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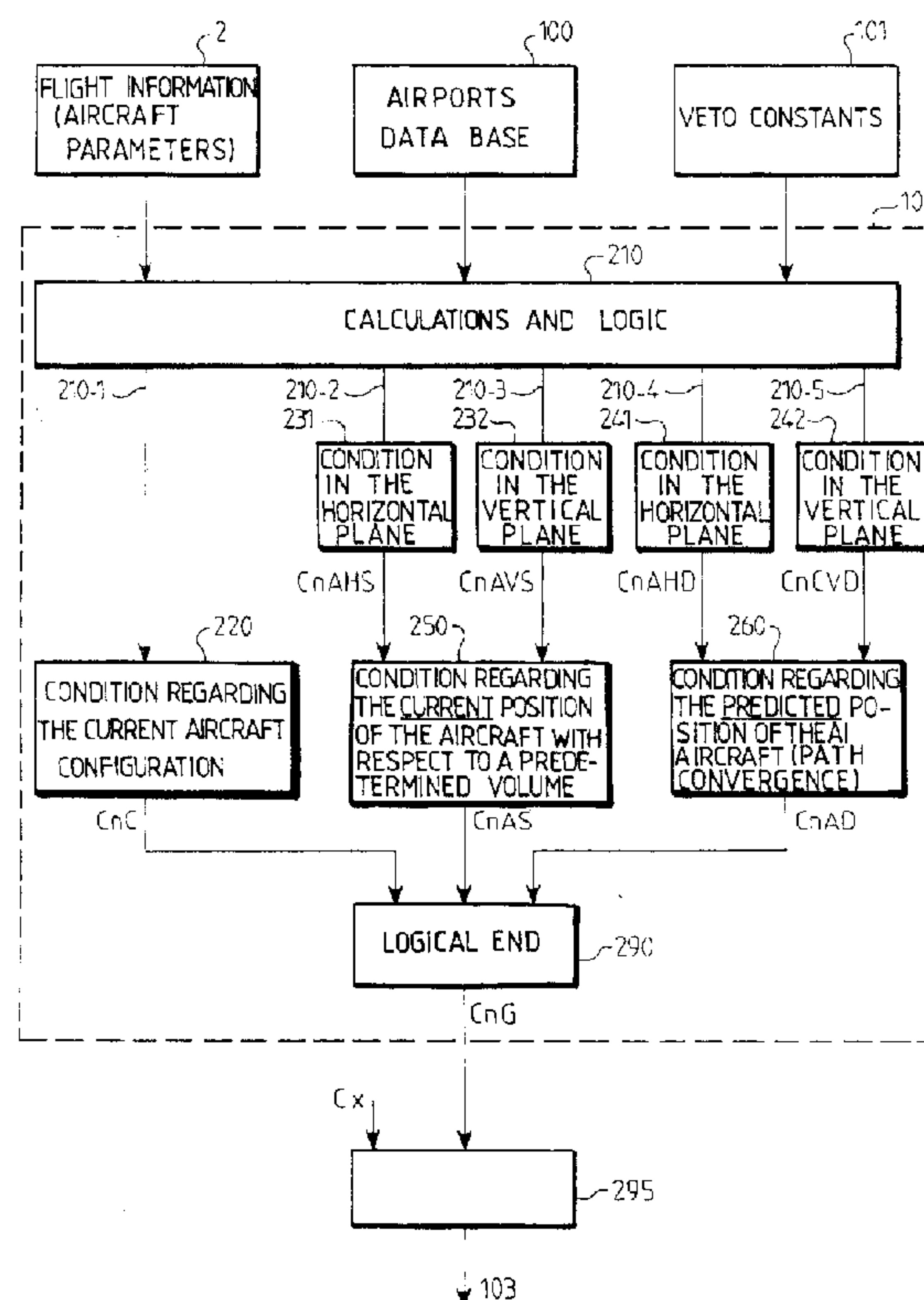
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(54) **DISPOSITIF D'AIDE A L'ATERRISSAGE, PLUS
PARTICULIEREMENT EN TANT QU'ALERTE POUR
PREVENIR UNE COLLISION AU SOL**

(54) **LANDING AID DEVICE, ESPECIALLY FOR ANTI-GROUND-
COLLISION ALERT VETOING**



(57) A landing aid device comprises processing means, which receive aircraft path data, and data regarding the position of at least one runway towards which the aircraft is steering. These processing means comprise calculation means which supply a state signal, comprising at least one condition which is dependent on the path data and on the runway data, this function being chosen so as to express the fact that the path of the aircraft converges towards the runway.

ABSTRACT OF THE DISCLOSURE

Landing aid device, especially for anti-ground-collision alert vetoing

A landing aid device comprises processing means, which receive aircraft path data, and data regarding the position of at least one runway towards which the aircraft is steering. These processing means comprise calculation means which supply a state signal, comprising at least one condition which is dependent on the path data and on the runway data, this function being chosen so as to express the fact that the path of the aircraft converges towards the runway.

Landing aid device, especially for anti-ground-
collision alert vetoing

FIELD OF THE INVENTION

5 The invention relates to the landing of
aeroplanes.

Aircraft are now furnished with anti-ground-
collision alerting devices. However, landing is a form
of gentle collision with the ground. Therefore, onwards
10 of a certain moment in the landing approach, the
alerting device will continually generate an untimely
alert. It is desirable for this alert to be selectively
vetoed, so as not to needlessly hinder the pilot, whose
attention is especially demanded during landing.

15

PRIOR ART

A known solution consists in vetoing the
alert when the height of the aircraft from the ground
remains below a given threshold.

20

This solution is not entirely satisfactory.
Specifically, if the threshold is fixed fairly low, the
pilot is needlessly inconvenienced by an alert. If the
threshold is fixed fairly high, the hindrance due to
the untimely alert is diminished; on the other hand,
25 the benefit of the anti-ground-collision alerting
device is lost at a moment when its indications may be
valuable, most particularly when the anti-ground-
collision alerting device involved is of high
performance.

30

A landing aid device comprising processing means,
which receive on the one hand aircraft path data, and

on the other hand data regarding the position of at least one runway, may be regarded as known.

OBJECTS OF THE INVENTION

5 It is a principal object of the invention to provide means to effect a veto whose qualities are connected with those of the anti-ground-collision alert itself, so as to avoid undesirable alert conditions during supposedly normal landing approaches.

10 Having posed and analysed this problem, the Applicants have sought to define automatically one or more conditions indicating that a landing approach is normal.

15 SUMMARY OF THE INVENTION

 According to the invention, the processing means comprise calculation means able to supply a state signal, comprising at least one condition which is a function of the path data and on the runway data, this
20 function being chosen so as to express the fact that the path of the aircraft converges towards the runway.

 Preferably the calculation means are organized so as to define a volume which possesses a chosen outline, positioned in a chosen manner with
25 respect to the said runway, which is advantageously defined by a representation stored in memory. In addition, the state signal comprises a so-called static condition, pertaining to the belonging of the current position of the aircraft to this volume.

30 More preferably the state signal furthermore comprises a so-called dynamic condition, pertaining to

the convergence of a predicted path of the aircraft towards the said runway, according to a chosen criterion.

According to other aspects of the invention,
5 which will be described hereinafter in detail, within the static condition there is distinguished a horizontal static subcondition and a vertical static subcondition, and, preferably, within the dynamic condition there is distinguished a horizontal dynamic
10 subcondition and a vertical dynamic subcondition.

A very important application of the invention is the vetoing of some at least of the alerts generated by an anti-ground-collision alerting device for an aircraft, during the landing approach. The invention
15 applies most particularly in the precise case where the alert-generator means are based on comparing positions situated on at least one predicted path of the aircraft with a stored representation of the said terrain, in which case the stored representation of the runway is
20 referred to the same co-ordinate system as the stored representation of the terrain which serves for the alert-generator means.

BRIEF DESCRIPTION OF THE DRAWINGS

25 Other objects and advantages of the invention will become apparent on examining the detailed description below, as well as the appended drawings in which:
- Figure 1 is a very general basic diagram of an aerial navigation aid device, of GCAS type, such as those
30 described in EP-A-0 565 399 and FR-96 04678 (now 2 747 492);

- Figure 2 is a more detailed diagram of an exemplary embodiment of a device according to the invention;
- Figure 3 is a still more detailed diagram of the vetoing device according to the invention;
- 5 - Figure 4 is a diagrammatic view from above of a runway, illustrating a horizontalwise vetoing sector;
- Figures 5, 6A and 7 are graphs relating to horizontalwise vetoing;
- Figure 6 is a drawing illustrating various particular
10 situations of the horizontal convergence towards the landing axis;
- Figures 8 and 9 are two graphs relating to verticalwise vetoing.

15 DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

The appended drawings comprise numerous elements which, in essence, are of definite character. Accordingly, they will be able not only to serve to better elucidate the invention, but also to contribute
20 to the definition thereof, as the case may be. The same holds for the relations collated, in an appendix of formulae, at the end of the description.

Furthermore, and in view of the technical nature of the subject, the descriptive contents of
25 EP-A-0 565 399 and EP-A-0 802 469 are to be regarded as incorporated fully into the present description by way of reference. The disclosure of French Patent Application No. 98 00 207 (now 2 773 609) is also incorporated herein by reference.

30 Use will also be made of units which do not belong to the MKSA system, in so far as they are

employed in civil aeronautics.

Reference will firstly be made to Figure 1.

The device described in EP-A-0 565 399 is essentially intended to be installed on board an
5 aircraft. The latter comprises equipment 2 capable of supplying, in the form of electrical signals, indications of flight parameters (position and "dynamics", in particular), such as an inertial or baro-inertial rig, and/or a radionavigation instrument,
10 such as a GPS receiver, a radio-altimeter, or other airborne navigation sensors.

The inertial rig supplies the components of the speed (V) and acceleration vectors of the aircraft. From this it is possible to deduce all or some of the
15 associated characteristic angles (attack, sideslip, slope, pitch, heading, list, in particular), or directly to gather the values of these angles used internally by the inertial rig. These angular values may be displayed and/or used at the flight deck. For
20 the altitude, the inertial rig co-operates with a barometric altimeter (not represented), in a known manner.

The GPS receiver supplies raw measurements of latitude L1, longitude G1 and altitude Z1, refreshed at
25 a rate p1 of a few seconds to a few minutes. By integration over the speed and acceleration vectors, the inertial rig supplies other measurements of latitude L2, longitude G2 and altitude Z2, which are accurate but drift over time. These magnitudes are
30 mutually validated, according to known validation techniques. The validated measurements L2, G2, Z2 are

available at the rate p1. However, they are refined on the basis of the inertial rig at a rate p2 of around one second.

All of this is dubbed the "consolidated
5 flight parameters" and is supplied by the unit 2.

The following notation is defined:

- Z is the height of the aircraft above the ground, emanating for example from a radio-altimeter and/or from the barometric altitude, minus the level of the
10 ground;
- x and y are the horizontal co-ordinates of the aircraft in a reference frame fixed with respect to the ground. For simplicity, the x axis is taken here as the axis of the relevant runway.

