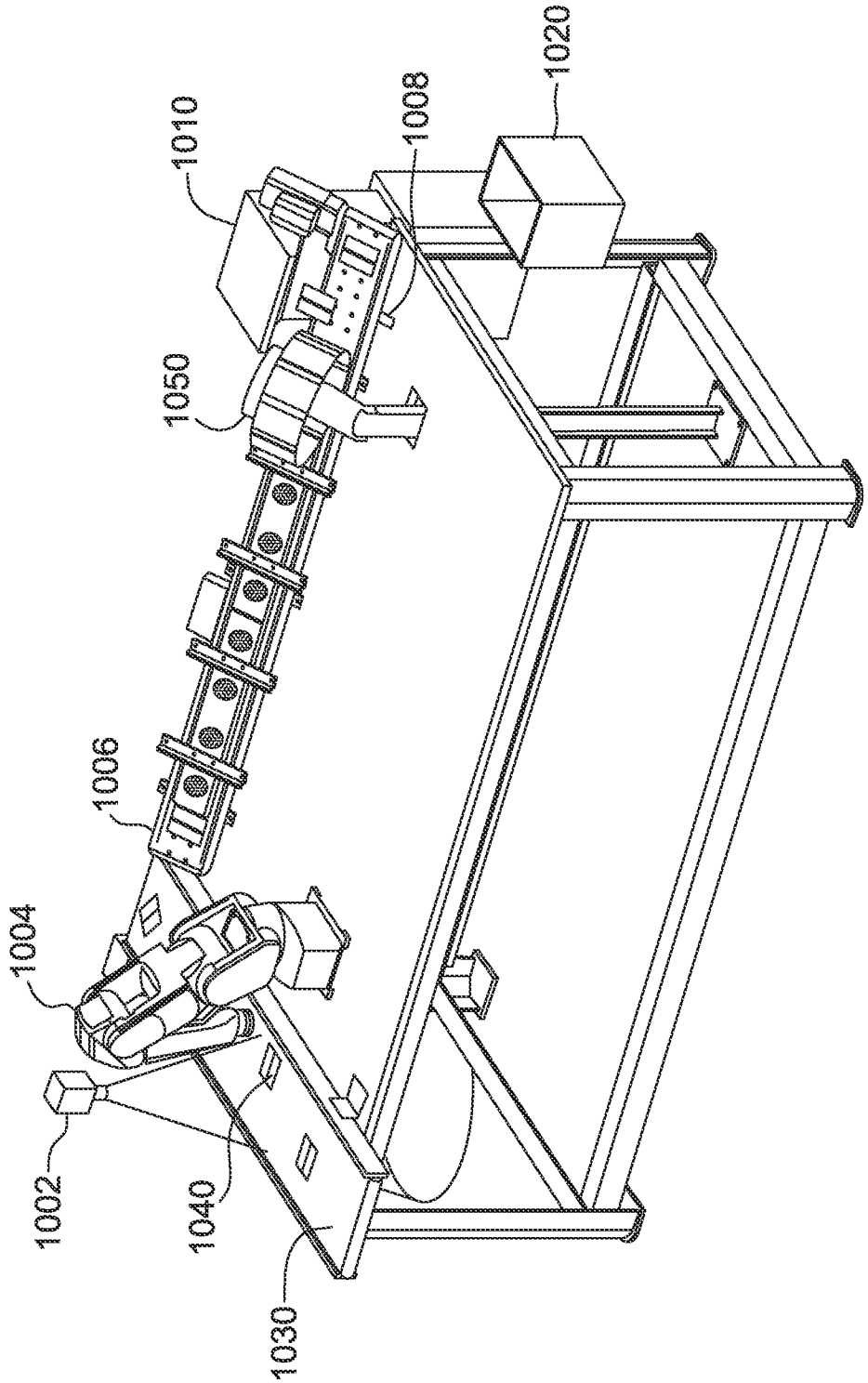

FIG. 10

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2011/064596

A. CLASSIFICATION OF SUBJECT MATTER
INV. G01N21/35 B07C5/34 B07C5/342 C12Q1/04 G01J3/42
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)
G01N B07C C12Q G01J

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 practical, 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 2010/124763 A1 (WALSH JOHN [US] ET AL) 20 May 2010 (2010-05-20) paragraphs [0002], [0003], [0015] - [0023], [0037], [0053], [0054], [0059] - [0067], [0080] - [0091], [0122]	1-15
X	US 2008/180111 A1 (FEDERICI JOHN F [US] ET AL FEDERICI JOHN FRANCIS [US] ET AL) 31 July 2008 (2008-07-31) paragraphs [0002], [0004], [0007] - [0015], [0023], [0034] - [0048], [0056] - [0058], [0080]; figures 1-3,6	1-11, 13-15
X A	EP 1 607 736 A1 (RIKEN [JP]) 21 December 2005 (2005-12-21) paragraphs [0001], [0012] - [0022], [0032] - [0058], [0069]; figure 3	1,3,4,6, 8 7,10, 12-15

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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
15 February 2012	24/02/2012

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Duijs, Eric

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2011/064596

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 0 828 143 A2 (LUCENT TECHNOLOGIES INC [US]) 11 March 1998 (1998-03-11)	1,3-6,8
A	column 1, lines 5-35 column 2, lines 21-30 column 5, lines 17-48; figure 1	7,10, 13-15
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2011/064596

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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		US 2009198466 A1	06-08-2009