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(54) CONTROL METHODS AND SYSTEMS

(71) We, ROBERT BOSCH GMBH, a German Company, of Postfach 50, 7 Stuttgart 1, Federal Republic of Germany, do hereby declare the invention, for which we
5 pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The invention relates to a control
10 method, such as may be used for timing the instant of ignition in a spark-ignited internal combustion engine in dependence upon at least one varying operating parameter, such as engine speed, pressure in
15 the intake pipe, temperature load, and the like, which influence the desired value of the ignition timing.

Control methods, in which the desired value, varies in dependence upon other
20 operating parameters, are known for a large number of examples of application. In a large number of control methods, such as process control, the desired value simulation for the main control path varies in conformity with predetermined functions
25 which are not infrequently additionally influenced in the partially complicated control system by the actual parameters which occur. This means that a large amount of
30 information has to be collected and has to be converted and evaluated by means of complicated circuit systems such as transducers or function generators in order to compute the desired value which then
35 finally leads to a change in the adjusted value in a conventional manner by comparison with the prevailing actual value. Thus, the desired value, ensuing as a dependent variable of such a large number
40 of pieces of information and signals, is determined from the individual pieces of information at each instant and for each operating state and is fed as, for example, a voltage to a summing point or a com-
45 parator in the control system.

The expense thus involved in producing the command variable is extremely high even in the control system which, in part, is relatively simple, and is not always justified by the result obtained since the
50 essence of all control resides in avoiding the risk, always existing in the case of control, of an increasing shift in the actual adjusted value position or of the actual final value obtained in a control operation,
55 by feeding back an actual value signal, proportional thereto, to the input of the control path and thus subjecting the entire operating behaviour to strict closed loop control.
60

The present invention is based on the knowledge that, in the case of a large number of control operations, the error summation in many technical fields remains below a predetermined limiting value when,
65 for example, there is no closed loop control intervention in the operating behaviour by means of a feedback for long periods of time.

An object of the invention is to provide
70 a universal control method and a system for carrying it out, which method also renders it possible to adjust the adjusting member and influence the output variable or value in a complicated manner without
75 requiring complicated systems, function generators, and the like, for this purpose in the region of the desired value generator. In particular, a control method of this type is to be suitable for the automatic
80 monitoring of the instant of ignition in spark-ignited internal combustion engines and, with precise control of the instant of ignition over the entire range of operation is to automatically eliminate errors caused
85 by wear or other changes in the drive, chiefly long-term errors and undesirable changes in the instant of ignition.

The present invention provides a control method which employs a desired value
90

varying in conformity with a predetermined curve shape and in which an adjusting member adjusting an actual value is re-adjusted during a preselected operating state by means of a closed control loop and in accordance with the desired value which remains constant only during such operating state and the actual value is adjusted in accordance with at least one operating parameter during all operating states other than the preselected operating state by means of an open loop.

The invention includes a control system for controlling and adjusting an adjustable member comprising a control loop by means of which an actual value adjusted by the adjusting member can be compared with a desired value to re-adjust the adjusting member accordingly, and a function switch located in said control loop and adapted to respond to the existence of a preselected operating state within which said desired value remains substantially constant, whereby the control loop is closed when said predetermined operating state exists and is opened during other operating states in which the actual value is adjusted without closed loop control in accordance with at least one operating parameter.

The present invention is particularly applicable to the timing of the instant of ignition in a spark-ignited internal combustion engine wherein the desired value, i.e. the ignition advance, is influenced by one or more operating parameters of the engine.

It will be appreciated that, as already mentioned, a control method of this type can be used in a large number of control operations. The invention will be described hereinafter chiefly with reference to the factors which ensue when adjusting and controlling the instant of ignition over the operating range of an internal combustion engine. When the control method in accordance with the invention is used for the adjustment of the instant of ignition, it is possible to ignore the entire complicated formulation of the desired value for the instant of ignition and, only at the instant of the commencement of closed loop control which intervenes only during a possibly very narrow range of operation, to produce, in a very simple manner, a desired value which is then constant, and to effect any necessary re-adjustment of the adjusting member for adjusting the instant of ignition until the original setting has been re-established. The entire closed loop control is switched off again when leaving this operating state, and the further adjustment of the instant of ignition over the full range of operation is effected without any closed loop control.