15 A unit 3 contains a terrain file, established in a manner described in the prior patents. Depending on the longitude and latitude quantities, a part of this file, the so-called local map, is accessed, this being a three-dimensional representation of the relief
20 of the region overflown by the aeroplane. On the basis of this local map and of the position quantities of the aircraft, the unit 4 performs anti-collision calculations which may be accompanied by terrain avoidance calculations.

25 In the presence of a risk of collision, an alert (51) is issued. A command director 53 can suggest an avoidance manoeuvre. This is destined for the flight deck (or control deck). The local map can also be used for generating a synthetic image, with its display
30 device.

All of this is described in the aforesaid

patents, which also indicate how to cross-check and verify the various items of information available, especially verticalwise.

One of the basic essentials of EP-A-0 565 399 is the fact that Applicants have perceived the possibility of storing on board an aeroplane a terrain file for representing almost the entire terrestrial globe, within the outline and resolution limits suitable for the requirements of an aeroplane. Thus, Applicants have proposed an anti-ground-collision alerting device for an aeroplane of a novel kind, which uses an on-board database, of worldwide scope, and containing data of the "altitude of the terrain" type. This innovation is of such a nature as to increase the safety of aerial navigation. It can in particular substantially reduce the false alert rate encountered with the prior anti-collision alerting systems. The harmful influence of a high false alert rate is readily understood: the more often the alerting system is mistaken, the less attentive the pilot is to it.

Applicants have sought to effect a vetoing whose qualities are connected with those of the anti-ground-collision alert itself, in particular that defined hereinabove, so as to avoid undesirable alerts during supposedly normal landings, that is to say problem-free ones.

In Figure 2, the unit 3 represents a "terrain database" file defined on the basis of information regarding the terrain, which is loaded for example on the ground (unit 1). Appended thereto is an "airport database" file 100, which contains data defining the

identification and the exact position of each of the runways of the airport, with the desired accuracy. Very advantageously, appended thereto is the standard landing and/or approach slope at each end of some at
5 least of the runways.

In this regard, the word "runway" denotes a rectangular area kitted out to serve over its length for the movements of aeroplanes. As a general rule, landing may be effected along the runway in either
10 direction. When the context so demands, we shall speak of an "oriented runway" so as to define a runway when considered taken in a given landing direction. The "threshold" of the runway is the start of its pavement. Usually, a runway (oriented) includes a "displaced
15 threshold", marked on its pavement.

An oriented runway can be defined by the heading of its axis, and the co-ordinates (longitude, latitude and altitude of its threshold). The words "upstream" and "downstream" refer to the direction of
20 landing, both for the oriented runway and for the landing approach.

As in Figure 1, on the basis of information or flight parameters 2 and of the "terrain database" 3, the unit 4 carries out the anti-collision calculations
25 which allow it to actuate one or more alerts 51, as the case may be. These alerts are customarily dubbed "caution" and "warning".

A unit 102 formulates the command (state) for vetoing the unit 4. More generally, vetoing is
30 applicable to any Collision Prediction and Alerting function ("CPA").

For this purpose, the unit 102 receives (Figure 3, at the top) on the one hand the flight information from the unit 2 and on the other hand the information output by the airport database 100, as well
5 as information forming "veto constants", stored in memory at 101.

The unit 102 comprises a unit 210, which carries out calculation and/or logic operations so as to supply working quantities to 5 outputs, in the
10 embodiment illustrated, namely:

- an output 210-1, going to a unit 220, which, on the basis of the working quantities which it receives, formulates a first condition CnC (aircraft configuration subcondition) relating to the current
15 aircraft configuration,
- an output 210-2, going to a unit 231, which supplies a second condition CnAHS (horizontal static subcondition), which is a condition relating to the approach, considered in the horizontal plane and
20 statically (position of the aircraft),
- an output 210-3, going to a unit 232, which supplies a third condition CnAVS (vertical static subcondition), which is a verticalwise static approach condition,
- an output 210-4, going to a unit 241, which supplies
25 a fourth condition CnAHD (horizontal dynamic subcondition), which is an approach condition considered in the horizontal plane and dynamically, and
- an output 210-5, going to a unit 242, which supplies
30 a fifth condition CnAVD (vertical dynamic subcondition), which is a verticalwise dynamic approach condition.

To lighten the account, the subconditions will hereinafter be referred to simply as "conditions".

The unit 250 supplies a general static condition CnAS, by a logical AND on the horizontal static conditions CnASH and the vertical static condition CnASV (relation I). Likewise, the unit 260 supplies a general dynamic condition CnAD, by a logical AND on the horizontal dynamic condition CnADH and the vertical dynamic condition CnADV (relation II).

10 The unit 290 carries out a logical AND of the three conditions CnC, CnAS and CnAD, so as to define an overall veto condition CnG (relation III). As an option (lighter line in the drawing), the facility 295 carries out an additional processing, as will be seen
15 hereinafter.

The output from the unit 290 is equivalent to formulating an overall approach condition CnA by a logical AND of the general static condition CnAS and of the general dynamic condition CnAD (relation IV), then
20 to defining the global veto condition CnG by a logical AND of the conditions CnC and CnA (relation V).

The overall approach condition CnA may also be regarded as being a logical AND on the four approach subconditions (relation VI), or else as being a logical
25 AND (relation VII) on a horizontal approach condition CnAH and a vertical approach condition CnAV, themselves defined by relations VIII.

These two different presentations make it possible to undertake:

30 - on the one hand, an "aircraft analysis",
distinguishing that which appertains to the position of

the aircraft (Figures 5 and 8), or else to its path prediction (Figures 7 and 9),
- on the other hand, a "ground analysis", distinguishing the "vertical plane" (projection of the path of the aircraft in a vertical plane) from the horizontal plane (projection of the path of the aircraft in a horizontal plane).

Moreover, the splitting up of Figure 3 into units is of a functional nature. In practice, all or some of the operations appearing inside the box 102 could be carried out by the same processing and calculation unit, which works repetitively. The latter must be able to undertake calculations of a geometrical and trigonometrical kind, as well as to process the logical conditions. For this purpose, use is made, for example, of a microcomputer of the POWER PC 603 type, together with programs written, for example, in the C language of the C.ANSI type, if appropriate with the assistance of a DSP type supporting processor.

The genesis of each of the conditions will now be described.

The aircraft configuration condition CnC indicates that the aircraft is ready to land hardwarewise. According to the current standards, it can, for example, comprise, as a logical AND (relation X):

- a condition CnC1 pertaining to the lowering of the landing gear ("gear down"), and
- a condition CnC2 indicating that the wing flaps are deployed ("full flaps"), preferably as a logical OR with a state CnC3, permitting the condition CnC2 to be

overridden, for example on request by the pilot ("flaps override").

According to the invention, the horizontal static condition CnASH is defined with the aid of a
5 horizontal approach sector SHA, a preferred example of which is given in Figure 4.

The information regarding the planned oriented runway must be made accessible to the vetoing device. It is known that a runway is generally
10 horizontal, or nearly so. Hence, the plane of the runway (as the case may be, the midplane of the runway) will here be referred to as the horizontal plane.

Automatic determination of the relevant oriented runway can be achieved on the basis of one
15 and/or other of the following two criteria, applied below a distance threshold equal for example to 5000 metres (distance G-G3):

- we take the stored runway whose axis is closest to the horizontal projection of the instantaneous speed
20 vector, or of a representation, for example by averaging, of the latter vector,
- we take the oriented runway whose runway threshold is closest to the aircraft in terms of horizontal projection.

25 As a variant, in an aircraft equipped with a flight management system (FMS), in this system we take the information regarding the planned oriented runway. Another variant consists in the pilot indicating this runway to the on-board electronics of the aeroplane,
30 since, when he is preparing to land, the pilot always receives verbally the designation of his planned

oriented runway.

Thereafter, the device according to the invention can, in the memory 100, isolate the coordinates of the relevant runway. Thus, the coordinates and the shape of this runway are those
5 illustrated as LP in Figure 4.

G denotes a reference point of the runway for defining the horizontal approach sector SHA. It is desirable for this point G to correspond to the
10 grounding point of the landing path. In the embodiment described, by way of example, this point G is, in order of priority:

- the so-called "glideslope position" sighted point extracted from the memory 100, if this point exists,
15 and
- the displaced threshold point extracted from the unit 100, if this point exists,
- a point displaced 300 metres in the direction of landing, based on the runway threshold extracted from
20 the unit 100.

Based on this point G, two points W and E are then defined as follows (in the embodiment described):

- the length of the segment WE equals 200 m (lateral positional tolerance),
- 25 - the segment WE is perpendicular to the axis of the runway,
- the point G is the middle of the segment WE.

A point N is furthermore defined as follows: the point N is on the axis of the runway, 300 m
30 downstream of the point G (the direction of landing of the aircraft).

The person skilled in the art will understand that these points may be determined with the aid of simple mathematical processings.

In Figure 4, to the right of the segment WE, the approach sector comprises a rectangular zone of length WE, which goes as far as the point N.

The shape of the approach sector leftward of the segment WE will now be defined, according to the horizontal projection of Figure 4.

The aircraft is at the point A. β and γ respectively denote the angles which the segments AE and AW make with the axis GN of the runway (or any parallel thereto). α denotes the smaller of the two angles β and γ . D_h denotes the projection of AG on the horizontal plane passing through G.

Figure 5 is a graph having the horizontal distance D_h as abscissa and the angle α as ordinate. In order to correspond to the conditions of a landing (and to Figure 4), the abscissae are decreasing from left to right.

An outline HSGL is defined by the points Q10 to Q14, and the origin O. The interior of this outline is a closed domain HSG (the outside is distinguished by short hatching).

The condition CnAHS is true if the angle α belongs to the domain HSG of Figure 5. The interval of the values of α situated in the domain HSG is a function of the horizontal distance D_h . This is expressed by relations XI.

The shape of the horizontal approach sector SHA stems from that of this domain or template HSG. It is described hereinbelow in the direction reverse to that of landing.

5 The outline HSGL of Figure 5 includes a horizontal plateau Q10-Q11, of from 0 to 900 metres. This defines the following parts of the outline of the approach sector (Figure 4):

- To the left of the point W, a segment W-SM1, which
10 stands on a line L8W, which diverges upwards by an angle β_0 , equal to 8° here, with respect to the runway axis GN.
- To the left of the point E, a segment E-SM2, which stands on a line L8E, which diverges downwards by an
15 angle β_0 , also equal to 8° here, with respect to the runway axis GN.
- On the runway axis, a segment G-G1.

To facilitate understanding, these three sets of points (at the top, at the bottom and on the axis)
20 are recalled under the corresponding limits of the template of Figure 5.

Next, the outline HSGL of Figure 5 possesses an increasing zone Q11-Q12 (here linear), for the values of α which go from $\beta_0 = 8^\circ$ to $\beta_1 = 40^\circ$. The
25 following parts of the outline of the approach sector correspond to this (Figure 4):

- curvilinear top segment SM1-SN1, whose concavity faces upwards,
- curvilinear bottom segment SM2-SN2, whose concavity
30 faces downwards,

- on the runway axis, a segment G1-G2.

