(12) **Oversettelse av europeisk patentskrift**

(11) **NO/EP 3058398 B1**

NORGE

(19) NO

(51) Int Cl.

G01V 99/00 (2009.01)

Patentstyret

(45)	Oversettelse publisert	2021.09.27
(80)	Dato for Den Europeiske Patentmyndighets publisering av det meddelte patentet	2021.04.28
(86)	Europeisk søknadsnr	14786977.0
(86)	Europeisk innleveringsdag	2014.08.25
(87)	Den europeiske søknadens Publiseringsdato	2016.08.24
(30)	Prioritet	2013.10.14, FR, 1359960
(84)	Utpekte stater	AL ; AT ; BE ; BG ; CH ; CY ; CZ ; DE ; DK ; EE ; ES ; FI ; FR ; GB ; GR ; HR ; HU ; IE ; IS ; IT ; LI ; LT ; LU ; LV ; MC ; MK ; MT ; NL ; NO ; PL ; PT ; RO ; RS ; SE ; SI ; SK ; SM ; TR
(73)	Innehaver	TOTAL SE, La Défense 6 2 Place Jean Millier, 92400 Courbevoie, Frankrike
(72)	Oppfinner	MASSONNAT, Gérard, c/o TOTAL SA CSTJF-EB 279 Avenue Larribau, F-64000 Pau, Frankrike
(74)	Fullmektig	BRYN AARFLOT AS, Stortingsgata 8, 0161 OSLO, Norge

(54) Benevnelse **METHOD AND DEVICE FOR THE CONTROLLED DETERMINATION OF CHANNELS**

(56) Anførte publikasjoner

US-A1- 2013 144 579
EP-A1- 1 926 033

Vedlagt foreligger en oversettelse av patentkravene til norsk. I hht patentloven § 66i gjelder patentvernet i Norge bare så langt som det er samsvar mellom oversettelsen og teksten på behandlingsspråket. I saker om gyldighet av patentet skal kun teksten på behandlingsspråket legges til grunn for avgjørelsen. Patentdokument utgitt av EPO er tilgjengelig via Espacenet (http://worldwide.espacenet.com), eller via søkemotoren på vår hjemmeside her: https://search.patentstyret.no/

METHOD AND DEVICE FOR THE CONTROLLED DETERMINATION OF CHANNELS

The present invention relates to the field of determining mesh geological models and in particular mesh models validating a certain number of inherent dynamic constraints.

To adequately determine hydrocarbon reserves contained in a reservoir, it is useful to establish reservoir grids (or mesh models), for example on the basis of the 3D seismic interpretation of the subsoil.

These models must be determined so as to represent the actual subsoil containing the reservoir as faithfully as possible.

In the oil industry, a well test may make it possible to better understand the properties of the hydrocarbons and to determine the characteristics of the reservoir in which the hydrocarbons are trapped. Usually, a well test alternatively comprises the opening (the so-called “draw down” phase) and the closing (the so-called “build up” phase) of the well in question: the variations in flow rate and pressure over time are then recorded. The document “*Well testing interpretation method (Fundamentals of Exploration and Production), Gilles Bourdarot, Institut Français du Pétrole Publications, ISSN 1271-9048*” or the document “*Well test analysis: the use of advanced interpretation method, Dominique Bourdet, Elsevier, ISBN 0444509682*” present a certain number of methods for interpreting these variations in flow rate and pressure.

One of the objectives of a well test may be to determine the capacity of the reservoir for the production of hydrocarbons, such as oil or natural gas.

Another objective of such a test may be descriptive, i.e. making it possible to determine the geometries and the characteristics of the reservoir (i.e. porosity of the rocks, presence of boundaries, etc.).

“Dynamic modelling constraints” means all the information determined by means of these well tests (e.g. volume connected to the well, presence of boundaries in the reservoir and associated distance or distances, property of flow of the fluids towards the well, porosity of rocks, permeability, etc.).

In order to satisfy the dynamic modelling constraints, the well engineers or geologists usually determine a large number of “candidate” models using known methodologies (such as for example those described in the patent application FR1257649, for determining channels) and then eliminate the models that do not satisfy these dynamic constraints (with optionally a given margin of tolerance). US2013/144579 and EP1926033 disclose methods for determining the channel paths.

However, such methods are not free from faults.

This is because only a small number of models (with a possible element of unpredictability) statistically satisfy the dynamic constraints.

Thus the complete calculation of the models that are ultimately caused to be rejected may consume computing resources and considerably slow down the determination of a suitable model.

There is thus a need to take into account the dynamic constraints as soon as possible when the geological model is determined in order to optimise the computing resources.

The present invention aims to improve the situation.

To this end, the present invention proposes to take into account the presence of boundaries in the reservoir and/or the volume constraints in determining geological models.

The present invention therefore relates to a method implemented by computer for the controlled determination of channels on the basis of a model including at least:

- a space of points, said points having coordinates in said space,

- a representation of a well in said space, said representation having coordinates in said space, a minimum distance to boundary being associated with said representation.

The method includes the steps of:

- determining a first channel path in said model, said first path including a first casing, said first casing being internally tangent to a polar form having a centre that is part of the representation and having a radius that is said minimum distance to boundary associated with said representation, said casing being tangential at a point of minimum tangency;

- determining at least one minimum exclusion region in said model as a function of said point of minimum tangency;

- determining at least one second channel path in said model, said second path including a second casing, the intersection of the at least one minimum exclusion region and said second casing being empty, and determining a union between said first path and said at least one second path.

The step of determining at least one second path is repeated if at least one condition is satisfied in a set of conditions including:

/c1/ the intersection of said well representation and said determined union is empty.

The minimum distance to boundary is a distance in the mathematical sense and may correspond to numerous different distances. In addition, it is possible for the distance to be a function of the direction in the space of the model.

The polar form having a centre that is part of the representation and having a radius that is said minimum distance to boundary may for example be a circle or a square (2D case) or a sphere or a cube (3D case) if the minimum distance to boundary is independent of the directions of the space. Moreover, this polar form may be a cylinder having a vertical axis of revolution.

“Casing” means a set of meshes or points situated in proximity to the associated path and defining a channel in the model. This channel may be composed of various facies defined upstream by an operator for example.

When the step of determining at least one second path is repeated, the union determined in this step is “augmented” on each occasion by a new path.

The condition /c1/ makes it possible to generate the number of second paths necessary in order to connect the well to the network of paths determined previously (first or second).

In addition, the group of conditions may further include:

/c2/ the intersection of the points of the model located at a distance less than the minimum distance to boundary of said representation and the complement of said union forms at least one continuous set of points of at least a predetermined number of points.

The condition /c2/ makes it possible to generate the number of second paths necessary in order to ensure that there is no “block” of points of significant size. The existence of such “blocks” could be seen as a detectable boundary situated at a distance less than the minimum distance to boundary.

