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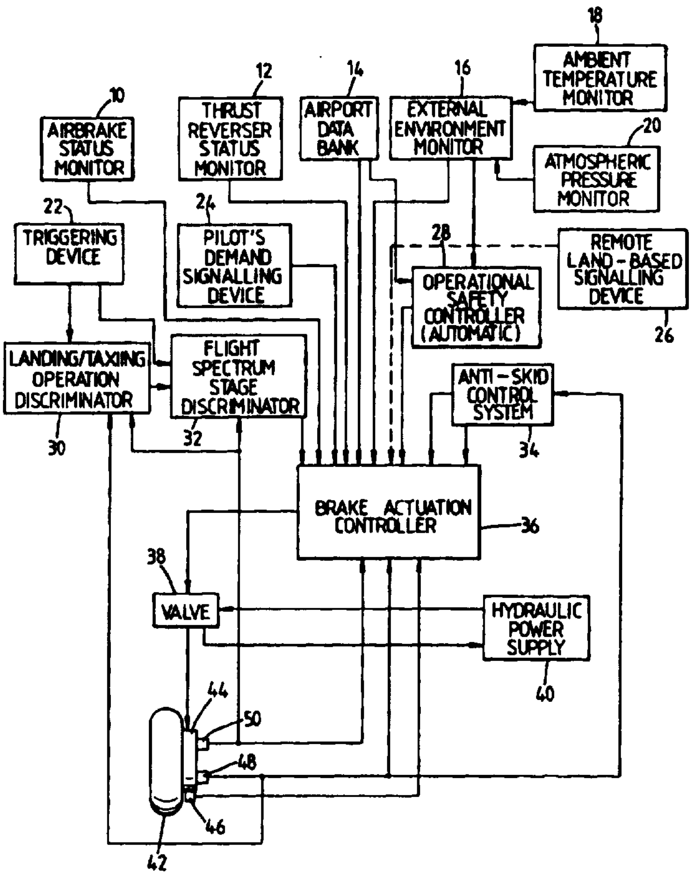
(54) Title: SEQUENTIAL SELECTIVE OPERATION OF AIRCRAFT BRAKES

(57) Abstract

The invention relates to sequential selective operation of aircraft brakes in a manner in which the braking level requirement is continually monitored and the number of brakes in operation is adjusted continuously or at frequent intervals so that the number of brakes in operation at any one moment is just sufficient for the braking requirement.



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SEQUENTIAL SELECTIVE OPERATION OF AIRCRAFT BRAKES

The present invention relates to an aircraft brake control system for the control of a plurality of carbon brakes and to an aircraft braking system comprising a plurality of carbon brakes operatively associated with said brake control system.

The term carbon brakes is used to mean brakes having friction discs of a carbon-carbon composite material comprising a carbon fibre reinforcing material within a carbon matrix.

The ability to stop an aircraft both quickly and economically is of great importance and enormous amounts of kinetic energy have to be dissipated in order to bring a moving aircraft to rest, particularly in an RTO (refused or rejected take-off) situation. The aircraft velocity may be decreased and the kinetic energy thereby dissipated by drag forces, by application of the engine thrust reversers, and by application of the aircraft wheel brakes. The drag forces can be increased by deploying of airbrakes or speed brakes on the aircraft wings.

However, very high energy brake applications in a RTO situation are fortunately rare events and therefore play little, if any, part in determining overall brake operating economics.

It is now recognised that the rate of wear of carbon brake discs is not proportional to the energy dissipated during the time the brakes are applied, brake wear being disproportionately high when the energy input to the brake is low. Consequently, it is beneficial to apply only a restricted number of the available brakes when the required braking action is relatively low.

The concept of applying only limited numbers of brakes during taxiing operations but all the available brakes in a landing run has already been disclosed in GB 2216209B and US 4986610. The concept has been described variously as brake disabling, selective operation or as taxi-brake select.

In accordance with one of its aspects the present invention provides an aircraft braking system comprising a plurality of carbon brakes, each said brake having brake actuating means for actuating the brakes in response to an applied control signal, each said signal being a function at least of pilot demand whereby operation of at least one of the brakes is inhibited if each of a plurality of control input signals applied to the control means comprising a brake actuation controller lies beyond a respective predetermined control signal threshold, in relation to the braking level requirement of the aircraft, said control means being operable to limit the number and/or proportion of brakes that may be disabled at at least one stage of a flight spectrum which may comprise taxi-out, take-off, landing and taxiing-in and being operable also such that the number and/or proportion of disabled brakes is a function of monitored conditions applicable to the aircraft status at any given time thereby to ensure that the overall safety of the aircraft is not hazarded.

In accordance with another of its aspects the invention provides that operation of an aircraft brake control system is controlled at least in part by an on-board brake control implementation means actuated by a remote land-based signalling means.

Said system may be used to activate the selective brake operating means in response to signalling means located at the junction between an aircraft runway and its ancillary taxi-ways. It is envisaged to "ring-fence" or likewise define the boundary of part of the runway and arrange that the manner of operation of the selective braking means is a function of whether the aircraft is operating within the designated runway area.

At an airport having more than one runway, a further, auxiliary control system may be provided to select from a limited number of a plurality of remote signalling means. Said selection (or inhibition) may be a function of whether (or not) a given runway is designated as being in operational use.

Said remote signalling means may be used in combination with other selective brake operation means.

The control system may comprise an on-board data bank which stores information concerning the conditions relating to those airports to which the aircraft flies frequently and the selective braking control system may receive input from such a data bank. Thus, in use, before an aircraft lands the minimum proportion of the brakes to be operated may be preset to take account of fixed parameters, e g runway length, airport altitude, and variable parameters such as ambient temperature, runway status (dry/wet/icy).

The invention further provides a method of operating the brakes of a multi-wheel aircraft during taxiing thereof where the aircraft has a total of N brakes and wherein a variable number of brakes n_1, n_2 .... n_x may be selectively operated and $N > n_x > n_2 > n_1$, said method comprising:-

- operating the aircraft with n_1 brakes during taxiing with n1 brakes selected for use and with the operation of $N-n_1$ brakes inhibited,
- detecting a condition which at least potentially requires the use of additional brakes,
- selecting additional brakes whereby an additional number of brakes, n_2-n_1 are selected for use and the number of inhibited brakes is reduced from $N-n_1$ to $N-n_2$,
- detecting whether a condition requiring the use of additional brakes continues to exist, and
- increasing the number of brakes selected for use progressively or incrementally from n_2 to n_x while said condition requiring the use of additional brakes continues to exist.

This sequential application of additional brakes is one type of cascade operating system. In general the cascade operation system may be used either to increase or decrease the number of brakes always provided that the safety of the aircraft operation is always fully maintained.

The invention provides also a method of controlling an aircraft braking system comprising a plurality of carbon disc brakes, said method comprising providing brake actuating means for actuating the brakes in response to an applied control signal, providing control means for inhibiting any one of a plurality of different numbers of brakes and arranging the control means to be responsive to the braking level requirement of the aircraft to inhibit a number of brakes selected as a function of said braking level requirement.

A brake control system of the invention may be programmed to determine the minimum number n_1 of brakes that are required to control the aircraft in a safe manner. Selective brake operation may be limited if the anti-skid control system is active (i e during pressure to limit the brake actuation pressure) at any aircraft speed. If n_1 brakes operate initially out of a total N brakes fitted to the aircraft, then after receipt of an input signal for example denoting anti-skid activity of one or more of said n_1 brakes the number of brakes which are selectively operated may be increased to n_2 where $N > n_2 > n_1$ provided that the aircraft can continue to operate in a completely safe manner. Similarly, if anti-skid activity then continues to occur in one or more of the n_1 brakes, or is initiated in the additional $n_2 - n_1$ brakes which are further selectively operated, then the number of selectively operated brakes may be increased to n_3 where $N > n_3 > n_2 > n_1$. In more general terms, the number of selectively operated brakes may be increased incrementally from n_1 to n_x where $N > n_x > n_1$ and n_1 of the n_x brakes shall operate without anti-skid activity at any one time.