In order to improve comprehension, there will follow a brief discussion of the measures which, for example, were previously required in order to meet the many demands which are nowadays made in the control of operations relating to internal combustion engines, particularly the timing of the ignition, also including the requirement with respect to exhaust gases free from injurious substances.

In the simplest case, the instant of ignition in conventional ignition systems is controlled by mechanical interruption of the ignition current and mechanical distribution of the high voltage by means of switching members which have an accurately defined correlation, generally only dependent upon the engine speed and the load on the engine, with the position of the crankshaft. Such correlation is intended to obtain economical and complete combustion of the fuel/air mixture over the entire range of speed and load with a maximum of efficiency.

However, in this connection, it is important that, as far as possible, all the important parameters characterising the operating state and thus the composition of the exhaust gas of an internal combustion engine should be combined, there then being formed from all these parameters a desired value which additionally intervenes in and influences a control circuit which determines the ignition operation and the fixing of the instant of ignition in an internal combustion engine. In this manner, the instant of ignition is advanced or retarded by an angle determined by the desired value thus formed. If it is desired to meet all the requirements in the interest of satisfactory adjustment and control of the instant of ignition, the desired value would, for example, have to be formed such that it responds to a large number of varying operating parameters and is attributable to the latter in more or less complicated functional relationships. Such variable quantities acting as operating parameters are, for example, the engine speed and the variation, with respect to time, in the engine speed relative to, for example, a rotating part of the internal combustion engine, the pressure in the intake pipe, the composition of the exhaust gas, the angular position of the butterfly valve and, for example, the temperature of the internal combustion engine measured at a suitable point. Such use is frequently prohibited by the high cost of detecting all these variables and combining them to form a single desired value for sensitive adjustment of the instant of ignition.

This is where the invention intervenes and renders it possible to control and monitor the instant of ignition in an in-

ternal combustion engine in no less a precise manner or, generally speaking, the position of the adjusting member, without requiring the instantaneous detection of a large number of external positions and actual operating parameters in order to obtain the particular desired value required for the control operation. It is assumed that the ideal characteristic of the instant of ignition for all operating states is known for every specific type of internal combustion engine or that, as is also the case nowadays, mechanisms exist which, responding to the prevailing operating state of the internal combustion engine, i.e., controlled by the latter, influence and adjust the ignition system such that the ignition pulse is produced accurately at the desired and necessary instant during all operating states. This means that, for example, vacuum boxes are available which adjust the position of a plate, carrying the contact breaker pulse generator, relative to the contact breaker shaft, and that, for example, a centrifugal timer is also provided which, in dependence upon the engine speed, influences the basic angle of adjustment for the contact breaker shaft.

This means, when applied to the general case of control, that a sufficient number of control mechanisms are provided which influence the adjusting members in normal forward control and in dependence upon the prevailing operating state. In this manner, it is always possible to include all the parameters required for accurately producing the instant of ignition or to simulate them in a curve adjustment, although there is the risk, recognized by all those skilled in the art, that, in the case of pure adjustment without feedback or closed loop control, undesirable variations in the instant of ignition occur which impair performance, fuel consumption and composition of the exhaust gas.

The present invention is further described hereinafter, by way of example, with reference to the accompanying drawings, in which:

Fig. 1 is a block circuit diagram of an embodiment of the invention for the adjustment and automatic re-adjustment of the instant of ignition;

Fig. 2 shows a first possibility of momentarily regulating the instant of ignition; and

Fig. 3 shows a second embodiment which permits regulating intervention in the instant of ignition and the determining thereof.

Referring to Fig. 1, an adjusting member 1 is primarily responsible for the production of the ignition pulse and the precise adjustment of the instant of ignition. The adjusting member may be the

mechanical contact breaker system which is frequently used to produce the ignition pulse or pulses and which operates in conjunction with an ignition coil connected on the output side. The breaker contacts through which battery current is applied to the ignition coil are switched in dependence upon a rotating part of the internal combustion engine which is hereinafter designated "cam element", and which carries breaker cam lobes equal in number to the number of ignition pulses to be produced during each revolution of the crankshaft. The breaker contact system will be assumed to be fixed in the first instance, the instant of ignition then being determined by the cooperation, with respect to time, between the rotating cam element and the contact breaker actuated thereby. Other possibilities of adjustment in dependence upon operating parameters can be incorporated in the adjusting member and are generally indicated by the double arrow 2. These possibilities of adjustment include, for example, possible additional centrifugal adjustment of the cam element, a vacuum-operated relative adjustment of the carrier plate for the contact breaker system, wherein the vacuum in the carburettor may be used, and other additional possibilities of intervention, such as temperature-dependent adjustment. In this manner, the required variation of the instant of ignition can be satisfactorily ensured over all the operating states, although, since only a control operation is involved in the present instance, the actual instant of ignition can deviate from its desired value to a considerable extent when operation is effected without closed loop control.