It will be noted that the average inclination of the curvilinear segments SM1-SN1 and SM2-SN2 is greater than $\beta_0 = 8^\circ$.

5 Finally, the outline HSGL of Figure 5 possesses another plateau Q12-Q13, for $\beta_1 = 40^\circ$, and the abscissae from 4000 to 5000 metres. In the approach sector (Figure 4) this corresponds to:

- at the top, a segment SN1-SQ1, which diverges at the
10 angle β_1 with respect to a parallel to the runway axis,
- at the bottom, a segment SN2-SQ2, which diverges at the angle β_1 with respect to a parallel to the runway axis, but downwards,
- on the runway axis, a segment G2-G3.

15 The outline HSGL is noteworthy through its intermediate part which decreases with the reduction of the distance D_h from the aircraft to the chosen point G. It should be noted that the second plateau is optional; the template can terminate on its decreasing
20 zone Q11-Q12.

Moreover, the approach sector SHA as described is symmetric with respect to the runway axis. It is conceivable for it to be made asymmetric, at least for certain airports, by modifying or displacing
25 the template on one side, and/or by placing the points W and E asymmetrically with respect to G.

The plateaux and the rectilinear climb of Figure 5 correspond to conditions which are simple to calculate. Additionally, this results in the approach

sector having geometrically simple outlines, which are straight for the most part. The person skilled in the art will understand that it is possible to produce more complex equivalent outlines, while increasing the
5 calculation power, if appropriate.

The horizontal approach sector makes it possible to verify that, in the horizontal plane, the successive positions of the aircraft converge towards the runway.

10 Thus, the condition CnAHS can be defined on the basis of the following parameters:

- position A of the aircraft,
- direction of the runway axis and point G,
- "constants" defining the template of Figure 5, for
15 example by its four points of transition Q10 to Q13, or else in the form of a table $HSG(D_h)$, sampled with a sufficiently fine spacing over the distance D_h .

 Thereafter, it is necessary to calculate the positions of the points W and E, the distance D_h , and
20 the angle α , derived from β and γ . These calculated quantities are obtained in the unit 210, which transmits the values D_h and α to the unit 231 together with the constants defining the template of Figure 5, or better still the ordinate value of the template for
25 the current value of D_h .

As regards the leftward limit of the approach sector, this is defined by the outline SQ1-G3-SQ2. This corresponds to the fact that the distance D_h of the aircraft from the point G must be less than a given

threshold value, here fixed at 5000 m.

It is therefore apparent that to the left of the segment WE, the horizontal approach sector SHA is entirely defined by the template HSG of Figure 5. As a
5 variant, the sector SHA could be parametrized directly as a function of D_h .

We now deal with the dynamic horizontal approach condition, denoted CnAHD. This condition is, in the preferred embodiment described, slightly more
10 complex than the previous one.

Specifically, account is now taken, not only of the current position A of the aircraft, but also of a prediction of its future path in the horizontal plane. This prediction is defined in this instance by a
15 point B, on the basis of a vector AB, such that:

- the length or norm of the vector AB is equal to the horizontal speed (or ground speed) of the aircraft, and
- the sense or direction DIR of the vector AB is equal to the track angle of the aircraft.

20 The angle between the vector AB and the oriented runway axis is then denoted δ (Figure 4).

Moreover, a convergence sector is defined in a manner which can be partly likened to the defining of the horizontal approach sector. In Figure 6, two points
25 W2 and E2 are defined (as were W and E) on either side of G, perpendicularly to the runway axis. LKW2 denotes a boundary comprising a half-line departing leftwards from W2 and diverging from the runway axis by an angle θ , here equal to 8° , extended as required to the right
30 of W2 by a parallel to the runway axis. Likewise, LKE2

denotes a half-line departing leftwards from E2 and diverging from the runway axis by an angle θ , extended as required to the right of W2 by a parallel to the runway axis. The convergence sector is the zone lying
 5 between LKW2 and LKE2. Preferably, according to the embodiment described, we have $E2 = E$, $W2 = W$, and $\theta = \beta_0$.

Dkw denotes the distance between A and the half-line LKW2, and Dke the distance between A and the
 10 half-line LKE2.

It is firstly assumed that δ is between 0° and 180° (the case of Figure 6). If A is beyond the half-line LKW2 (the case A_4B_4), then any vetoing is prohibited, for example by forcing Dkw to an impossible
 15 value, such as -1. It is thus supposed that, in this case, the aircraft is incapable of landing correctly.

Symmetrically, it is now assumed that δ is between 180° and 360° (in Figure 6, the direction DIR would be replaced by its symmetric inverse with respect
 20 to the oriented runway axis). If A is shy (below in the figure) of the half-line LKE2, then any vetoing is prohibited, for example by forcing Dke to an impossible value, such as -1.

The other cases will now be dealt with.

25 Consider for example the half-line LKW2. Assume that the aircraft is steering towards it from the bottom of Figure 6. Applicants have observed that it is possible to define, as a function of the angle δ (in practice, of $\delta + \theta$), a distance Dkw to be complied

with, if one wishes to be certain that the aircraft can turn towards the runway while remaining below the half-line LKW2. This distance advantageously makes allowance for the time taken by the aircraft to bank before turning. This yields for example (Figure 6A) the curve dv_1 (solid line) for a horizontal aircraft speed of around 70 m/s, and the curve dv_2 (broken line) for a horizontal aircraft speed of around 90 m/s. The curves dv_1 and dv_2 have the form of an ArcSine function.

Although it is conceivable to use these curves themselves, Applicants have observed that the stricter limit, here dv_2 , can be approximated by three straight segments, Q20w-Q21w, Q21w-Q22w, and Q22w-Q23w, together forming the boundary HDGLw, situated below dv_2 , hence still stricter.

It is then sufficient to calculate Dkw and to verify that it lies below the curve HDGLw, as a function of δ . The same is done, symmetrically, for Dke and a curve HDGLe. Vetoing is possible if both conditions are satisfied.

Applicants have also observed that it is possible to further simplify the calculations, by considering just a single distance, denoted Dhd. The foregoing elements are modified as follows:

- if δ is between 0° and 180° (the case of Figure 6), and so long as A remains shy (below in the figure) of the half-line LKW2 (the case A_1B_1, A_2B_2, A_3B_3), Dhd is taken equal to the distance Dkw between A and the half-line LKW2;

- if δ is between 180° and 360° (in Figure 6, the direction DIR would be replaced by its symmetric inverse with respect to the oriented runway axis), and so long as A remains beyond (above in the figure) the half-line LKE2, Dhd is taken equal to the distance Dke between A and the half-line LKE2.

As indicated by relation XII, the dynamic horizontal approach condition CnADH is then defined by the fact that the angle δ belongs to the domain or template HDG (Figure 7), which is itself dependent on the distance or "turning margin" Dhd, along the abscissa. HDGL denotes the outline of this domain.

Figure 7 is, like Figure 5, established with abscissae which decrease from left to right. For Dhd going from 0 to Dhd1, the curve includes a plateau Q20-Q21, of level δ_0 of close to 0° . From Dhd1 to Dhd2, the outline HDGL comprises a segment Q21-Q22, here rectilinear, which increases with Dhd. From Q22 to Q23 there is another plateau of level $\delta_1 = 60^\circ$, for Dhd going from Dhd2 to a limit value Dhd3 = 4000 metres for example. The outline HDG is closed by the vertical Q23-Q24, the abscissa axis, and the vertical between the origin and Q20.

In practice, and especially according to the characteristics of the aircraft, it will be possible to take Dhd1 = 75 to 150 metres, Dhd2 = 900 to 2000 metres, and the maximum Dhd3 = 4000 metres for example.

Thus, the convergence of the planned path towards the runway axis is predicted with a tolerance either side of this axis. The "rigorousness" of the

convergence demanded increases as the aircraft approaches the runway. More precisely, the dynamic horizontal approach condition CnAHD makes it possible to verify that, in the horizontal plane, the component
 5 of the speed of the aircraft which is transverse to the runway axis remains compatible with a return in time to the runway axis (centre line).

Providing, instead of the theoretical curves on both sides, a single template HDGL in accordance
 10 with Figure 7, with a plateau at small distances, from Q20 to Q21, amounts to authorizing a permitted veto "corridor", of width Dhd1, to the inside of the lines LKW2 and/or LKE2, for $0 < \delta < \delta_0$. Specifically, if the aircraft is close for example to LKW2 on the inside
 15 ($Dhd < Dhd1$), vetoing is authorized, whereas $\delta > 0$ indicates that the aircraft is tending to leave the convergence sector; however, if the aircraft continues in the same direction, it will cross to the other side of LKW2, with $Dhd = -1$ which prevents vetoing. Vetoing
 20 therefore endures only if the aircraft remains in the corridor, or, better still, is approaching the runway axis.

The condition CnAHD can be defined on the basis of the following parameters:

- 25 - as before, position A of the aircraft, direction of the runway axis and point G,
- direction of the vector AB, points W2 and E2, which, here, coincide with W and E,
- "constants" defining the template of Figure 7, for
 30 example by its four points of transition Q20 to Q23, or

else in the form of a table $HVG(Dhd)$, sampled with a sufficiently fine spacing over the distance Dhd .

Most of these calculations can be likened to those already undertaken in respect of the horizontal approach sector: points $W2$ and $E2$, and half-lines $LKW2$ and $LKE2$. From this is derived, according to the pertinent case, the distance Dhd . On its part, the calculation of the angle δ is of the same nature as that of the angles β and γ . These calculated quantities are obtained in the unit 210, which transmits the values Dhd and δ to the unit 241 together with the constants defining the template of Figure 7, or better still the ordinate value of the template for the current value of Dhd .

It will be noted that the horizontal dynamic condition $CnADH$ described above takes account not only of dynamic data (speed), but also of position data. It will also be noted that the convergence sector, in the example described, coincides with the part $SM1-W-E-SM2$ of the horizontal approach sector which is close to the runway. The condition $CnAHD$ therefore at least partially contains the condition $CnAHS$. It is therefore possible to define combinations of these two conditions other than the one proposed here.

Reference is now made to Figure 8 in respect of the static vertical approach condition $CnAVS$.

A point S is defined, situated 900 m upstream of G in the direction of landing (Figure 8).

Furthermore, a point $N2$ is defined which is situated 50 feet (around 15 metres) vertically above N . This

height of 50 feet is the tolerance in the vertical position error (for the veto).

