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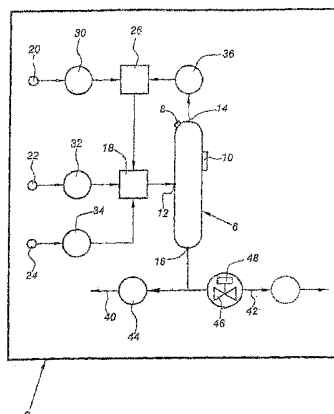
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(54) Title: METHOD AND SYSTEM FOR SELECTING RELEVANT VARIABLES SO AS TO DISCERN A FAILURE AND RECORDING MEDIUM AND PROGRAM FOR THIS METHOD



(57) Abstract: This method of automatically selecting relevant variables for discerning a failure of an automated installation for producing a product comprises a step (220) of measuring the variations of a pair of correlated variables, a step (234) of verifying the consistency of the variations of the correlated variables by calculating a correlation symptom (at 270), then by comparing (at 292) the calculated value of this symptom with a predetermined threshold, and a step (294) of selecting the pair of variables in the guise of relevant variables, if the predetermined threshold is overstepped.

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Method and system for selecting relevant variables so as to discern a failure and recording medium and program for this method

The present invention relates to a method and system for selecting relevant variables so as to discern a failure and a recording medium and program for this method.

These methods are in particular used with procedures for diagnosing faults in automated production installations.

Typically, an automated production installation, such as, for example, a refinery, comprises thousands of sensors and actuators placed throughout this installation to determine its state of functioning. These sensors may be as simple as detectors able to carry out an acquisition of an "on or off" Boolean value. Likewise an actuator may have only two states. These sensors and actuators are linked to a computing system for commanding and controlling this installation. The computing system is equipped with acquisition cards for capturing the physical quantities measured by the sensors and/or control presets delivered by the actuators. In the computing system, each value acquired is contained in a computing variable corresponding to a sensor or to an actuator. Given the number of sensors and actuators, there exists a very large number of such variables in the computing system. Conventionally, the computing system contains several thousand such variables.

The computing system is capable of commanding and/or controlling the installation on the basis of the values of these variables, each of them being representative of the state of functioning of the installation at the current instant.

Here, since each variable contains a measured or acquired value, the expression "measurement of a variable" will designate the steps consisting in measuring with the aid of a sensor a corresponding physical quantity or in acquiring a control preset and in storing this measured or acquired value in the variable.

In this context, procedures for diagnosing faults use these variables to attempt to

automatically identify a failure of the installation.

Generally, a failure may be identified by studying a limited number of relevant variables chosen from among the set of variables of the computing system. It is therefore
5 possible to considerably accelerate the execution of a diagnostic procedure if the relevant variables for discerning the failure have already been selected and identified.

To this end, methods of automatically selecting the relevant variables are known. In these known methods, a value simulated for each variable is calculated with the aid of a
10 computer model of the installation. This simulated value corresponds to the value that one expects to measure on the installation. Thereafter, the simulated value is compared with the measured value contained in the corresponding variable of the computer system. If the deviation between the simulated value and the measured value exceeds a predetermined threshold, then this variable is selected as being relevant for discerning a failure.
15 Specifically, such a deviation between the expected value and the measured value probably results from the presence of a fault or of a failure in the installation.

By virtue of these selection methods, the number of variables to be studied to discern a failure is reduced very significantly, thereby accelerating the implementation of a
20 diagnostic procedure.

However, these known methods of selection are complicated, since they require the calculation of values simulated with the aid of a model of the installation.

25 The invention aims to remedy this drawback by proposing a simpler method of automatically selecting relevant variables for discerning a failure.

A subject of the invention is therefore such a method of selection comprising:

- for each pair of correlated variables that is formed of a main influential
30 variable and of a controlled variable, a step of measuring the variations of the main influential variable and of the controlled variable with the aid of sensors, the variations of the main influential variable and of the controlled

variable being correlated by way of a causal relation,

- a step of verifying that the controlled variable varies in a proportion explicable by the variation of the main influential variable by calculating a correlation symptom whose value is dependent both on the measured variations of the main influential variable and the controlled variable, then by comparing the calculated value of this symptom with a predetermined threshold, and
- a step of selecting the main influential variable and the controlled variable in the guise of relevant variables, if the predetermined threshold is overstepped.

In the above method, a pair of correlated variables, that is to say here, the main influential variable and the controlled variable, is selected as being relevant if the variations of the controlled variable cannot be explained by the variations of the main influential variable. This verification is done by calculating a symptom whose value is dependent on the measured variations of the main influential variable and the controlled variable. This method therefore does not calculate a simulated value for one of the two variables and does not compare the simulated value with the measured value so as to deduce therefore whether this variable is relevant for discerning a failure. It is not therefore necessary to have available a model of the installation making it possible to calculate the simulated value of a variable. On the contrary, the above method utilizes the existing causal relations between two correlated variables to select the relevant variables. Specifically, when the variations of two correlated variables do not comply with the causal relation which binds them, this probably manifests the presence of a failure. This pair of variables is therefore relevant for diagnosing a fault. The utilization of the causal relations between correlated variables is simpler to implement than the modelling of an installation followed by the simulation of this model.

The modes of realization of this method of selection may comprise one or more of the following characteristics:

- during the initialization of the method, a step of defining for each pair of correlated variables an expected direction of variation of the controlled

variable with respect to the direction of variation of the main influential variable, and

- a step of reducing the number of potentially relevant variables so as to discern a failure while systematically eliminating all the pairs of correlated variables wherein the direction of variation of the controlled variable with respect to the direction of variation of the main influential variable corresponds to the expected direction of variation defined during the initialization of the method;

- the correlation symptom calculated is proportional to the product of the measured variations of the main influential variable and of the controlled variable;

- during the initialization of the method, a step of defining for each pair of correlated variables a predetermined delay representing the time elapsed between the instant at which the main influential variable varies and the instant at which the controlled variable varies in response to this variation of the main influential variable, and

- the correlation symptom calculated is proportional to the product of the measured variation of the controlled variable at the current instant and of the measured variation of the main influential variable at the current instant minus the predetermined delay defined for this pair during the initialization of the method;

- a step of calculating a confidence coefficient proportional to the mean of the variations measured for one of the variables of the pair divided by the standard deviation of the variations measured for this same variable, and the correlation symptom calculated is also dependent on this calculated confidence coefficient;

- a step of calculating an influence ratio of the variations of the main influential variable over the variations of the controlled variable as a function of the measured variations of the main influential variable and of the measured variations for one or more disturbing variables, each disturbing variable being able to influence the variations of the controlled variable, and the correlation symptom calculated is dependent on the

influence ratio calculated;

- during the initialization of the method, a step of defining a predetermined gain between the variations of the main influential variable and the variations of the controlled variable and a gain between the variations of each disturbing variable and the variations of the controlled variable, and the calculated influence ratio is also dependent on these predetermined gains;
- a step of measuring one and the same physical quantity of the installation with the aid of a pair of two different sensors, the values measured by each sensor being contained in respective variables of a pair of redundant variables,
- a step of verifying whether a deviation between the values measured by each sensor remains inside predetermined limits by calculating a redundancy symptom whose value is dependent on the deviation between the values measured by each of the sensors of the pair, then by comparing the value calculated for this symptom with a predetermined threshold, and
- a step of selecting the pair of redundant variables in the guise of relevant variables if the predetermined threshold is overstepped;
- for at least one material storage receptacle, a step of measuring the amounts of material entering and leaving the receptacle and a step of measuring the amount of material stored inside the receptacle with the aid of sensors, each measured amount being contained in a corresponding variable,
- a step of verifying a material balance by calculating an instantaneous material balance symptom whose value is dependent on the difference between on the one hand the measured amounts of material entering and leaving between a current instant and a previous instant and, on the other hand, the difference between the measured amounts of material stored at the current instant and at the previous instant, then by comparing the calculated value of this instantaneous material balance symptom with a predetermined threshold, a step of selecting the variables containing the measured amounts of material in the guise of relevant variables if the predetermined threshold is overstepped,

- a step of verifying an aggregate material balance for this receptacle by calculating an aggregate material balance symptom whose value is dependent on the accumulation of the calculated values of the instantaneous material balance symptom, during a period of time over which the direction of variation of the amount of material stored does not change, then by comparing the calculated value of the aggregate material balance symptom with a predetermined threshold, and a step of selecting the variables containing measured amounts of material in the guise of relevant variables if the predetermined threshold is overstepped.

The modes of realization of the method of selection furthermore exhibit the following advantages:

- the simple verification that the direction of variation of a correlated variable with respect to another corresponds to the expected direction of variation already by itself makes it possible to avoid selecting a large number of variables which are not relevant for discerning a failure in the installation, and to do so in a simple manner;
- the use of a correlation symptom whose value is proportional to the product of the measured variations makes it possible to obtain a value which does not favour either of the two variables of a pair of correlated variables;
- the use of the predetermined delay or of the confidence coefficient makes it possible to avoid unnecessary selections of variables;
- the use of the influence ratio avoids the unnecessary selection of a pair of correlated variables, when the main influential variable plays a minor role on the variations of the controlled variable;
- the use of the redundancy which exists between two variables makes it possible to select in a simple and reliable manner a pair of redundant variables if necessary;
- the use of a material balance also makes it possible to select in a simple and effective manner relevant variables; and
- the use of an aggregate material balance makes it possible to select relevant variables when the failure is a slow drift in a material balance.

A subject of the invention is also an information recording medium and a computer program that are adapted for the implementation of the method of selection above.

5 A subject of the invention is also a system for automatically selecting relevant variables for discerning a failure in an automated production installation, this system comprising

- for each pair of correlated variables that is formed of a main influential variable and of a controlled variable, sensors able to measure the variations
10 of the main influential variable and of the controlled variable, the variations of the main influential variable and of the controlled variable being correlated by way of a causal relation,
- a verification module able to verify whether the controlled variable varies in a proportion explicable by the variation of the main influential variable by
15 calculating a correlation symptom whose value is dependent both on the measured variations of the main influential variable and the controlled variable, then by comparing the calculated value of this symptom with a predetermined threshold, and
- a module for selecting the main influential variable and the controlled
20 variable in the guise of relevant variable if the predetermined threshold is overstepped.

The invention will be better understood on reading the description which follows, given merely by way of example and offered while referring to the drawings in which:

- 25 - Figure 1 is a diagrammatic illustration of the architecture of an automated installation for producing a product;
- Figure 2 is a diagrammatic illustration of the architecture of a system for selecting relevant variables for discerning a failure in the installation of Figure 1;
- 30 - Figures 3A and 3B are each a part of a flowchart of a method of selecting relevant variables for discerning a failure, implemented in the system of Figure 2;

- Figures 4A, 4B and 4C are graphs illustrating the functioning of the system of Figure 2 in the case of a failure of a level sensor of the installation of Figure 1;
- Figure 5 is a graph illustrating the functioning of the system of Figure 2 in the case of a failure of a valve of the installation of Figure 1; and
- Figures 6A to 6C are graphs illustrating the functioning of the system of Figure 2 in the case of a failure of a flow meter of the installation of Figure 1.

Figure 1 represents a part of an automated installation 2 for producing a product. Here, this automated installation is an oil refinery. The part illustrated in Figure 1 of the refinery comprises a drum 6 forming a material receptacle equipped with two sensors 8 and 10 of the level inside this drum 6. The sensors 8 and 10 are not placed at the same location on the drum 6 and do not, for example, call upon the same technologies to measure the level inside the drum 6.

The drum 6 comprises a material inlet 12 and two material outlets 14 and 16.

The inlet 12 is coupled by way of a mixer 18 to a main source 20 of supply of material and to two secondary sources 22 and 24 of supply of material.

More precisely, the material provided by the source 20 is sent into an air-cooled exchanger 26 so as to be cooled. The cooled material in the air-cooled exchanger 26 is then transmitted to the mixer 18.