The evaluation of the number of points of a set can be determined according to:

- the number of absolute points of the set;

- the number of points “visible” from the representation of the well;

- the solid angle of the set of points seen from the representation of the well;

- etc.

In one embodiment of the invention, the set of conditions may further include:

/c3/ the intersection of the points of the model located at a distance less than the minimum distance to boundary of said representation and said determined union in the space forms a plurality of sets of points that are discrete.

The condition /c3/ makes it possible to generate the number of second paths necessary in order to ensure that all the channels determined constitute a single network of channels in the region situated at a distance less than the minimum distance to boundary. This is because, if there were a plurality of disconnected networks, another boundary could exist at a distance less than the minimum distance to boundary.

Furthermore, a second distance to boundary being associated with said representation, the method may further comprise:

- determining a third channel path in said model, said third path including a third casing, said third casing being internally tangent to a polar form having a centre that is part of the representation and having a radius that is said second distance to boundary, said casing being tangential at a second point of tangency;

- determining at least one second exclusion region in said model as a function of said second point of tangency;

and wherein:

- the intersection of the at least one second exclusion region and said first casing or the at least one second casing or the third casing is empty.

- the intersection of the at least one minimum exclusion region and the third casing is empty.

In particular, the second point of tangency, a point that is part of the representation, and the point of minimum tangency may be aligned.

In an alternative embodiment, a first straight line passing through:

- the second point of tangency and

- a point that is part of the representation

and a second straight line passing through:

- the point that is part of the representation and

- the point of minimum tangency

may form an angle of between 180° and a predetermined angle.

The predetermined angle is an angle close to the angle of 180°. For example, it may correspond to an angle of 160° or 170°.

In addition or as a variant to the method described above, a model may include at least:

- a space of points, said points having coordinates in said space,

- a minimum connected volume value;

- at least one representation of a well in said space, said representation having coordinates in said space, a minimum distance to boundary being associated with said representation.

Then the method may include the steps, for each current representation in the at least one well representation:

/a/ determining a first channel path in said model, said first path including a first casing, said first casing including the at least one well representation, and adding said first path to a set of paths;

/b/ determining at least one second channel path in said model, said second path having a second casing;

/c/ if the second path is connected to a path in the set of paths, adding said second path to the set of paths, otherwise repeating steps /b/ and /c/;

/d/ determining a connected volume as a function of the paths in the set of paths, and if the determined volume is less than the minimum value, repeating steps /b/ and /c/.

The steps /a/, /b/ may be the same as the steps previously described.

This method makes it possible to determine new channels as long as the minimum volume is not reached.

In a particular embodiment of the invention, said model including at least one maximum connected volume value, the method may further include:

/a_{bis}/ determining a target connected volume value that is between the minimum value and the maximum value;

/b_{bis}/ determining at least a fourth channel path in said model, said fourth path having a fourth casing;

/c_{bis}/ determining a first connected volume as a function of the paths in the set of paths, and determining a second connected volume as a function of the paths in the set of paths and of the fourth path;

/d_{bis}/ if the fourth path is connected to a path in the set of paths and if the first determined volume is less than or equal to the target value, adding said fourth path to the set of paths and repeating steps /b_{bis}/, /c_{bis}/, /d_{bis}/, and /e_{bis}/;

/e_{bis}/ if the fourth path is connected to a path in the set of paths and if the second determined volume is greater than the target value:

- adding said fourth path to the set of paths and repeating steps /b_{bis}/, /c_{bis}/, /d_{bis}/, and /e_{bis}/ if a distance between the second volume and the target value is less than a distance between the first volume and the target value.

Naturally, it is possible to implement this particular embodiment independently of the other embodiments proposed.

In addition, the target value may be the maximum value.

A device intended for the controlled determination of channels on the basis of a model may be advantageous, in itself, provided that it makes it possible to take into account dynamic constraints for generating channels.

Thus the present invention also relates to a device intended to implement all or part of the method described above.

A computer program implementing all or part of the method described above, installed on pre-existing equipment, is in itself advantageous, provided that it allows the controlled determination of channels on the basis of a model.

Thus the present invention also relates to a computer program including instructions for implementing the method previously described, when this program is executed by a processor.

This program may use any programming language (for example an object language or other) and be in the form of an interpretable source code, a partially compiled code or a completely compiled code.

Figure 4, described in detail hereinafter, can form the flow diagram of the general algorithm of such a computer program.

Other features and advantages of the invention will also emerge from reading the following description. This is purely illustrative and must be read with regard to the accompanying drawings, on which:

- figure 1 illustrates an example of a pressure variation curve during a well test and during a so-called build up phase illustrating a determination of boundaries;

- figure 2 illustrates an example embodiment of a model including a representation of wells in an embodiment according to the invention;

- figures 3a and 3b illustrate horizontal cross sections of a model in an embodiment of the invention;

- figure 3c illustrates a vertical section of a model in an embodiment of the invention;

- figure 4 shows an example of a flow diagram that can represent a possible implementation of the invention;

- figure 5 shows a device for implementing an embodiment of the invention.

Figure 1 illustrates an example of a pressure variation curve 100 during a well test and more precisely during a so-called build up phase.

When a production well is closed (corresponding to t_0 of the curve in figure 1). The pressure variation 101 at the output of the well changes secondly to stabilise (region 102, corresponding to a constant increase in the pressure of the well).

If the pressure variation increases abruptly (region 104) and then re-stabilises (region 105), the well engineers can interpret this phenomenon by the presence, in the reservoir connected to the well, of a boundary (e.g. the presence of a subsoil region not containing hydrocarbons or gases, the presence of impermeable rocks, etc.). The time t_1 of appearance of such a phenomenon (region 103) can enable them to determine the distance r_1 of this first boundary to the well. These determinations may use methods as described in the works cited previously.

In the case of the presence of a second boundary in the reservoir (substantially opposite to the first boundary), the pressure variation curve then shows an increase (region 107) as from an instant t_2 (region 106). The time t_2 of appearance of such a phenomenon (region 106) can enable the well engineers to determine the distance r_2 from this second boundary to the well.

It is also possible to define an investigation distance corresponding to the time t_{inv} as from which the pressure variation data are no longer available or are no longer considered to be reliable.

Figure 2 illustrates an example embodiment of a model 200 including a well representation in an embodiment of the invention.

Usually, a well can be represented in a model by a vertical line passing through a first point 201 (the drilling point or the well head) and by a second point 202 (or a set of points 202). The point or the set of points 202 corresponds to a region of the well including perforations and making it possible to connect the subsoil to the well in order to extract hydrocarbons therefrom. The point or the set of points 202 is called "representation of a well" for simplification.

