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Young et al.

[11] **3,915,134**

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[54] **EXHAUST GAS RECIRCULATION SYSTEM FOR INTERNAL COMBUSTION ENGINES**

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[21] Appl. No.: **447,573**

[52] **U.S. Cl.** .... **123/119 A**; 123/119 A
[51] **Int. Cl.²** **F02M 25/06**
[58] **Field of Search** .... 123/119 A

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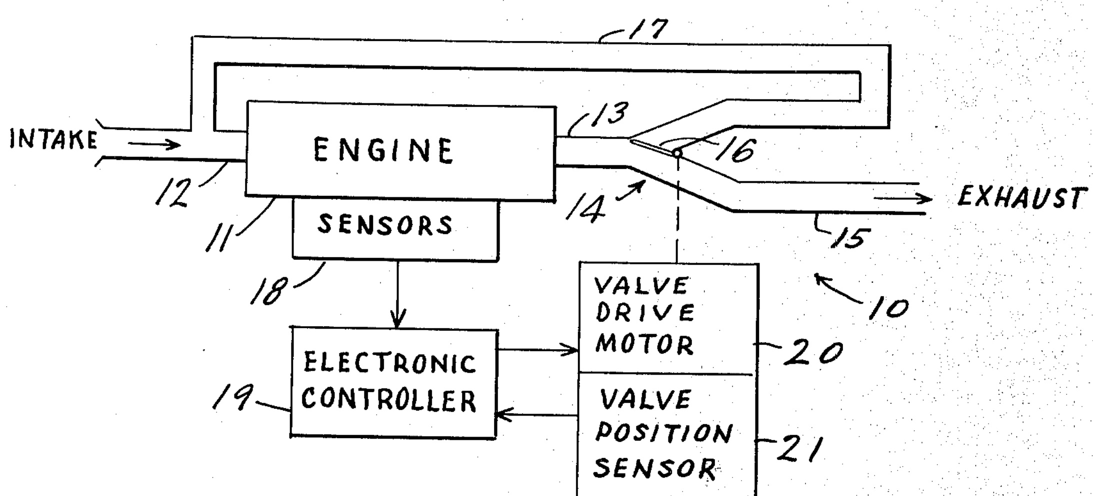
Assistant Examiner—David D. Reynolds
Attorney, Agent, or Firm—Oliver E. Todd, Jr.

[57] **ABSTRACT**

Apparatus for electronically controlling exhaust gas recirculation in an internal combustion diesel engine to reduce nitrogen oxide emissions. An exhaust gas recirculation control valve is driven by a feedback circuit which compares the valve position with the engine load. A maximum amount of exhaust gas is recirculated under a no-load condition. As the load increases to 100%, the amount of recirculated exhaust gas is decreased down to zero percent. The amount of recirculated exhaust gas also may be affected by the engine speed to minimize smoke in the engine exhaust.