The mixer 18 mixes the material exiting the air-cooled exchanger and that exiting the secondary supplies 22 and 24.

The installation 2 is also equipped with flow meters 30, 32 and 34 for measuring the incoming flow rate of material delivered respectively by the sources 20, 22 and 24.

The installation 2 is also equipped with a flow meter 36 for measuring the extracted

amount of gas from the outlet 14 and sent to the air-cooled exchanger 26.

The outlet 16 is coupled to two pipelines 40 and 42, so as to be able send material extracted from the inside of the drum 6 in two different directions. The pipeline 40 is
5 equipped with a flow meter 44 for measuring the flow rate of material travelling through this pipeline.

The pipeline 42 is equipped with a valve 46 whose control is retrieved by a sensor
48.
10

No sensor able to directly measure the flow rate in the pipeline 42 is provided in this installation 2.

Figure 2 represents a system for selecting relevant variables for discerning a failure
15 in the installation 2. This system comprises an electronic computer 60. This computer 60 is equipped with acquisition cards 62, 64 and 68. This selection system is preferably integrated into a computer system for command and/or control of the installation 2 so that the acquisition cards are common to these two systems.

20 The acquisition card 62 is coupled to the set of sensors of the installation 2. To simplify Figure 2, only the coupling of the card 62 to the flow meters 30, 32 and 34 is represented.

The card 64 makes it possible to acquire the control presets output by a control
25 desk 70 in response to the instructions of an operator of the installation 2. These control presets are likewise transmitted to regulators of the installation 2 which control, as a function of these presets, actuators of the installation 2. To simplify Figure 2, only one regulator 72 and one actuator 74 have been represented. These regulators may be flow rate or pressure regulators and the actuators may be valve actuators or the like such as speed
30 variators for air-cooled exchangers.

The card 68 is intended to acquire the commands transmitted from the regulators to

the regulated actuators.

These acquisition cards 62, 64 and 68 record the physical quantities acquired, that is to say the levels, flow rates, temperatures or the like measured by sensors, the control
5 presets and the commands in respective variables, so that this information may be manipulated by the computer 60. Each of these variables has a name.

The table below indicates, in the particular case of the installation 2, the name of the variables in which the values measured by the sensors 8, 10, 30, 32, 34, 36, 44 and 48
10 are stored.

Numerical reference of the sensor	Name of the corresponding variable
8	KLCA0203
10	KLCA0283
30	KFCL0201
32	KFIL0214
34	KFC0237
36	KFCL0202
44	KFC0289
48	KLX0203

The computer 60 is equipped with a module 80 for validating the signals measured by the sensors and with a module 82 for calculating virtual measurements on the basis of
15 the values measured by the sensors.

The validated signals, the virtual measurements calculated, the control presets acquired by the cards 64 and the commands acquired by the card 68 are transmitted to a module 84 for automatically selecting relevant variables for discerning a failure. This
20 module 84 is coupled to a memory 86 in which are recorded definitions of symptoms. For this purpose, the module 84 comprises a submodule 90 for defining symptoms.

The module 84 also comprises a submodule 92 for measuring variations of the

variables and for confidence coefficient calculation and calculation of influence ratio between these variables. On the basis of the data established by the submodule 92, a verification submodule 94 is able to verify the mutual consistency of the diverse variables measured. Finally, as a function of the result of the verification carried out by the
5 submodule 94, a selection submodule 96 selects or otherwise a variable as being relevant for discerning a failure.

The computer 60 also comprises a man/machine interface 100 on which may be displayed the relevant variables selected by the module 84 and a module 102 for
10 automatically diagnosing a fault in the installation 2 on the basis of the relevant variable selected by the module 84.

Typically, the modules 80, 82, 84 and 102 are software modules.

15 The computer 60 is, here, embodied on the basis of a conventional programmable computer able to execute instructions recorded on an information recording medium. For this purpose, the memory 86 comprises instructions for the execution of the method of Figures 3A and 3B, when these instructions are executed by the computer 60. These instructions comprise in particular the instructions corresponding to the modules 80, 82, 84
20 and 102 and form a computer program.

The functioning of the selection system of Figure 2 will now be described in regard to the method of Figure 3A and 3B, in the particular case of the installation 2.

25 Before even beginning to initialize the selection method, a step 120 of archiving the values of the variables acquired over long periods where the installation 2 functions without failure, is executed. Typically, during step 120, the variables measured with the aid of sensors are archived with a sampling period of one minute for example.

30 Once these archives have been constructed, a phase 122 of initializing the selection method begins. The phase 122 is carried out by a manager of the application. This phase 122 is aimed at initializing the set of parameters which will make it possible, during a

subsequent phase 124, to automatically select the relevant variables for discerning a failure.

During phase 122, a step 130 of defining the virtual measurements is carried out. A virtual measurement is a calculation of the value of a measurable physical quantity at a given point of the installation 2, on the basis of the measurements carried out by other sensors. This makes it possible in particular to cope with the absence of certain sensors in the installation 2. Here, by way of example, the relation making it possible to calculate the flow rate of material inside the pipeline 42 is defined. The flow rate inside the pipeline 42 is, for example, calculated on the basis of the flow rates measured by the flow meters 30, 32, 34 and 44 and of the position of the valve 46. This calculated flow rate is stored in a variable named KYFV0203. This variable KYFV0203 is used subsequently as a variable storing the value of a physical quantity measured directly by a sensor.

During a step 132, redundancy symptoms are defined. During this step 132, pairs of redundant variables are selected, during an operation 134. Here, redundant variables is understood to mean variables each containing the value measured for one and the same physical quantity of the installation 2 by different sensors. These variables are therefore interchangeable. There exists a bijective relation between the values of these two variables involving constants only.

For example, here, the variables KLCA0203 and KLCA0283 are redundant and are therefore selected during the operation 134.

When these redundant variables are measurements of level, inside a drum or a receptacle, the data making it possible to convert the measured height into a mass of material stored in the drum or the receptacle are recorded during an operation 136. For example, the data recorded for the levels measured by the sensors 8 and 10 are here:

- a chart of the drum 6 giving the volume as a function of height; and
- the density of the product stored in the drum 6.

The conversion of the heights into a unit of mass makes it possible to compare

these heights even if the level sensors are placed at various heights inside the drum 6.

Thereafter, during an operation 138, a mean deviation E_{R-ref} between the values measured for the two redundant variables of the selected pair is calculated during an operation 138. This mean deviation E_{R-ref} is, for example, calculated on the basis of the data archived during step 120.

A top limit HL and a bottom limit LL for the redundancy symptom are then calculated during an operation 140. For this purpose, a period of archived data where the variations of the level are significant in the drum 6 and where the sensors 6 and 8 have functioned correctly is selected. A next value Red is then calculated at various instants of this period to determine its maximum value Red_{max} over this selected period:

$$Red = \left| \left(\sum_{i=0}^{i=4} (pv1_{t-i} - pv2_{t-i}) \times K_i \right) - E_{R-ref} \right| \quad (1)$$

where

- Red is the value Red calculated;
- i is a parameterizable index varying from 0 to 4, for example;
- $pv1_{t-i}$ is the value of the first redundant variable at the instant t-i;
- $pv2_{t-i}$ is the value of the second redundant variable at the instant t-i;
- t is the current instant;
- K_i is a weighting coefficient; and
- E_{R-Ref} is the mean deviation calculated during the operation 138.

All the coefficients K_i are, for example, chosen to be equal.

Thereafter, once the value Red_{max} has been determined over the selected period, the values of the limits HL and LL are determined with the aid, for example, of two following relations:

$$(Red_{max} - LL) / (HL - LL) = 0.1 \quad (2)$$

$$HL = 25 \times LL \quad (3)$$

where:

- "×" is the multiplication function;
- HL is the value of the limit HL; and
- LL is the value of the limit LL.

5

The ratio "25" between the values of the limits HL and LL is merely illustrative and depends on the application envisaged. This ratio is not necessarily the same for all the symptoms.

10 Finally, a threshold SL_R for selecting redundancy symptoms is fixed during an operation 142. For example, here, the threshold SL_R is equal to 0.5.

By way of numerical example, the reference deviation E_{R-Ref} for the variables KLCA0203 and KLC0283 is equal to -0.38 and the limits HL and LL are respectively
15 equal to 0.66 and 0.026.

During a step 150, instantaneous and aggregate material balance symptoms are defined for each measurement of level in a drum or a receptacle. These material balances makes it possible to verify the consistency between the measured amounts of material
20 entering and leaving and the measured variation of the amount of material stored in a drum or a receptacle.

For this purpose, during an operation 152, the variables containing the measured amounts of material entering and leaving a receptacle are selected. During this operation
25 152, the variable containing the measurement of the amount of material stored in this receptacle is also selected.

For example, the variables KFCL0201, KFIL0214 and KFC0237 are selected as containing the measured amounts of material entering the assembly formed by the drum 6,
30 the air-cooled exchanger 26 and the mixer 18. The variable KFC0289 and the calculated variable KYFV0203 are selected as containing the amounts of material leaving this assembly. Finally, for a first material balance, the variable KLCA0203 is selected as

containing the amount of material stored in the drum 6. A second material balance different from the first material balance is defined by simply replacing the variable KLCA0203 with the variable KLCA0283.

- 5 If it has not already been done, during an operation 154, the data making it possible to convert a height measurement into a mass of material stored in the drum are recorded.

During an operation 156, a mean reference deviation E_{BM-Ref} is calculated. This is, for example, carried out by taking the mean of the deviations noted in several
10 instantaneous material balances established on the basis of measurements archived during step 120. The formula making it possible to calculate the instantaneous material balance at a given instant t is as follows:

$$MBinst(t) = \sum_{Fin} Fin(t) - \sum_{Fout} Fout(t) + \sum_L (Mi(t) - Mi(t-1)) \quad (4)$$

where:

- 15 - $MBinst(t)$ is the value of the instantaneous material balance at the instant t ;
 - $\sum_{Fin} Fin(t)$ is the aggregate of the measured amounts of material entering between the instant t and the instant $t-1$;
 - $\sum_{Fout} Fout(t)$ is the aggregate of the measured amounts of material leaving between the instant t and the instant $t-1$;
 20 - $Mi(t)$ is the amount of material stored inside the drum at the instant t ;
 - $Mi(t-1)$ is the amount of material stored inside the drum as measured at the instant $t-1$; and
 - t is the current sampling instant and $t-1$ the previous instant.

- 25 The mean deviation E_{BM-Ref} is calculated by taking the mean at several instants of the instantaneous material balance $MBinst(t)$.

During an operation 158, the limits HL and LL for an instantaneous material balance symptom are determined. For example, for a period of archived data where no

failure is present, the maximum deviation $E_{\text{BMI-max}}$ between the value of the instantaneous material balance $\text{MB}_{\text{inst}}(t)$ is the deviation $E_{\text{BM-Ref}}$ is charted. Thereafter, the limits HL and LL are calculated with the aid, for example, of the following relations:

$$(E_{\text{BMI-max}} - \text{LL}) / (\text{HL} - \text{LL}) = 0.1 \quad (5)$$

5 $\text{HL} = 25 \times \text{LL} \quad (6)$

By way of numerical example, for the material balance involving the variable KLCA0203, the deviation $E_{\text{BM-Ref}}$ is equal to 10.76 and the limits HL and LL are respectively equal to 830 and 33. For the instantaneous material balance involving the
10 variable KLCA0283, the deviation $E_{\text{BM-Ref}}$ is equal to 10.75 and the limits HL and LL are respectively equal to 830 and 33.