Thus, a control loop (servo loop) is provided with checks, for example, the position of the adjusting member at specific instants and readjusts it if necessary. However, this control loop can be of very simple construction and does not require the extremely complicated desired value generator required with continuous closed loop control.

The instant of ignition signal 3 is present at the output of the adjusting member 1 and is further processed in a conventional manner and is finally fed to the combustion chambers of the internal combustion engine. The instant of ignition signal 3 is applied by way of a feedback lead 4 to an actual value generator 5 by means of which the instant of ignition signal, which is only a needle-shaped pulse existing at a specific instant, is prepared such that this signal is available as an actual value on the lead 6 and can be fed to an input 7 of a comparator/variable-gain amplifier 8 connected on the output side.

The construction of the actual value generator 5 is, in itself, of no substantial relevance, although it will be briefly discussed for the purpose of improving comprehension. The actual value generator 5 is a bistable circuit element (flip-flop) which is triggered into its set state by a control pulse fed by way of a lead 9. This control pulse is produced by a pulse generator 10, connected on the input side, at the same instant by, for example, sensing a mark on a rotating part of the internal combustion engine, and is converted into the setting pulse on the lead 9 for the flip-flop 5. The flip-flop 5 is reset by the instant of ignition signal 3 on the lead 4, and the output signal formed by the flip-flop 5 in this manner and having a predetermined duration dependent upon the instant of ignition signal 3, and can then be converted into an output voltage of specific amplitude by way of an integrating network connected on the output side. In this manner, a voltage signal of suitable shape and amplitude, and which, as an actual voltage, is representative of the instant of ignition signal, can be fed to the input 7 of the variable-gain amplifier 8. The desired value is fed to the other input 11 from a desired value generator 12, the desired value being obtained as a constant voltage value by, for example, simple adjustment of a potentiometer.

The essential feature is that this desired value, obtained in the form of a desired voltage on a potentiometer by fixed adjustment, is compared, only during the above-mentioned, possibly very short preselected operating state, with the actual voltage to which this desired value is also applicable.

The output of the variable-gain amplifier 8 is connected to a function switch arrangement 15 which has at least one switching contact 16. The function switch 15 is constructed such that it is able to detect the above-mentioned preselected operating state or working range of the entire system and to complete the control loop. For this purpose, the function switch 15 closes its switching contact 16, and the output signal of the variable-gain amplifier is applied as the difference between the desired value and the actual value to the adjusting member 1 optionally by way of an interposed output amplifier 17. If the setting of the system has been shifted during the preceding operation which is based on adjustment without using a closed control loop, in other words if changes and errors have occurred, this affects the control loop, now connected as a closed loop, such that the differential voltage at the output of the variable-gain amplifier acts upon the adjusting member 1 and adjusts the latter until the original setting has been re-established,

i.e. in the case of an ignition system, until the original ignition setting exists again. The control loop system is then maintained only for as long as this existing predetermined operating state is detected by the function switch 15. If the system enters another operating state, i.e. the engine speed or the pressure in the intake pipe increases for example, again in the case of an ignition system, the function switch 15 interrupts the closed control loop by opening at least the illustrated switching contact 16, and closed loop control is again rendered ineffective until the operating state is re-established for which the correct desired voltage has been set once and for all on the desired value generator 12. For the purpose of elucidation, two arrows 15a and 15b are illustrated on the function switch 15 and indicate two of the operating parameters (for example n = engine speed; p = pressure in the intake pipe) fed externally to the function switch. The function switch 15 can be designed such that, with the formation of the closed control loop, it responds when the preselected operated state corresponds to, for example, the starting range of the internal combustion engine.