10 Claims, 5 Drawing Figures



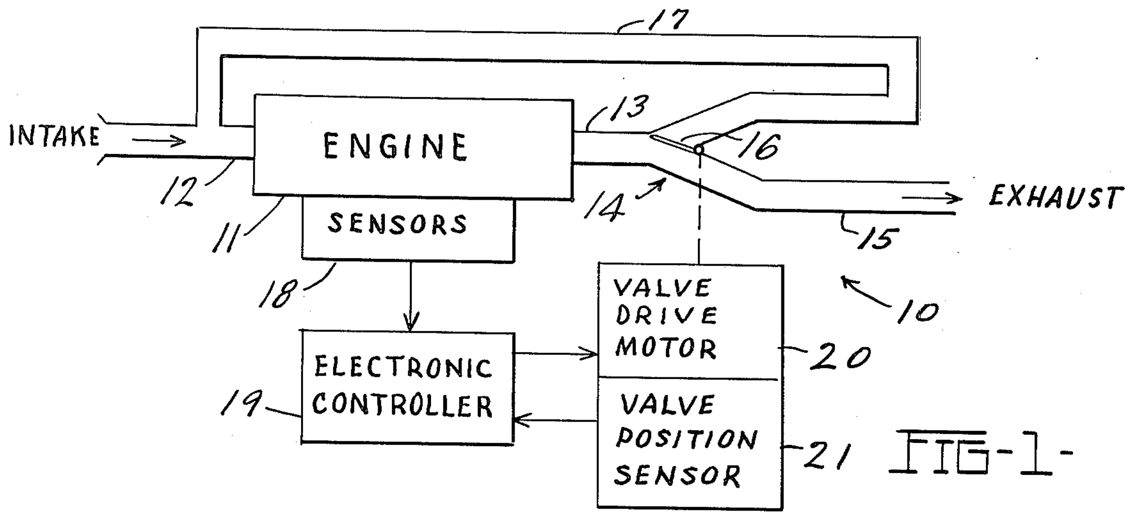


FIG-1-

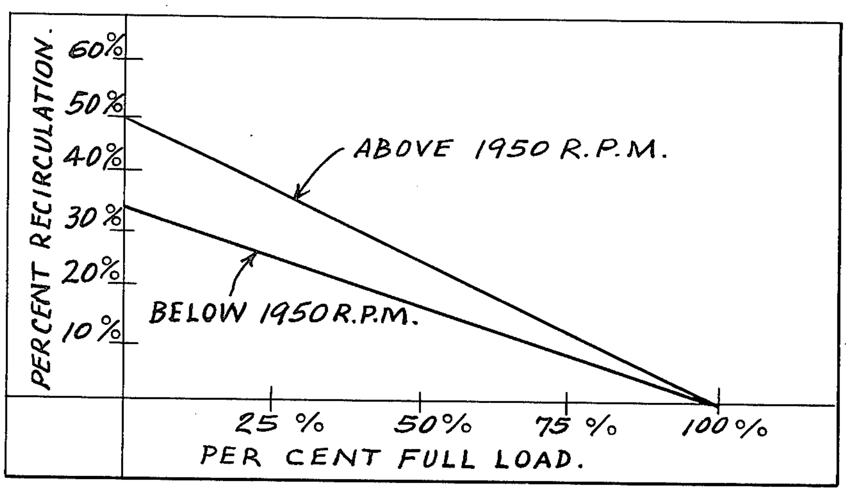


FIG-4-

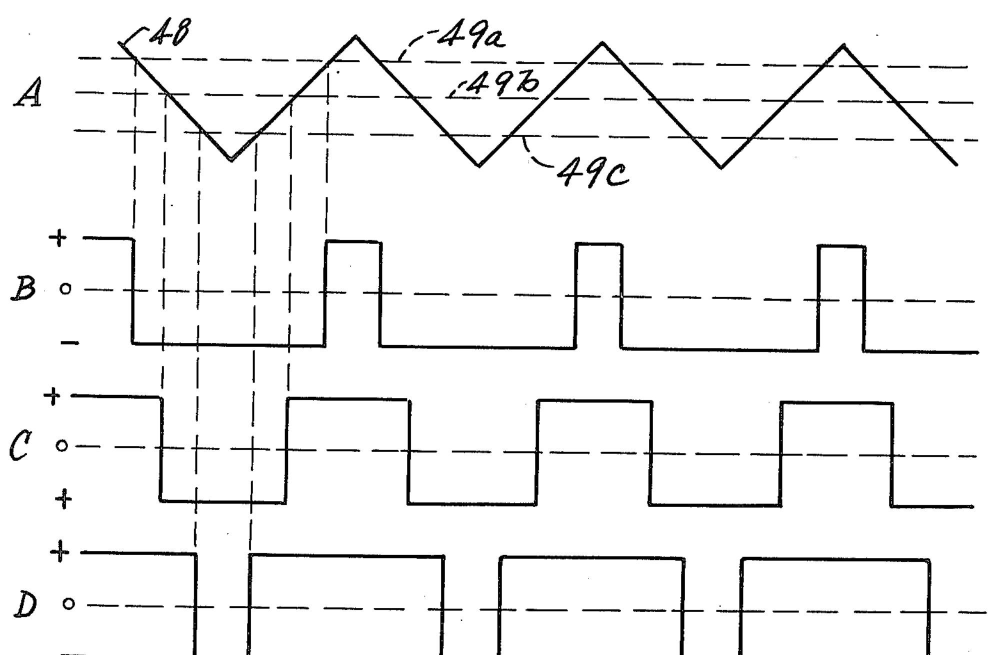


FIG-3-

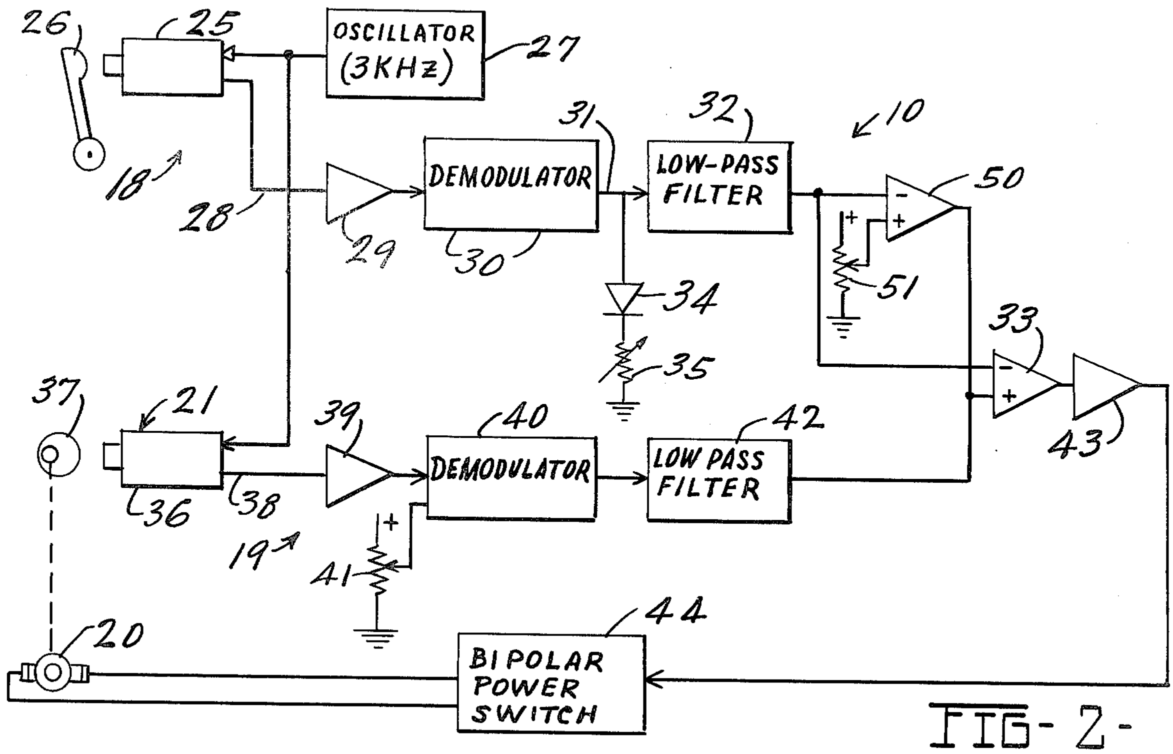

OSCILLATOR (3KHz)
DEMODULATOR
LOW-PASS FILTER
DEMODULATOR
LOW PASS FILTER