To define a aggregate material balance symptom on the basis of the instantaneous material balance, a maximum number of cycles before reinitialization is fixed, during an
15 operation 160. The aggregate material balance corresponds to the sum of the instantaneous material balances successively calculated at the maximum over the number of cycles defined, during the operation 160. The number of cycles corresponds to the maximum number of sampling periods and to the maximum number of instantaneous material
20 balances to be added up. The accumulation of the instantaneous material balances is interrupted before the maximum number of cycles is reached if the direction of variation of the level measurement changes, with a certain tolerance so as to avoid straightforward noise in the measurement of level interrupting the accumulation. For example, the number
of cycles before reinitialization is fixed at 232 and at 200 for the aggregate material balances involving the variables KLCA0203 and KLCA0283 respectively.

25

During an operation 162, limits HL and LL for the aggregate material balance symptom are calculated in a manner similar to what was described in regard to the operation 158.

30

By way of example, limits HL and LL for the aggregate material balance involving the variable KLCA0203 are respectively equal to 9500 and 380. These limits HL and LL are equal to 14 000 and to 550 for the aggregate material balance involving the variable

KLCA0283.

Finally, a selection threshold SL_{BMI} for the instantaneous material balance and a selection threshold SL_{BMC} for the aggregate material balance are fixed during an operation
 5 164. For example, these thresholds SL_{BMI} and SL_{BMC} are both chosen equal to 0.3.

During a step 170, correlation symptoms for pairs of correlated variables are defined. In each pair of correlated variables, a variable MV is called the main influential variable and the other variable CV is called the controlled variable. The variable MV is
 10 that which normally most influences the variations of the variable CV.

For this purpose, during an operation 172, the variables MV and CV of a pair of correlated variables are selected and so-called disturbing variables DV are also selected. The disturbing variables are variables liable to influence the variations of the variable CV.

15

Each row of the table below indicates the name of the correlated variables as well as the name of the corresponding disturbing variables for the part of the installation 2 of Figure 1.

MV	CV	DV
KL V0203	KYFV0203	None
KL V0203	KLCA0203	KFCL0201; KFCL0202; KPV0210; KFC0289
KYFV0203	KLCA0203	KFCL0201; KFCL0202; KPV0210; KFC0289
KL V0203	KLCA0283	KFCL0201; KFCL0202; KPV0210; KFC0289
KYFV0203	KLCA0283	KFCL0201; KFCL0202; KPV0210; KFC0289

20

For example, the interpretation of the second row of this table is as follows. A modification of the position of the valve 46 (variable KL V0203) gives rise to a corresponding modification of the level (variable KLCA0203) inside the drum 6. However, this causal relation between a modification of the position of the valve 46 and the
 25 modification of the level inside the drum 6 may be disturbed by the entry of material originating from the primary source 30 (variable KFCL0201) or originating from the

secondary sources 32 and 34 (variables KFCL0202 and KPV0210). This causal relation may also be disturbed by a modification of the flow rate (variable KFC0289) inside the pipeline 40.

5 Thereafter, for each pair of correlated variables, a expected direction of variation S_{atd} of the variable CV with respect to the direction of variation of the variable MV is defined during an operation 174. Here, the direction S_{atd} takes only either the value +1, or the value -1. When the direction S_{atd} is equal to +1 this signifies that the variables MV and CV vary in the same direction, whereas when the direction S_{atd} is equal to -1, this signifies
10 that the variables MV and CV vary in opposite directions. The value of the direction S_{atd} is defined, either on the basis of observations of the data archived during step 120, or by observing the causal relation which in the installation 2 links these two correlated variables.

15 For example, an increase in the opening of the valve 46 gives rise to an increase in the variable KLV0203 and to an acceleration in the reduction of the level in the drum 6. The expected direction of variation S_{atd} between the variations of the variable KLV0203 and of the acceleration of the variable KLCA0203 is then defined as being equal to -1. It will be noted that in the particular case of the variables containing level measurements, it is
20 the variations of the variations or acceleration of level which are taken into account, as will be explained in greater detail hereinbelow. This remark applies also to the parameters relating to the level measurements defined during subsequent operations.

 During an operation 176, the delay δ_{MV}^{CV} between a variation of the variable MV
25 and the resulting variation of the variable CV is recorded. Typically, this delay is measured on the basis of the observation of the data archived during step 120 over a period of functioning with no failure. The delays δ_{DV}^{CV} between variations of the disturbing variables DV and the resulting variation of the variable CV are likewise recorded during this
30 operation 176.

 During an operation 178, a gain G_{MV}^{CV} between the variations of the variable MV

and the resulting variations of the variable CV is recorded. Likewise, during an operation 178, for each disturbing variable DV, a gain G_{DV}^{CV} between the variation of this variable DV and the resulting variation in the variable CV is recorded.

5. The table below gives, by way of illustration for each pair of correlated variables defined, the value of the various parameters input during operations 174 to 178:

Correlated Variable pairs Parameters	KL V0203- KLCA0203	KYFV0203- KLCA0203	KL V0203- KLCA0283	KYFV0203- KLCA0283	KL V0203- KYFV0203
S_{atd}	-1	-1	-1	-1	1
HL	3.5E-03	3.4E-01	7.0E-03	6.7E-01	1.0E+00
LL	1.4E-04	1.3E-02	2.8E-04	2.7E-02	0.0E+00
G_{MV}^{CV}	1.1E+02	1.0E+00	1.1E+02	1.0E+00	1.0E+00
δ_{MV}^{CV}	0	0	0	0	0
$G_{KFCL0201}^{CV}$	1.0E+00	1.0E+00	1.0E+00	1.0E+00	None
$\delta_{KFCL0201}^{CV}$	0	0	0	0	None
$G_{KFCL0202}^{CV}$	1.0E+00	1.0E+00	1.0E+00	1.0E+00	None
$\delta_{KFCL0202}^{CV}$	0	0	0	0	None
$G_{KPV0210}^{CV}$	-3.2E+01	-3.2E+01	-3.2E+01	-3.2E+01	None
$\delta_{KPV0210}^{CV}$	0	0	0	0	None
$G_{KFC0289}^{CV}$	1.0E+00	1.0E+00	1.0E+00	1.0E+00	None
$\delta_{KPC0289}^{CV}$	0	0	0	0	None

- 10 Thereafter, limits HL and LL of correlation symptoms are determined during an operation 180 on the basis of the values of the variables archived, during step 120, over a period with no failure.

During a suboperation 182, the variables MV, CV and DV are filtered, so as to

obtain the corresponding filtered variables $MV_{filt}(t)$, $CV_{filt}(t)$ and $DV_{filt}(t)$ with the aid of the following relations:

$$MV_{filt}(t) = (MV(t) \times \alpha + MV_{filt}(t-1) \times (1-\alpha)) \quad (8)$$

$$CV_{filt}(t) = (CV(t) \times \alpha + CV_{filt}(t-1) \times (1-\alpha)) \quad (9)$$

$$DV_{filt}(t) = (CV(t) \times \alpha + DV_{filt}(t-1) \times (1-\alpha)) \quad (10)$$

5

where α is a constant equal, for example, to 0.2.

Thereafter, during a suboperation 184, the variations

$\overline{dMV(t)}$, $\overline{dCV(t)}$ and $\overline{dDV(t)}$ respectively for the variables $MV_{filt}(t)$, $CV_{filt}(t)$ and

10 $DV_{filt}(t)$ are calculated with the aid of the following relation:

$$\overline{dF(t)} = \frac{\sum_{j=1}^n \sum_{i=0}^{n-j} (F_{filt}(t-i) - F_{filt}(t-i-j))}{\sum_{j=1}^n \left(\sum_{i=0}^{n-j} (j) \right)} \quad (11)$$

where:

- 15 - $\overline{dF(t)}$ is the calculated variation of a variable F, the symbol F here being used in place of one of the symbols MV, CV and DV previously defined:
- $F_{filt}(t-i)$ is the filtered value of the variable F at the instant t-i;
- i is an index varying from 0 to n-j;
- j is an index varying from 1 to n; and
- 20 - n is a constant defining the number of values taken into account for the calculation of the variation of the variable F.

n is, here, fixed equal to 5.

For the variable L containing a level measurement, the double variation $\overline{ddL(t)}$ is used instead of the variation $\overline{dL(t)}$. The double variation $ddL(t)$ is calculated with the aid of the following relation, during the operation 184:

$$\overline{ddL(t)} = \overline{dL(t)} - \overline{dL(t-1)} \quad (12)$$

5

This remark applies to everything that follows.

Next, during a suboperation 186, the standard deviation in the variations of the filtered values of the variables MV, CV and DV is calculated with the aid of the following relation:

10

$$\sigma(dF(t)) = \sqrt{\frac{\sum_{j=1}^n \sum_{i=0}^{n-j} \left(\frac{(F_{fil}(t-i) - F_{fil}(t-i-j))}{j} - \overline{dF(t)} \right)^2}{\sum_{j=1}^n \left(\sum_{i=0}^{n-j} (j) \right)}} \quad (13)$$

During a suboperation 188, for each of the variables MV, CV and DV a confidence coefficient $C_{dF(t)}$ is calculated according to the following relation:

15

$$C_{dF(t)} = \frac{\overline{dF(t)}}{\sigma(dF(t))} \text{ if } \sigma(dF(t)) \text{ non zero, else } C_{dF(t)} = 0 \quad (14)$$

This confidence coefficient indicates the confidence that may be had in the fact that the variation calculated during suboperation 184 is representative of the actual progression of the installation.

20

During a suboperation 190, the product $\overline{p(dMV(t))}, \overline{p(dCV(t))}$ of the variations of the variables MV and CV is calculated with the aid of the following relation:

$$\overline{p(dMV(t))}, \overline{p(dCV(t))} = \overline{dMV(t - \delta_{MV}^{CV})} \times \overline{dCV(t)} \quad (15)$$

25

During a suboperation 192, for each pair of correlated variables, the weighted direction of variations S_{pond} is calculated with the aid of the following relation:

$$S_{pond}(\overline{dMV(t)}, \overline{dCV(t)}) = P(\overline{dMV(t)}, \overline{dCV(t)}) \times \text{Min}(\text{Abs}(C_{dMV(t)}), \text{Abs}(C_{dCV(t)})) \quad (16)$$

5 where:

- $C_{dMV(t)}$ and $C_{dCV(t)}$ are the confidence coefficients for the variation of the variables MV and CV respectively calculated during suboperation 188;
- $\text{Abs}(.)$ is the absolute value function;
- $\text{Min}(.)$ is the function which returns the minimum value among several

10 possible values.

During a suboperation 194, the influence $I(\overline{dMV(t)}, \overline{dCV(t)})$ of the variations of the variable MV on the variations of the variable CV is calculated with the aid of the following relation:

$$15 \quad I(\overline{dMV(t)}, \overline{dCV(t)}) = \text{Abs}[G_{MV}^{CV} \times dMV(t - \delta_{MV}^{CV})] \quad (17)$$

Likewise, during this suboperation 194, the influence $I(\overline{dMV(t)}, \overline{dCV(t)})$ of each disturbing variable DV on the variations of the variable CV is calculated with the aid of the following relation:

$$20 \quad I(\overline{dDV(t)}, \overline{dCV(t)}) = \text{Abs}[G_{DV}^{CV} \times dDV(t - \delta_{DV}^{CV})] \quad (18)$$

The various influences calculated during suboperation 194 are used, during a suboperation 196, to calculate an influence ratio making it possible to measure the share of the variations of the variable CV which may be explained by the variations of the variable

25 MV. This influence ratio $R(\overline{dMV(t)}, \overline{dCV(t)})$ is calculated according to the following relation:

$$R(\overline{dMV(t)}, \overline{dCV(t)}) = \frac{I(\overline{dMV(t)}, \overline{dCV(t)})}{I(\overline{dMV(t)}, \overline{dCV(t)}) + \sum_{i=1}^n I(\overline{dDV_i(t)}, \overline{dCV(t)})} \quad (19)$$

The influence ratio is used during a suboperation 198, to calculate an attenuated direction of variations S_{att} according to the following relations:

$$\text{if } S_{pond}(\overline{dMV(t)}, \overline{dCV(t)}) \times S_{atd}(\overline{dMV(t)}, \overline{dCV(t)}) > 0 \text{ then } S_{att}(\overline{dMV(t)}, \overline{dCV(t)}) = 0 \quad (20)$$

else

5

$$S_{att}(\overline{dMV(t)}, \overline{dCV(t)}) = \text{Abs}[S_{pond}(\overline{dMV(t)}, \overline{dCV(t)})] \times [R(\overline{dMV(t)}, \overline{dCV(t)})]^{+\alpha} \quad (21)$$

where:

- α is a constant chosen equal to 10 by default,
- $S_{atd}(\overline{dMV(t)}, \overline{dCV(t)})$ is the expected direction of variation defined for this pair of correlated variables, during operation 174.