The invention is described later herein in greater detail in relation to embodiments given by way of example only and with reference to the accompanying drawings in which:-

Figure 1 is a block schematic illustration of an aircraft braking system in accordance with the invention in which, for simplicity, only one of the plurality of wheel and brakes is shown;

Figure 2 is a diagrammatic plan view of a typical aircraft landing gear or truck that could be used in accordance with the invention;

Figure 3 is a chart relating wheel speed and brake temperatures to different phases of a flight spectrum with conventional braking, i e in the absence of selective braking;

Figure 4 is a schematic diagrammatic plan view of an airport;

Figure 5 is a diagrammatic side elevation showing aircraft final descent paths and the effect on the minimum number of brakes that should be activated on landing;

Figure 6 is a block schematic illustration of an automatic operational safety controller in accordance with the invention, and

Figure 7 is a block schematic illustration of a triggering device.

Consideration is now given, by way of example, to the case of an aircraft with 16 brakes where initially 4 brakes are sufficient to provide the necessary braking during a taxi-stop or taxi-snub (i e deceleration during taxiing), but anti-skid activity then initiates. If the selective operation of 8 brakes would still enable the aircraft to be safely controlled, then it may be arranged advantageously that only the 8 brakes rather than the full 16 brakes are applied, as selective operation of the said 8 brakes would effectively reduce the overall brake wear on the aircraft and give a substantial life saving when the aforedescribed type of cascade operating system is used, rather than the arrangement in which the selective operation sequence is "cancelled" and all sixteen brakes are immediately applied upon onset of anti-skid or some other occurrence.

In a further embodiment when control input signals indicative of pilot demand, anti-skid control activity, or the proximity of other vehicles or objects changes so that they lie outside a first range of acceptable instantaneous value it may be provided that it is still not always necessary to apply all brakes simultaneously, i e to terminate the selective braking activity.

The present invention seeks to optimise the benefits of the selective operation/brake disabling procedure whilst ensuring that the airworthiness status and the overall safety of the aircraft are not hazarded. For that purpose the invention provides that limitations are placed on the number and/or proportion of brakes that may be disabled not only at stages of the complete flight spectrum (i e taxiing-out, take-off, in flight, landing, taxiing-in or stationary on the ground) but also that said number and/or proportion applicable during said stages shall be further adjusted in response to the specific conditions applicable to the aircraft status at any given time.

The brake control system which provides a selective operation facility may utilise closed-loop feedback systems to regulate the brake actuation procedures.

As depicted in Figures 1 and 7 the brake control system may be interlinked with an airbrake deployment system control and an engine thrust reverse control so that full braking action is provided at all times when such other features are operational.

In setting the specification for an aircraft a constructor must design for a worst case scenario.

The constructor must consider the likely increase in maximum aircraft take-off (TO) weight that may occur during his programme as he introduces new variants within his model range. For a maximum TO weight increase of 10%, which is typical, the brake energy requirement will increase by 20% as a higher TO velocity will be required in order to produce the increased lift required for take-off.

The constructor needs also to specify brakes capable of use under extreme conditions e g corresponding to those appertaining to airports at high altitude in hot locations e g Mexico City or Denver during the summer.

The constructor needs to ensure also that the aircraft has the capability to land and take off at airports with relatively short runways.

Consequently there will be many instances where the actual landing conditions are far less onerous than the specification requirement. Furthermore the landing requirement is always far less onerous than the rejected take off requirement as by the end of the flight the bulk of the aircraft fuel will have been consumed.

A further object of the invention is to reduce the overall wear during the landing run by operating at least one less than all the available brakes during the landing run provided that this is consistent with maintaining operational safety and such means will be considered further.

Previously it has been taught either (1) that above an upper velocity threshold representing the maximum taxiing velocity all brakes shall be operative in order to ensure operational safety or (2) that selective braking can continue above the operational threshold without the benefit of additional safety features as in EP 0443213 A2 or (3) the only additional safety feature being provided by a second manual override system as in US 5172960.

Operation of the selective brake control system may be conditional on other, e g flight, parameters being normal. Thus the system may be inhibited at least in part if for example the approach rate of aircraft or point of landing is not within prescribed boundaries. There may be one boundary outside which there is complete inhibition of the selective braking means, i e inhibition of the brake inhibition means thereby to result in full braking. There may be another boundary which results in only partial inhibition, i e a greater number of brakes are brought into operation than would normally be the case, but not all of the brakes are brought into operation. The system may be operable to detect parameters prior to touch down and pre-select or pre-establish whether or not flight and related parameters lie within one or more prescribed boundaries.

The invention provides in another of its aspects e g in Figures 6 and 7 automatic means for activating additional brakes in a selective braking operation in response to transducer signals indicative (1) of at least one of the following parameters of the aircraft external environment:

a) the proximity of other vehicles
b) relative velocity of other vehicles or objects in relation to the subject aircraft
c) the tyre-ground friction coefficients
d) the location of the aircraft within the airport confines
e) any other significant operating considerations
f) external signalling means

(2) the interaction between at least one said signal indicative of the external environment and a transducer signal indicative of at least one characteristic of the aircraft such as

a) aircraft velocity

b) wheel velocity

c) aircraft all up weight

d) degree of wear of brake disc assembly

Data concerning 1(a) and 1(b) above may be provided by signal processing software utilising data provided from means such as F.M. pulse doppler radar and infra red lasers.

Conventionally the wear of a brake assembly is normally monitored by visual inspection of a mechanical indicator, i e a wear pin. By incorporating a transducer to measure the amount of wearable material remaining in the heat pack, those brakes having the smaller amounts of wearable material could be excused from duty, i e they would not be selectively operated. In the case where sets of brakes are selected for use in successive operations, e g four sets of four brakes on an aircraft having 16 main wheels then the set containing the brake with the least wear remaining would not be selected. It would be advantageous to change the make up of the sets at intervals during the brake life in order to minimise the variation between the overall wear of individual brakes.

Furthermore, by summating or otherwise analysing the transducer signals the system may assess the overall wear of the brakes and adjust maximum allowable number of brakes to be disabled at any stage of the flight spectrum in the light of such information.

These selections provide a sophisticated override system which may ensure that a cascade operating system only operates in a manner which is compatible with maintaining the overall safety of the aircraft at all times.

Thus a variable number of brakes may be selected and proportional or incremental actuation of such brakes may be adopted when an aircraft braking operation is needed. The number of brakes to be used is not pre-selected but may be determined by the aircraft operation parameters at the particular time that the braking application is required. The number of selected brakes may be adjusted sequentially in accordance with one or more of the various parameters detailed above.

A suitable proximity means, for example as shown in Figure 6, may rotate to ensure that all necessary directions are scanned.

Suitable brake control systems for the above comprise electronic control boxes, microprocessors or dedicated landing gear computers, it being envisaged that in use of the cascade operating procedure on an aircraft, the operation of brakes may be controlled in relation to, and may be used in relation to the control or operation of, other aircraft systems and devices.

Because of the airworthiness implications of a systems failure it is also contemplated within the scope of this invention to provide multiple discrimination means so that a measure of redundancy is built into the selective braking system.

The discrimination between landing and taxiing operations may be accomplished by means either contained within, or fitted externally to, the aircraft.

Means, as shown diagrammatically in Figure 7, to identify that the aircraft is about to land or has already landed, may be triggered for example by operation of the flying or flight surface controls in a sequence which is indicative of an imminent landing, by the deployment of air brakes or by the operation of the engine controls. Alternative means may respond to the results of operation of the said controls i e be triggered when the rate of descent falls below a threshold value, i e indicative of the aircraft touching down; this means may be triggered by one or more of the depicted wheel speed sensors when said speed rises above a threshold level indicative of wheel spin-up on touch down. Landing or imminent landing of the aircraft may be detected by a ground proximity warning/signalling device.

One or more of the triggering means recited in the preceding paragraph and shown in the attached drawings may be used in combination with a timing delay means of sufficient length to inhibit operation of the selective taxi braking system during the delay period and thereby ensure that the aircraft has completed its landing run before the selective taxi brake system is implemented.

In an alternative arrangement the triggering means could activate an aircraft speed sensing means which inhibits the operation of the selective brake operation means until the aircraft speed falls below a threshold value. In this case the selective braking function will commence operation at a fixed speed. The aircraft speed could be determined by measuring the aircraft wheel speed as is a standard practice in the industry.