When a boundary is determined as described previously in relation to figure 1 for example, it is possible to determine a region 206 around the point 202 representing potential points of existence of this boundary. In this figure the distance from one end of this region to the point 202 may vary according to the direction. For example, the distance represented by the vector 203 may be different from the distance represented by the vector 204 (both in the plane $(\vec{x},\vec{y})$). This difference may in particular be explained by knowledge of particular constraints (e.g. subsoil anisotropy). Likewise, the distance represented by the vector 203 may be different from the distance represented by the vector 205 (the vertical distance often being known as being smaller than the horizontal distances, the geological strata being mainly horizontal).

Figure 3a illustrates a horizontal cross section 300 of a model in one embodiment of the invention.

This cross section 300 is produced so that the point 301 corresponds to a region of the representation of a well.

In this example, the first distance r_1 represents a minimum distance to boundary and is constant in all the directions of the cutting plane $(\vec{x},\vec{y})$. The distance r_{inv} represents an investigation distance and is constant in all the directions of the cutting plane $(\vec{x},\vec{y})$. In other examples, the distances r_1 and r_{inv} may vary according to the distance in question. The distance r_1 defines the polar form 302_1 (here a circle of radius r_1 and with the point 301 as its centre) and the distance r_{inv} defines the polar form 302_{inv} (here a circle of radius r_{inv} and with the point 301 as its centre).

Initially, it is possible to determine a first path 304a. This path may in particular be determined by means of a method as described by the patent application FR1060053 or FR1257649.

This path is determined so that the casing 304b of this path 304a is tangent to the polar form 302_1 (here a circle, the radius r_1 being constant in all the directions of the cutting plane $(\vec{x},\vec{y})$ at the point 305, also called the "point of minimum tangency". Naturally, it is possible to consider that the casing is tangent to the polar form even if this tangency is imperfect: the model usually being discrete because of the meshing thereof, it is possible to provide a tolerance value (e.g. a limit angle) below which the casing is considered to be tangent. In order to ensure that the tangency is provided at the casing, it is possible to reduce the distance r_1 by a casing half-thickness e_{hab304} at the point of tangency 305 and to determine a new polar form with a centre that is the point 301 and of radius $r_1 - \frac{e_{hab304}}{2}$ and to determine the path 304a so that it is tangent to this new polar form.

Once the path 304a and the casing 304b of this path have been determined, it is possible to determine an exclusion region in the model in which no path and no casing are determined. This exclusion region may for example be:

- the region 306a defined by a region lying between the polar form 302_1 and the polar form 302_{inv} and in an angle α from the point 301 and centred on the point 305;

- the region 306b defined by a region lying between the polar form 302_1 and the polar form 302_{inv} and having a given width l_{excl};

- the region 306c defined by a region lying beyond the polar form 302_1 tangent thereto, having a given width l_{excl} and a given thickness e_{excl}.

Naturally other forms of exclusion region are possible and combinations of forms as described previously can be envisaged.

It is then possible to determine a new path 307a and a new associated casing 307b in the model 300. This determination may also be made in accordance with a method as described in the previously cited applications.

No point on this path or this casing belongs to the exclusion region as defined previously.

It is stated that the distance r_1 represents the existence of a boundary situated at this distance r_1 detected from the well. Thus it is useful for the latter (or more precisely the representation thereof) to be connected to the casing 304b. Thus, if the well is not connected to the casing 304b through other cases, it may be useful to determine new casings until the time that the well 301 is connected: if the union of the casings 304b and 307b does not include the well 301, new paths (308a) and new casings (308b) are determined.

In addition, on the other hand, if the distance r_1 represents the existence of a minimum boundary, this may also signify that there is no boundary (or boundary detectable by current methods) in the region delimited by the polar form 302_1. Consequently it may be useful to determine new paths and new casings as long as the region delimited by the polar form 302_1 includes large regions (309a) not belonging to any casing. The size of each region may, for example, be evaluated:

- by number of points;
- by volume;
- by surface area;
- by solid angle value seen from the point 301.

The limit value below which the region 309a is considered to be too large can be fixed according to the sensitivity of the measuring instruments available. In one embodiment, this limit may be fixed at zero.

Moreover (and if there are no other limits detected for example in the limit of the investigation region, i.e. of the polar form 302_{inv}), it is also possible to determine new paths and new casings. This determination is made as long as the region delimited by the polar form 302_{inv} includes large regions (309a and 309b) not belonging to any casing.

Naturally, in the latter case, the exclusion regions determined may not be taken into account in determining these large regions since, by definition, the exclusion regions cannot include any casing. In addition, the regions “masked” by the exclusion regions (i.e. the regions of the polar form 302_{inv} but situated behind the exclusion regions with respect to the representation of the well 301) may not be taken into account in determining the large regions.

Finally, and non-limitatively, if the distance r_1 represents the existence of a minimum boundary, this may also signify that all the points situated in the region delimited by the polar form 302_1 and belonging to a casing are connected to the well. This is because, if some points of the casings present in this region are not connected to the well (i.e. there are no paths passing through casings making it possible to connect the representation of the well and this point, the pathway being included in the form 302_1), this may signify that a plurality of casing networks coexist in the form 302_1 without being connected together: thus a boundary closer than the boundary represented by the distance r_1 will have had to be detected. Consequently, it may be useful to determine new paths and new casings if the latter condition is not validated.

This condition can also be reformulated by considering the intersection between:

- the region formed by the polar region 302_1, and
- the union of the casings determined in the model.

If this intersection forms a plurality of sets of connected points (i.e. continuous), then this condition is considered to be validated.

Moreover (and if there are no other limits detected for example in the boundary of the investigation region, i.e. of the polar form 302_{inv}), it is also possible to determine new paths and new casings as long as the region delimited by the polar form 302_{inv} includes casings disconnected from the representation of the well.

Figure 3b illustrates another example of a horizontal cross section 300' of a model in one embodiment of the invention.

In this cross section, two boundaries have been determined:

- a boundary situated at the point 305 and represented by the exclusion region 306c. This boundary is situated at a distance r_1 from the representation of the well 301;

- a boundary situated at the point 325 and represented by the exclusion region 326c. This boundary is situated at a distance r_2 from the representation of the well 301.

As indicated previously in relation to figure 1, detecting a second boundary during a well test may make it possible to know whether it is situated substantially opposite the first boundary. This is because the signature of the pressure variation curve may be characteristic of such a situation.

Thus, usually, it is necessary to consider that the points 305, 301 and 325 are aligned. Naturally, because of the discretisation of the model and the limited precision of the pressure variation detection tools, these points may also not be perfectly aligned: for example, the angle formed by the straight lines (305-301) and (301-325) may be within the limit of $180° \pm \varepsilon$ with ε an angle fixed by an operator. In the case of figure 3b, $\beta \leq \varepsilon$.