10

During a suboperation 200, the maximum value $S_{att-max}$ of the direction S_{att} , calculated over the selected archived period, is charted. The maximum value R_{max} of the influence ratio is also charted during suboperation 200.

15

Thereafter, during a suboperation 202, the limits HL and LL of the correlation symptom are calculated with the aid of the following relations:

$$HL = 25 \times LL \quad (22)$$

20

$$LL = \left[\frac{S_{att-max}(\overline{dMV(t)}, \overline{dCV(t)})}{[(25 - 1) \times 0,1] + [R_{max}(\overline{dMV(t)}, \overline{dCV(t)})]^{+\alpha}} \right] \quad (23)$$

where:

25

- $S_{att-max}(\overline{dMV(t)}, \overline{dCV(t)})$ is the maximum value of the direction S_{att} , charted during suboperation 200; and
- $R_{max}(\overline{dMV(t)}, \overline{dCV(t)})$ is the maximum value of the influence ratio likewise charted during suboperation 200.

Once the limits HL and LL have been determined for each pair of correlated variables, a selection threshold SL_{MLK} is recorded during an operation 206. Here, this threshold SL_{MLK} is chosen equal to 0.8 for all the pairs of correlated variables.

5 The initialization phase is then complete and the phase 124 can then be executed by the computer 60 at the same time as the installation 2 is functioning.

10 During the functioning of the installation 2, the physical quantities representing a state of functioning of this installation are measured, during a step 220, by the various sensors placed in this installation. The measured values are acquired, during a step 222, by the acquisition card 62 and stored in the corresponding variables. During step 222, if it is necessary, the control presets and the commands are likewise acquired and recorded in corresponding variables.

15 The values acquired by the card 62 are then subjected to a validation process, during a step 224. During step 224, various tests are carried out on the measured values, so as to determine those which emanate from a failed sensor. For example, the following points are verified by the module 80:

- 20 - Is the measured value not outside the scale of the sensor?
- Is the measured value not outside the limits of functioning of the installation 2?
- Do the measured successive values for a sensor not correspond to a flat signal?
- 25 - Are the values measured by a sensor not representative of a slow drift of this sensor?
- Does the rate of variation of the successive measured values not exceed a predetermined limit?

30 If the response to one of these verification points is yes, then the measured value is invalid, and the latter is not used for the remainder of the method. Henceforth none of the symptoms using the variable containing the invalid measured value is calculated.

Thereafter, during a step 226, the virtual measurements, such as, for example, the variable KYFV0203, are calculated on the basis of the validated measured values.

Then, the consistency of the measured values is verified with the aid of the redundancy symptoms, the instantaneous and aggregate material balance symptoms and the correlation symptoms defined during phase 122. In fact, the module 80 verifies the consistency of the values measured with the aid of redundancy, material balance and correlation symptoms respectively during steps 230, 232 and 234.

During step 230, a redundancy symptom $Sy_R(t)$ is calculated for each pair of redundant variables, during an operation 240.

More precisely, during a suboperation 242, the redundancy Red is calculated with the aid of relation (1). Then, during a suboperation 244, the value of the symptom $Sy_R(t)$ is calculated with the aid of the following algorithm:

if Red $\geq$ HL, *then* $Sy_R(t) = 1$;
else {*if* Red $\leq$ LL, *then* $Sy_R(t) = 0$;
else $Sy_R(t) = (Red - LL) / (HL - LL)$ }

where: HL and LL are the values of the limits determined during suboperation 140 for this pair of redundant variables.

The calculated value of the symptom $Sy_R(t)$ is compared, during an operation 246, with a selection threshold SL_R . If the value of the symptom $Sy_R(t)$ is greater than the threshold SL_R , then the variables of this pair of redundant variables are selected, during an operation 248, as being relevant for discerning a failure in the installation. Specifically, in this case, a significant deviation exists between the values of these redundant variables, this signifying that one of the corresponding sensors has perhaps failed and that these variables and the information that they represent are of interest to the diagnostic procedure.

In the converse case, that is to say if the value of the symptom $Sy_R(t)$ is less than the threshold SL_R , then no variable is selected as being relevant. The operations 240 to 246 are reiterated for each pair of redundant variables.

5 Step 232 commences with the calculation of the value of a symptom $Sy_{BMI}(t)$ of an instantaneous material balance. To do this, the instantaneous material balance $MB_{inst}(t)$ is calculated with the aid of relation (4). Thereafter, the value of the symptom Sy_{BMI} is calculated with the aid of the following relations:

$$\begin{aligned} & \text{if} \quad (MB_{inst}(t) - E_{BM-Ref}) \geq HL \text{ then } Sy_{BMI}(t) = 1 \\ & \text{else} \quad \left\{ \begin{array}{l} \text{if} \quad (MB_{inst}(t) - E_{BM-Ref}) \leq LL \text{ then } Sy_{BMI} = 0 ; \\ \text{else} \quad Sy_{BMI}(t) = (MB_{inst}(t) - E_{BM-Ref} - LL) / (HL - LL) \end{array} \right\} \end{aligned}$$

10

where:

- HL and LL are the limits determined for this instantaneous material balance during the operation 158;
- E_{BM-Ref} is the reference deviation calculated during the operation 156 for this instantaneous material balance.

15

Thereafter, during an operation 252, the calculated value of the symptom $Sy_{BMI}(t)$ is compared with the fixed selection threshold SL_{BMI} , during operation 164. If the calculated value of the symptom $Sy_{BMI}(t)$ is greater than the threshold SL_{BMI} , then the variables involved in the calculation of this instantaneous material balance are selected, during an operation 254, as being relevant for discerning a failure. Specifically, the material balance carried out around a drum is not complied with, this signifying that one of the sensors measuring an amount of material has probably failed.

20

25 In the converse case, that is to say if during operation 252, the calculated value of the symptom Sy_{BMI} is less than the threshold SL_{BMI} , then no variable is selected.

Thereafter, an aggregate material balance symptom $Sy_{BMC}(t)$ is calculated, during an operation 260. To do this, the accumulated material balance $BM_{accum}(t)$ is firstly

calculated by accumulating the instantaneous material balances $BM_{inst}(t)$ during a number of cycles fixed during the suboperation 160 for this instantaneous material balance. The aggregate material balance is, for example, calculated with the aid of the following relation:

$$BM_{accum}(t) = \sum_{i=0}^n (BM_{inst}(t) - E_{BM} - Ref) \quad (26)$$

where:

- n is the number of cycles.

Thereafter, during the operation 260, the value of the symptom $Sy_{BMC}(t)$ is calculated with the aid of the following relation:

$$\begin{aligned} & \text{if} \quad BM_{accum}(t) \geq HL \text{ then } Sy_{BMC}(t) = 1 \\ & \text{else} \quad \left\{ \begin{array}{l} \text{if} \quad BM_{accum}(t) \leq LL \text{ then } Sy_{BMC}(t) = 0 ; \\ \text{else} \quad Sy_{BMC}(t) = (BM_{accum}(t) - LL) / (HL - LL) \end{array} \right\} \end{aligned} \quad (27)$$

where:

- HL and LL are the limits determined, during the operation 162, for this aggregate material balance.

Once the value of the symptom $Sy_{BMC}(t)$ has been calculated, the latter is compared, during an operation 262, with the value of the threshold SL_{BMC} , fixed during the operation 164. If the value of the symptom $Sy_{BMC}(t)$ is greater than the threshold SL_{BMC} , then the variables involved in the calculation of this aggregate material balance are selected during a step 264 in the guise of relevant variables for discerning a failure. In the converse case, no variable is selected.

If the value of the symptom $Sy_{BMC}(t)$ is greater than SL_{BMC} , this signifies that at least one of the sensors used to measure the amounts of material has probably failed.

The operations 250 to 262 are reiterated for each material balance defined, during step 150.

During step 234, a correlation symptom $S_{YMLK}(t)$ is calculated for each pair of
5 correlated variables defined during step 170. This calculation is carried out during an operation 270.

More precisely, during the operation 270, the values of the variables MV, CV and DV are filtered with the aid of relations (8), (9) and (10), during a suboperation 272. On
10 the basis of these filtered values, the variations $\overline{dMV(t)}$, $\overline{dCV(t)}$ and $\overline{dDV(t)}$ are calculated during a suboperation 274, with the aid of relation (11). For the variables containing a level measurement, the double variation $\overline{ddL(t)}$ is calculated with the aid of relation (12). This double variation is thereafter used instead of the variation $\overline{dL(t)}$.

15 Thereafter, the standard deviation in the variations of the variables MV, CV and DV is also calculated, during a suboperation 276, with the aid of relation (13).

The confidence coefficients $C_{dMV(t)}$, $C_{dCV(t)}$ and $C_{dDV(t)}$ in the variations of the variables MV, CV and DV are calculated, during a suboperation 278, with the aid of
20 relation (14).

Then, the products of the variations $\overline{dMV(t)}$ and $\overline{dCV(t)}$ are calculated, during a suboperation 280, with the aid of relation (15).

25 Afterwards, during a suboperation 282, the weighted direction of variation $S_{pond}(\overline{dMV(t)}, \overline{dCV(t)})$ is calculated with the aid of relation (16).

Next, the influence $I(\overline{dMV(t)}, \overline{dCV(t)})$ and, if there exist disturbing variables DV, the influences $I(\overline{dDV(t)}, \overline{dCV(t)})$ are calculated with the aid of relations (17) and
30 (18), during a suboperation 284. The calculated influences are thereafter used, during a

suboperation 286 to calculate the influence ratio $R(\overline{dMV(t)}, \overline{dCV(t)})$ with the aid of relation (19).

5 The attenuated direction of variation S_{att} is then calculated for each pair of correlated variables, with the aid of relations (20) and (21), during a suboperation 288.

Finally, the value of the symptom $Sy_{MLK}(t)$ is calculated with the aid of the following relation, during a suboperation 290:

$$10 \quad \text{if } S_{pond}(\overline{dMV(t)}, \overline{dCV(t)}) \times S_{atd}(\overline{dMV(t)}, \overline{dCV(t)}) > 0 \quad \text{then } Sy_{MLK}(t) = 0 \quad (28)$$

$$\text{else } Sy_{MLK}(t) = \frac{(Abs[S_{att}(\overline{dMV(t)}, \overline{dCV(t)})] - LL)}{(HL - LL)} \quad (29)$$

where:

- 15
- HL and LL are the limits determined during suboperation 202 for this pair of correlated variables;
 - $S_{atd}(\overline{dMV(t)}, \overline{dCV(t)})$ is the expected direction of variation, defined during operation 174 for this pair of correlated variables.

20 Thereafter, during an operation 292, the calculated value of the symptom $Sy_{MLK}(t)$ is compared with the threshold SL_{MLK} . If the value of the symptom $Sy_{MLK}(t)$ is greater than the threshold SL_{MLK} , then the correlated variables of the pair are selected in the guise of relevant variables for discerning a failure of the installation, during an operation 294. In the converse case, neither of the variables of the pair is selected in the guise of relevant

25 variable.

If the symptom $Sy_{MLK}(t)$ is greater than the threshold SL_{MLK} this signifies that the variations of the variables MV and CV do not comply with the causal relation which binds them, that is to say, stated otherwise, that the variations measured for the variable MV do

not make it possible to explain the variations measured for the variable CV. This therefore manifests the presence of a failure in the installation 2.