Triggering means as described above and illustrated herein may operate independently or in combination (thereby increasing overall reliability) and may additionally be used in combination with means of landing/taxi mode differentiation and selective brake operation inhibiting means of types known per se.

The operational status of the aircraft may be monitored by a pressure gauge mounted in or on the aircraft which measures the atmospheric pressure outside the aircraft. It may be provided that selective braking during a landing run is only possible if the atmospheric pressure exceeds a threshold value; thus selective braking may be prevented whilst the aircraft is landing at airports/airfields at high altitude. This may be a particularly desirable additional safety feature.

Similarly the operational status of the aircraft may be monitored by a temperature measuring device which measures a temperature outside the aircraft and selective braking during a landing run may be permitted only when the temperature is above a threshold level, e g 0°C.

Turning now to the drawings in greater detail, in Figure 1 an aircraft wheel 42 and brake 44 fitted with temperature, wheel speed and brake wear sensors or transducers (50, 48 and 46 respectively) is connected to a hydraulic power supply 40 and the brake pressure is controlled, via the electrohydraulic valve 38, by the brake actuation controller 36. The brake actuation controller determines the number of brakes to be actuated from the plurality of brakes fitted to the aircraft. The controller 36 receives inputs from the airbrake status monitor 10 the thrust reverser status monitor 12, the airport data bank 14, the external environment monitor 16, the pilot's demand signalling device 24 the remote land-based signalling device 26 the operational safety controller 28, the flight spectrum stage discriminator 32, the anti-skid control system 34, the wheel speed transducer 48, the temperature sensor 50 and the wear sensor 46. The wheel speed transducer output is also connected to the anti-skid control system 34 and the landing/taxiing operation discriminator 30. The temperature output sensor 50 is also connected to the landing/taxiing operation discriminator 30 and the flight spectrum stage discriminator 32. The triggering devices output signal 22 is fed to the two discriminators 30,32.

In practice the said functions 10-36 may be incorporated into a single computer.

Figure 2 shows a six wheel truck comprising wheels 110, 112, 114, 116, 118 and 120, each of which provide input 52-76 to the brake actuation controller 36 from wheel speed transducers 48 and temperature sensors 50. (N.B. for simplicity transducer 48 and sensor 50 are only identified in relation to wheel 110).

In the absence of selective braking Figure 3 shows schematically that on landing, wheel speed is high and the brake temperature rises as the aircraft decelerates so that in the taxi-out mode although the speed is low the brakes are hot. On taxi-out the brakes have cooled so both wheel speed and brake temperature are low and in a normal take-off the brake temperature remains low as the wheel speed increases to a maximum at lift off.

In Figure 4, runways 77, 78 and taxi ways 80 are delineated by sensors 82 and the runways themselves are identified by location/signalling devices 84 and 86 which are unique to each runway. The runways are fitted with positioning devices 88, 90, 92 which signal the remaining runway length to the brake actuation controller 36. The sensors/devices 82-92 comprise the remote landing-based signalling means 26 of Figure 1 and their function will now be described by reference to Figure 5.

The devices 82 provide a positive means of identifying the transition from the landing-mode to the taxi-mode. The devices 92 are placed at the edge of the target touch down zone. If the aircraft overflies the target touch down zone, then a greater number of brakes need to be selected for braking during the landing run and if the aircraft successively overflies the further sensors 90 and 88 then all the brakes must be ready for use. If the aircraft touches down at the intermediate position then an intermediate number of brakes will be sufficient.

Figure 6 shows an automatic operational safety controller 28 which receives signals from a proximity device 94 closing speed monitor 96, aircraft position location device 98 weight data recorder 100, airport data bank 14 and tire/ground friction monitors 102 and pre-processes the signals to provide the brake actuation controller a signal indicative of the minimum number of brakes that must be achieved to provide a safe landing.

Figure 7 shows a landing/taxiing operation discriminator which receives signals from a ground proximity device 104 a flying controls monitor 106 an airbrake deployment monitor 108 an engine control monitor 122 a rate of descent monitor 124 and one or more wheel speed transducers 48 and identifies whether the aircraft is operating in a landing or a taxiing mode and transmits an output signal to the brake actuation controller 36, indicative of whether the aircraft is in said landing or taxiing mode.

CLAIMS:

1. An aircraft braking system comprising a plurality of carbon brakes, each said brake having brake actuating means for actuating the brakes in response to an applied control signal, each said signal being a function at least of pilot demand whereby operation of at least one of the brakes is inhibited if each of a plurality of control input signals applied to the control means comprising a brake actuation controller lies beyond a respective predetermined control signal threshold, in relation to the braking level requirement of the aircraft, said control means being operable to limit the number and/or proportion of brakes that may be disabled at at least one stage of a flight spectrum which may comprise taxi-out, take-off, landing and taxiing-in and being operable also such that the number and/or proportion of disabled brakes is a function of monitored conditions applicable to the aircraft status at any given time thereby to ensure that the overall safety of the aircraft is not hazarded.

2. An aircraft braking system comprising a plurality of carbon brakes, each said brake having brake actuating means for actuating the brakes in response to an applied brake control signal supplied by a control means output said control means receiving a plurality of control means input signals one said input signal being a function of the pilot's demands and other input signals being indicative of the aircraft's braking level requirement whereby operation of at least one of the brakes in inhibited if each of a plurality of input signals applied to the control means lies beyond a predetermined control input signal threshold in relation to the braking level requirement of the aircraft, said control means being operable to determine the maximum number and/or proportion of brakes that may be disabled and the minimum number and/or proportion of brakes that may be actuated during at least one stage of a flight spectrum comprising taxi-out, take-off, landing and taxiing-in and being operable also such that the maximum number and/or proportion of disabled brakes is a function of monitored conditions applicable to the aircraft status at any given time thereby to ensure that the overall safety of the aircraft is not compromised.

3. An aircraft braking system comprising a plurality of carbon brakes, each said brake having brake actuating means for actuating the brakes in response to an applied brake control signal supplied by a control means output said control means receiving a plurality of control means input signals one said input signal being a function of the aircraft's braking level requirement whereby operation of at least one of the brakes is inhibited if each of a plurality of input signals applied to the control means lies beyond a predetermined control input signal threshold in relation to the braking level requirement of the aircraft, said control means being operable to determine the maximum number and/or proportion of brakes that may be disabled and the minimum number and/or proportion of brakes that may be actuated during at least one stage of a flight spectrum comprising taxi-out, take-off, landing and taxiing-in and being operable also such that the maximum number and/or proportion of disabled brakes is a function of monitored conditions applicable to the aircraft status at any given time thereby to ensure that the overall safety of the aircraft is not compromised.

4. An aircraft braking system according to any one of the preceding claims wherein the control means is adapted to inhibit none of the brakes if at least one control input signal applied to the control means is indicative of a requirement for maximum available braking.

5. An aircraft braking system according to any one of claims 1 to 3 wherein said control means is adapted to allow operation of n brakes out of a total of N brakes during the landing phase of the flight spectrum provided that a control input signal applied to the control means is not indicative of a braking level requirement in excess of nB/N where B is the maximum braking action provided by said N brakes.

6. An aircraft braking system according to any one of claims 1 to 4 wherein the control means is adapted to select or inhibit additional brakes incrementally whereby, as a control input signal applied to the control means changes, the number of brakes which are inhibited changes incrementally one brake at a time.

7. An aircraft braking system according to any one of claims 1 to 4

wherein the control means is adapted to select or inhibit additional brakes incrementally whereby as a control input signal applied to the control means changes, the number of brakes which are inhibited changes incrementally two brakes at a time.

8. An aircraft braking system according to any one of claims 1 to 4 wherein the control means is adapted to select or inhibit additional brakes incrementally whereby as a control input signal applied to the control means changes, the number of brakes which are inhibited changes incrementally four brakes at a time.

9. An aircraft braking system according to claim 7 wherein said two brakes lie respectively at right and left-hand sides of a longitudinal, fore-and-aft centre line of the aircraft.

10. An aircraft braking system according to claim 9 wherein, of said four brakes, two brakes are respectively at right- and left-hand sides of a longitudinal fore-and-aft centre line of the aircraft and the two brakes on one side of the aircraft lie respectively on the right- and left-hand sides of a landing gear.

