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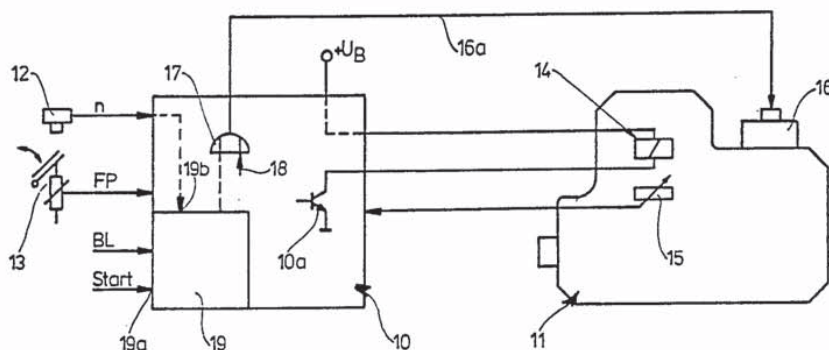
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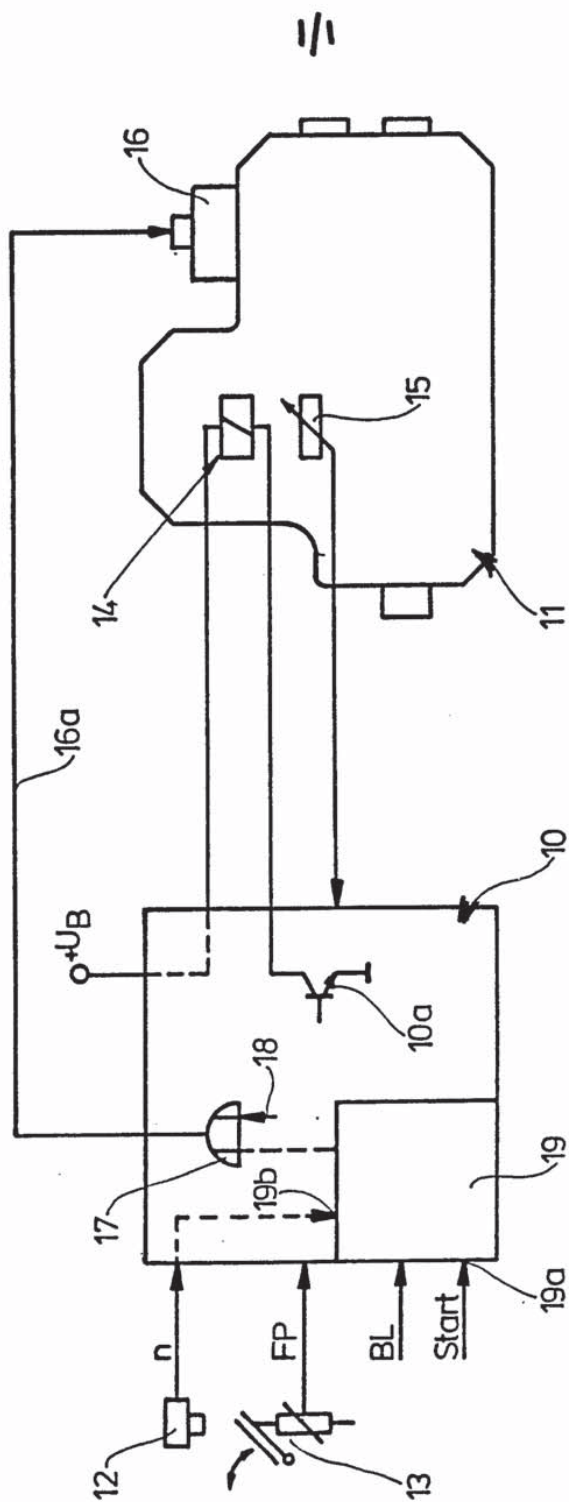
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(57) A method of monitoring the integrity of a redundant safety shut-off valve (16) in an internal combustion engine comprises the steps, carried out during steady idling operation as indicated by maintenance of prescribed boundary conditions, of reducing the feed pressure and the injected quantity to a fuel quantity setting mechanism by closing of the valve (16) by means of test circuitry (19), and of observing the reaction of an idling regulator resulting therefrom. A rise in the output magnitude of the regulator, or a resultant greater fuel pump regulating travel or setting angle, is evaluated as an indication confirming the correct function of the valve.



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MONITORING THE INTEGRITY OF A SAFETY SHUT-OFF DEVICE

The present invention relates to a method of monitoring the integrity of a safety shut-off device in the form of an electromagnetic valve in an internal combustion engine and to monitoring means for such
5 a purpose.