Finally, three angles α_0 , α_1 , $\leq \alpha_0$ and $\alpha_2 \geq \alpha_0$ are defined, with:

- 5 - α_0 = standard landing slope angle for an oriented runway, taken by default equal to 3° ,
- α_1 = minimum acceptable landing slope angle, here taken by default equal to the minimum acceptable alert-free angle for an approach on glideslope, i.e.
- 10 $\alpha_1 = 2.5^\circ$,
- α_2 = maximum acceptable landing slope angle, taken by default at 4.5° , or else at 8° if steep-angled approaches are possible for the relevant airport (information item stored in the airports database).
- 15 The approach sector in the vertical plane is then defined by the template of Figure 8. Its outline VSGL is delimited:
 - by a segment S-N at ground level, passing through G,
 - to the right, by the vertical N-N₂,
 - 20 - at the top, by the line N₂-M₂ which climbs leftward at the angle α_2 ,
 - at the bottom leftward, by a line which starts from the point S, at an angle α_1 , up to M₁,
 - vertically to the left, by a vertical line M₁-M₂
 - 25 situated here 5000 m to the left of the point G.

The domain situated inside this outline is denoted VSG. It is itself the vertical approach sector. Its vertical extent is dependent on the distance D_h , which is the projection of AG onto the horizontal plane

passing through G. The height of the aircraft above the horizontal plane passing through G is denoted z_A , with $z_A = D_z$.

The condition CnAVS then corresponds to the
5 fact that z_A is situated inside the domain VSG, itself dependent on D_h , as indicated by relation XIII.

The vertical approach sector makes it possible to verify that, in the vertical plane, the successive positions of the aircraft converge towards
10 the runway, without passing prematurely too near to the ground.

Thus, the condition CnAVS can be defined on the basis of the following parameters:

- as before, position A of the aircraft, direction of
15 the runway axis and point G,
- point S,
- "constants" defining the template of Figure 8, for example in one of the ways used for the previous templates, or in any appropriate way.

20 The unit 210 transmits the values D_h (component of AG in the horizontal plane) and D_z (component of AG in the vertical plane) to the unit 232. It also transmits the definition of the template of Figure 8, or better still the ordinate value of the
25 template for the current value of D_z .

We now deal with the fifth condition CnAVD, which is a dynamic approach condition in the vertical plane. It is defined on the basis of the vertical approach sector.

In Figure 8, h_z denotes the vertical height (in feet, in accordance with aeronautical usage) between the point A and the bottom limit M1-S-N of the outline VSGL. V_z denotes the vertical speed of the aircraft.

The template of Figure 9 expresses a limit in terms of height h_z in feet (ordinate), as a function of the vertical speed V_z in feet per minute (abscissa). As the vertical speed of the aircraft is negative when the aircraft is approaching the ground, the abscissa axis is reversed.

The contour VDGL of the veto domain is established by the horizontal axis, starting from decreasing positive vertical speeds, down to around -1450 feet/minute. Thereafter, a first oblique segment climbs rightward up to the point $V_{z1} = -3000$ feet/minute and $h_{z1} = 1000$ feet. A second vertical segment, slightly shallower, goes from the previous point up to the point $V_{z2} = -5500$ feet/minute for $h_{z2} = 2450$ feet. The remainder of the outline is a horizontal plateau at 2450 feet. The outline VDGL has no limit other than a physical one (maximum speed of the aircraft) either to the right or to the left. If necessary, a limit can be fixed at 10,000 feet/min.

The domain VDG, for which a veto is possible, is the open domain situated above the broken-line outline VDGL.

The condition CnAVD is then defined by equation (XIV), expressing the fact that the vertical

speed V_z belongs to the domain VDG, which is itself dependent on h_z . (Unlike in the case of the previous templates, here the abscissa V_z is expressed as a function of the ordinate h_z).

5 The requisite parameters are the same as for the condition CnAVD, plus the vertical speed V_z . The unit 210 transmits the values h_z and V_z to the unit 242 together with the definition of the template of Figure 9. As a variant, the unit 210 transmits the value D_z to
10 the unit 242, and the unit 242 takes into account the oblique base segment M1-S, of inclination α_1 , so as to deduce h_z therefrom.

 The dynamic vertical approach condition CnAVD makes it possible to verify that, in the vertical
15 plane, the speed of the aircraft decreases sufficiently as a function of height to allow the aircraft a landing at very low vertical speed, rather than a collision. It is therefore also a dynamic criterion of convergence of the path of the aircraft towards the runway.

20 As already indicated in respect of the condition CnAHD, the condition CnAVD can be modified so as to design a variant thereof which is a different function of vertical speed and of position in the vertical plane.

25 The embodiment described above corresponds to the case in which one wishes to automatically veto the anti-ground-collision alerting device which the aircraft comprises. It is particularly relevant in the case where the alert-generator means (2, 3, 4, 51) are

based on a comparison (4) between positions situated on
at least one predicted path of the aircraft and a
stored representation of the said terrain, in
particular because the stored representation (100) of
5 the runway (LP) is referred to the same co-ordinate
system as the stored representation (3) of the terrain
which serves for the alert-generator means.

However, the means described allow, more
generally, automatic detection of the conditions
10 representative of a supposedly correct landing, that is
to say which has every reason to take place normally.
This information item could form the subject of a
simple display at the flight deck, or of other
applications, which differ from alert vetoing. Of
15 course, the parameters affecting the safety conditions
are then to be tailored as a function of the
application.

It is possible to envisage various ways of
establishing a global alert vetoing condition CnG
20 derived from the elementary conditions expressed above.

Applicants currently prefer the simplest way,
which is equivalent to a logical AND of the five
conditions. Stated another way, the vetoing means (102)
are organized so as to veto the alert when all the
25 foreseen conditions join together.

Preferably, the veto condition CnG is
evaluated repetitively continually, at a sufficiently
fast rate, for example typically every 0.5 seconds.
However, this repetitive calculation can be limited to
30 the case where a runway is sufficiently close.

Vetoing ceases as soon as the condition

ceases to be satisfied. However, it is conceivable to act otherwise, at least in certain cases. In other words, these veto means (102) veto the alert only so long as all the foreseen conditions join together;
5 nevertheless, these veto means (102) can be frozen in the veto state, as a function of a special condition (Cx) implying for example that the altitude of the aircraft is less than a chosen threshold value.

Thus, Applicants envisage that the veto will
10 persist by exception (function 295), in the presence of a condition Cx which depends, for example, on one or more of the following conditions:

- the height D_z remains less than a threshold z_{min} , fixed for example at 90 feet,
- 15 - the condition CnAHS remains true,
- a veto has already been obtained at the point 103 of Figure 3 at the conclusion of the previous cycle of calculations.

This exception signifies that the veto is
20 maintained if the aircraft is very low. The condition that the phases of the landing which have already taken place are normal, and/or that the aircraft has remained in the horizontal approach sector may be added thereto.

In the description, the point G serves as
25 reference in several respects. It is naturally possible to take another point as reference. What is essential is to preserve a good definition of the nominal point of grounding of the landing path.

The dynamic aspects, relating to the
30 convergence of the path of the aircraft towards the identified runway, are very relevant in themselves,

independently of the static aspects, which may conceivably be modified or even omitted. In this regard it will be observed that the dynamic conditions derived from the templates HDG and VDG may be sufficient to
5 indicate a correct landing approach, at least in certain cases.

Besides this, the qualifier "dynamic" implies that the motion of the aircraft is taken into account, in particular through its instantaneous speed; it does
10 not exclude the possibility of also taking its position into account, as is the case for the horizontal dynamic subcondition in the example described.

Likewise, the processing in the horizontal plane can be separated from the processing in the
15 vertical plane, although these processings interact partially.

Applicants currently deem the static aspects to be important. Thus, a volumewise approach sector is defined by the horizontal approach sector SHA, and the
20 vertical approach sector VSG. However, in so far as it would be necessary to define a priority between the two, Applicants also deem the horizontal plane to be more important than the vertical plane.

Thus, the subcondition currently regarded as
25 the most important is the horizontal static subcondition CnAHS. It is deemed preferable for it to be interdictive. It will be noted that it plays a privileged role in the unit 295 of Figure 3. For the remainder, variants may be envisaged.

30 Moreover, the principle is that all the airport data are contained in the database 100.

However, it may be admitted that in addition to the "constants", the unit 101 contains default values for the case where data might be missing from the database 100 or might be incorrect, for example as regards the geometry of the runway; the unit 101 may also contain one or more sets of standard values, which can be designated individually by codes, for the geometry of the runway in particular.

It is also possible to designate in the airports database one or more predefined standard approach sectors, from which particular airports would be excepted and would be assigned specific approach sectors, defined in detail by their template and/or their outline. In particular, the points W and E as well as W2 and E2 may be placed asymmetrically with respect to the point G.

The individual capabilities of each type of aircraft may be taken into account with regard to those parameters and constants of the invention which are linked, directly or indirectly, with the approach speed.

Instead of being stored in the database, some at least of the "airport information" can be transmitted to the aircraft just before landing. This is appropriate in particular in the case of aircraft carriers and/or seaplanes.

Numerous parameters and constants for which specific values are given appear in the example described. The values indicated are those regarded as currently preferable, in view of the studies conducted by Applicants. These parameters are however liable to

alter, especially as a function of the applicable standards, of the type of aircraft concerned, and of the approach conditions for the runways.

Appendix of formulae

Notation: $\cap$ denotes the logical AND function
 $\cup$ denotes the logical OR function

5

$$\text{CnAS} = \text{CnAHS} \cap \text{CnAVS} \quad (\text{I})$$

$$\text{CnAD} = \text{CnAHD} \cap \text{CnAVD} \quad (\text{II})$$

$$10 \quad \text{CnG} = \text{CnC} \cap \text{CnAS} \cap \text{CnAD} \quad (\text{III})$$

$$\text{CnA} = \text{CnAS} \cap \text{CnAD} \quad (\text{IV})$$

$$\text{CnG} = \text{CnC} \cap \text{CnA} \quad (\text{V})$$

$$15 \quad \text{CnA} = \text{CnAHS} \cap \text{CnAHD} \cap \text{CnAVS} \cap \text{CnAVD} \quad (\text{VI})$$

$$\text{CnA} = \text{CnAH} \cap \text{CnAV} \quad (\text{VII})$$

$$\begin{cases} \text{CnAH} = \text{CnAHS} \cap \text{CnAHD} \\ \text{CnAV} = \text{CnAVS} \cap \text{CnAVD} \end{cases} \quad (\text{VIII})$$

$$20 \quad \text{CnC} = \text{CnC1} \cap (\text{CnC2} \cup \text{CnC3}) \quad (\text{X})$$

$$\begin{cases} \alpha = \min(\beta, \gamma) \\ \text{CnAHS} = (\alpha \in \text{HSG}(D_h)) \end{cases} \quad (\text{XI})$$

$$25 \quad \text{CnAHD} = (\delta \in \text{HDG}(D_{hd})) \quad (\text{XII})$$

$$\text{CnAVS} = (z_A \in \text{VSG}(D_h)) \quad (\text{XIII})$$

$$\text{CnAVD} = (v_z \in \text{VDG}(h_z)) \quad (\text{XIV})$$

Claim

1. Landing aid device, comprising
processing means, which receive on the one hand
5 aircraft path data, and on the other hand data
regarding the position of at least one runway,
characterized in that the processing means comprise
calculation means able to supply a state signal
comprising at least one condition which is a function
10 of the path data and on the runway data, this function
being chosen so as to express the fact that the path of
the aircraft converges towards the runway.