In a situation with two boundaries, it is possible to add new conditions that have to be validated by the model, failing which new paths and new casings are determined:

- the region lying between the polar form 302_1 and the polar form 302_2 do not include a set of continuous points and do not belong to a casing of more than a predetermined number of points. For this condition, it is possible to exclude, from the region lying between the polar form 302_1 and the polar form 302_2, the region masked by the exclusion regions of the model, here in this case the region 330 masked by the exclusion region 306c. This region 330 is the region formed by a sector the region lying between polar form 302_1 and the polar form 302_2 and the solid angle defined by the exclusion region: thus the region lying between the polar form 302_1 and the polar form

302_2 that does not have to include the set of continuous points not belonging to a casing of more than a predetermined number of points is the region 331;

- the casings present in the region lying between the polar form 302_1 and the polar form 302_2 (to the possible exclusion of the region 330 as explained above) do not form continuous sets of regions.

Figure 3c illustrates a vertical section of a model 300" in one embodiment of the invention.

If figures 3a and 3b show horizontal sections, the models may be three-dimensional models and allow a representation by vertical sections.

In this example, the representation of the well 301 may include a plurality of superimposed meshes of the model. Furthermore, the exclusion zone 306c may include a plurality of meshes of the model distributed in a given parallelepiped.

The casings of the channels may include various sizes, forms or compositions. By way of illustration, a channel may consist of a single facies in the model such as the channels 315, 312 or 316. The channels may also include several facies (e.g. the presence of a channel bed but also accretions, lobes, heavings, etc.): for example, the region 314b is an accretion region of the channel 314a, the region 313b or 313c is an accretion region of the channel 313a, the region 311b is an accretion region of the channel 311a.

A channel may include a large number of constituent elements but the term "casing" is given solely to the elements among these constituent elements that are considered to allow a flow and/or storage of hydrocarbons sufficiently (or according to other particular criteria, in particular geophysical criteria). Thus the well engineer or any other operator can select the elements which according to him form part of the casing within the meaning of the invention.

The union of the casings presented in figure 3c comprises two sets of unconnected (or discontinuous) casings:

- a first set comprising the casing 316;

- a second set comprising the casings 315, 314b-314a, 312, 313a-313b-313c and 311a-311b.

In the second set, it is possible to identify at least one pathway 350 making it possible to connect the representation of the well 301 to the minimum boundary tangency point 305.

Figure 4 shows an example of a flow diagram that can represent a possible implementation of the invention.

On reception of a model 400, it is possible to make a controlled determination of channels. This model 400 received includes a space of points (PTS) and various items of information (INF) such as a representation of a well in this space or the indication of a minimum distance to boundary associated with this representation.

Once received, it is possible to determine (step 401) a first channel path in this model 400.

Thus it is possible to clad (step 402) this path with an envelope or “casing”. The casing may be of constant width but it may also fluctuate along this path. In any event, it is determined so that it is internally tangent to a polar form with the well as its centre and the minimum distance to boundary received as its radius.

According to the point of tangency of this exclusion region to the polar form, it is possible to determine (step 403) at least one minimum exclusion region as described previously.

Consequently it is possible to wonder about the existence of a second boundary in the model. This is the case if a second distance to boundary is associated with the well representation.

If another boundary exists (test 404, output OK), it is then possible to determine a third channel path (step 412). This third path has a casing (step 405) under the same conditions as those described previously and this casing is internally tangent to the polar form with a centre that is part of the well (or more precisely to the representation thereof in the model) and having a radius that is this other distance to boundary.

Finally, it is possible to determine at least one second exclusion region of the point of tangency of this last casing with the polar form.

Naturally, the second exclusion region does not have any point in common with the first casing determined at step 402 or with any other casing determined at step 405. In addition, the third casing does not have any common point with the minimum exclusion region determined at step 403.

If no other boundary exists (step 404, output KO) or if all the steps 412, 405 and 406 have ended, a second channel path is determined (step 407). By means of this last path, it is possible to determine a corresponding casing as described previously (step

408). Naturally this last casing does not include any common point with an exclusion region determined previously (step 403 or step 406).

If one of the following conditions is validated (step 409, output OK) steps 407 and 408 can be reiterated:

- the representation of the well does not belong to any casing determined previously (step 402 or 405 or 408),

- there is a region of at least a predetermined number of points in the region situated at a distance less than the minimum distance to boundary and not belonging to any casing,

- the casings are not all connected in the region situated at a distance less than the minimum distance to boundary.

In addition, there may be other conditions causing steps 407 and 408 to be reiterated if the latter are not validated (test 410, output OK). It is possible for the test 409 or the test 410 to be the only test implemented in the method described in relation to figure 4.

For example, the model may furthermore include a minimum connected volume value. It is then possible to determine the volume of hydrocarbons connected to the well and present in the casings determined in the previous steps. The connected volume may be the volume of the casings for which there is a path in the casings determined passing through a point of the casing in question and through the well. This volume may be weighted by a weighting factor (for example related to the porosity of the subsoil at the casings in question). This volume may also depend on an exploration distance, for example the volumes situated beyond this distance not being taken into account for determining the connected volume (or being taken into account with a decreasing weighting according to the distance).

If the minimum connected volume value is not reached, it is possible to determine new paths and new casings (step 407 and 408).

If the minimum connected volume value is exceeded, this last path is adopted. It may happen under certain extreme conditions that it is impossible to validate the test conditions 409 and the test conditions 410. If at the end of a given number of iterations, it is found that the test conditions 410 cannot be satisfied (wholly or partially, e.g. the minimum volume value being very large, it is not possible to achieve it even by connecting or the regions situated at a distance less than the investigation distance, thus the value calculated as being connected does not change during a predetermined number of iterations), an alert can be raised.

In addition, the test 410 may include a condition relating to a maximum connected volume value. In this case, it is possible to determine a target connected volume value between the minimum value and the maximum value: this determination may be made in accordance with a stochastic method (linear or Gaussian for example).

Once this target value has been determined, it is possible to determine a new channel path (step 407) and a new casing (step 408).

This new path and this new casing are adopted in the final model only:

- if the volume connected with this new casing is always smaller than this target value; or

- if the volume connected with this new casing is larger than this target value and the distance of the volume connected with this new casing to the target value is less than the distance from the connected volume without this new casing to the target value.

Moreover, if the volume connected with this new casing is always smaller than this target value, steps 407 and 408 are reiterated.

Once all the conditions of the tests 409 and 410 have been invalidated, the model 411 including the new paths and new casings is returned.

Moreover, the functional diagram presented in figure 4 is a typical example of a program, certain structures of which can be implemented with the device described. In this regard, figure 4 may correspond to the flow diagram of the general algorithm of a computer program within the meaning of the invention.