BIPOLAR POWER SWITCH
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FIG-2-

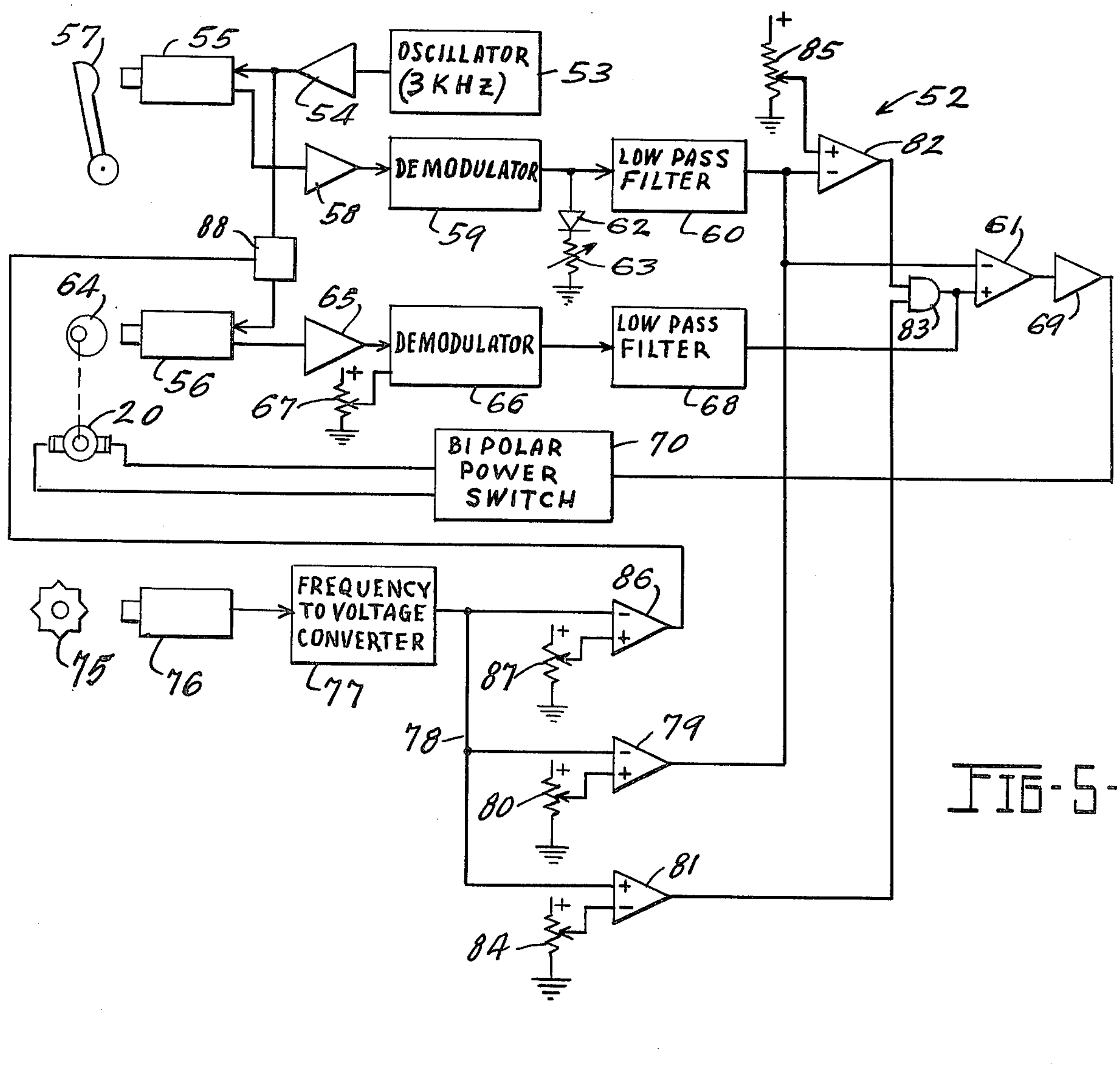
OSCILLATOR (3KHz)
DEMODULATOR
LOW PASS FILTER
DEMODULATOR
LOW PASS FILTER
BIPOLAR POWER SWITCH
FREQUENCY TO VOLTAGE CONVERTER
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FIG-5-