This resetting, or rather re-adjustment, of a switching point which has deviated from a desired value can also be regarded as an adjustment within a larger range of adjustment, the particular setting correction effected by re-adjustment by means of the system in accordance with the invention being of fixable or lockable construction, thus preventing an error from occurring again when the above-described control operation loses its effect on the adjusting member by switching-off by way of the function switch 15 when the working outside the predetermined operating state. Thus, a locking block 18 is provided in the circuit diagram of Fig. 1 and is actuated by way of a switching contact 19 which is provided in the function switch 15 and which is actuated simultaneously with the switching contact 16, which locking block ensures that the fresh adjustment value obtained by the re-adjustment operation is locked.

To improve comprehension, a first embodiment, again relating to an ignition system, will be explained briefly with reference to Fig. 2. A carrier plate 20 carries a contact-breaker system 21 which will not be further described hereinafter. The contacts 22 of the contact-breaker system 21 are separated by the running of an actuating projection 23 onto one of the cam lobes 24 of the engine-driven cam element 25. It will be seen that the instant at which the contacts are separated can be influenced by turning the carrier plate 20. The carrier

plate can be turned by a vacuum system 26 acting upon the horizontal bearing position of the carrier plate 20 by means of a connection rod 27 which is articulated to the carrier plate 20 at 28.

The vacuum system includes the housing 29 of a vacuum box in which a diaphragm 30 supports an actuating element 31, which is prestressed by means of a spring 32. That end of the actuating element 31 directed towards the bearing plate 20 carries the connection rod 27 and, as may be seen, upon a change in the vacuum acting upon the vacuum system which, for example, can be connected to the region of the intake pipe of the internal combustion engine, the actuating element can effect a piston-like displacement movement in the housing 29 of the vacuum box, the displacement movement being imparted to the carrier plate 20 by way of the connection rod 27. This is a conventional form of the above-mentioned control of the instant of ignition in dependence upon an external operating parameter, the pressure in the intake pipe in the present instance. Other controls can act upon other elements in a similar manner. By way of example, centrifugal control can additionally influence the position of the cam element 25.

In order that the above-mentioned automatic re-adjustment can take place, the actuating element 31 is in the form of a so-called rotary armature magnet whose housing is illustrated at 34. Pole shoes 35 and a winding 36 are located in the interior of the housing 34, and the actual rotary armature 37 is provided with a screw-thread 38 which turns in the internal screw-thread of an outer screw-threaded sleeve 39 made preferably from plastics material. The mode of operation is such that, when an electric current is flowing in the winding 36 (the control circuit is correspondingly closed and an output signal of the output amplifier 17 exists), the rotary armature magnet rotates to displace the connecting rod in one of the directions of the double arrow A and the ignition system is corrected to regulate to the original ignition setting. As soon as this has been achieved, and the internal combustion engine enters other working ranges, the control loop of Fig. 1 can be designed such that locking by way of the block 18 is effected again in the first instance. For this purpose, the arrangement shown in Fig. 2 has two brake shoes 40a and 40b which are shown separately in plan view on the right of the illustration of the vacuum system. The brake shoes 40a and 40b can be pressed into their closed locking positions by the force of the initial stress of springs. When a current is fed to the winding 41 mounted on the brake

shoes, the locking action is released, and the system is released to turn the rotary armature and to reset the ignition. Furthermore, the pitch of the thread of the screw-threaded sleeve and the rotary armature can be designed such that it is equal to or less than the self-locking pitch.

Fig. 3 shows a second embodiment which, again in the case of an ignition system, permits momentary regulating intervention in the existing system. In this instance, the adjusting member 1 is in the form of a servo motor 45 and is bolted to the engine block 47 by way of a corresponding attachment flange 46. The output shaft of the servo motor 45 has a worm thread 48 which cooperates with a complementary counter-thread 49 on a clamping bracket 50. The clamping bracket is constructed such that it can determine the angular position of a conventional ignition distributor 51 arranged thereon. In a manner familiar to one skilled in the art, the instant of ignition can be advanced or retarded by turning the ignition distributor.