2. Device according to Claim 1,
characterized in that the calculation means are
15 organized so as to define a volume which possesses a
chosen outline, positioned in a chosen manner with
respect to the said runway, and in that the state
signal comprises a so-called static condition,
pertaining to the belonging of the current position of
20 the aircraft to this volume.

3. Device according to Claim 1,
characterized in that the state signal comprises a so-
called dynamic condition, pertaining to the convergence
of a predicted path of the aircraft towards the said
25 runway, according to a chosen criterion.

4. Device according to claim 1,
characterized in that the runway is defined by a
representation stored in memory.

5. Device according to claim 1,
30 characterized in that the calculation means are
organized so as to define the said volume with the aid

of a horizontal approach sector, by projection on a plane containing the said runway, and in that the static condition comprises a horizontal static subcondition, representative of the coincidence of the
5 current position of the aircraft with this horizontal approach sector.

6. Device according to Claim 5, characterized in that the data regarding the position of the runway comprise a representation of a reference
10 point, in the guise of nominal point of grounding of the landing path, together with the orientation of the runway axis in the landing direction;

in that the calculation means are organized so as to define two auxiliary points, situated at
15 chosen distances either side of the reference point, on a straight line transverse to said identified runway and passing through the reference point; and

in that the horizontal approach sector is delimited laterally by two lines which depart
20 respectively from said two auxiliary points and diverge on either side of the runway axis, receding from the runway, up to a maximum distance with respect to the reference point.

7. Device according to Claim 6,
25 characterized in that the calculation means are organized so as to calculate the angles between the axis of the runway and the straight lines joining the current position of the aircraft to the two auxiliary points, respectively, whilst the horizontal approach
30 sector comprises points for which the smaller of the two angles is less than an angle/distance limit curve,

part of which curve is decreasing with the reduction in the distance from the aircraft to the reference point.

8. Device according to Claim 7,
characterized in that the decrease in the limit curve
5 goes from around 40° for a distance of around 4000
metres to around 8° for a distance of around 900
metres.

9. Device according to Claim 6,
characterized in that the horizontal approach sector
10 furthermore comprises a substantially rectangular zone,
one side of which is defined by said two auxiliary
points, and the opposite side of which passes through a
point situated a chosen distance downstream of the
reference point on the runway axis.

15 10. Device according to Claim 3,
characterized in that the dynamic condition comprises a
horizontal dynamic subcondition, representative of the
fact that the series of position, projected in the
plane containing the said runway, of the predicted path
20 of the aircraft, satisfies a criterion of convergence
towards the runway.

11. Device according to Claim 10,
characterized in that the calculation means are
organized so as to calculate the angle between the
25 horizontal projection of the approach heading of the
aircraft and the axis of the runway, so as to determine
two boundaries which can be likened to a part at least
of the said horizontal approach sector, as well as a
margin, derived from the distance between the
30 horizontal position of the aircraft and the more remote
of the two boundaries, except if the aircraft is

receding from both boundaries simultaneously; and in that the horizontal dynamic subcondition is satisfied when the said approach heading is less than a heading/margin limit curve, an intermediate part of which limit curve is decreasing with the reduction in the said margin.

12. Device according to Claim 11, characterized in that the approach heading is defined on the basis of a direction vector departing from the current position of the aircraft together with a measurement and a direction which are derived from the instantaneous horizontal speed of the aircraft, and from the angle which this vector forms with the axis of the runway.

13. Device according to Claim 2, characterized in that the static condition comprises a vertical static subcondition, representative of the presence of the aircraft inside a vertical approach sector.

14. Device according to Claim 13, characterized in that the calculation means are organized so as to define two other auxiliary points, one situated on the runway axis a chosen distance upstream of the reference point, the other a chosen distance downstream of the reference point and at a chosen height, and in that the vertical approach sector comprises the points whose distance upstream of the reference point is less than a threshold, and which lie between a straight line of slope which decreases downstream and passes through the first point and a straight line of slope which decreases downstream and

passes through the second point, the second slope being greater than the first.

15 15. Device according to Claim 3,
characterized in that the dynamic condition comprises a
vertical dynamic subcondition, representative of the
fact that positions of the predicted path of the
aircraft satisfy a criterion of convergence to the said
identified runway, in a vertical plane intersecting the
said runway.

10 16. Device according to Claim 13,
characterized in that the dynamic condition comprises a
vertical dynamic subcondition, representative of the
fact that positions of the predicted path of the
aircraft satisfy a criterion of convergence to the said
15 identified runway, in a vertical plane intersecting the
said runway; in that the calculation means are
organized so as to establish the vertical speed of the
aircraft towards the ground, and the residual height of
the aircraft above the bottom boundary of the vertical
20 approach sector; and in that the vertical dynamic
subcondition is satisfied when the said residual height
is greater than a height/speed limit curve, an
intermediate part of which limit curve is decreasing
with the reduction in speed towards the ground.

25 17. Device according to claim 1,
characterized in that the state signal comprises a
condition regarding the configuration of the aircraft.

 18. Device according to Claim 17,
characterized in that the condition regarding the
30 configuration of the aircraft comprises a condition
pertaining to the lowering of the landing gear, and at

least one condition relating to the flaps.

19. Device according to claim 1, comprising
first means capable of generating an alert in the event
of the imminence of an aircraft/ground collision, and
5 second means capable of vetoing some at least of the
alerts in the presence of a veto signal,
characterized in that this veto signal is derived from
the state signal.