EXHAUST GAS RECIRCULATION SYSTEM FOR INTERNAL COMBUSTION ENGINES

BACKGROUND OF THE INVENTION

This invention relates to controlling exhaust gas emissions from internal combustion diesel engines and in particular to controlling the emission of oxides of nitrogen in such exhaust gas. The worldwide population increase and the uncontrolled increased use of mechanization in everyday living has caused increased concern about the environment. Governments have only recently been regulating to protect the environment from pollutants such as those produced by internal combustion engines. The exhaust from internal combustion engines consists of various constituents including fully oxidized products of combustion such as carbon dioxide and water plus undesirable pollutants such as partially oxidized, cracked and other hydrocarbons, carbon monoxide, oxides of nitrogen and traces of miscellaneous other pollutants. The carbon dioxide and water emissions are unharmful. However, the other exhaust emission constituents are considered highly undesirable.

It is generally understood that the presence of nitrogen oxides in engine exhaust is determined by the combustion temperature. An increase in combustion temperature causes an increase in the amount of nitrogen oxides present in the engine exhaust. It is therefore desirable to control the combustion temperature to limit the oxides of nitrogen present in the exhaust of an internal combustion engine. One method suggested in the prior art for limiting or controlling the combustion temperature has been to recirculate a portion of the exhaust gas back to the engine air intake. Since the exhaust gas is low in oxygen, this will result in a richer combustion mixture which will burn at a lower temperature. The lower combustion temperature will, in turn, reduce the amounts of nitrogen oxides produced during combustion.

The operating conditions which result in the highest combustion temperatures depend upon the type of internal combustion engine. In a spark-ignited gasoline engine, for example, the combustion temperature will be at a low point during idle. The temperature will also be at a low point at wide open throttle since engines of this type will normally have a rich fuel mixture under this condition. Ideally, there should be no exhaust gas recirculation while the engine is idling. From an idle, the amount of recirculated exhaust gas should increase up to a partial load condition and decrease from such partial load condition to a wide open throttle. In a diesel engine, on the other hand, a maximum combustion temperature occurs during a no-load condition at idle. Therefore, it is desirable to have a maximum amount of exhaust gas recirculation during idle and to decrease this amount as the load increases to 100% of the rated load.

Various types of controls for exhaust gas recirculation have been suggested in the prior art. U.S. Pat. No. 2,456,213 which issued on Dec. 14, 1948 to Plec, for example, teaches an early type control system for use with a diesel engine. In this system, the recirculated exhaust gas flows through two separate series connected valves. One valve is pneumatically controlled in response to the intake manifold vacuum and the other valve is mechanically controlled in response to engine speed. The net result of the two controls is that the recirculated exhaust gas is controlled in response to engine load, which is a function of both intake vacuum and engine speed. In another prior art recirculation control system, such as is shown in U.S. Pat. No. 3,703,164 which issued on Feb. 19, 1971 to Weaving, a third valve is provided for each cylinder for introducing exhaust gas directly into the cylinder. A mechanical valve is provided in series between the engine exhaust and all of the valves which introduce the exhaust gas into the cylinders to control the amount of exhaust gas recirculated. Various systems have also been adapted to spark-ignited internal combustion engines. However, each of the prior art recirculation systems has incorporated a mechanical control operating from devices such as cams, centrifugal speed sensors, pneumatic vacuum or pressure sensors, and the like. Although prior art systems reduce the nitrogen oxide components in engine exhaust gas, they generally will not produce an accurate control resulting in a minimum amount of nitrogen oxide under all operating conditions and all use mechanical controls which can be unreliable.

SUMMARY OF THE INVENTION

According to the present invention, an electronic control is provided for exhaust gas recirculation in internal combustion engines. The control is particularly suitable for meeting the various requirements of a diesel engine to reduce nitrogen oxide emissions. The control includes a sensor which measures the load on the engine. The engine load signal is used as a primary control over the position of an exhaust gas recirculation valve. Preferably, a feedback circuit is provided for sensing the position of the exhaust gas recirculation valve. The valve position is compared with the engine load for generating a signal which operates a valve drive motor. The control circuit is also provided with means for maintaining the recirculation valve wide open or in a maximum recirculation condition whenever the load is at a minimum or the engine is idling.