The operations 270 to 292 are reiterated for each pair of correlated variables.

5

Phase 124 is reiterated at each current instant so as to be able to select in real time the relevant variables.

On completion of the selection phase 124, the relevant variables selected are transmitted to the man/machine interface 100 to display the name and the content of these variables, during a step 300. If the number of variables selected is small, an operator by examining these variables can himself determine what is the cause of the failure and it is not necessary to execute an automatic diagnostic procedure.

10 The variables selected are also transmitted to the fault diagnosis module 102. This module automatically determines, solely on the basis of the relevant variables selected, what is the fault or the failure, during a step 302.

15 Figures 4A to 4C illustrate the functioning of the method of Figures 3A and 3B in the case of a failure of the level sensor 8 giving rise to a constant drift of the measured value, whereas the level does not move.

In the graph of Figure 4A, a curve 320 represents the value of the level measured by the sensor 10 which is functioning normally. This level is stable and does not move.

25

A curve 322 represents the value of the level as measured by the sensor 8. This value increases steadily over time, so that after two hours a deviation of 12% exists between the actual value of the level and the value measured by the sensor 8.

30 Finally, in Figure 4A, a curve 324 represents the value of the redundancy symptom calculated for the pair of variables KLCA0283 and KLCA0203. As represented, the value of this symptom $Sy_R(t)$ very rapidly reaches the value 1 thereby bringing about the

selection of the variables KLCA0203 and KLCA0283, as being relevant for discerning this failure. The ordinate axis on the left of the graph represents the value of the symptom $Sy_R(t)$.

5 Figure 4B represents by way of example the progression of the value of one of the correlation symptoms during the course of the same period of time. As illustrated, this symptom, like the other correlation symptoms defined here, is of no use for selecting the relevant variables, in the particular case of this type of fault. Specifically, a continuous and constant drift of a sensor is not manifested as a change of the value of the double variation
10 $\overline{ddL(t)}$ (acceleration of the level), so that this failure remains undetectable with the aid of correlation symptoms.

 In the graph of Figure 4C, the curves 340 and 342 represent the progression over time, respectively of the symptoms $Sy_{BMI}(t)$ and $Sy_{BMC}(t)$ for the material balances
15 involving the variable KLCA0203. As illustrated in this graph, the failure remains indiscernible with the aid of the symptom $Sy_{BMI}(t)$. On the other hand, the value of the symptom $Sy_{BMC}(t)$ exceeds, after a certain time, the threshold SL_{BMC} , thereby resulting in the selection of the variables involved in the calculation of this aggregate material balance in the guise of relevant variables.

20 The graph of Figure 5 comprises a curve 350 representing the progression over time of the correlation symptom correlating the variables KYFV0203 and KLV0203, in the particular case where the measured value of the position of the valve 46 increases steadily over time without this corresponding to an actual displacement of the valve. As illustrated in the graph of Figure 5, the value of the symptom $Sy_{MLK}(t)$ for the pair of correlated
25 variables KYFV0203 and KLV0203 exceeds at a given moment the threshold SL_{MLK} , thereby giving rise to the selection of these variables in the guise of relevant variables for discerning a failure. Specifically, in the case of such a failure, the measured variations of the position of the valve are no longer correlated with the flow rate measured in the pipeline 42. It will also be noted that none of the other correlation symptoms defined here
30 reacts to this failure of the sensor 48.

The graph of Figure 6A represents a particular case of failure of the installation 2 which gives rise to a sawtooth progression of the calculated variable KYFV0203 as illustrated by the curve 356.

5 The graph of Figure 6 also comprises curves 358 and 360 respectively representing the progression over time of the value of the variables KLCA0203 and KLV0203.

Such a failure of the installation has no impact on the redundancy symptoms. On the other hand, as illustrated by a curve 370, in the graph of Figure 6B, the value of the correlation symptom correlating the variables KYFV0203 and KLV0203 several times exceeds the value of the threshold SL_{MLK} , thereby leading to the selection of these two variables as being relevant for discerning a failure. Specifically, the sawtooth variations of the flow rate in the pipeline 42 do not correspond, here, to a corresponding variation of the position of the valve 46. It is therefore probable that these sawtooth variations result from a failure of the installation 2.

10
15

The value of the other symptoms is only slightly affected by this failure of the installation 2.

20 This failure also has repercussions on the material balances and in particular on the instantaneous and aggregate material balances involving the variable KLCA0203. The graph of Figure 6C comprises curves 372 and 374 representing the progression over time respectively of the symptoms $Sy_{BMI}(t)$ and $Sy_{BMC}(t)$ calculated for the material balances involving the variable KLCA0203. As illustrated in the graph of Figure 6, on several occasions these two symptoms exceed the selection thresholds SL_{BMI} and SL_{BMC} , so that the variables involved in the calculation of these symptoms are selected in the guise of relevant variables.

25

Numerous other modes of implementation of the system of Figure 2 and of the method of Figures 3A and 3B are possible. For example, as a variant, when the influence ratio calculated indicates that the main influential variable MV is not the only one to influence the variations of the controlled variable CV, the correlation symptom is not used.

30

This makes it possible to simplify the calculations and therefore accelerates the execution of the method. Thus in this variant, only the correlation symptoms involving no disturbing variable are taken into account.

5 Instantaneous and aggregate material balances have been described here, in the particular case of a part of an installation comprising a single drum. However, the principle described for calculating an instantaneous material balance and an aggregate material balance may also be applied to a group of several drums or receptacles. Likewise, a material balance may not only be calculated for a drum but for all sorts of vessels or
10 reactors, that is to say for any item of equipment forming a material storage receptacle.

Here, only the variables measured by sensors have been used to define redundancy, material balance and correlation symptoms. As a variant, the variables containing control presets or containing commands may also be used to define such symptoms.

Claims:

1. Method of automatically selecting relevant variables for discerning a failure in an automated installation for producing a product, each of the variables containing the value of a physical quantity representative of the state of functioning of the installation, characterized in that this method comprises:
 - for each pair of correlated variables that is formed of a main influential variable and of a controlled variable, a step (220) of measuring the variations of the main influential variable and of the controlled variable with the aid of sensors, the variations of the main influential variable and of the controlled variable being correlated by way of a causal relation,
 - a step (234) of verifying that the controlled variable varies in a proportion explicable by the variation of the main influential variable by calculating a correlation symptom (at 270) whose value is dependent both on the measured variations of the main influential variable and the controlled variable, then by comparing (at 292) the calculated value of this symptom with a predetermined threshold, and
 - a step (294) of selecting the main influential variable and the controlled variable in the guise of relevant variables, if the predetermined threshold is overstepped.
2. Method according to Claim 1, characterized in that it comprises:
 - during the initialization of the method, a step (174) of defining for each pair of correlated variables an expected direction of variation of the controlled variable with respect to the direction of variation of the main influential variable, and
 - a step (292) of reducing the number of potentially relevant variables so as to discern a failure while systematically eliminating all the pairs of correlated variables wherein the direction of variation of the controlled variable with respect to the direction of variation of the main influential variable corresponds to the expected direction of variation defined during the initialization of the method.

3. Method according to any one of the preceding claims, characterized in that the correlation symptom calculated is proportional to the product of the measured variations of the main influential variable and of the controlled variable.

5 4. Method according to any one of the preceding claims, characterized in that it comprises:

- during the initialization of the method, a step (176) of defining for each pair of correlated variables a predetermined delay representing the time elapsed between the instant at which the main influential variable varies and the instant at which the controlled variable varies in response to this variation of the main influential variable, and
- in that the correlation symptom calculated is proportional to the product of the measured variation of the controlled variable at the current instant and of the measured variation of the main influential variable at the current instant minus the predetermined delay defined for this pair during the initialization of the method.

10 5. Method according to Claim 3 or 4, characterized in that it comprises a step (278) of calculating a confidence coefficient proportional to the mean of the variations measured for one of the variables of the pair divided by the standard deviation of the variations measured for this same variable, and in that the correlation symptom calculated is also dependent on this calculated confidence coefficient.

20 6. Method according to any one of the preceding claims, characterized in that it comprises a step (286) of calculating an influence ratio of the variations of the main influential variable over the variations of the controlled variable as a function of the measured variations of the main influential variable and of the measured variations for one or more disturbing variables, each disturbing variable being able to influence the variations of the controlled variable, and in that the correlation symptom calculated is dependent on the influence ratio calculated.

30 7. Method according to Claim 6, characterized in that it comprises:

- during the initialization of the method, a step (178) of defining a predetermined gain between the variations of the main influential variable and the variations of the controlled variable and a gain between the variations of each disturbing variable and the variations of the controlled variable, and
 - 5 - in that the calculated influence ratio is also dependent on these predetermined gains.
8. Method according to any one of the preceding claims, characterized in that it comprises:
- 10 - a step (220) of measuring one and the same physical quantity of the installation with the aid of a pair of two different sensors, the values measured by each sensor being contained in respective variables of a pair of redundant variables,
 - a step (230) of verifying whether a deviation between the values measured by each sensor remains inside predetermined limits by calculating (at 240) a
 - 15 redundancy symptom whose value is dependent on the deviation between the values measured by each of the sensors of the pair, then by comparing (at 246) the value calculated for this symptom with a predetermined threshold, and
 - a step (248) of selecting the pair of redundant variables in the guise of relevant variables if the predetermined threshold is overstepped.
- 20
9. Method according to any one of the preceding claims, characterized in that it comprises:
- for at least one material storage receptacle, a step (220) of measuring the amounts of material entering and leaving the receptacle and a step (220) of
 - 25 measuring the amount of material stored inside the receptacle with the aid of sensors, each measured amount being contained in a corresponding variable,
 - a step (232) of verifying an instantaneous material balance by calculating (at 250) an instantaneous material balance symptom whose value is dependent on the difference between on the one hand the measured amounts of material
 - 30 entering and leaving between a current instant and a previous instant and, on the other hand, the difference between the measured amounts of material stored at the current instant and at the previous instant, then by comparing (at 252) the

calculated value of this instantaneous material balance symptom with a predetermined threshold,

- a step (254) of selecting the variables containing the measured amounts of material in the guise of relevant variables if the predetermined threshold is overstepped.

10. Method according to Claim 9, characterized in that it comprises a step of verifying an aggregate material balance for this receptacle by calculating (at 260) an aggregate material balance symptom whose value is dependent on the accumulation of the calculated values of the instantaneous material balance symptom, during a period of time over which the direction of variation of the amount of material stored does not change, then by comparing (at 262) the calculated value of the aggregate material balance symptom with a predetermined threshold, and in that it comprises a step (264) of selecting the variables containing measured amounts of material in the guise of relevant variables if the predetermined threshold is overstepped.

11. Information recording medium, characterized in that it comprises instructions for the execution of a method of selection in accordance with any one of the preceding claims, when these instructions are executed by an electronic computer.

12. Computer program, characterized in that it comprises instructions for the execution of a method of selection in accordance with any one of the preceding claims, when these instructions are executed by an electronic computer.