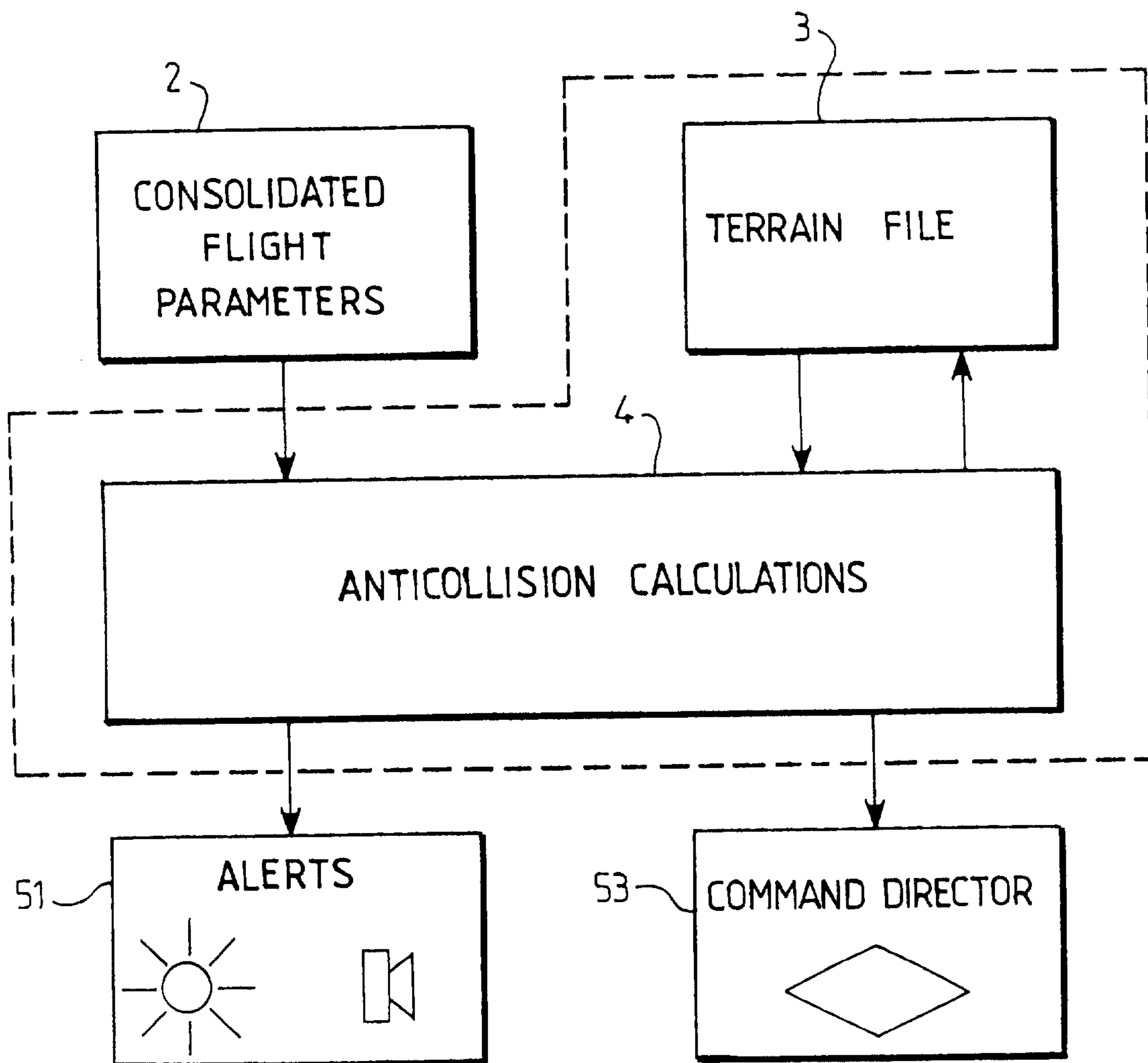


FIG.1

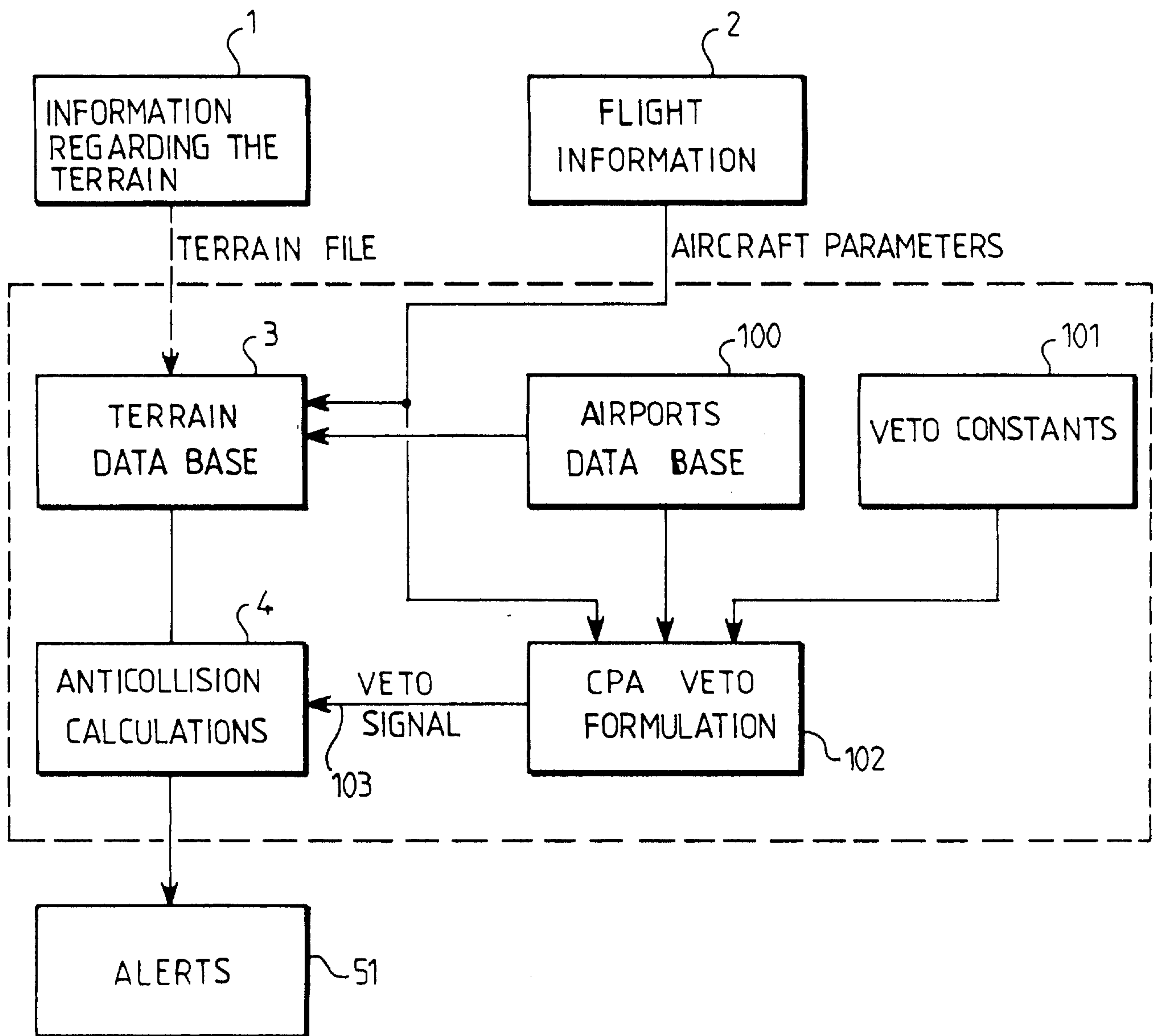


FIG. 2

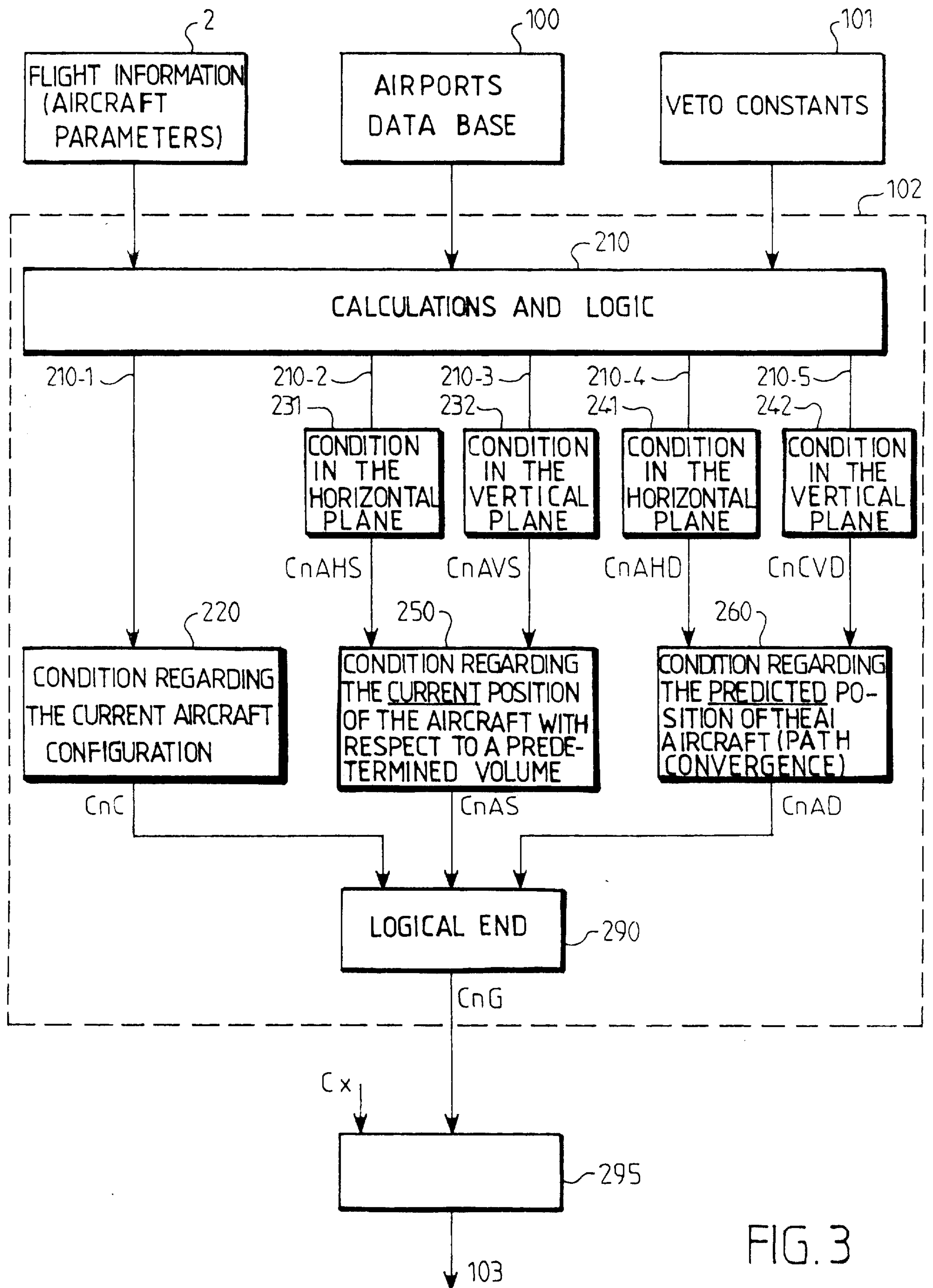


FIG. 3