In general, the locking of the setting of the adjusting member, obtained by re-adjustment, can be effected in an optional way, by linear electro-magnets subjected to the initial stress of springs or, advantageously, as is shown in the embodiment of Fig. 3, electrically by a retarding field acting upon the servo motor 45. Advantageously, the entire locking system is designed such that, in the diagram of Fig. 1, the locking action is first cancelled or released by the function switch 15 upon detecting the preselected operating state, readjustment subsequently being effected by means of the closed control loop, whereupon the locking action is re-established in all cases before the output amplifier ceases to act upon the adjusting member 1 as the result of switching off. If desired, the corresponding operating sequence with respect to time can be ensured by suitable timers.

It has already been pointed out above that a regulating system of this type, which can be applied for only a short period of time, can also be used for other control operations in which operation has to be carried out with complicated desired value adjustments, and wherein only a specific operating or working state is selected for automatic re-adjustment and for which the desired value is constant and known. Control in this narrow range is then effected to accurate values, and after leaving this working range, the system is again left to normal control which is able, with sufficient accuracy, to simulate the desired positions of the adjusting member until testing and re-adjustment by means of the control loop can again be effected upon reaching the same operating and working state.

A control method of this type is particularly advantageous in that it is unnecessary to provide the required desired value and actual value signals at each instant from a large number of external operating parameters, and their values continuously varying over the working range, by means of complicated circuits, converters, transducers and other electro-mechanical systems, and, if required, to further process the signals by way of function generators. The solution, in accordance with the invention, of punctual re-adjustment is considerably more economical without having to accept a perceptible loss of accuracy.

The electrical power requirement for control is considerably reduced by the punctual re-adjustment, since the adjusting members only have to be switched on during a re-adjustment operation. This is particularly important for use in motor vehicles.

WHAT WE CLAIM IS:—

1. A control method which employs a desired value varying in conformity with a predetermined curve shape and in which an adjusting member adjusting an actual value is re-adjusted during a preselected operating state by means of a closed control loop and in accordance with the desired value which remains constant only during such operating state and the actual value is adjusted in accordance with at least one operating parameter during all operating states other than the preselected operating state by means of an open loop.

2. A method as claimed in claim 1 in which the curve shape of the variable desired value is influenced by said operating parameter or parameters.

3. A method as claimed in claim 2 in which said closed control loop is brought into operation at the beginning of said preselected operating state when said operating parameter or parameters attain a predetermined value and is put out of operation at the end of said preselected operating state when said operating parameter or parameters depart from said predetermined value.

4. A method as claimed in claim 1, 2 or 3 wherein the desired value is obtained as a constant divider voltage for the preselected operating state and is compared with the actual value.

5. Method as claimed in claim 1, 2, 3 or 4 wherein the adjusting member is locked in its fresh position after it has been re-adjusted by the closed control loop.

6. A method as claimed in any preceding claim for timing the instant of ignition in a spark-ignited internal combustion engine, wherein the operating parameter or parameters are one or more operating para-

meters of the engine.

7. A control system for controlling and adjusting an adjusting member comprising a control loop by means of which an actual value adjusted by the adjusting member can be compared with a desired value to re-adjust the adjusting member accordingly, and a function switch located in said control loop and adapted to respond to the existence of a preselected operating state within which said desired value remains substantially constant, whereby the control loop is closed when said predetermined operating state exists and is opened during other operating states in which the actual value is adjusted without closed loop control in accordance with at least one operating parameter.

8. A control system as claimed in claim 7 which includes a desired value generator adapted to produce a preadjustable fixed voltage corresponding to said constant desired value existing in said preselected operating state and in which the control loop contains means for comparing a voltage corresponding to said actual value with said fixed voltage.

9. A control system as claimed in claim 8 in which said comparing means comprises a comparator/variable gain amplifier.

10. A control system as claimed in claim 8 or 9 for determining the instant of ignition in an internal combustion engine, wherein the control loop contains a bistable circuit element producing the voltage corresponding to the actual value and is set into one state by a setting pulse which arrives at a predetermined interval with respect to time, and is reset by the instant of ignition signal, and an average value former connected to the output of the bistable circuit element.

11. A control system as claimed in claim 7, 8, 9 or 10, wherein a device is provided for locking the adjusting member in its re-adjusted position during said other operating states.

12. A control system as claimed in claim 11, wherein the function switch contains switching contacts which in one state establish the closed control loop and in another state actuate the locking device such that the adjusting member is locked before the commencement and after termination of the re-adjustment operation.