In safety equipment for an internal combustion engine with compression ignition, it is known (DE-OS 33 01 742) to continuously detect signals concerning the operation of the engine, such as accelerator pedal setting, calculated target value of fuel injection regulating travel,
10 engine speed, brake pedal setting and so forth, and to provide a corrected regulating travel target value by minimum value selection, the corrected value being fed to the setting regulator of an electronic diesel regulation (EDC) system. This corrected target value at the same time serves for ascertaining regulating deviation with the inclusion of
15 a regulating travel actual value signal that has been reported back. If preset limits are exceeded, the safety equipment reacts either by switching-off the injection pump, switching off current supply to the end stage of the setting regulator or switching on a redundant substitute function. However, in some circumstances problems can arise
20 in this known equipment, because not all possible boundary conditions are included in the detection of the safety conditions and separate checking of the electromagnetically operated fuel feed shut-off valve (ELAB) does not take place.

In a known fuel injection pump for diesel engines (DE-OS 29 45 484),
25 a pump piston arranged in the housing of the fuel injection pump is set into reciprocating and rotary movement, wherein fuel from the interior housing space - forming the suction space - of the pump flows to a conveying element. From there the fuel passes according to the

set quantity into the pressure ducts leading to the engine cylinders. A safety valve is arranged in the connecting duct between the suction space and the conveying element and interrupts fuel feed from the suction space to the element if certain safety conditions are exceeded.

5 It is also known to use electrical setting mechanisms (DE-OS 35 31 198), which are driven by electrical signals, for electronic regulation of the operation of compression ignition internal combustion engines, thus diesel engines, wherein a central control device in place of mechanical fuel metering and regulating systems produces the
10 required setting signals. Although mechanical fuel metering systems in diesel engines are reliable in respect of their fault-security, in some circumstances they are less able to take into account the multiplicity of different operating conditions and environmental influences.

 The use of electronic components in conjunction with electronic
15 diesel regulation makes comprehensive safety, monitoring and substitute measures desirable when the individual assemblies on their own incorporate capabilities for fault recognition and, optionally also, fault exclusion. Thus, it is known in the usual series and distributor pumps for diesel injection in electronic diesel control to provide an
20 electrical cut-off device in the form of an electromagnetic cut-off valve; this interrupts the feed of diesel fuel in the case of a defect in the control device, in the case of defective transmitters and in the case of disturbances or defects in the cabling or in the injection pump, and thus makes possible a controlled shut-down of the engine.

25 Since this electrical cut-off device makes redundant shutting-down possible in response to potentially dangerous operational states such as independent accelerating or racing of the diesel engine, the

safety of the system very much depends on the function of the cut-off valve. For this reason, a test of the valve is desirable during normal travel operation, which test as far as possible should not be apparent to the driver, for example through drop in engine speed.

5 There is therefore a need, with respect to the significance that an electromagnetic shut-off valve has as redundant safety device in an engine, to be able to monitor its correct function, preferably unnoticeably, in normal travel operation and to react, for example with an alarm indication, on detection of a fault. There is, however, 10 the consideration that the valve is part of the fuel supply system and separate checking of its function may switch off the engine. It is therefore not possible to check the valve simply in a time-controlled manner, thus at preset time intervals during normal operation of the vehicle, since this checking could lead to the engine cutting out. 15

On the other hand, a defective valve cannot be recognised by the driver, because not only is the current supply to the possibly defective valve interrupted when the voltage supply is switched off, but the voltage supply for the quantity setting mechanism and the other 20 components is also switched off. Moreover, the driver or user of a motor vehicle equipped with a safety cut-off valve is unlikely to monitor it continuously or wish to be involved in constantly checking safety components in the fuel quantity regulation.

According to a first aspect of the present invention there is 25 provided a method of monitoring the integrity of an electromagnetic safety valve responsive to a fault condition to cut off fuel feed in a vehicle internal combustion engine with electronically regulated

fuel metering, the method comprising the steps of completely or partially interrupting fuel feed by way of the valve during steady idling of the engine in normal vehicle travel operation and evaluating consequent change in an idling regulating parameter as an indication of correct functioning of the valve.

According to a second aspect of the present invention there is provided monitoring means for monitoring the integrity of an electromagnetic safety valve responsive to a fault condition to cut off fuel feed in a vehicle internal combustion engine with electronically regulated fuel metering, the monitoring means comprising test circuit means to detect steady idling of the engine and cause operation of the valve for complete or partial interruption of fuel feed during such steady idling and to evaluate consequent change in an idling regulation parameter as an indication of correct functioning of the valve.