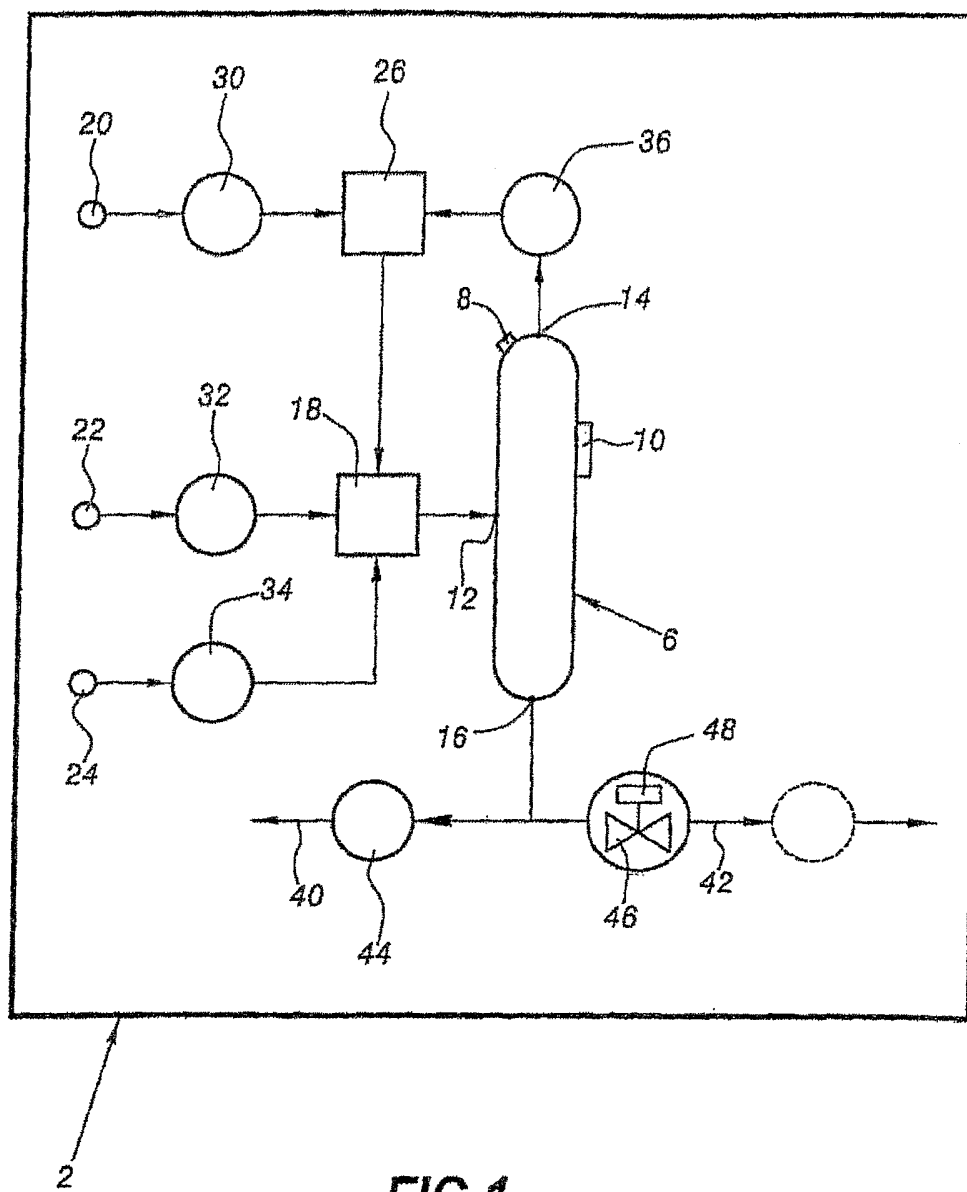
13. System for automatically selecting relevant variables for discerning a failure in an automated installation for producing a product, each of the variables containing the value of a physical quantity representative of the state of functioning of the installation, characterized in that it comprises:

- for each pair of correlated variables that is formed of a main influential variable and of a controlled variable, sensors (8, 10, 30, 32, 34, 44, 48) able to measure the variations of the main influential variable and of the controlled variable, the variations of the main influential variable and of the controlled

variable being correlated by way of a causal relation,

- a verification module (94) able to verify whether the controlled variable varies in a proportion explicable by the variation of the main influential variable by calculating a symptom whose value is dependent both on the measured variations of the main influential variable and the controlled variable, then by comparing the calculated value of this symptom with a predetermined threshold, and
- a module (96) for selecting the main influential variable and the controlled variable in the guise of relevant variable if the predetermined threshold is overstepped.

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**FIG.1**

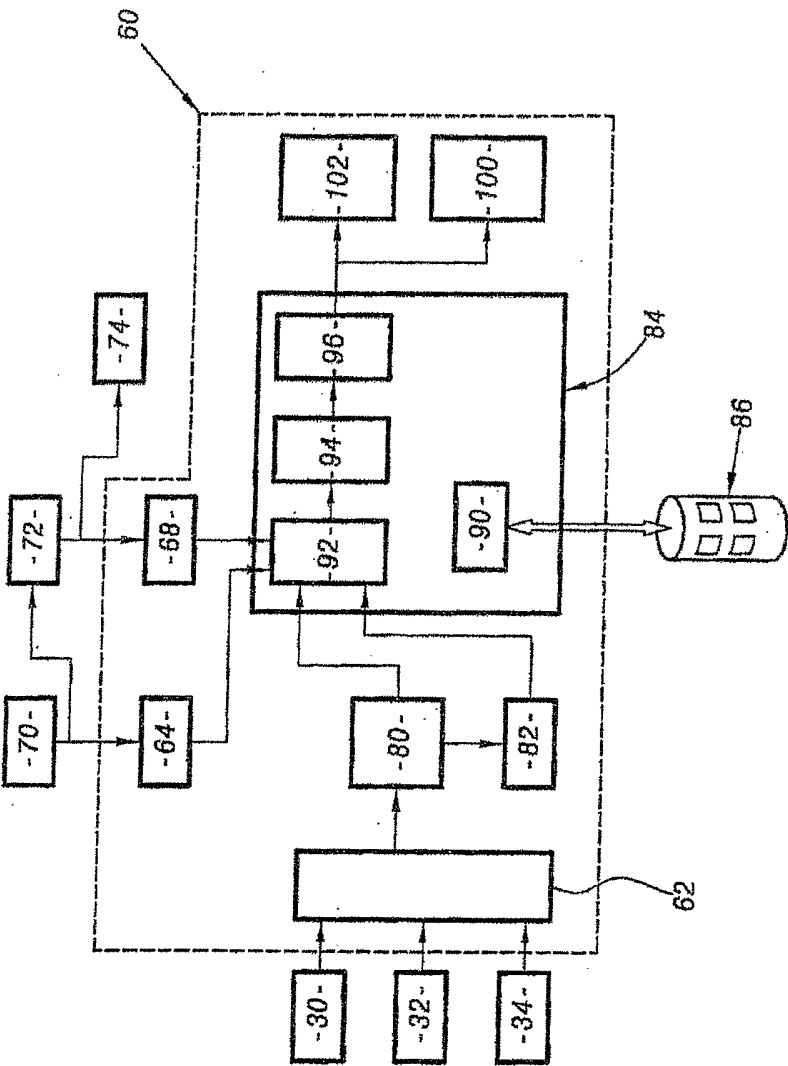
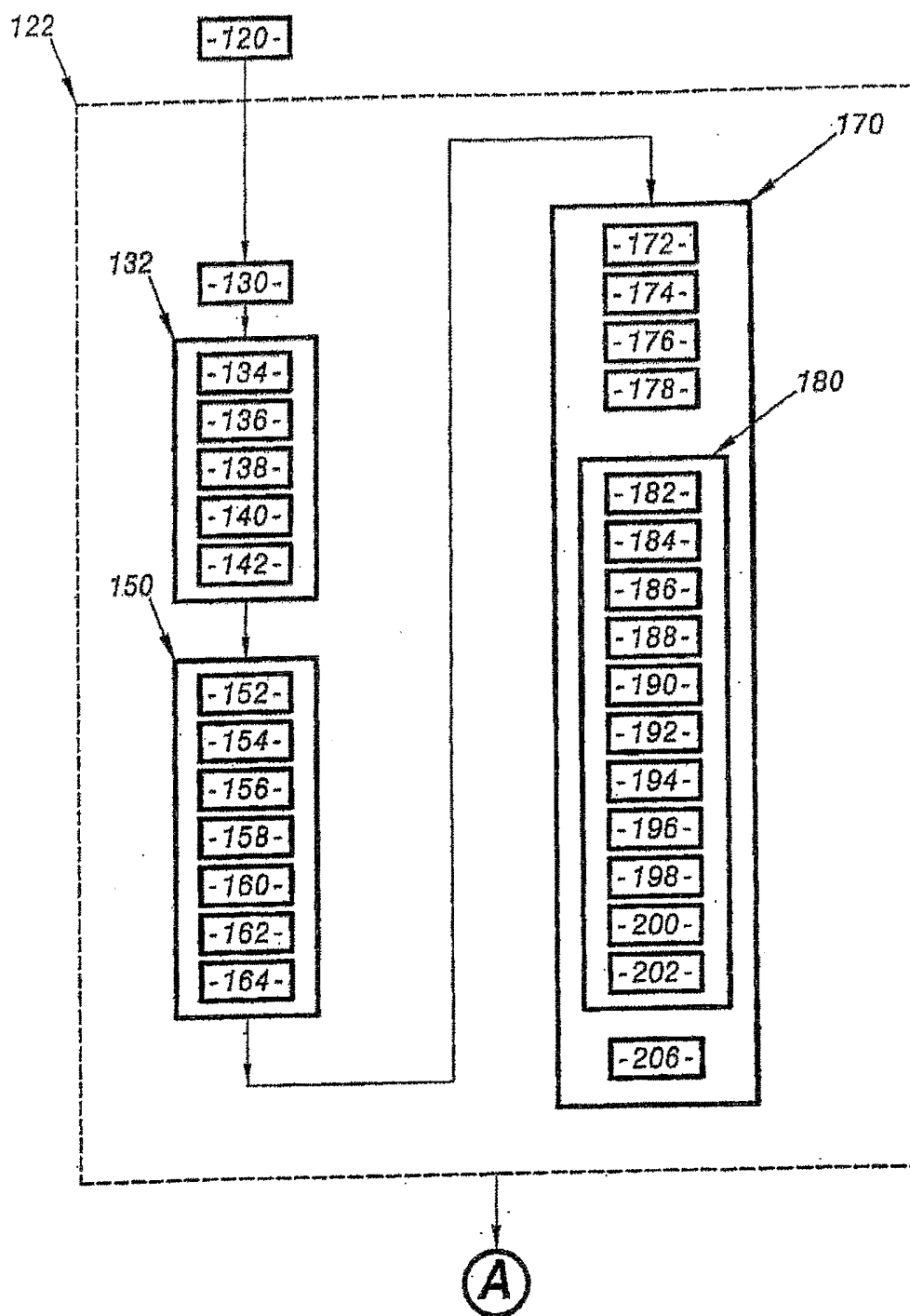