11. An aircraft braking system according to any one of the preceding claims wherein at least one said applied control signal is a function of the braking level requirement of the aircraft.

12. An aircraft braking system in according to any one of the preceding claims wherein the control means is operable to limit the number and/or proportion of brakes that may be disabled at any stage of the flight spectrum.

13. An aircraft braking system in accordance with any one of the preceding claims and including means to apply different brake actuation pressures to different brakes.

14. An aircraft braking system in accordance with claim 11 and arranged such that as additional brakes are brought into operation sequentially, different brake actuation pressures are applied to the additional brakes in a manner selected to increase the temperature of the additional brakes as quickly as practical the temperature of prior operating brakes.

15. An aircraft braking system according to any one of the preceding claims wherein the number of brakes that may be disabled is a function of at least one parameter of the aircraft external environment.

16. An aircraft braking system according to claim 15 wherein said at least one parameter is a parameter selected from the group comprising proximity of other vehicles, relative velocity of other vehicles or objects in relation to the subject aircraft, the tyre-ground friction coefficient, the location of the aircraft relative to predetermined zones or positions of an airport, and external signalling and/or sensing means.

17. An aircraft braking system in accordance with any one of the preceding claims wherein the number of brakes that may be disabled is a function of at least one parameter characteristic of the aircraft or its operation.

18. An aircraft braking system according to claim 17 wherein said parameter is a parameter selected from the group comprising aircraft velocity, wheel velocity, aircraft all up weight, and degree of wear of brake disc assemblies.

19. An aircraft braking system according to any one of claims 15 to 18 and comprising automatic means for activating additional brakes in a selective braking operation in response to a signal related to at least one of said parameters.

20. An aircraft braking system according to any one of the preceding claims wherein the control signal is responsive to remote signalling and/or sensing.

21. An aircraft braking system according to any one of the preceding claims and comprising an electronic database which stores information concerning characteristics of each of a plurality of potential aircraft landing locations, and selector means whereby in response to a setting of the selector means the data store is operable selectively to define specified operating parameters of the control means.

22. An aircraft braking system according to any one of the preceding claims and comprising proximity sensing means whereby operation of the

control means is a function of a signal from said proximity means.

23. An aircraft braking system in accordance with claim 1, claim 2 or claim 3 and substantially as described in the description of this application.

24. An aircraft brake control system according to any one of the preceding claims wherein the brake actuating means is on board an aircraft and is responsive at least in part to a signal from a remote signalling means.

25. An aircraft braking system according to claim 22 wherein the remote signalling means is a remote land-based signalling means.

26. An aircraft braking system according to claim 24 or claim 25 wherein said system is operable to activate selective brake operating means in response to signalling means located between an aircraft runway and ancillary taxiways.

27. An aircraft brake control system according to claim 24, claim 25 or claim 26 wherein the manner of operation if a function of whether the aircraft is operating within a designated runway area.

28. An aircraft braking system according to claim 27 and comprising an auxiliary control system operable to select from a specified number of a plurality of remote signalling means.

29. Method of operating the brakes of a multi-wheel aircraft during taxiing thereof where the aircraft has a total of N brakes and wherein a variable number of brakes n_1, n_2 .... n_x may be selectively operated and $N > n_x > n_2 > n_1$, said method comprising:-

- operating the aircraft during taxiing with n_1 brakes selected for use and with the actuation of $N-n_1$ brakes inhibited,
- detecting a condition which at least potentially requires the use of additional brakes,
- selecting additional brakes whereby an additional number n_2-n_1 of brakes are selected for use and the number of inhibited brakes is reduced from $N-n_1$ to $N-n_2$,
- detecting whether a condition requiring the use of additional brakes continues to exist, and
- increasing the number of brakes selected for use progressively

or incrementally from n_2 to n_x whilst said condition requiring the use of additional brakes continues to exist.

30. Method according to claim 29 wherein the control means operates to inhibit the maximum number of brakes consistent with operational safety.

31. Method according to claim 29 or claim 30 wherein control means is operable to limit the number and/or proportion of brakes disabled at a plurality of stages of a flight spectrum and is operable also such that the number and/or proportion of brakes operable during said phases may be further adjusted in response to the conditions applicable to the aircraft status at a specified moment in time.

32. Method of controlling an aircraft braking system comprising a plurality of carbon disc brakes, said method comprising providing brake actuating means for actuating the brakes in response to an applied control signal, providing control means for inhibiting any one of a plurality of different numbers of the brakes and arranging the control means to be responsive to a braking level requirement of the aircraft to inhibit a number of brakes selected as a function of said braking level requirement wherein the minimum number of brakes is selected and actuated consistent with controlling the aircraft in a safe manner in accordance with the instantaneous braking requirement of the aircraft.

33. Method according to claim 31 and comprising monitoring for anti-skid activity and increasing the number of operational brakes progressively or incrementally in the event of anti-skid activity until the anti-skid activity ceases or decreases to below a preselected threshold on a designated number n_1 of the active brakes.

34. Method in accordance with claim 32 or claim 33 and comprising monitoring parameters on which the onset of a skid condition is known to depend and arranged that when the onset of a skid condition is predicted or whilst the occurrence of a skid condition continues the number of operational brakes progressively or incrementally increases.

35. Method according to claim 32 or claim 33 and comprising monitoring conditions on which a requirement for increased braking force is known to

depend and in the event of detecting a potential requirement for increased braking force arranging that said control means brings into operation at least some or all of the brakes the operation of which has been inhibited.

36. Method in accordance with any one of claims 29 to 35 wherein the control means brings into operation all of the brakes in the event of a specified condition occurring.

37. Method in accordance with claim 36 wherein said specified condition is operation of an air brake deployment system control or is operation of engine reversed thrust control.

38. Method of operating the carbon disc brakes of an aircraft braking system according to claim 29 or claim 32 and substantially as hereinbefore described.

39. An aircraft braking system comprising a plurality of carbon brakes, each brake having an associated actuating means for actuating the brake in response to an applied control signal, control means, said control means being operable to limit the number of brakes that may be disabled at stages of a flight spectrum including taxi-out, take-off, landing and taxiing-in whereby the number of disabled brakes is a function of monitored conditions applicable to an aircraft status at any given time, said conditions including at least one parameter of the aircraft external environment selected from the group consisting of proximity of other vehicles, relative velocity of other vehicles or objects in relation to a subject aircraft, tyre-ground friction coefficient, location of the aircraft relative to predetermined zones of an airport, and external signalling means thereby to ensure that the overall safety of the aircraft is not compromised.

40. An aircraft braking system comprising a plurality of carbon brakes, each brake having an associated actuating means for actuating the brake in response to an applied control signal, control means operable to limit the number of brakes that may be disabled at stages of a flight spectrum including taxi-out, take-off, landing and taxiing-in whereby the number of disabled brakes is a function of monitored conditions applicable to an aircraft status at any given time, said conditions including at least one

parameter characteristic of the aircraft or its operation selected from the group consisting of aircraft velocity, wheel velocity, aircraft all up weight, and degree of wear of brake disc assemblies such that a minimum number of brakes which satisfies the instantaneous braking level requirement is applied thereby to ensure that the overall safety of the aircraft is not compromised.

41. An aircraft braking system comprising a plurality of carbon brakes each brake having an associated actuating means for actuating the brakes in response to an applied control signal, control means of a type which is operable to bring into operation any one number of a plurality of different numbers of brakes such that the control means brings into operation a number less than a total of the brakes if that lesser number is potentially sufficient to control the aircraft in a safe manner, at stages of a flight spectrum including taxi-out, take-off, landing and taxiing-in whereby the number of disabled brakes is a function of monitored conditions applicable to an aircraft status at any given time thereby to ensure that the overall safety of the aircraft is not compromised.