A method exemplifying and monitoring means embodying the invention may have the advantage of being able to check the safety cut-off valve in its function effectively during operation of the engine, in particular without interruption of or disturbance in the vehicle travel or a noticeable drop in engine rotational speed. There is selection of an instant, suitable for this checking, in the operational course of the engine and a particular reaction which must then occur is detected. Nevertheless, the test function is still such that it can ascertain whether the valve lets fuel through in the closed state or whether it remains in the opened state and has, for example, seized in its seating.

The steady idling operation of the engine represents a particularly suitable instant for the checking. The test function can be

performed during each steady idling operation. It can, however, be arranged to check the valve function only after a given number of occurrences of the steady idling operation.

It is feasible to so construct the valve that it is reversible or to so structure peripheral conditions that the reversibility of the valve results.

It is advantageous that the monitoring means may be able to be realised through small additional circuitry in an electronic control device for fuel regulation or entirely without additional hardware through a corresponding software program structuring in the electronic control region, since the control device usually has the form of a small computer or microprocessor with storage. No additional inputs at the control device need be necessary; the control device already has peripheral signal inputs from external sensors as well as a drive line for the safety valve, by way of which the drive may be able to be undertaken for valve function checking.

The method and monitoring means may thus make possible, in advantageous manner, the constrained monitoring of the valve in engine operation (a regular monitoring according to the service intervals cannot otherwise be expected, since this is at the discretion of the vehicle user), the avoidance of undefined influences, the possible absence of additional hardware or software, and an increase in the reliability of the safety system, since the failure probability for the entire system is reduced by the valve monitoring.

Performance of the valve checking within the idling program course of electronic diesel regulation may be particularly advantageous.

An example of the method and an embodiment of the monitoring means

of the invention will now be more particularly described with reference to the accompanying drawing, the single figure of which is a schematic block diagram of an electronic diesel regulation system in association with a quantity setting mechanism.

5 Referring now to the drawing, there is shown an embodiment of monitoring means based on hardware as opposed to software. The illustration of discrete switching stages does not represent a restriction, but merely serves to show the basic functional effect of the monitoring means and to indicate special functional courses. It is
10 self-evident that individual components and blocks can be based on analog, digital or hybrid technique or, combined entirely or partially, can occupy corresponding regions of a program-controlled digital system, for example a microprocessor, microcomputer, digital or analog logic circuit and the like, in which case the operating course of the monitoring
15 means can be stored as a program.

The control device of an electronic diesel regulating (EDC) system is denoted by 10 and the quantity setting mechanism acted on by the device 10 is denoted by 11. The device 10 receives indications of engine rotational speed n from a rotational speed transmitter 12,
20 accelerator setting and optionally also clutch pedal setting from an accelerator or clutch pedal setting transmitter 13 as well as, if desired, brake actuation (brake light) and start information, together with signals from further sensors in respect of, for example, constant temperature, battery voltage and the like. The device 10 acts by
25 way of an end stage 10a on an electromagnetic setting mechanism 14 in a fuel injection pump of the quantity setting mechanism 11, which also includes a position-reporting device 15. An electromagnetic

safety shut-off valve (ELAB), which is associated with the quantity setting mechanism or the fuel injection pump, is denoted by 16 and is acted on by the device 10 by way of a drive line 16a, for example as illustrated in the drawing, through an OR member 17. The member
5 17 receives signals, which derive from a multiplicity of parameters detected by a safety logic system and lead to switching-off of the valve, thus blocking of further fuel feed, according to the arrow 18 from a logic circuit within the device 10.

Separately from this, the drive of the valve 16 takes place through
10 an additional test circuit 19, which is so arranged that the valve is closed through appropriate drive in the case of steady idling operation recognised by appropriate external sensors. This means that the feed pressure of the fuel reduces and thereby also the injected quantity. Also provided is an idling regulator circuit, which regulates towards
15 a constant rotational engine speed. This leads to an idling regulator (not shown) reacting at once to such a reduced injected quantity in that it presets a higher target quantity. As long as fuel is still present in the suction space of the injection pump, the pump can supply this higher quantity at higher target regulating travel and
20 thus counteract a drop in engine speed.

It is therefore possible to recognise a correctly functioning ELAB valve in steady idling operation at constant rotational idling speed through a rise in the idling regulator output magnitude or the higher regulating travel resulting from this (greater setting
25 angle in the case of a distributor pump) in the regulating circuit, since the idling regulator increases the target magnitude in the setting regulator.