Figure 5 shows an example of a device in one embodiment of the invention.

In this embodiment, the device includes a computer 500, comprising a memory 505 for storing instructions for implementing the method, the measurement data received, and temporary data for implementing the various steps of the method as described previously.

The computer also includes a circuit 504. This circuit may for example be:

- a processor able to interpret instructions in the form of a computer program, or

- an electronic card wherein the steps of the method of the invention are described in the silicon, or

- a programmable electronic chip such as an FPGA (standing for "field-programmable gate array") chip.

This computer includes an input interface 503 for receiving measurement data, and an output interface 506 for supplying models. Finally, the computer may include, to allow easy interaction with a user, a screen 501 and a keyboard 502. Naturally the keyboard is optional, in particular in the context of a computer in the form of a touch tablet for example.

Naturally, the present invention is not limited to the embodiments described above by way of examples; it extends to other variants.

Other embodiments are possible.

For example, the examples given with reference to the figures relate to three-dimensional models but an embodiment of the invention on the basis of a two-dimensional model can also be implemented.

PATENTKRAV

1. Fremgangsmåte som er implementert av en datamaskin, for kontrollert bestemmelse av kanaler på grunnlag av en modell som omfatter i det minste:

- et rom med punkter (300), idet nevnte punkter har koordinater i nevnte rom,
- en representasjon (301) av en brønn i nevnte rom, idet nevnte brønnrepresentasjon har koordinater i nevnte rom, der en minimal avstand til grense (r_1) er assosiert med nevnte representasjon,

hvor fremgangsmåten omfatter trinnene med:

- å bestemme en første kanalbane (304a) i nevnte modell, idet den første banen har et første fôringsrør (304b), idet det første fôringsrøret er internt tangent til en polær form (302) som har et senter (301) som er en del av representasjonen, og som har en radius som er den minimale avstanden til grensen assosiert med nevnte representasjon, idet fôringsrøret er tangensielt ved et punkt med minimal tangens (305);
- å bestemme minst ett minimalt ekskluderingsområde (306a, 306b, 306c) i nevnte modell som en funksjon av nevnte punkt med minimal tangens;
- å bestemme minst én andre kanalbane i nevnte modell, idet den andre banen (307a) har et andre fôringsrør (307b), idet skjæringspunktet mellom det minst ene minste ekskluderingsområdet og det andre fôringsrøret er tomt, og å bestemme en forening mellom den første banen og den minst ene andre banen,

og hvor trinnet med å bestemme minst én andre bane blir gjentatt hvis minst én tilstand / betingelse er oppfylt i et sett med betingelser / tilstander som omfatter:

/c1/ skjæringspunktet mellom nevnte brønnrepresentasjon og den bestemte foreningen er tomt.

2. Fremgangsmåte ifølge krav 1, hvor settet med betingelser / tilstander videre omfatter:

/c2/ skjæringspunktet mellom punktene til modellen er lokalisert ved en avstand som er mindre enn den minimale avstanden til grensen for nevnte representasjon, og kompletteringen av nevnte forening danner minst ett kontinuerlig sett med punkter for i det minste et forhåndsbestemt antall av punkter.

3. Fremgangsmåte ifølge et av de foregående kravene, hvor settet med tilstander / betingelser videre omfatter:

/c3/ skjæringspunktet mellom punktene til modellen er lokalisert ved en avstand som er mindre enn den minimale avstanden til grensen for nevnte representasjon, og den bestemte foreningen i rommet danner et flertall av sett med punkter som er diskrete.

4. Fremgangsmåte ifølge et av de foregående kravene, hvor en andre avstand til grensen er assosiert med nevnte representasjon, idet fremgangsmåten videre omfatter:

- å bestemme en tredje kanalbane i nevnte modell, idet den tredje banen har et tredje fôringsrør, idet det tredje fôringsrøret er internt tangent til en polær form som har et senter som er en del av representasjonen, og som har en radius som er den andre avstanden til grensen, idet fôringsrøret er tangensielt ved et andre tangenspunkt;

- å bestemme minst ett andre ekskluderingsområde i nevnte modell som en funksjon av det andre tangenspunktet;

og hvor:

- skjæringspunktet mellom det minst ene andre ekskluderingsområdet og det første fôringsrøret eller det minst ene andre foringsrøret eller det tredje fôringsrøret er tomt,

- skjæringspunktet mellom det minst ene minimale ekskluderingsområdet og det tredje fôringsrøret er tomt.

5. Fremgangsmåte ifølge krav 4, hvor det andre tangenspunktet, et punkt som er en del av representasjonen og punktet med minimal tangens er innrettet.

6. Fremgangsmåte ifølge krav 4, hvor en første rett linje som passerer gjennom det andre tangenspunktet og et punkt som er en del av representasjonen, og en andre rett linje som passerer gjennom punktet som er en del av representasjonen og punktet med minimal tangens, danner en vinkel som er mellom 180° og en forhåndsbestemt vinkel.

7. Fremgangsmåte som er implementert av en datamaskin, for kontrollert bestemmelse av kanaler på grunnlag av en modell som omfatter i det minste:

- et rom med punkter, idet nevnte punkter har koordinater i nevnte rom,
- en minimumtilkoblet volumverdi;
- minst én representasjon av en brønn i nevnte rom, idet nevnte brønnrepresentasjon har koordinater i nevnte rom, der en minimal avstand til grensen er assosiert med nevnte representasjon,

hvor fremgangsmåten omfatter de følgende trinn for hver nåværende representasjon i den minst ene brønnrepresentasjon:

/a/ å bestemme en første kanalbane i nevnte modell, idet den første banen har et første fôringsrør, idet det første fôringsrøret omfatter den minst ene brønnrepresentasjonen, og å addere den første banen til et sett med baner;

/b/ å bestemme minst én andre kanalbane i nevnte modell, idet den andre banen har et andre fôringsrør;

/c/ hvis den andre banen er koblet til en bane i settet med baner, å addere den andre banen til settet med baner, ellers å gjenta trinn /b/ og /c/;

/d/ å bestemme et tilkoblet volum som en funksjon av banene i settet med baner, og hvis det bestemte volumet er mindre enn den minimale verdien, å gjenta trinn /b/ og /c/.