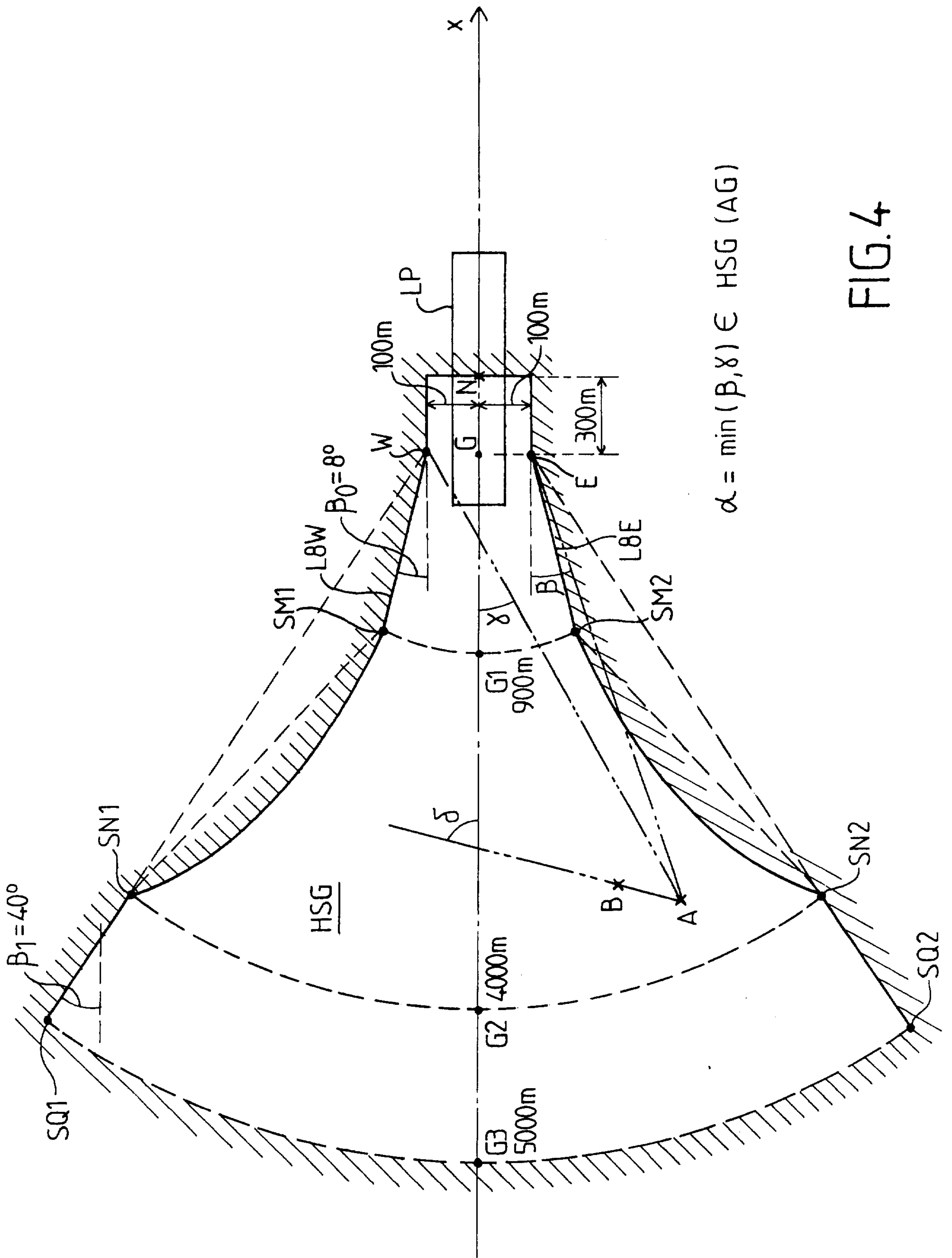


FIG. 4

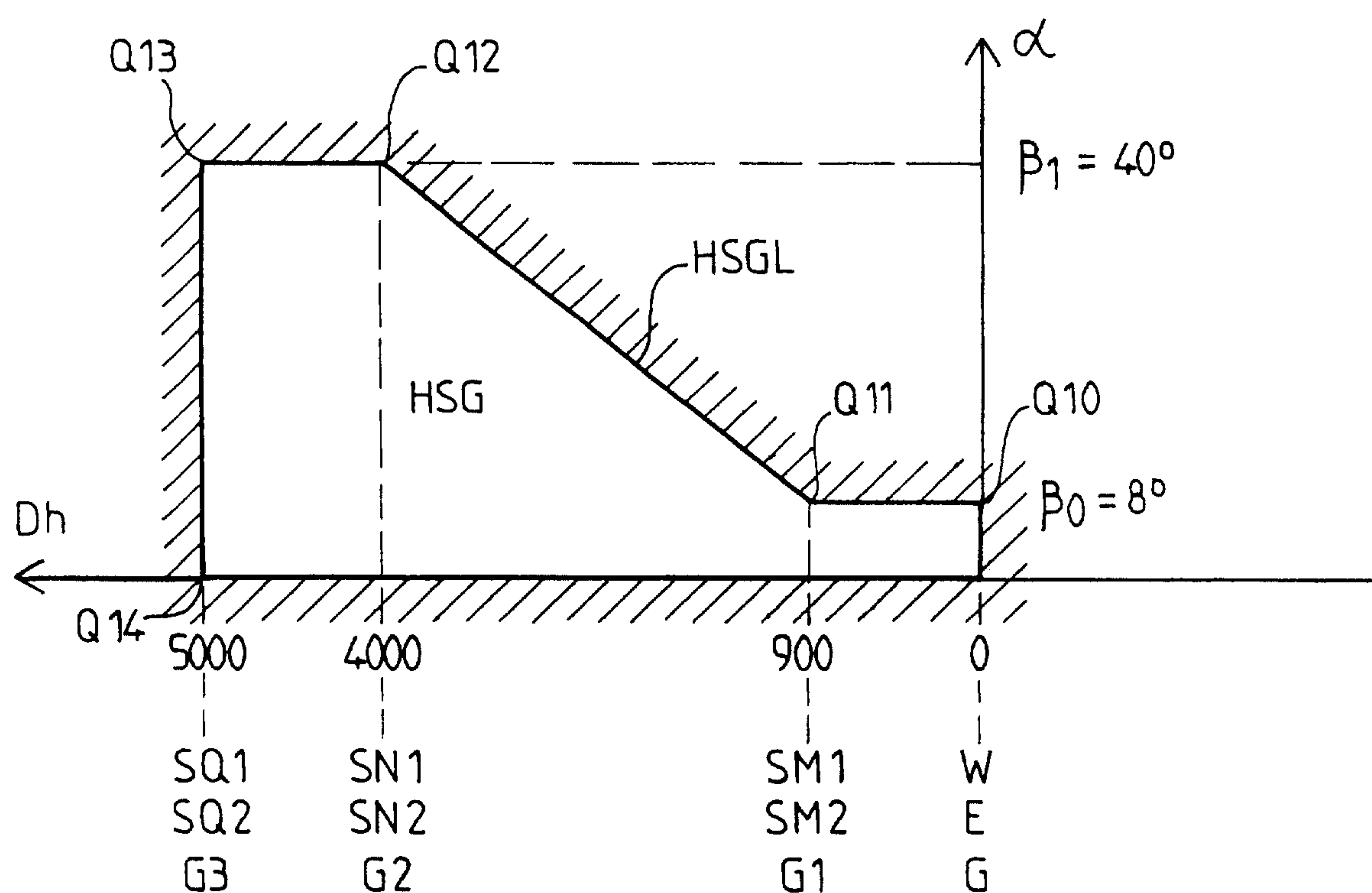


FIG. 5

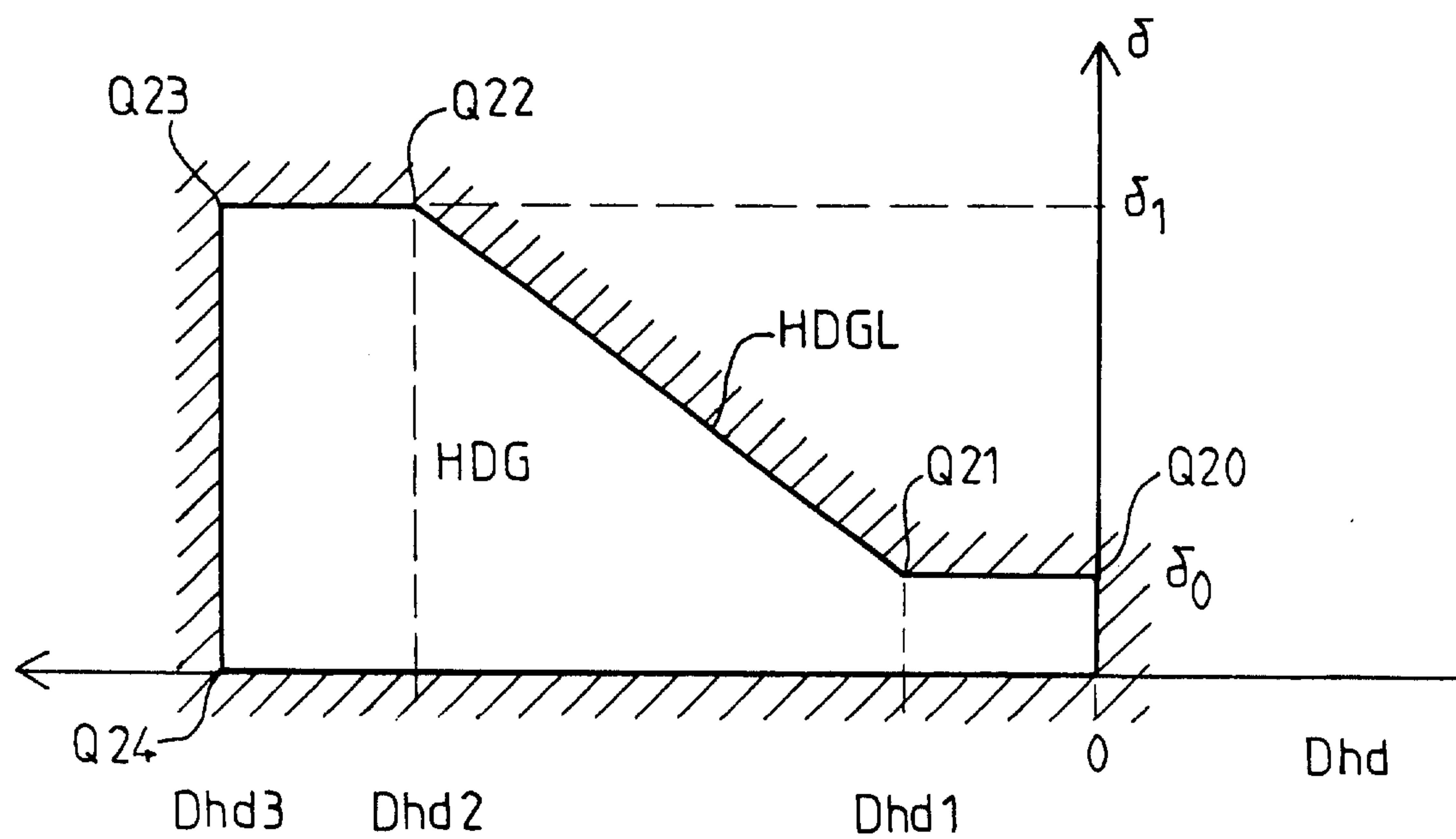


FIG. 7

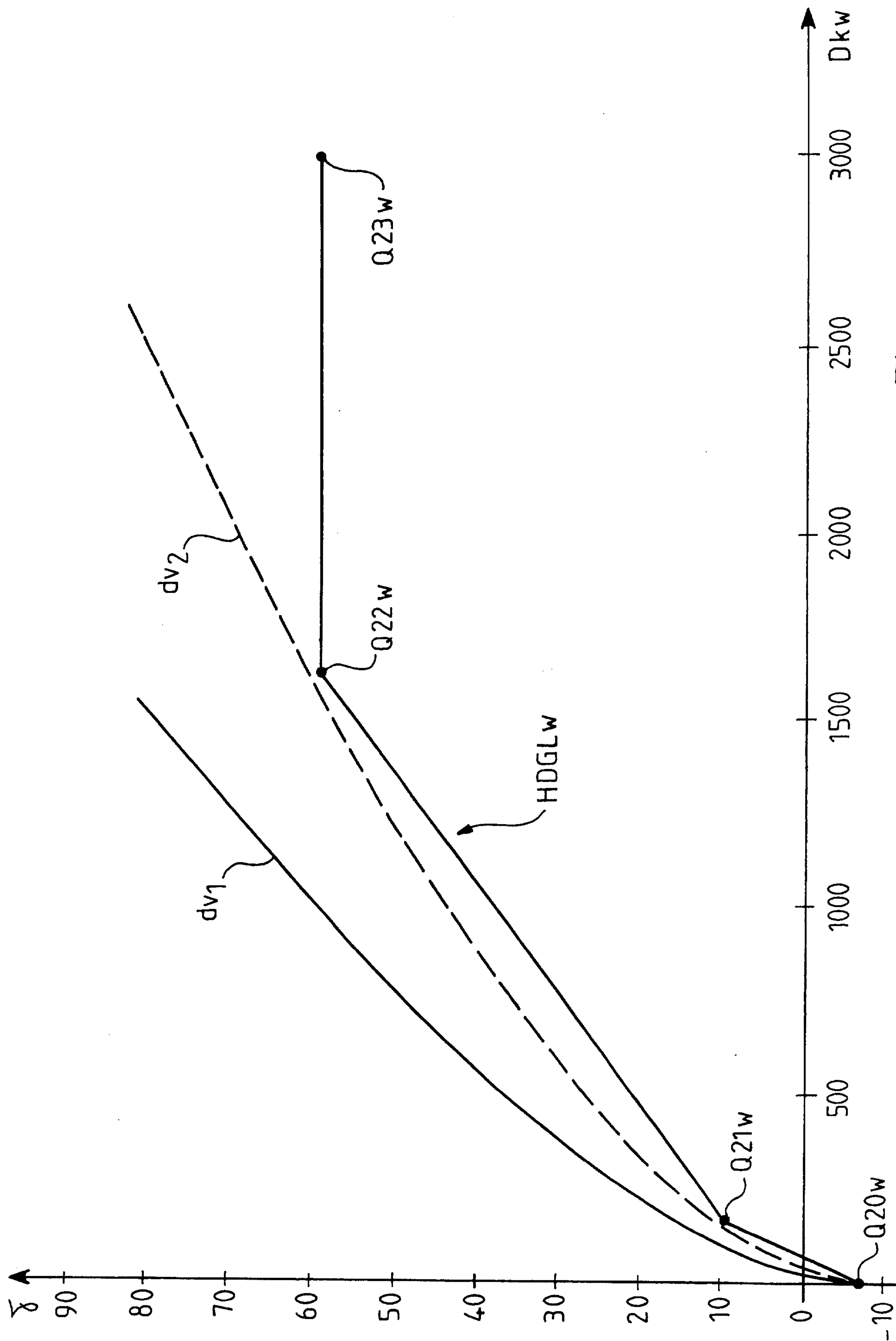