Such a rise in the idling regulator output magnitude or in the regulating travel can be correspondingly evaluated as a criterion for the question of whether or not the valve 16 is able to correctly function.

5 A few boundary conditions are associated with the ELAB test and are explained in detail in the following or comprehended by the following flow diagram, which illustrates an example of the invention in the form of a sub-program in a fuel metering program.

- 1) When steady idling operation is present, testing of the valve 16
10 is initiated when the following conditions are fulfilled:
- the start counter has exceeded a preset threshold,
 - the injection quantity lies in a range typical for idling,
 - travel speed is zero or below a minimum threshold,
 - the clutch is engaged, i.e. the engine is idling and no gear is
15 engaged, and
 - the accelerator pedal is disposed in the idling position.

It may also be desirable to interrogate cooling water temperature so as to ensure that the test is carried out only with the engine hot, because in this operational state the idling regulator can best
20 regulate out the disturbance caused by the test.

2) The functional test of the valve 16 is discontinued when one of the afore-named conditions is infringed. The functional test is then initiated anew so often until the steady idling operation is maintained during the entire test duration.

25 During the test, the idling regulator output magnitude or the regulating travel (or setting angle) is checked for the course which is to be expected with a correctly functioning valve 16.

If the test is not interrupted for the reason that the steady idling operation is departed from, the test can be performed to the end and, if the preset correct course of the idling regulator output magnitude (or the regulating travel or setting angle) proving a
5 _ correctly functioning valve 16 does not then result, a suitable warning can be communicated to the driver. For example, the driver can be notified by way of a diagnostic lamp that workshop attention is needed.

3) If the test indicates that the valve is functioning correctly the
10 start counter is reset to zero.

4) After the test decision, the valve 16 is immediately driven open again. It is also opened if a dip in engine speed or an infringement of the afore-mentioned boundary conditions takes place during the course of the test. By this means it is ensured that even
15 abrupt accelerator pedal changes (acceleration steps) are accepted at once.

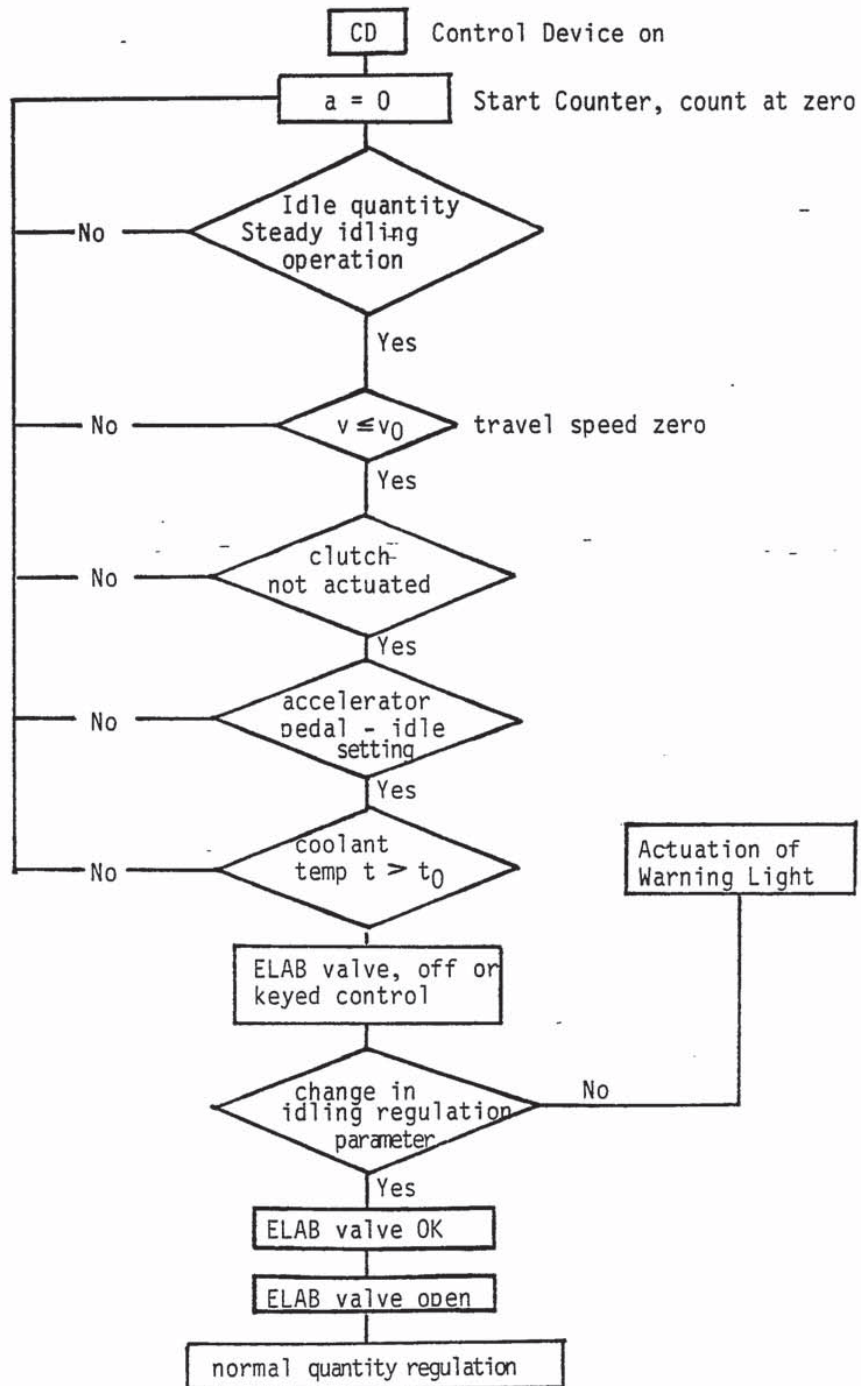
Alternatively, it is possible in place of complete closing of the valve 16 ELAB to key its operation by an appropriate drive over time in accordance with a preset function; thus, for example, the
20 valve can be opened for 60% of the time and closed for 40% of the time.