The control may also be modified to further increase its efficiency in reducing nitrogen oxide and other emissions. An engine speed sensor may be provided for modifying at higher engine speeds the rate at which the exhaust gas recirculation valve is closed under increasing load conditions. The speed sensor may further be adapted to assure that the recirculation valve is closed when a predetermined maximum engine speed is exceeded and the load on the engine is simultaneously at a minimum, as when the engine is coasting at a high speed. Such controls will have the advantage of not only minimizing the nitrogen oxide emissions, but also minimizing the amount of smoke produced by the engine which, although not considered highly harmful, is also undesirable.

Accordingly, it is a preferred object of the invention to provide an electronic control over exhaust gas recirculation in internal combustion engines to minimize nitrogen oxide emissions.

A further object of the invention is to provide an improved exhaust gas recirculation system for diesel engines.

Still another object of the invention is to provide an improved exhaust gas recirculation control for diesel engines which operates at maximum efficiency under various conditions of load and engine speed for reducing nitrogen oxide emissions.

Other objects and advantages of the invention will become apparent from the following detailed description, with reference being made to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic block diagram of an internal combustion engine incorporating an exhaust gas recirculation system constructed in accordance with the present invention;

FIG. 2 is a detailed schematic block diagram of an exhaust gas recirculation control constructed in accordance with a first embodiment of the invention;

FIG. 3 is a graph showing typical signals generated for operating the drive motor for the exhaust gas recirculation valve;

FIG. 4 is a chart showing typical operating characteristics for a second embodiment of a control for an exhaust gas recirculation system according to the present invention; and

FIG. 5 is a detailed schematic block diagram of the second embodiment of an exhaust gas recirculation control according to the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Turning now to the drawings and particularly to FIG. 1, a block diagram is shown for an exhaust gas recirculation system **10** embodying the principles of the present invention. The system **10** is shown connected to a conventional diesel engine **11** which, for example, may be of the type used in trucks, construction machinery and the like. The diesel engine **11** is provided with an air intake **12** and an exhaust gas outlet **13**. The exhaust gas outlet **13** is connected through a valve **14** to an exhaust pipe **15** which leads to the atmosphere. The exhaust pipe **15** may include a sound muffling system (not shown). The valve **14** includes an adjustable flap **16** which diverts a controlled portion of the exhaust gas through a return pipe **17** to the air intake **12**.

One or more sensors **18** are connected to the engine **11** for measuring at least the engine load and, in a preferred embodiment, also the engine speed. The output of the sensors **18** is applied to an electronic controller **19** which drives a motor **20** for positioning the valve flap **16**. A feedback circuit is preferably provided for assuring a positive operation of the exhaust gas recirculation system **10**. The feedback circuit includes a valve position sensor **21** which applies a signal to the electronic controller **19** which corresponds to the position of the valve flap **16**. The electronic controller **19** is designed to compare the signal corresponding to the actual position of the valve flap **16** with a desired position as determined by the engine load conditions monitored by the sensors **18** and to use a resultant signal for driving the valve drive motor **20**. Generally, the electronic controller **19** drives the motor **20** to position the valve flap **16** for permitting a predetermined maximum amount of exhaust gas recirculation under a no-load condition and to linearly decrease the amount of exhaust gas recirculation by closing the valve flap **16** as the engine load increases until at 100% rated load substantially no exhaust gas is recirculated through the return pipe **17**. The electronic controller **19** is also provided with means for assuring that the valve flap **16** is at its maximum open position for recirculating a maximum amount of exhaust gas whenever either the engine load or the engine speed is less than a predetermined amount. This will assure that the valve flap **16** will remain open during idle of or minimum load on the engine.

Referring now to FIG. 2, a schematic block diagram is shown for the exhaust gas recirculation system **10** with details of connections for an electronic controller **19** for performing the above-described functions. As previously indicated, it is necessary to sense the load on the engine. For a diesel engine, the load may be readily measured from the position of the rack which controls the amount of fuel injected into each cylinder. The rack position may be measured by various conventional manners. For example, a linear voltage differential transformer may be connected to have a core move by the rack. However, this arrangement has the disadvantage of placing a load on the rack which may affect the engine operation, particularly where the rack position is adjusted by a sensitive governor. Preferably, the rack position is determined by a proximity detector or other device which need not be connected directly to the rack.

As shown in FIG. 2, the load sensor **18** consists of a proximity probe **25** which senses the location of a cam surface **26** carried by the rack (not shown). An oscillator **27** is connected to provide a relatively low frequency alternating current signal to an input of the proximity probe **25**. The alternating current signal may, for example, be on the order of 3 kHz., although the frequency is not critical and will depend upon the probe design. The proximity probe **25** will then have an output **28** of the same frequency as that of the oscillator **27** and of a magnitude which is inversely dependent upon the spacing from the cam **26**.