8. Fremgangsmåte ifølge krav 7, hvor nevnte modell har minst én maksimumtilkoblet volumverdi, idet fremgangsmåten videre omfatter:

/a_{bis}/ å bestemme en målkoblet volumverdi som er mellom den minimale verdien og dem maksimale verdien;

/b_{bis}/ å bestemme minst én fjerde kanalbane i nevnte modell, idet den fjerde banen har et fjerde fôringsrør;

/c_{bis}/ å bestemme et første tilkoblet volum som en funksjon av banene i settet med baner, og å bestemme et andre tilkoblet volum som en funksjon av banene i settet med baner og av den fjerde banen;

/d_{bis}/ hvis den fjerde banen er koblet til en bane i settet med baner, og hvis det første bestemte volumet er mindre enn eller lik målverdien, å addere den fjerde banen til settet med baner og å gjenta trinn /b_{bis}/, /c_{bis}/, /d_{bis}/ og /e_{bis}/;

/e_{bis}/ hvis den fjerde banen er koblet til en bane i settet med baner, og hvis det andre bestemte volumet er større enn målverdien:

- å addere den fjerde banen til settet med baner, og å gjenta trinn /b_{bis}/, /c_{bis}/, /d_{bis}/ og /e_{bis}/ hvis en avstand mellom det andre volumet og målverdien er mindre enn en avstand mellom det første volumet og målverdien.

9. Fremgangsmåte ifølge krav 8, hvor målverdien er den maksimale verdien.

10. Anordning for kontrollert bestemmelse av kanaler på grunnlag av en modell som omfatter i det minste:

- et rom med punkter (300), idet punktene har koordinater i nevnte rom,
- en representasjon (301) av en brønn i nevnte rom, idet nevnte brønnrepresentasjon har koordinater i nevnte rom, idet en minimal avstand til grense (r1) er assosiert med nevnte representasjon,

hvor anordningen omfatter:

- en krets som er tilpasset for bestemmelse av en første kanalbane (304a) i nevnte modell, idet den første banen har et første fôringsrør (304b), idet det første fôringsrøret er internt tangent til en polær form (302) som har et senter (301) som er en del av representasjonen, og som har en radius som er den minimale avstanden til grensen assosiert med nevnte representasjon, idet fôringsrøret er tangensielt ved et punkt med minimal tangens (305);
- en krets som er tilpasset for bestemmelse av minst ett minimalt ekskluderingsområde (306a, 306b, 306c) i nevnte modell som en funksjon av nevnte punkt med minimal tangens;
- en krets som er tilpasset for bestemmelse av minst én andre kanalbane i nevnte modell, idet den andre banen (307a) har et andre fôringsrør (307b), idet skjæringspunktet mellom det minst ene minimale ekskluderingsområdet og det andre fôringsrøret er tomt, og for bestemmelse av en forening mellom den første banen og den minst ene andre bane,

og hvor kretsen som er tilpasset for bestemmelse av minst én andre bane, er tilpasset til å gjenta det siste trinnet hvis minst én tilstand / betingelse er oppfylt i et sett med betingelser / tilstander som omfatter:

/c1/ skjæringspunktet mellom nevnte brønnrepresentasjon og den bestemte foreningen er tom.

11. Datamaskinprogramprodukt omfattende instruksjoner for implementering av fremgangsmåten ifølge et av krav 1 til 9, når nevnte program er utført av en prosessor.

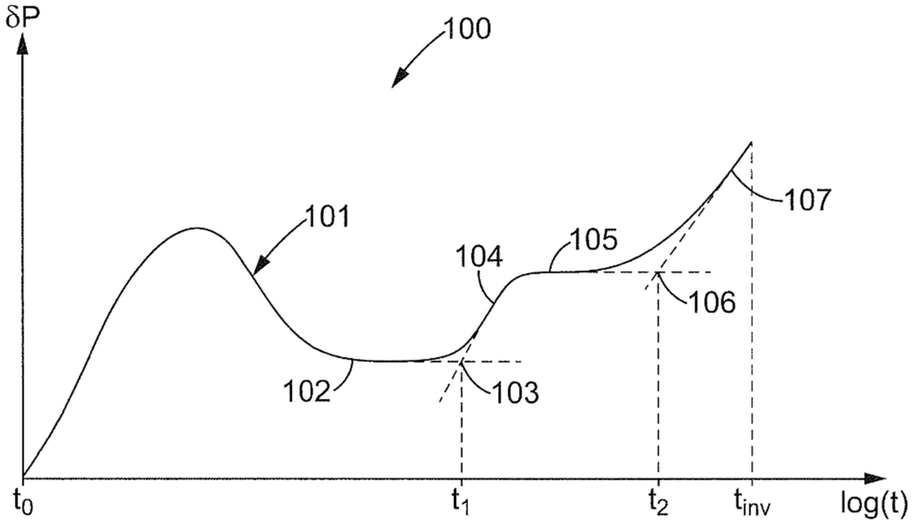
δP
100
101
104
105
107
106
102
103
t_0
t_1
t_2
t_{inv}
log(t)

FIG. 1

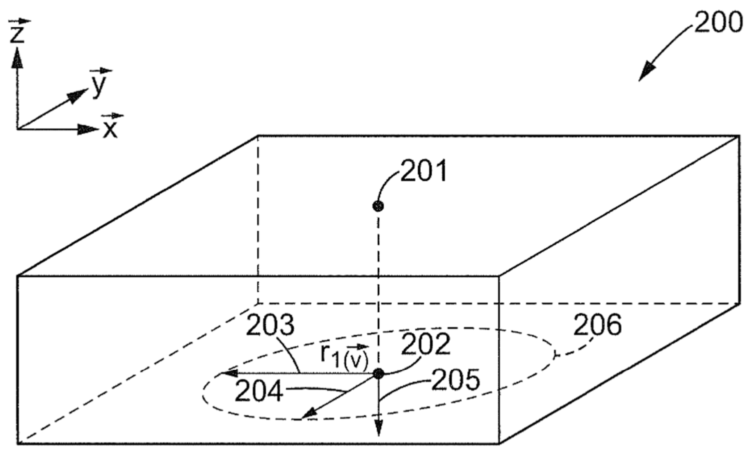
$\vec{z}$
$\vec{y}$
$\vec{x}$
200
201
203
$r_{1(\vec{v})}$
202
206
204
205