42. A method of controlling an aircraft braking system comprising a plurality of carbon disc brakes, said method comprising actuating the brakes in response to an applied control signal, providing control means for inhibiting any one of a plurality of different numbers of the brakes and monitoring for anti-skid activity, arranging the control means to be responsive to a braking level requirement of a subject aircraft to inhibit a number of brakes selected as a function of said braking level requirement wherein the minimum number of brakes is selected and actuated consistent with controlling the aircraft in a safe manner in accordance with an instantaneous braking requirement of the aircraft and increasing a number of operational brakes progressively or incrementally in the event of anti-skid activity until the anti-skid activity ceases or decreases to below a pre-selected threshold on said minimum number of active brakes.

43. An aircraft braking system comprising a plurality of carbon brakes, each brake having an associated brake actuation means for actuating the

brake and control means for automatically activating additional brakes in selective braking operation in response to at least one signal indicative of the instantaneous braking level requirement, said control means comprising a computer means and a control algorithm and being adapted to determine the number of brakes required to decelerate the aircraft as a function of said instantaneous braking level requirement and to select and to actuate said required number of brakes as necessary to control the aircraft in a safe manner.

44. An aircraft braking system comprising a plurality of carbon brakes, each brake having an associated brake actuation means for actuating the brake and control means for automatically inhibiting additional brakes in selective braking operation in response to at least one signal indicative of the instantaneous braking level requirement, said control means comprising a computer means and a control algorithm and being adapted to determine the number of brakes required to decelerate the aircraft as a function of said instantaneous braking level requirement and to select and to actuate said required number of brakes as necessary to control the aircraft in a safe manner.

45. An aircraft braking system comprising a plurality of carbon brakes, brake actuating means for actuating the brakes in response to an applied control signal and control means, said control means being operable to determine the number of brakes required to decelerate the aircraft as a function of the instantaneous braking level requirement and to limit the number of brakes that may be disabled at stages of a flight spectrum whereby the number of disabled brakes is a function of monitored conditions applicable to the aircraft status at any given time thereby to ensure that the overall safety of the aircraft is not hazarded.

AMENDED CLAIMS

[received by the International Bureau on 12 February 1996 (12.02.96); original claim 33 amended; remaining claims unchanged (1 page)]

or incrementally from n_2 to n_x whilst said condition requiring the use of additional brakes continues to exist.

30. Method according to claim 29 wherein the control means operates to inhibit the maximum number of brakes consistent with operational safety.

31. Method according to claim 29 or claim 30 wherein control means is operable to limit the number and/or proportion of brakes disabled at a plurality of stages of a flight spectrum and is operable also such that the number and/or proportion of brakes operable during said phases may be further adjusted in response to the conditions applicable to the aircraft status at a specified moment in time.

32. Method of controlling an aircraft braking system comprising a plurality of carbon disc brakes, said method comprising providing brake actuating means for actuating the brakes in response to an applied control signal, providing control means for inhibiting any one of a plurality of different numbers of the brakes and arranging the control means to be responsive to a braking level requirement of the aircraft to inhibit a number of brakes selected as a function of said braking level requirement wherein the minimum number of brakes is selected and actuated consistent with controlling the aircraft in a safe manner in accordance with the instantaneous braking requirement of the aircraft.

33. Method according to claim 32 and comprising monitoring for anti-skid activity and increasing the number of operational brakes progressively or incrementally in the event of anti-skid activity until the anti-skid activity ceases or decreases to below a preselected threshold on a designated number n_1 of the active brakes.

34. Method in accordance with claim 32 or claim 33 and comprising monitoring parameters on which the onset of a skid condition is known to depend and arranged that when the onset of a skid condition is predicted or whilst the occurrence of a skid condition continues the number of operational brakes progressively or incrementally increases.

35. Method according to claim 32 or claim 33 and comprising monitoring conditions on which a requirement for increased braking force is known to

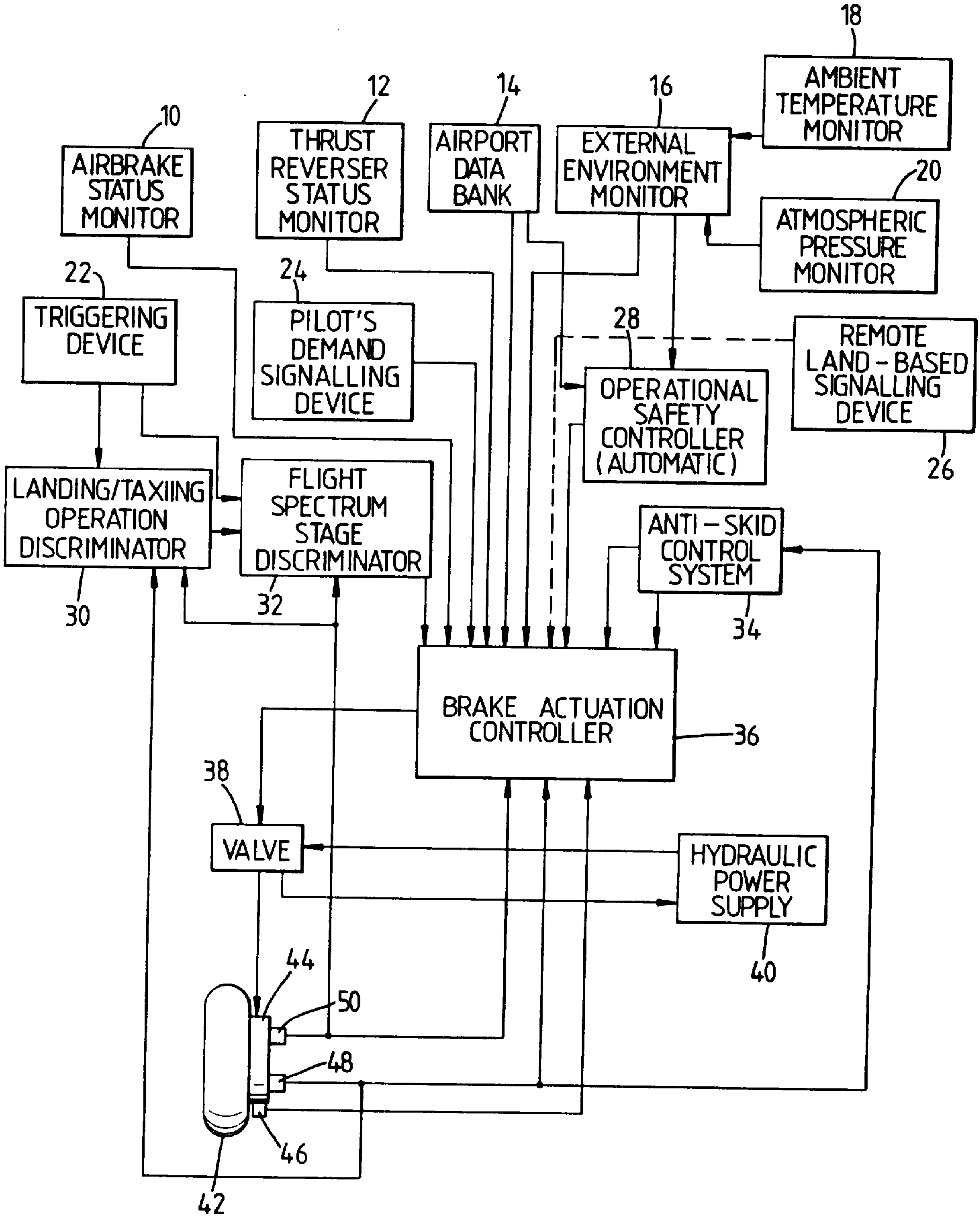
18
AMBIENT TEMPERATURE MONITOR
10
AIRBRAKE STATUS MONITOR
12
THRUST REVERSER STATUS MONITOR
14
AIRPORT DATA BANK
16
EXTERNAL ENVIRONMENT MONITOR
20
ATMOSPHERIC PRESSURE MONITOR
22
TRIGGERING DEVICE
24
PILOT'S DEMAND SIGNALLING DEVICE
28
OPERATIONAL SAFETY CONTROLLER (AUTOMATIC)
REMOTE LAND-BASED SIGNALLING DEVICE
26
LANDING/TAXIING OPERATION DISCRIMINATOR
FLIGHT SPECTRUM STAGE DISCRIMINATOR
ANTI-SKID CONTROL SYSTEM
30
32
34
BRAKE ACTUATION CONTROLLER
36
38
VALVE
HYDRAULIC POWER SUPPLY
40
44
50
48
46
42