The output **28** from the probe **25** is connected through a buffer amplifier **29** to a demodulator **30** which may, for example, consist of a half wave rectifier. The demodulator **30** has an output **31** which is applied through a low pass filter **32** to one input of a compare circuit **33**. The low pass filter **32** should have a sufficiently low cut-off as to filter any engine vibrations present on the cam **26**. The low pass filter **32** is designed to only partially filter the demodulator output **31**, leaving a ripple on the signal applied to the compare circuit **33** which is of the same frequency as the output from the oscillator **27**. The output **31** from the demodulator **30** is also connected through a diode **34** and a variable resistor **35** to ground. The variable resistor **35** may be used for adjusting the gain or load span over which the exhaust gas recirculation valve **14** is operated.

The output from the oscillator **27** is also connected to the valve position sensor **21** which consists of a proximity probe **36**. A cam **37** is connected to be driven by the valve drive motor **20** along with the adjustable valve flap **16**. The proximity probe **36** senses the spacing to the cam **37** and generates an output **38** which is inversely proportional to such spacing. Thus, the proximity probe output **38** will be of the same frequency as the output from the oscillator **27** and will increase in value as the cam **37** approaches the proximity probe **36**.

The proximity probe output **38** is connected through a buffer amplifier **39** to a demodulator **40**. A steady DC voltage is also applied to the demodulator **40** from a potentiometer **41** which is connected between a voltage source and ground. The steady DC voltage biases the demodulator **40** for establishing a zero point for the system **10.** The output of the demodulator **40** is connected through a low pass filter **42** to a second input of the compare circuit **33** for comparison with the output from the low pass filter **32.** In a typical diesel engine, the peak engine vibration is on the order of between **20** Hz. and **50** Hz. Such vibrations may cause the valve flap **16** to flutter and therefore should be filtered from the output **38** from the proximity probe **36.** It has been found that a cut-off frequency of **33** Hz. for the low pass filter **42** is effective for applying a substantially constant signal to the compare circuit **33.** This signal has a magnitude which is determined by the position of the valve flap **16.**

The output of the compare circuit **33** is applied through an amplifier **43** to a bipolar power switch **44** which controls power to the valve drive motor **20.** The operation of the compare circuit **33** and the bipolar power switch **44** for operating the motor **20** may be more clearly understood by referring now to FIG. **3.** Graph A in FIG. **3** shows typical inputs appearing on the comparator **33.** The low pass filter **32** applies a signal **48** to the comparator **33** while the low pass filter **42** applies a signal of the type shown as **49a, 49b** or **49c** to the comparator **33.** The comparator **33** may consist of a Schmitt trigger which acts as a threshold detector and has one of two outputs, depending upon which of its two inputs is highest. If during the majority of the time the valve position signal is above or nearest the highest ripple level of the load signal **48** as shown at **49***a*, then a signal of the type shown in FIG. **3B** is applied to the bipolar power switch **44.** If the ripple level of the load signal **48** is **50%** above and **50%** below the valve position signal as shown at **49***b*, then a signal of the type shown in FIG. **3C** is applied to the bipolar power switch **44.** If the majority of the ripple in the engine load signal **48** is above the valve position signal, as shown at **49c**, then a signal of the type shown in FIG. **3D** is applied to the bipolar power switch **44.** The bipolar power switch **44** will apply a signal to the valve drive motor **20** similar to those shown in FIGS. **3B, C** and **D.** These signals alternate between equal positive and negative voltages. If the output of the bipolar power switch **44** is of the type shown in FIG. **3C**, then there will be a **50%** duty cycle and the motor **20** will stand still since the motor **20** is not capable of following the three kilohertz pulses and therefore will not oscillate. However, if a comparison of the valve position and the load indicates that the valve should be opened or closed, the duty cycle will change from that shown in FIG. **3C** towards one of those shown in FIGS. **3B** or **3D.** When the power applied to the motor **20** is of the format shown in FIG. **3B**, a negative input will be applied to the motor **20** for a greater period of time than a positive input and the motor **20** will be driven in one direction. When the power applied to the motor **20** is changed to the format shown in FIG. **3D**, the signal on the motor **20** will be positive for a greater time than it is negative and the motor will be driven in the opposite direction. As the valve flap **16** is driven to a position satisfying the demands of the engine load, the duty cycle of the power applied to the motor **20** will approach **50—50** and the motor torque and speed will decrease.

In general, the valve **14** should be operated in a linear fashion with linear load changes. It is desirable to have maximum recirculation of exhaust gas at no-load and to have a minimum recirculation at **100%** rated load with the amount of recirculation varying linearly between these points. Although the valve **14** may be of a linear type, it is less expensive to use a non-linear valve. Non-linearities in the operation of the valve **14** may then be compensated for by providing an appropriately shaped surface on the cam **37** which is rotated with the valve flap **16.**

As previously discussed, it is desirable to maintain maximum exhaust gas recirculation when the engine is supplying a minimum load. This may be accomplished by the addition of a second comparator **50** to the circuit of FIG. **2.** The comparator **50** compares the output of the low pass filter **32** with a fixed voltage obtained from a potentiometer **51.** The potentiometer **51** is used for establishing a trip point at which the recirculation valve **14** is driven to a fully open condition. When the engine fuel rack moves below the trip point, the output from the comparator **50** changes. This output is applied to the comparator **33** along with the valve position signal from the low pass filter **42.** The comparator **33** will then have a constant output regardless of its input from the low pass filter **32** and will cause the motor **20** to drive the valve **14** to its fully open state.