13. A control system as claimed in any of claims 7 to 12, wherein the adjusting member has an actuating element which, when acted upon by a differential signal obtained from the desired value and the actual value, effects a rotary movement and thereby adjusts a basic setting.

14. A control system as claimed in claim 13 when appendant to claim 11 or 12 wherein the actuating element is in the

- form of a rotary armature and wherein the locking device comprises two brake shoes carrying a magnet winding for locking the armature in its readjusted position.
- 5 15. A control system as claimed in any of claims 7 to 14 for determining the instant of ignition in an internal combustion engine in which the adjusting member is incorporated in a vacuum ignition timing
- 10 device and is adapted to re-adjust a basic setting of a carrier plate of a contact breaker system, the engine intake pipe vacuum constituting said operating parameter.
- 15 16. A control system as claimed in any of claims 7 to 12 for determining the instant of ignition of an internal combustion engine, wherein the adjusting member is a servo-motor which fixes the angular position of a contact carrier plate of the 20 ignition distributor by way of a worm drive.
17. Control method substantially as hereinbefore described with reference to the accompanying drawings.
18. Control system substantially as here- 25 inbefore described with reference to and as illustrated in the accompanying drawings.
- W. P. THOMPSON & CO.,
Coopers Building,
Church Street,
Liverpool, L1 3AB.
Chartered Patent Agents.

Fig.1

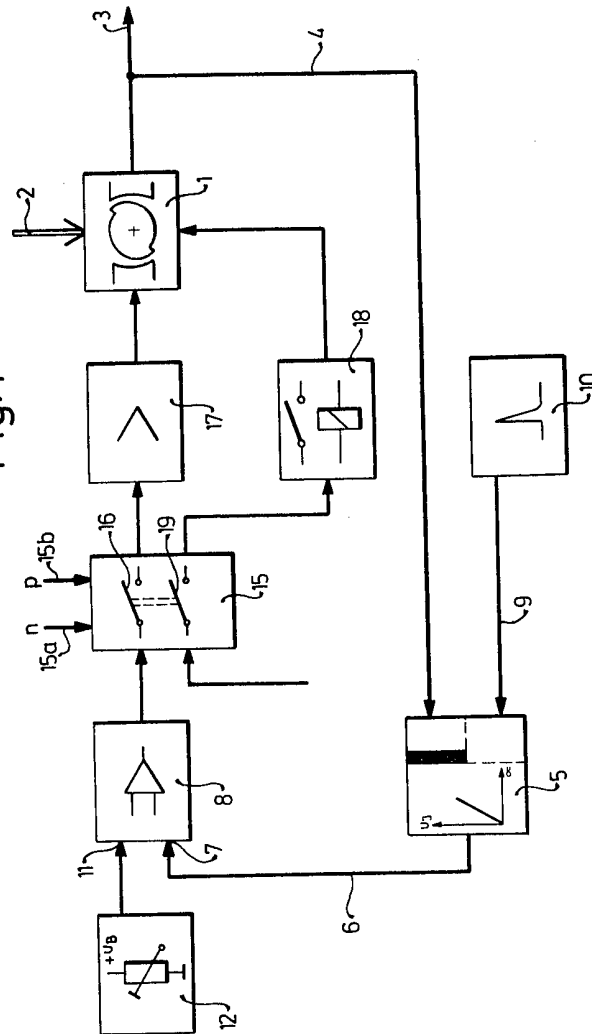


Fig. 2

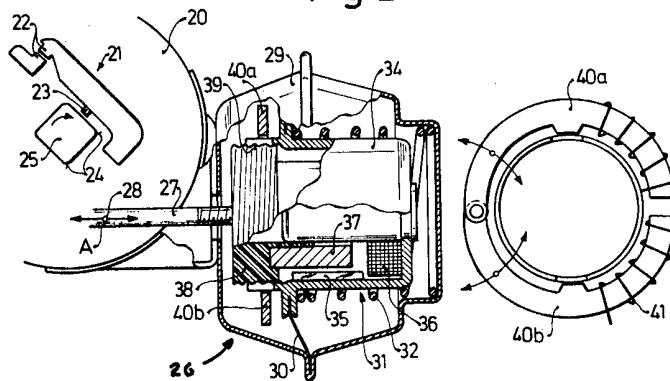


Fig. 3