Fig. 1

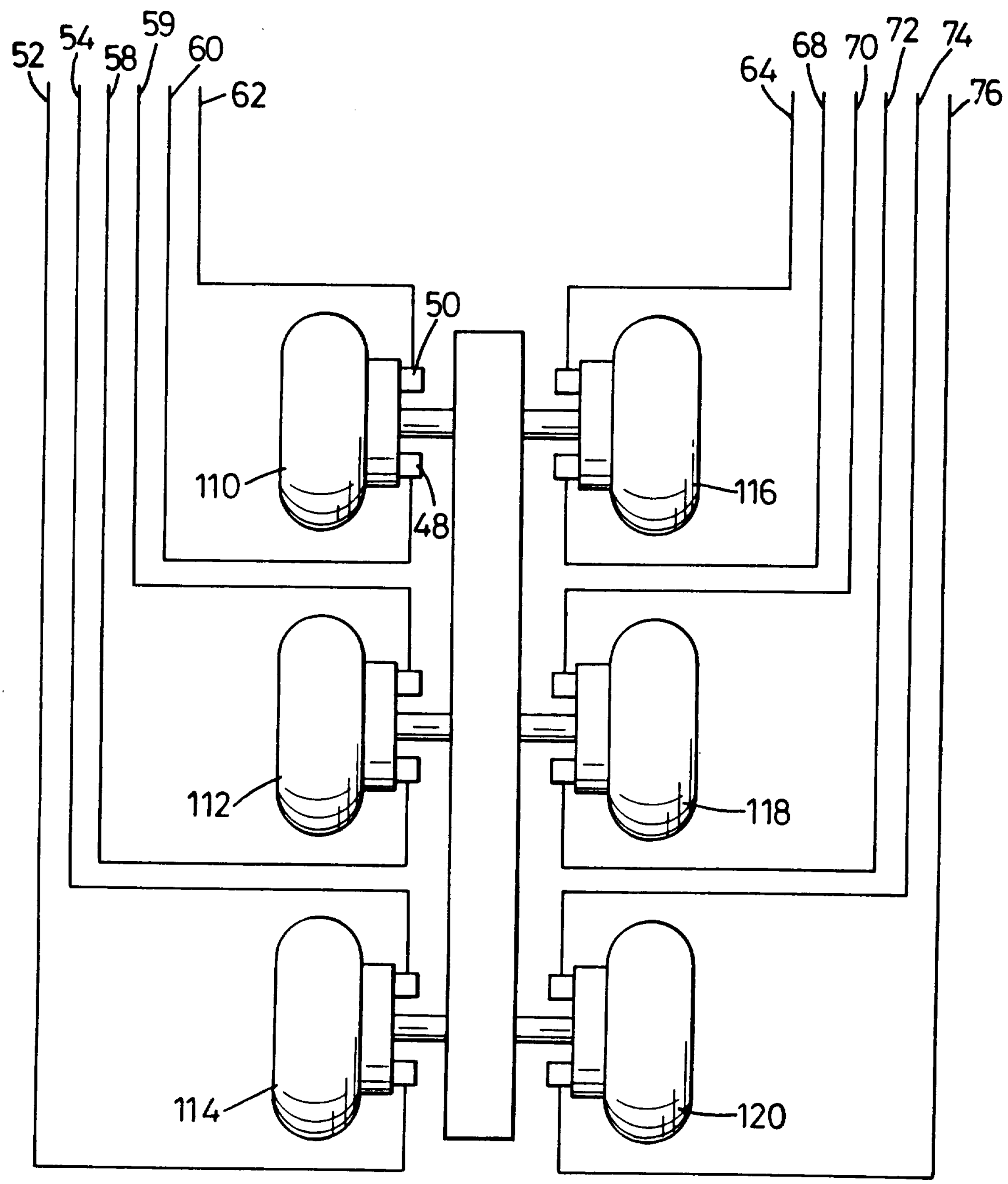

Fig. 2

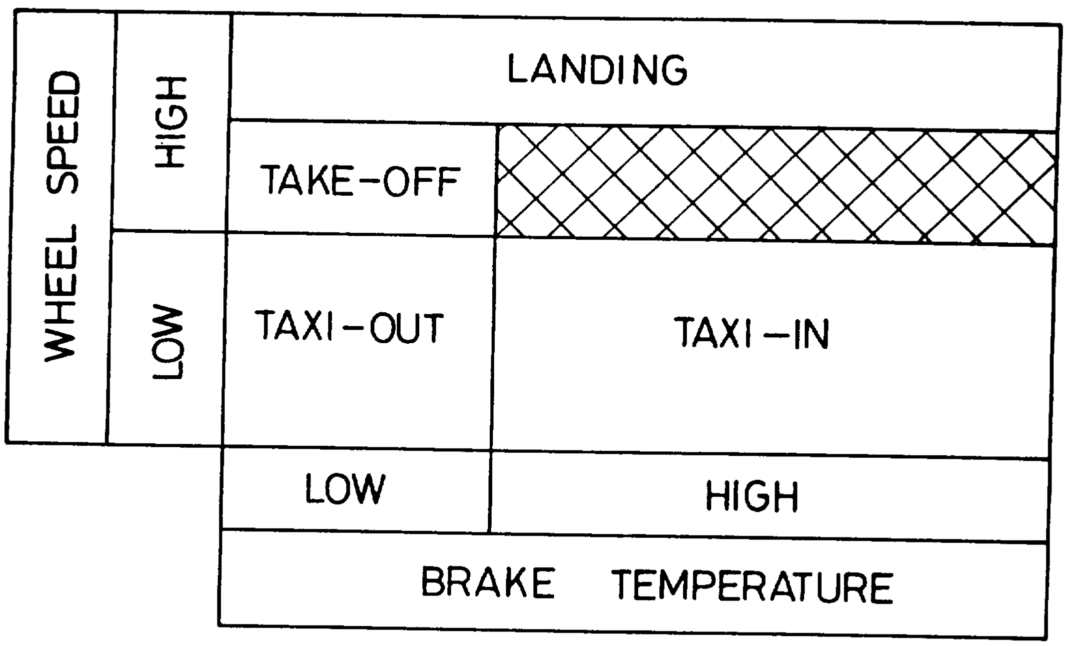
WHEEL SPEED
HIGH
LOW
LANDING
TAKE-OFF
TAXI-OUT
TAXI-IN
LOW
HIGH
BRAKE TEMPERATURE