By adding additional controls over the positioning of the exhaust gas recirculation valve **14,** the exhaust gas recirculation system **10** may be made even more efficient. For example, a diesel engine is typically operated in the range of **1,800** to **2,800** rpm. If the engine is used, for example, in a truck, the maximum normal operating speed may be exceeded when the truck is coasting down a hill. During coasting, the driver will normally let up on the accelerator. Since the rack indicates a no-load condition, the exhaust gas recirculation valve **14** will normally be driven fully open. Under these conditions, the engine may emit smoke when the driver again hits the accelerator. Therefore, a control may be added to drive the exhaust gas recirculation valve **14** to a fully closed position when the engine is under a no-load condition and the engine speed exceeds a preselected maximum speed, such as **3,000** rpm. A control may also be provided to drive the exhaust gas recirculation valve **14** to a fully open position at a preselected minimum engine speed, such as **1,200** rpm, regardless of the load on the engine. Still another control may be provided to minimize smoke in the normal operating range, which, although being appreciably less harmful than nitrogen oxide emissions, is undesirable. It has been determined that less exhaust gas recirculation can be tolerated at lower engine speeds than at higher engine speeds to prevent the engine from smoking. This is due primarily to the fact that at higher engine speeds a considerably higher volume of air passes through the engine. Therefore, a control may also be added to shift the linear curve on which the exhaust gas recirculation valve **14** is operated in response to a predetermined engine speed. For example, smoking may be minimized if the exhaust gas recirculation valve **14** recirculates between **35%** and **0%** of the exhaust gas when the engine is operating between zero load and full load below **1,950** rpm and to recirculate between **50%** and **0%** of the exhaust gas when the engine is operating between no-load and full load above **1,950** rpm. This type of operation of the exhaust gas recirculation valve **14** is shown in the graph in FIG. **4.**

Turning now to FIG. **5,** a detailed block diagram is shown for apparatus **52** including the above-described controls. The apparatus **52** includes an oscillator **53** having an output applied through a buffer amplifier **54** to the inputs of proximity probes **55** and **56.** The proximity probe **55** is mounted to measure the position of a cam or lobe **57** carried by the fuel rack (not shown) which controls the fuel injectors in a diesel engine. The output of the proximity probe **55** is in the form of an alternating current signal having a level inversely proportional to the spacing to the cam **57** and the same frequency as the oscillator **53.** This output is applied through an amplifier **58** to a demodulator **59.** The output of the demodulator **59** is filtered by means of a low pass filter **60** and applied to one input of a comparator **61.** The gain of the signal applied to the comparator **61** may be controlled by means of a diode **62** and a variable resistor **63** connected between the input of the low pass filter **60** and ground in a manner similar to that described above for FIG. **2.**

The proximity probe **56** is connected to measure the spacing to a cam **64** which is driven by the valve drive motor **20** along with the flap **16** of the exhaust gas recirculation valve **14.** The alternating current output from the proximity probe **56,** which is indicative of the position of the valve **14,** is applied through an amplifier **65** to a demodulator **66.** A DC voltage is applied from a potentiometer **67** to the demodulator **66** for zeroing the apparatus **52.** The output from the demodulator **66** is applied through a low pass filter **68** to a second input of the comparator **61.** The output of the comparator **61,** which alternates between two levels, is applied through an amplifier **69** and a bipolar switch **70** for driving the valve motor **20.** The operation of the circuitry described so far for FIG. **5** is the same as that described above for the circuitry shown in FIG. **2.** However, a number of additional controls are added for further reducing both smoke and nitrogen oxide emissions.

The additional controls added in FIG. **5** require a signal indicative of the speed at which the engine is running. Therefore, a lobed cam **75** is mounted to be driven by the engine. A magnetic pickup **76** is positioned adjacent the lobed cam **75** for generating a pulse train having a frequency proportional to the engine speed. The output of the magnetic pickup **76** is applied to a frequency-to-voltage converter **77** which generates a DC output **78** having a voltage level proportional to the engine speed.

The converter output **78** is applied to one input of a comparator **79.** A second input to the comparator **79** is a fixed voltage determined by a potentiometer **80.** The comparator **79** will have one of two outputs which depend upon whether or not the converter output **78** is above or below the voltage set by the potentiometer **80.** The potentiometer is adjusted such that the output from the comparator **79** will change levels at a relatively low engine speed, such as **1,200** rpm. The output from the comparator **79** is applied along with the output from the low pass filter **60** to the comparator **61.** When the output from the comparator **79** changes due to the engine dropping below the preset speed, a signal is applied to the comparator **61** to drive the valve **14** to a fully opened condition, allowing a maximum amount of exhaust gas recirculation regardless of the position of the engine fuel rack. When the preset speed is exceeded, the comparator **79** will not affect operation of the exhaust gas recirculation valve **14.** Thus, the magnetic speed pickup **76,** the converter **77** and the comparator **79** function to assure that the valve **14** is fully opened whenever the engine is idling, regardless of load on the engine.