FIG. 2

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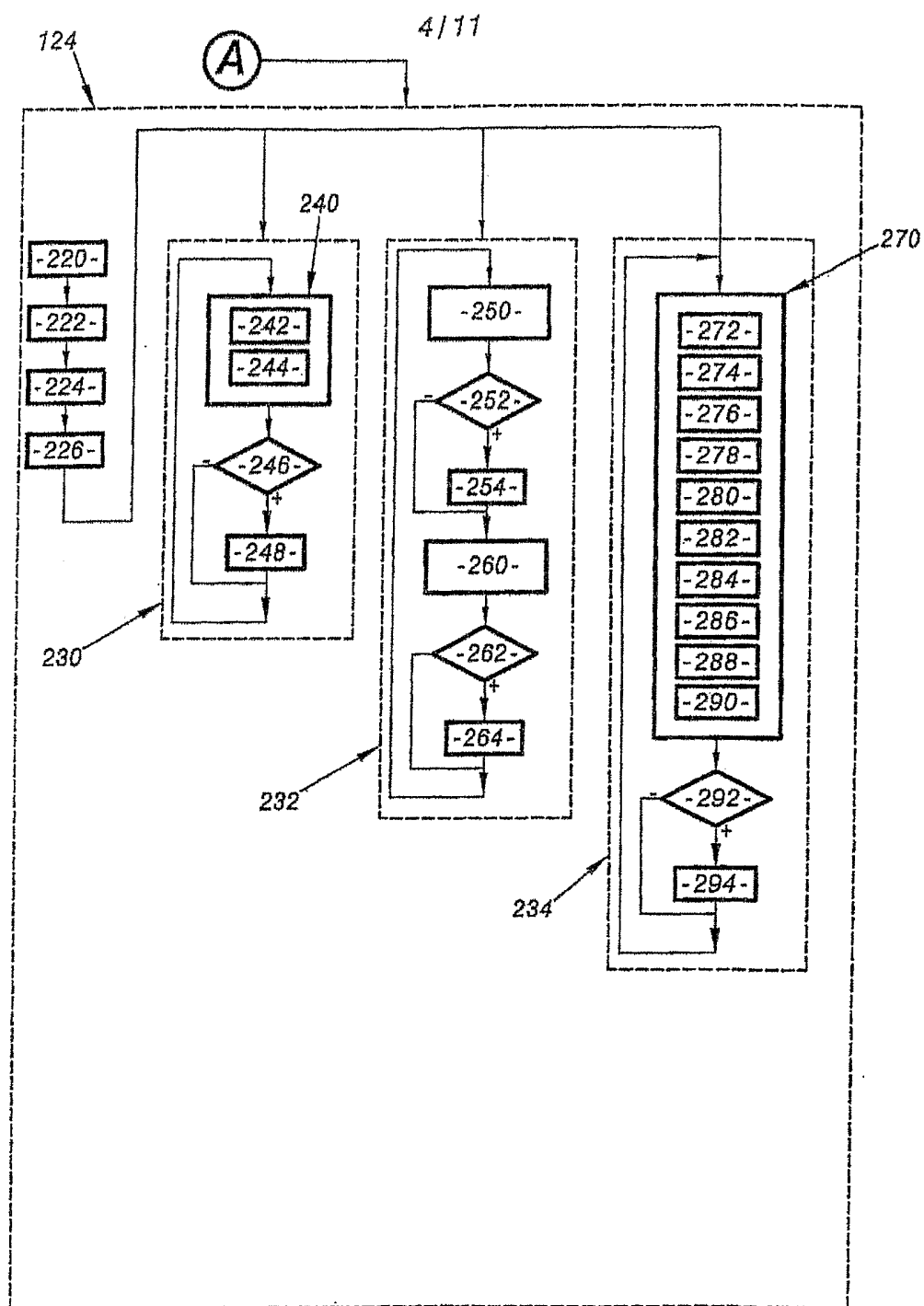


FIG. 3B

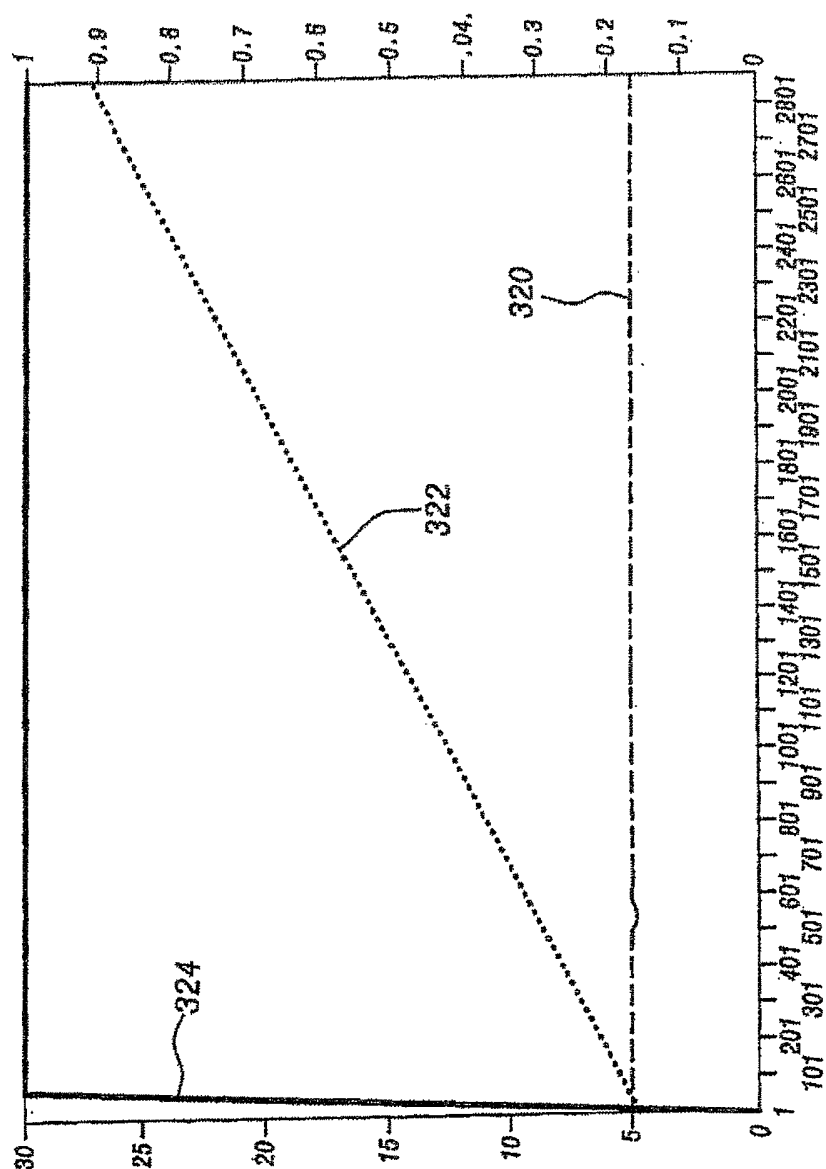


FIG.4A

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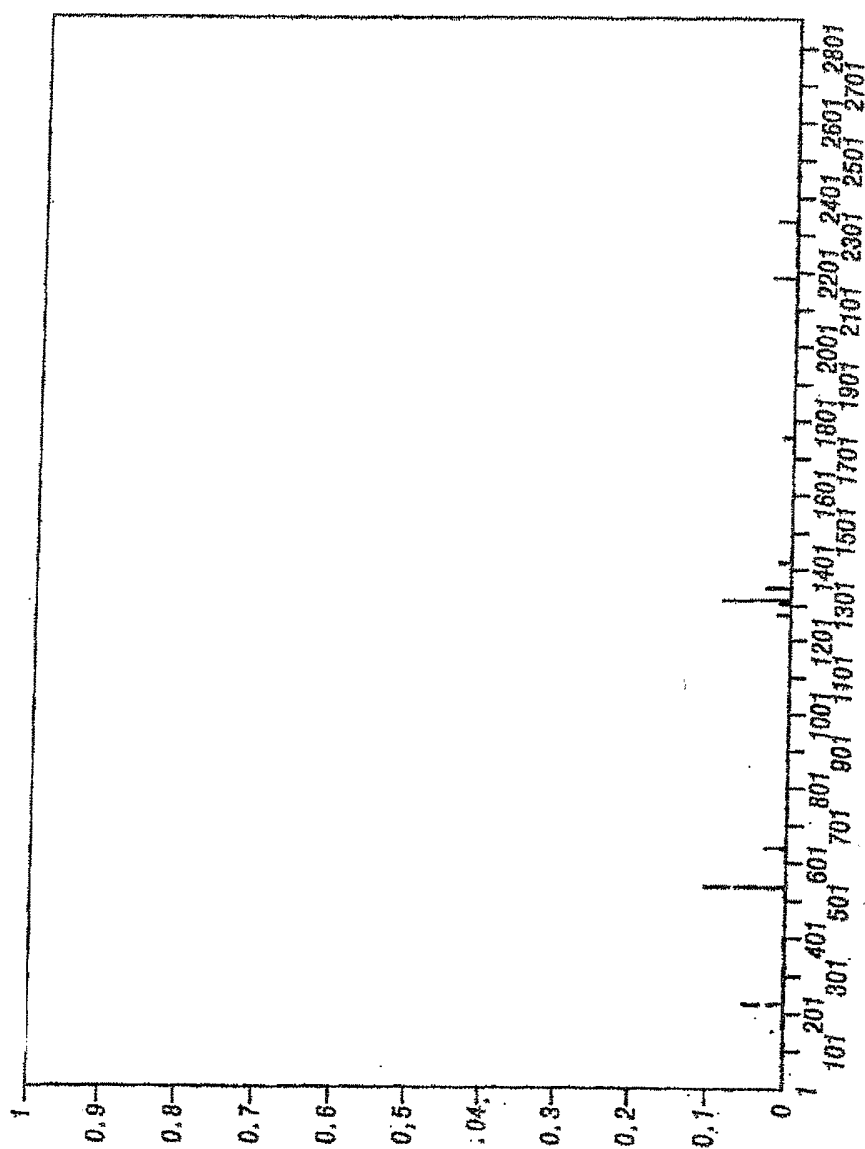


FIG. 4B

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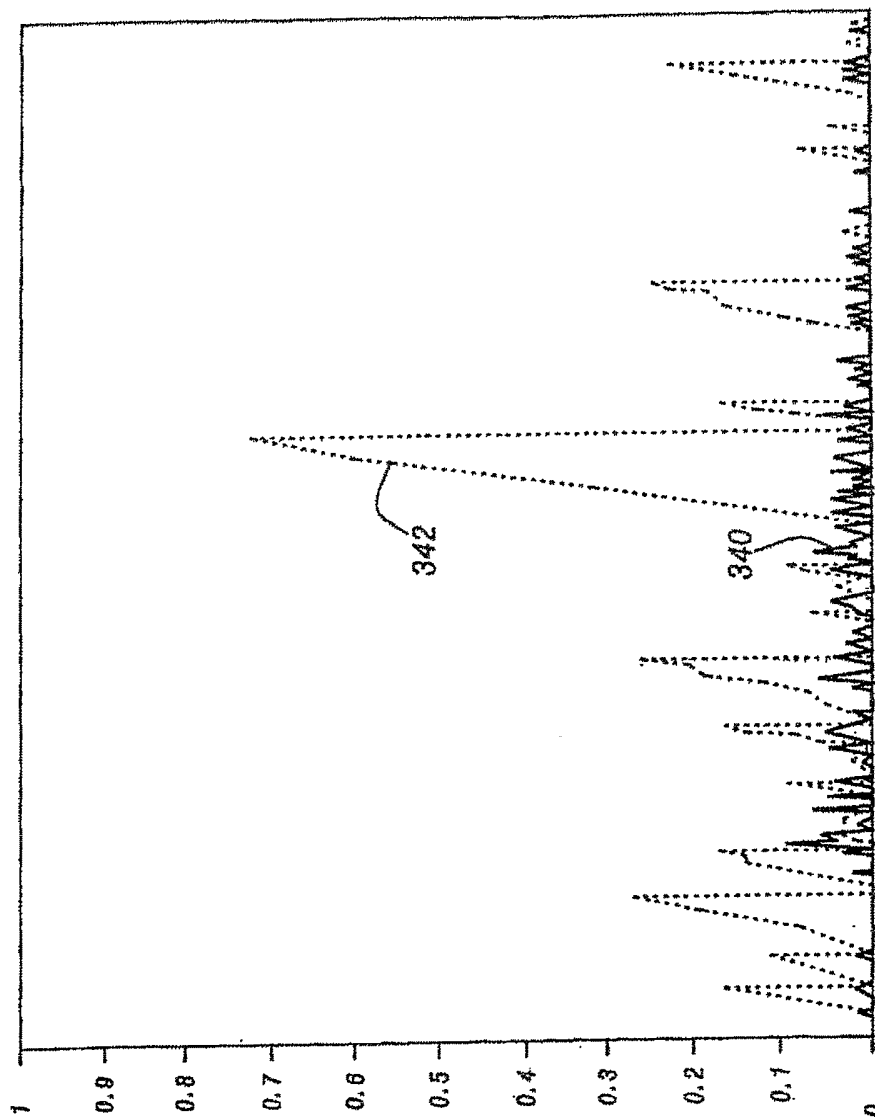