Fig. 3

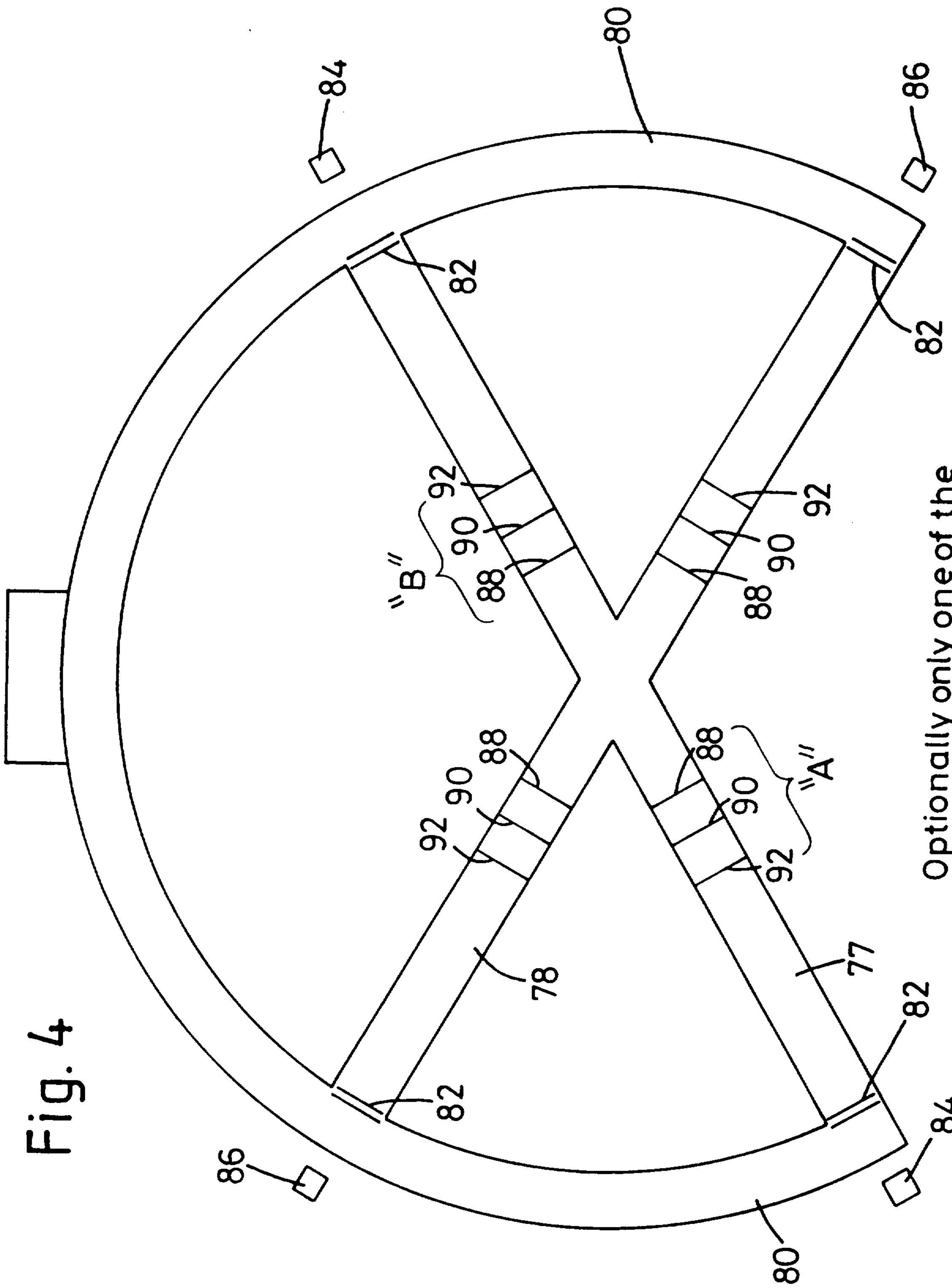

Fig. 4

Optionally only one of the sets "A" & "B" may be activated

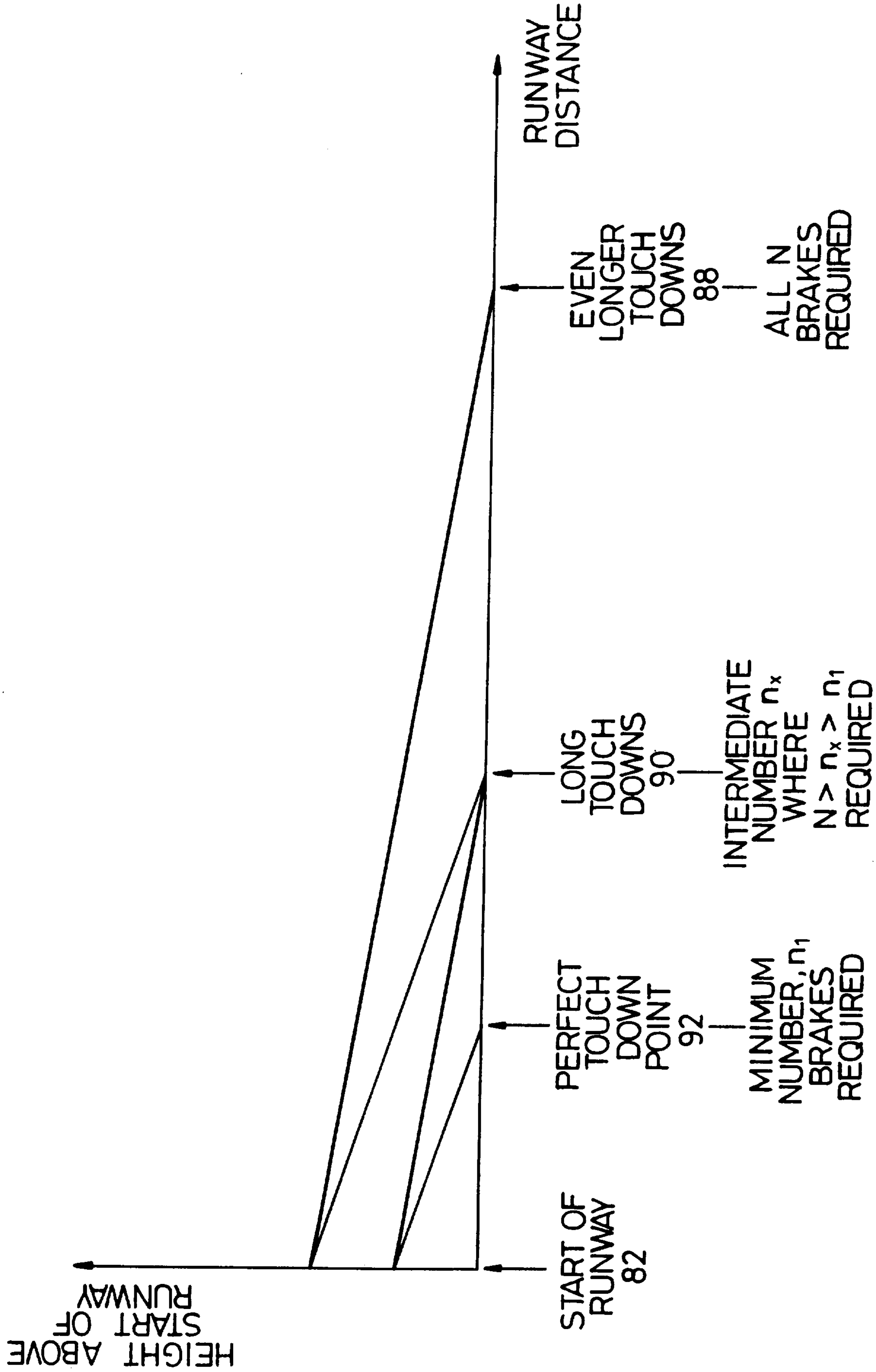
RUNWAY DISTANCE
EVEN LONGER TOUCH DOWNS 88
ALL N BRAKES REQUIRED
LONG TOUCH DOWNS 90
INTERMEDIATE NUMBER n_x WHERE $N > n_x > n_1$ REQUIRED
PERFECT TOUCH DOWN POINT 92
MINIMUM NUMBER, n_1 BRAKES REQUIRED
START OF RUNWAY 82
HEIGHT ABOVE START OF RUNWAY