FIG. 2

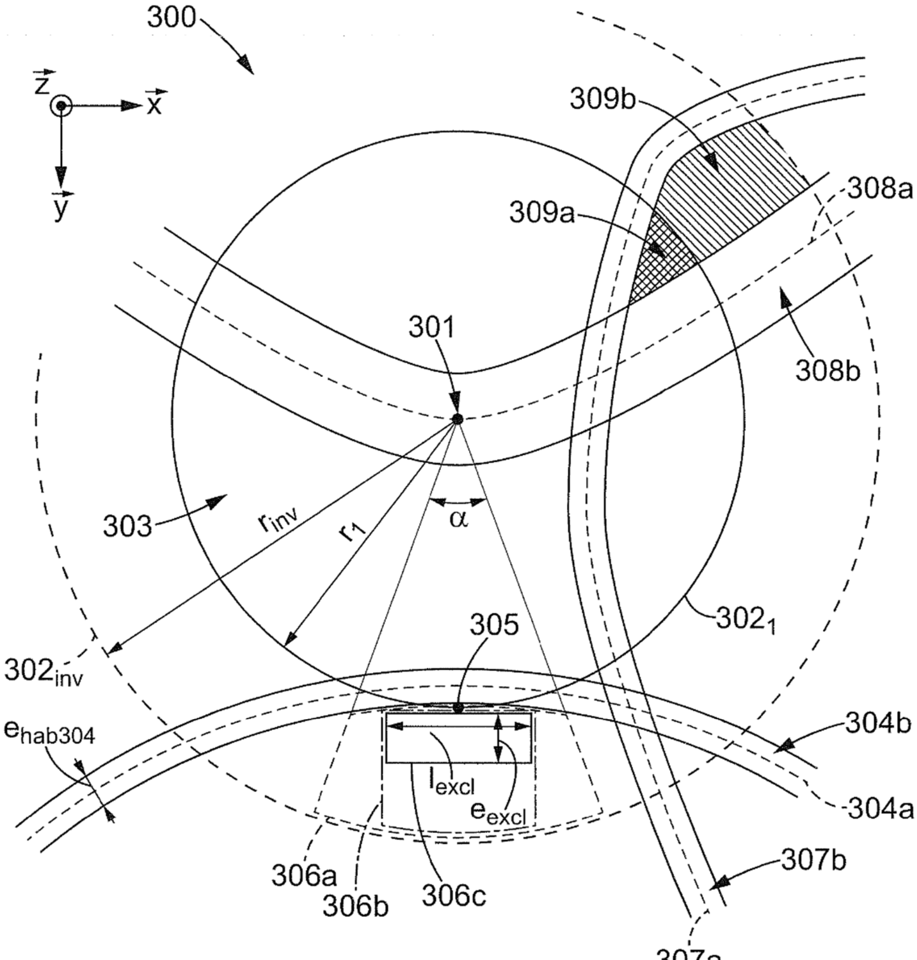
300
z
x
y
309b
308a
309a
301
308b
303
r_{inv}
r_1
α
302_1
305
302_{inv}
e_{hab304}
304b
l_{excl}
e_{excl}
304a
307b
306a
306b
306c
307a

FIG. 3a

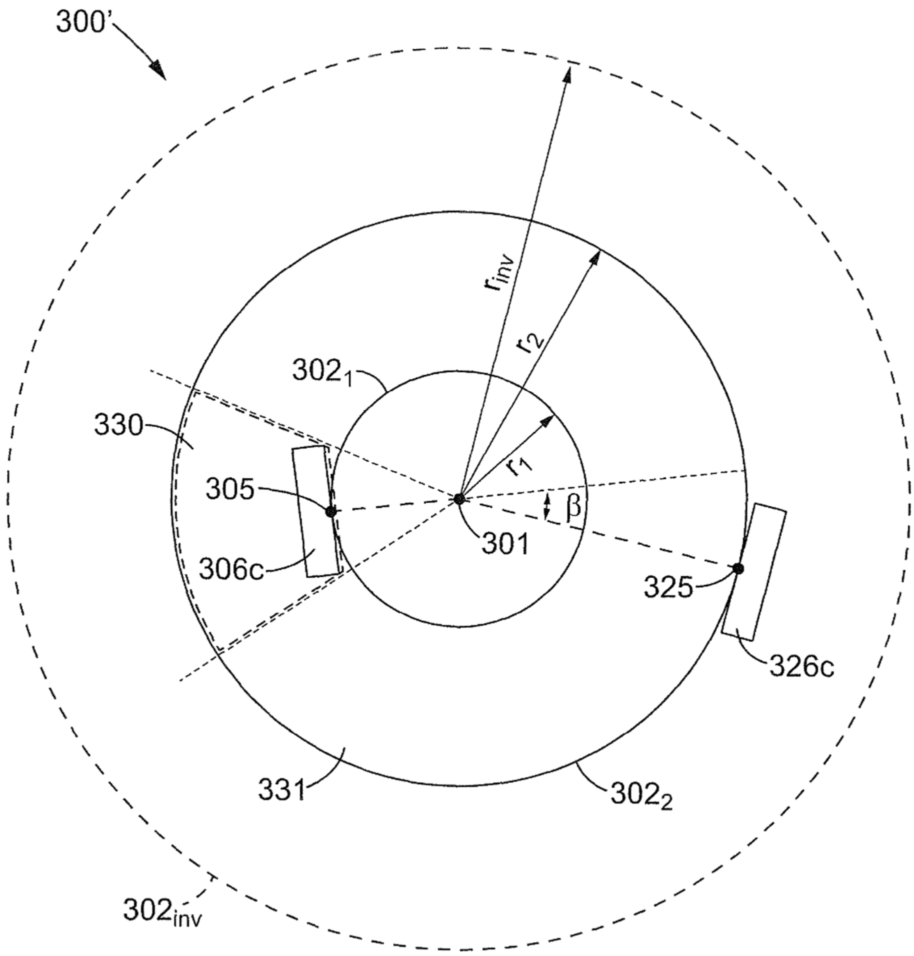

FIG. 3b

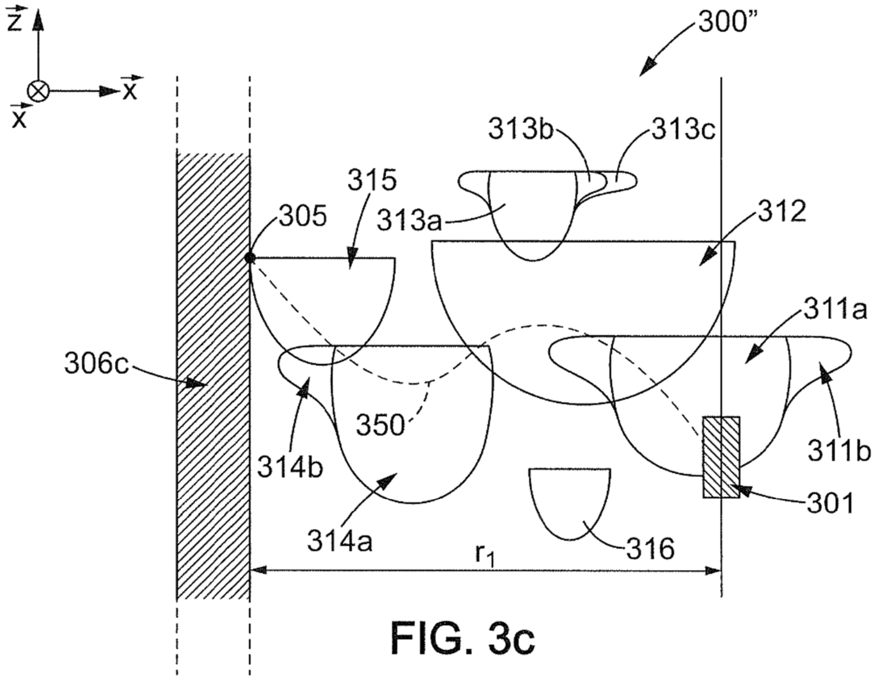
z
x
x
300"
313b
313c
315
305
313a
312
311a
306c
350
314b
311b
301
314a
316
r1