Since about half of the fuel flowing into the injection pump in the feed is injected, whilst the other half in normal operation is conducted through an overflow back to the tank, sufficient quantity
25 is always available even during keyed valve operation in order to correctly develop the injection processes. It is merely the overflow quantity that is reduced.

On the other hand, changes in feed pressure will also lead to quantity changes, which as a disturbing magnitude are regulated out in the idling regulator circuit and therefore in turn lead to corresponding reactions in the idling regulator output magnitude
5 (or in the regulating travel or setting angle). These reactions are evaluated for the checking of the operational function of the valve 16 in the manner described above.

The following flow diagram shows an example of the ELAB test realised in a computer as a program course (sub-program).

SUB-PROGRAM ELAB TEST



CLAIMS

1. A method of monitoring the integrity of an electromagnetic safety valve responsive to a fault condition to cut off fuel feed in a vehicle internal combustion engine with electronically regulated fuel metering, the method comprising the steps of completely or partially interrupting fuel feed by way of the valve during steady idling of the engine in normal vehicle travel operation and evaluating consequent change in an idling regulation parameter as an indication of correct functioning of the valve.
2. A method as claimed in claim 1, wherein the indication is provided by rise in an idling regulator output magnitude.
3. A method as claimed in claim 1, wherein the indication is provided by an increased travel of a regulating component in fuel injection pump means.
4. A method as claimed in claim 1, wherein the indication is provided by an increased setting angle of a regulating component in fuel distributor pump means.
5. A method as claimed in any one of the preceding claims, comprising the steps of recognising steady idling of the engine when the conditions are satisfied that a start counter has exceeded a preset threshold, the injection quantity lies in a predetermined normal range for engine idling, the vehicle travel speed is equal to zero or below a minimum threshold, the vehicle transmission is in neutral and the vehicle

accelerator pedal is in the idle setting.

6. A method as claimed in claim 5, comprising the step of recognising steady idling of the engine when the further condition is satisfied that water temperature indicates that the engine is warm.

5 7. A method as claimed in either claim 5 or claim 6, comprising the steps of discontinuing fuel feed interruption by the valve if any one of the conditions ceases to be satisfied and resuming the fuel feed interruption when steady idling is again recognised.

8. A method as claimed in any one of claims 5 to 7, comprising the
10 steps of resetting the counter to zero and opening the safety valve after indication of correct functioning of the valve.

9. A method as claimed in claim 1 and substantially as hereinbefore described with reference to the accompanying drawing.

10. Monitoring means for monitoring the integrity of an electromagnetic
15 safety valve responsive to a fault condition to cut off fuel feed in a vehicle internal combustion engine with electronically regulated fuel metering, the monitoring means comprising test circuit means to detect steady idling of the engine and cause operation of the valve for complete or partial interruption of fuel feed during such
20 steady idling and to evaluate consequent change in an idling regulation parameter as an indication of correct functioning of the valve.

11. Monitoring means as claimed in claim 10, wherein the indication is provided by rise in an idling regulator output magnitude or by an increased travel or setting angle of a regulating component in pump means.

5 12. Monitoring means substantially as hereinbefore described with reference to the accompanying drawing.