Fig. 5

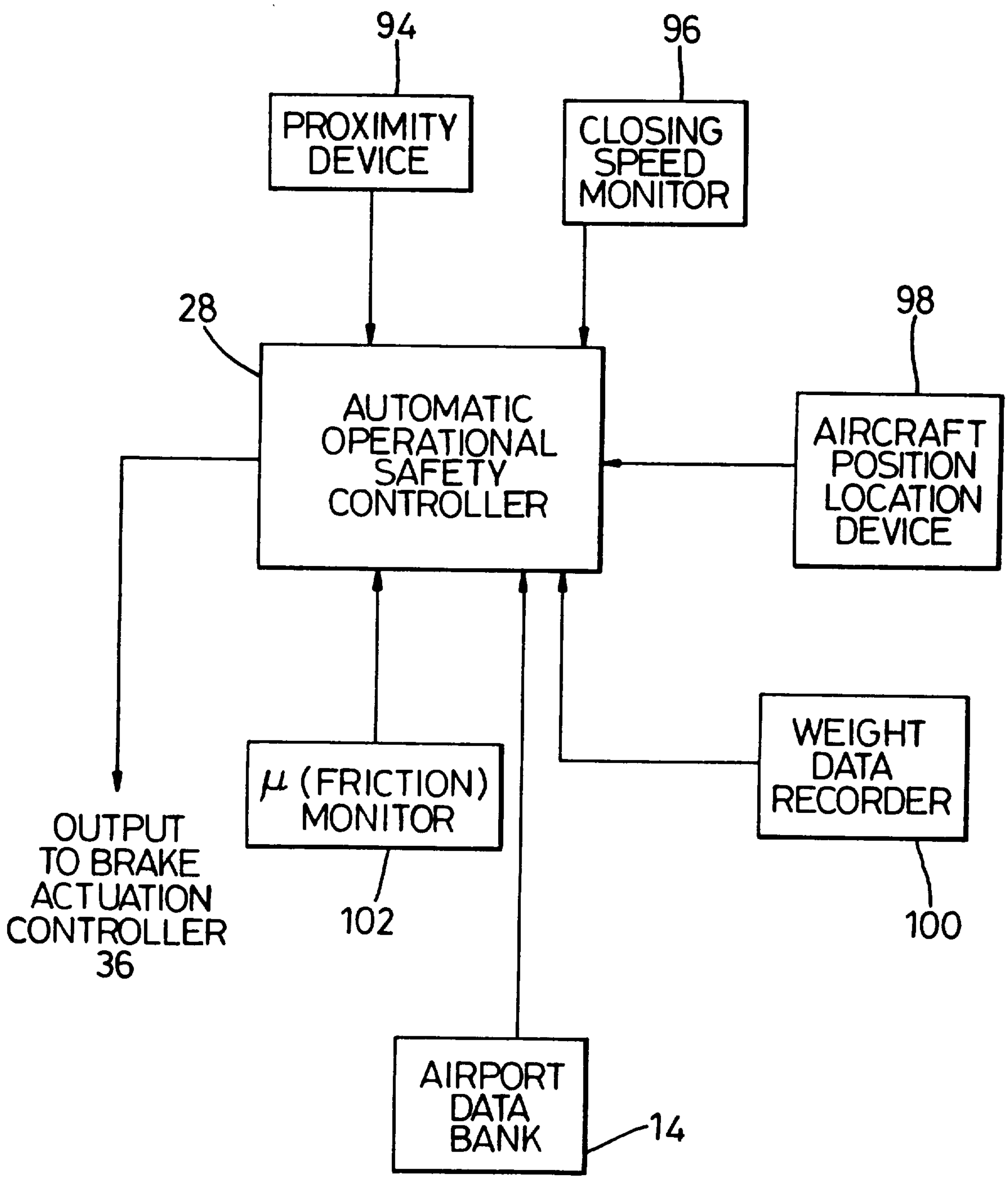
94
PROXIMITY DEVICE
96
CLOSING SPEED MONITOR
28
AUTOMATIC OPERATIONAL SAFETY CONTROLLER
98
AIRCRAFT POSITION LOCATION DEVICE
OUTPUT TO BRAKE ACTUATION CONTROLLER 36
μ (FRICTION) MONITOR
102
WEIGHT DATA RECORDER
100
AIRPORT DATA BANK
14

Fig. 6

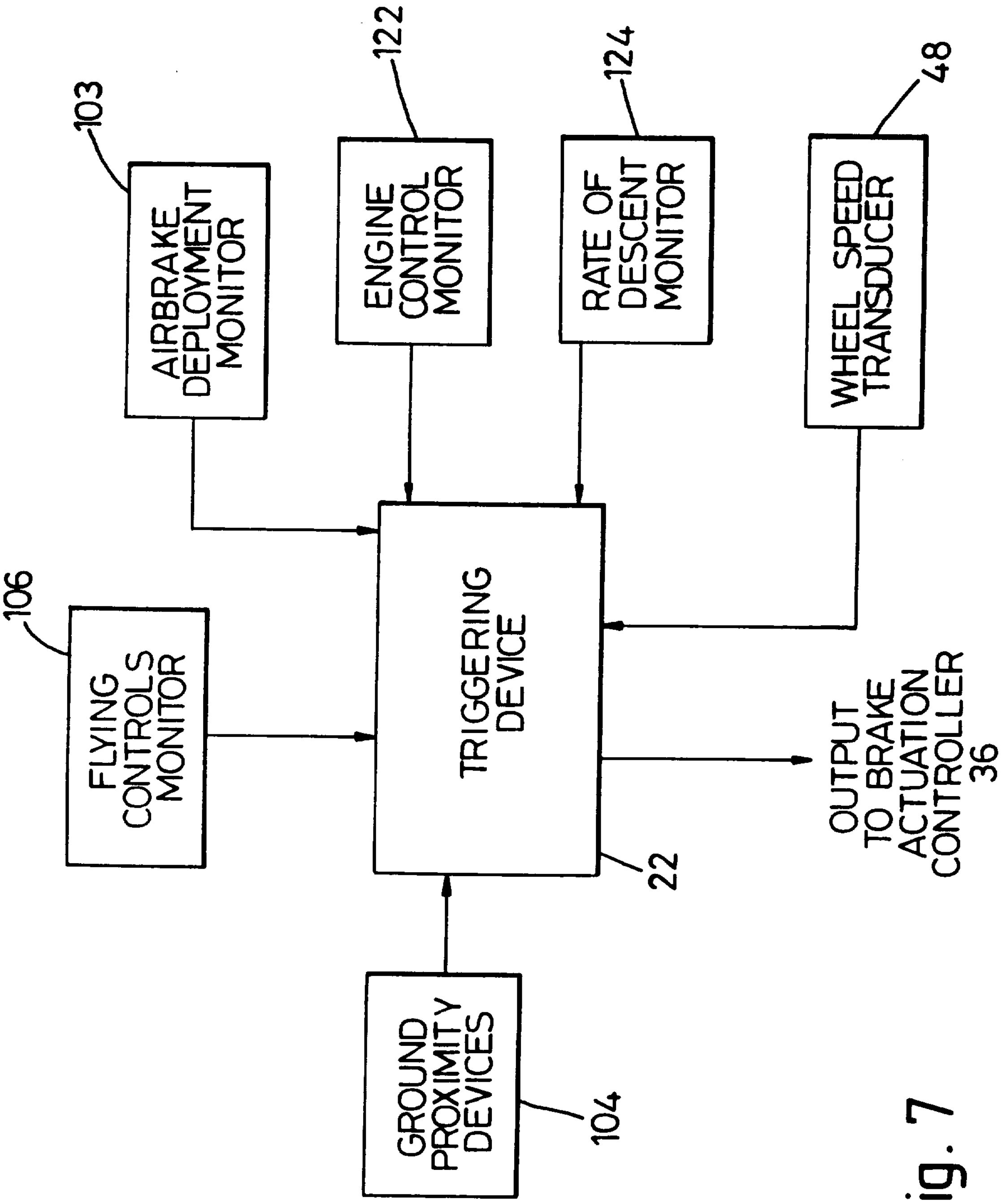
AIRBRAKE DEPLOYMENT MONITOR
103
ENGINE CONTROL MONITOR
122
RATE OF DESCENT MONITOR
124
WHEEL SPEED TRANSDUCER
48
FLYING CONTROLS MONITOR
106
TRIGGERING DEVICE
22
OUTPUT TO BRAKE ACTUATION CONTROLLER 36
GROUND PROXIMITY DEVICES
104

Fig. 7

INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB 95/02161

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 B60T8/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 B60T B64C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	EP,A,0 610 115 (MESSIER BUGATI) 10 August 1994 see the whole document ---	1-4,6, 9-11,13, 15,16, 21,23, 29,30, 32,36, 38-45
A	US,A,4 923 056 (AIRCRAFT BRAKING SYSTEMS CORP.) 8 May 1990 see the whole document -----	1-4,6, 9-12,15, 16,21, 23, 29-32, 36,38-45

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

* Special categories of cited documents :

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier document but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
19 January 1996	23.01.96
Name and mailing address of the ISA European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+ 31-70) 340-2040, Tx. 31 651 epo nl, Fax (+ 31-70) 340-3016	Authorized officer Geyer, J-L

INTERNATIONAL SEARCH REPORT

Interr   ıal Application No
PCT/GB 95/02161

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP-A-0610115	10-08-94	FR-A- 2701006	05-08-94
		CA-A- 2114603	02-08-94
		JP-A- 6270892	27-09-94
		US-A- 5417477	23-05-95
US-A-4923056	08-05-90	DE-D- 68912567	03-03-94
		DE-T- 68912567	05-05-94
		EP-A- 0384071	29-08-90
		US-A- 4986610	22-01-91