FIG. 4C

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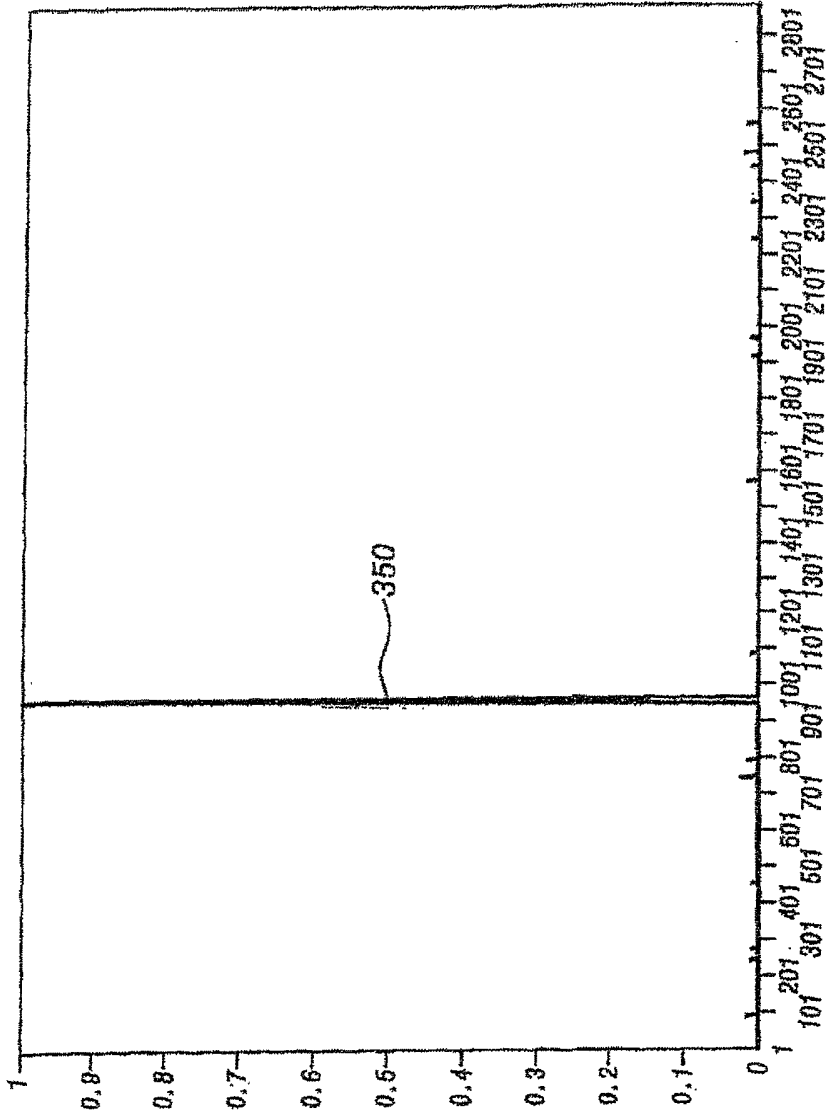
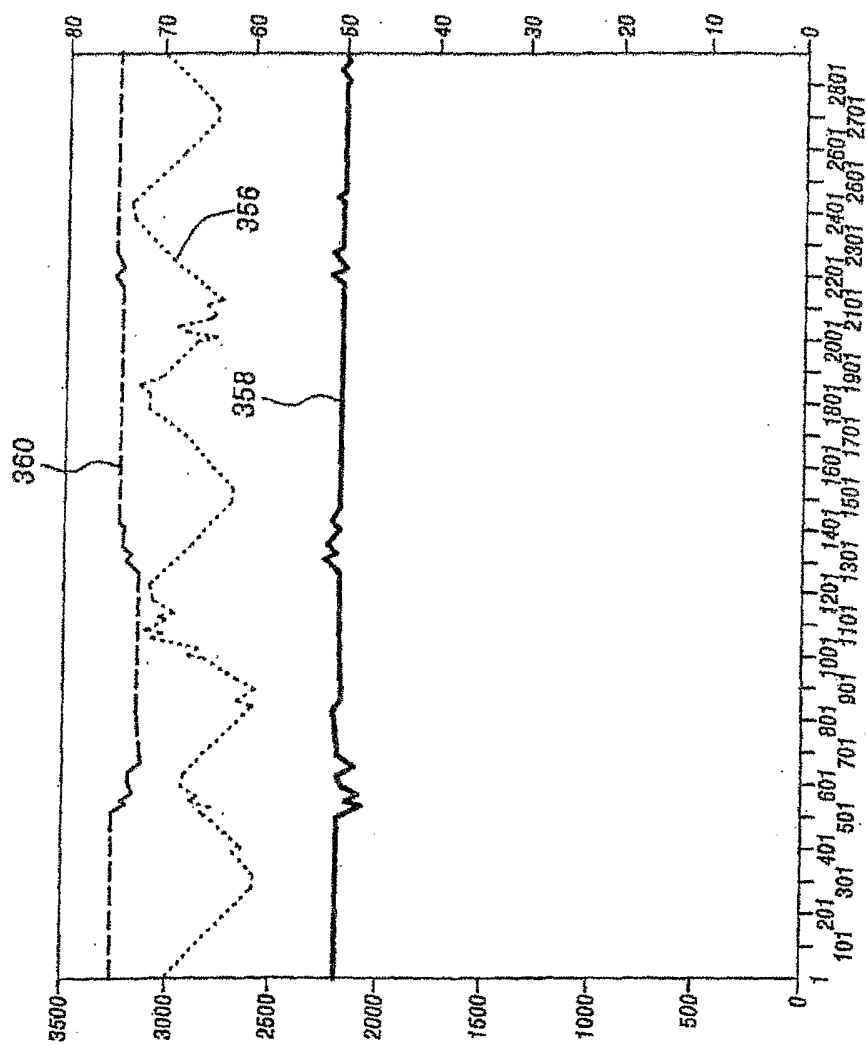


FIG.5

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**FIG. 6A**

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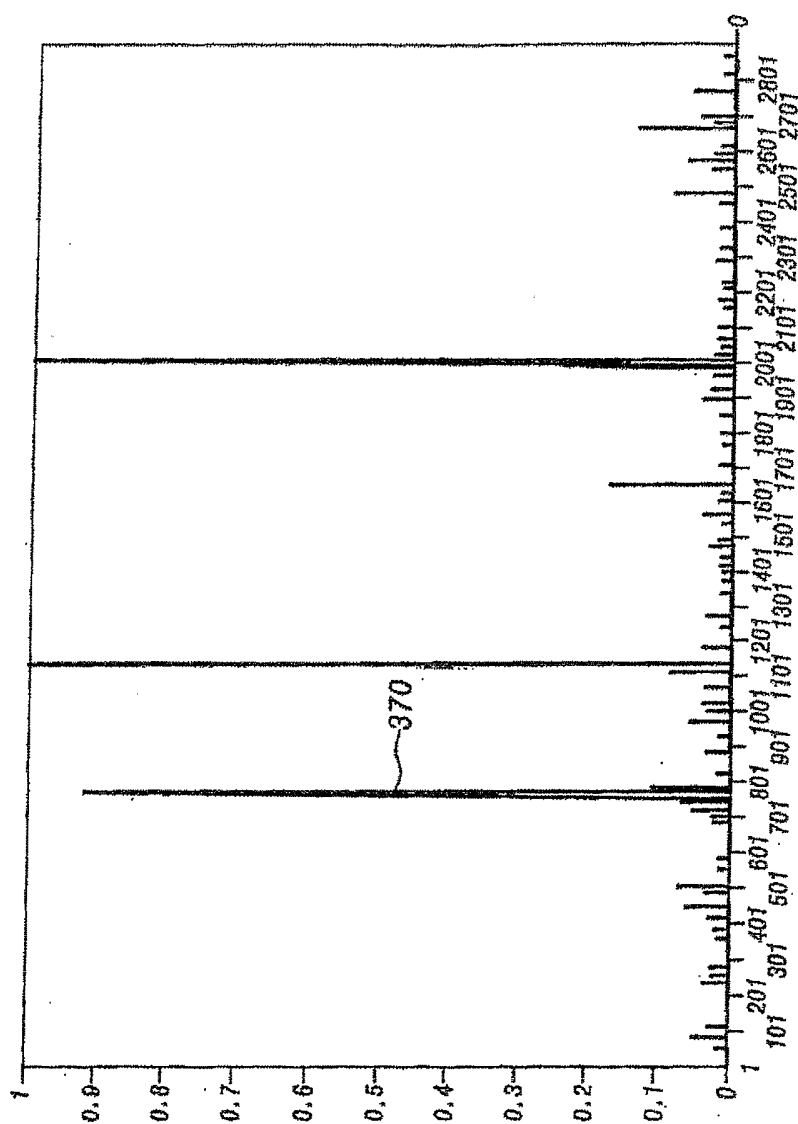


FIG. 6B

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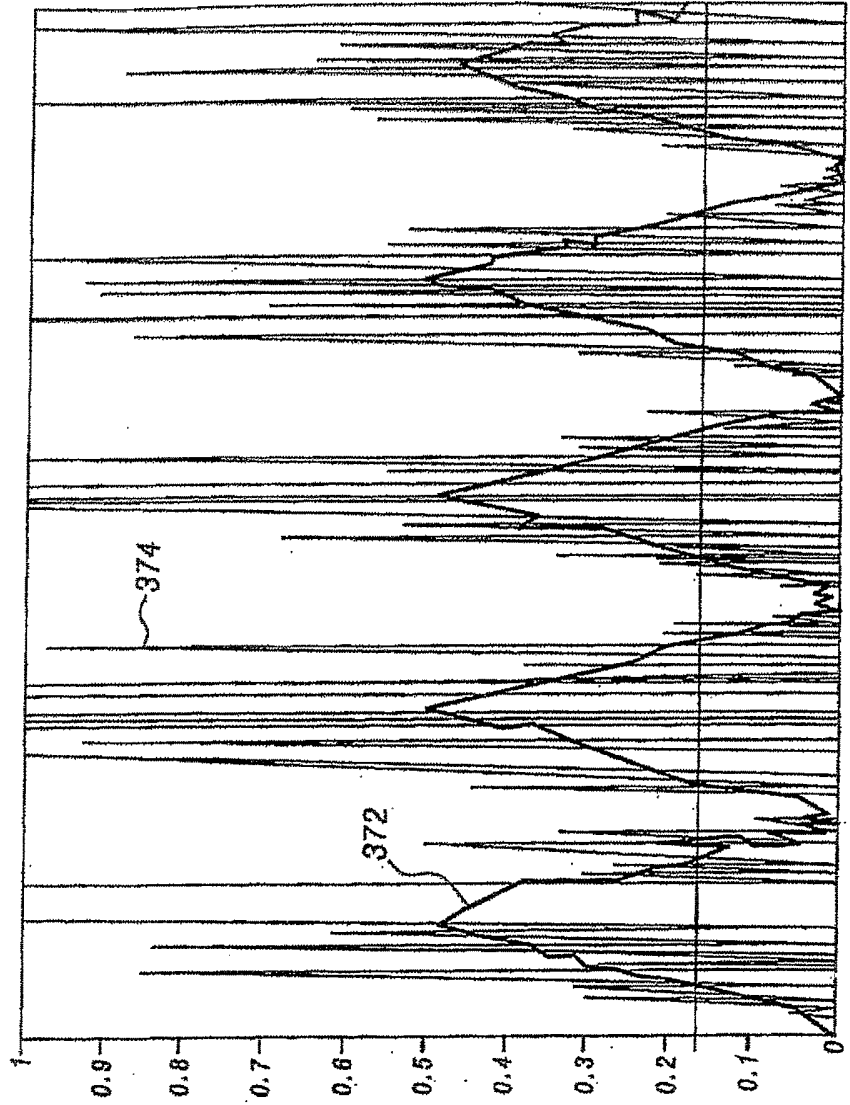


FIG. 6C