FIG. 6A

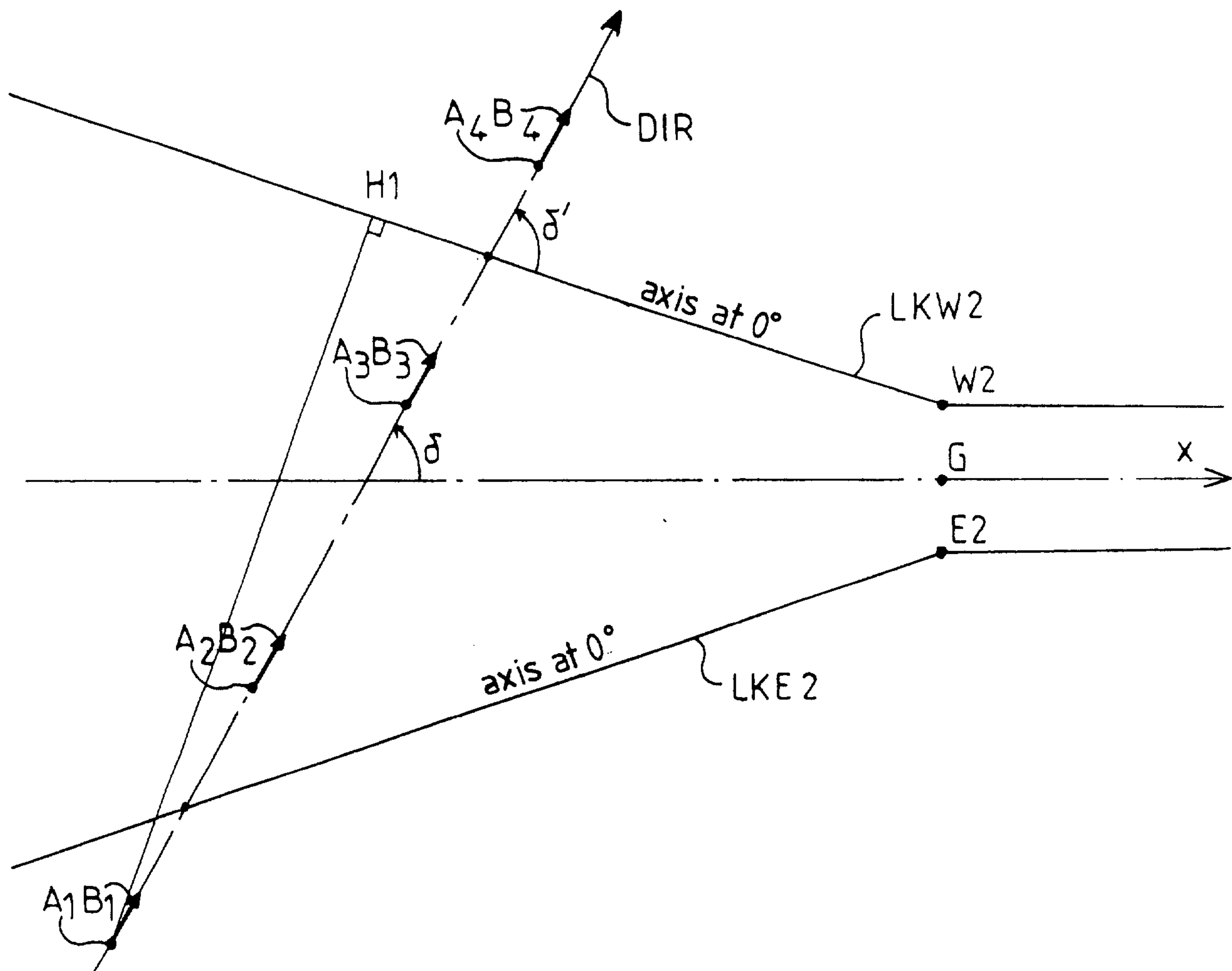


FIG. 6

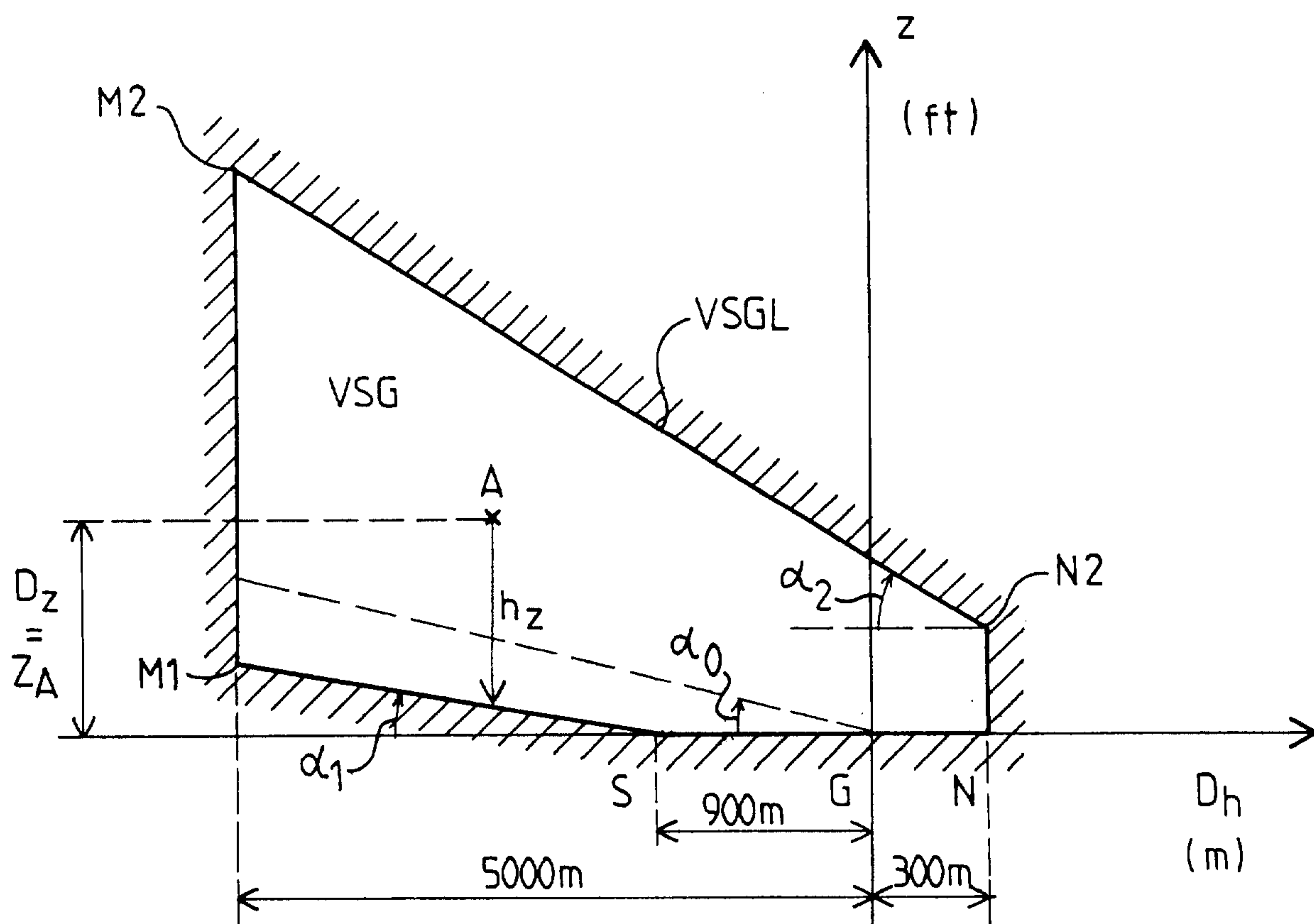


FIG. 8

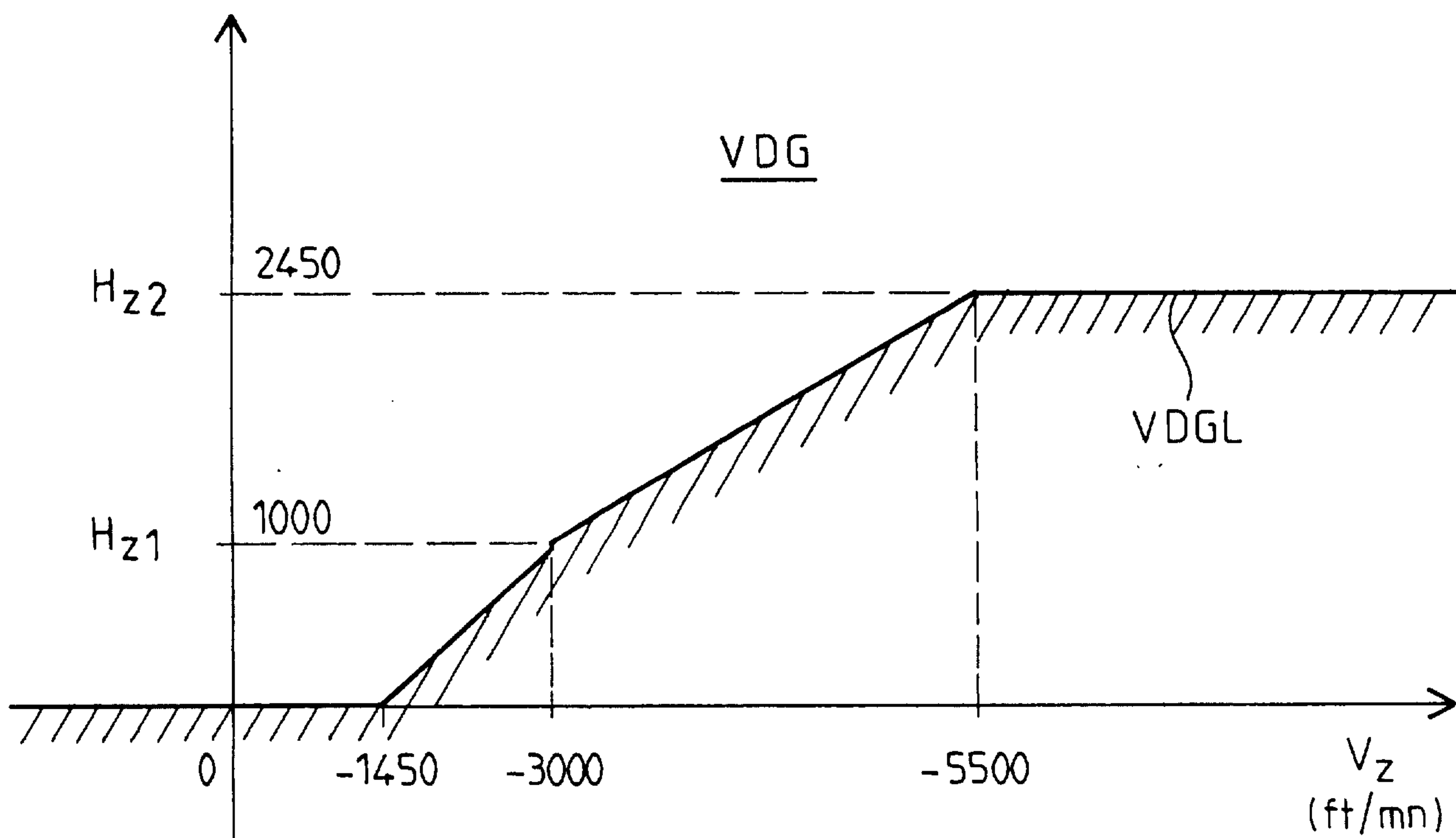


FIG. 9