FIG. 3c

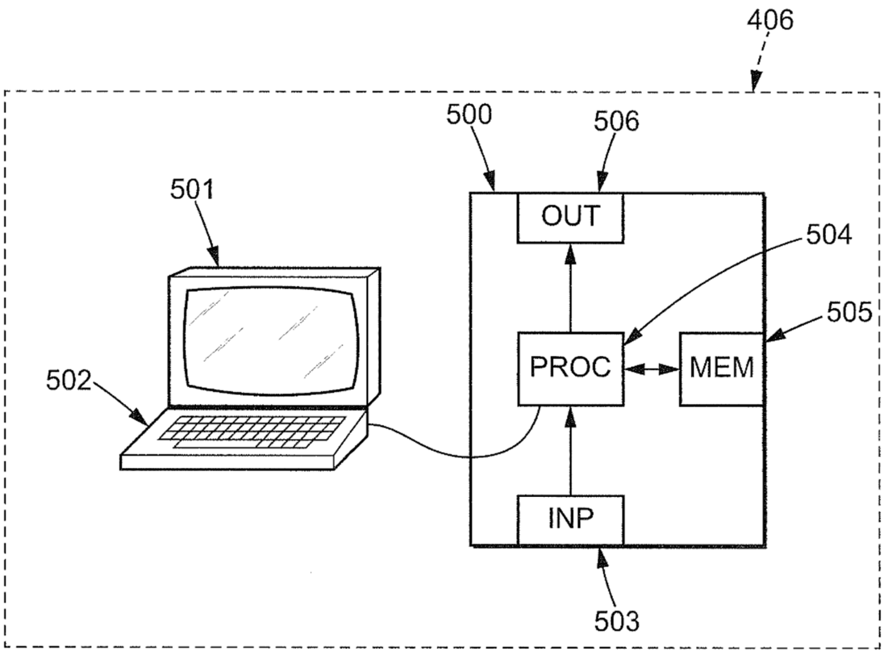
406
500
506
501
OUT
504
505
PROC
MEM
502
INP
503

FIG. 5

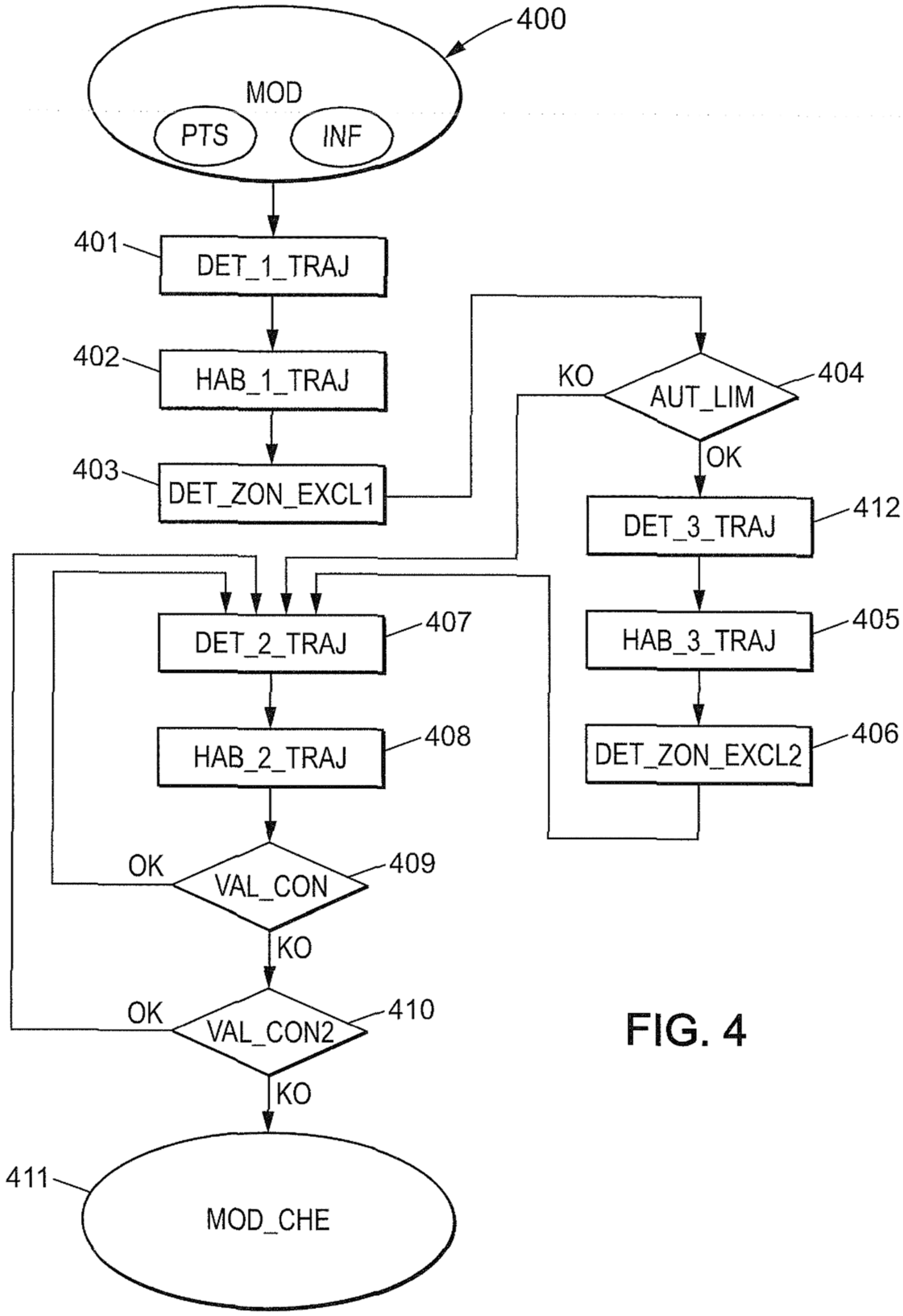
400
MOD
PTS
INF
401
DET_1_TRAJ
402
HAB_1_TRAJ
403
DET_ZON_EXCL1
KO
AUT_LIM
404
OK
DET_3_TRAJ
412
HAB_3_TRAJ
405
DET_ZON_EXCL2
406
DET_2_TRAJ
407
HAB_2_TRAJ
408
OK
VAL_CON
409
KO
OK
VAL_CON2
410
KO
411
MOD_CHE

FIG. 4