As previously indicated, another desirable operating condition is to have the valve **14** maintained in a fully closed position whenever the speed of the engine exceeds it normal operating range and simultaneously the fuel injection rack is at a minimum or low load setting. This is accomplished by means of a pair of comparators **81** and **82** and an AND gate **83.** The output **78** from the converter **77,** which is proportional to engine speed, is applied to one input of the comparator **81.** A potentiometer **84** applies a fixed voltage to the second input of the comparator **81** for determining the engine speed at which the output from the comparator **81** changes. Typically, the potentiometer **84** will be adjusted such that the output from the comparator **81** changes levels when the engine speed slightly exceeds its normal operating range, such as **3,000** rpm. The output from the comparator **81** is applied to one input of the AND gate **83.** The comparator **82** has one input which is connected to the output of the low pass filter **60,** which output is indicative of the position of the fuel injection rack, and a second input connected to a fixed DC voltage source such as a potentiometer **85** connected between a voltage source and ground. The potentiometer **85** is adjusted such that the output of the comparator **82** will change when the fuel injection rack is positioned for a minimum load. When the output of the comparator **81** indicates that the engine speed has exceeded the preselected maximum value and the output of the comparator **82** indicates that the fuel injection rack is at a predetermined minimum load position, the AND gate **83** will apply a signal to the comparator **61** for causing the motor **20** to drive the valve to a fully closed position. Thus, there will be minimal exhaust gas recirculation under these conditions. This will prevent the engine from emitting a cloud of smoke when the engine is again accelerated.

The output **78** from the converter **77** is also connected to a third comparator **86.** A potentiometer **87** applies a fixed DC voltage to a second input of the comparator **86.** The potentiometer **87** is adjusted such that the output from the comparator **86** changes when the engine passes through a preselected midrange speed, such as **1,950** rpm. When this preselected speed is exceeded, the comparator **86** sinks current from an attenuator **88** and reduces the oscillator signal to the proximity probe **56,** thereby shifting the linear curve along which the valve **14** is operated. As previously discussed, two typical curves are shown in the graph of FIG. **4** for the operation of the valve **14.** When the engine is run below **1,950** rpm, the maximum exhaust gas recirculation for one engine was found to be about **35%** for no-load for providing a good balance between smoke and nitrogen oxide pollutants. Thus, at idle or any speed below **1,950** rpm, about **35%** of the exhaust gas is recirculated for a no-load condition of the engine. As the load on the engine increases to **100%** of its rated value, the recirculated exhaust gas is linearly decreased to **0%** or to some other predetermined low level. At higher engine speeds, additional exhaust gas may be recirculated without having adverse affects on engine smoking. Therefore, above **1,950** rpm, about **50%** of the exhaust gas is recirculated for a no-load condition and this is decreased linearly to **0%** recirculation for a **100%** load. It will, of course, be appreciated that these percentages may vary for any given engine as well as the engine speed at which the curves are shifted. Furthermore, there may be several shifts in the recirculation curve for different engines or the curve may vary continuously with engine speed.

Although not shown in the drawings, it will be appreciated that various other modifications may be made in the above-described exhaust gas recirculation system. For example, it may be desirable to protect the motor when the valve is driven to a fully open or a fully closed position. This could be accomplished, for example, by the addition of circuitry which places a limit on the maximum time at which the motor can be operated at full power in either direction and to then reduce the current. This will not only protect the motor when it is driven fully closed or fully opened, but is would also protect the motor should the valve become jammed.

It should also be appreciated that the above-described exhaust gas recirculation system may also be adapted for use with other types of internal combustion engines, such as spark-ignited gasoline engines. The conditions under which the exhaust gas recirculation is controlled will, of course, be modified for the requirements of any particular engine. For example, a spark-ignited gasoline engine may require maximum recirculation at a mid-speed range rather than at minimum load and idle conditions.

Various other modifications and changes may be made to the present invention without departing from the spirit and the scope of the following claims.

What we claim is:

1. For an internal combustion engine having an air intake and an exhaust, an exhaust gas emission control system comprising, in combination, valve means for selectively recirculating a portion of the exhaust gas to the air intake, said valve means moving between a first position wherein a predetermined maximum amount of the exhaust gas is recirculated and a second position wherein a predetermined minimum amount of the exhaust gas is recirculated, means for generating an electric signal indicative of a load on the engine, and electrical means positioning said valve means at predetermined intermediate positions between said first and second positions in response to such signal for reducing the oxides of nitrogen present in the engine exhaust gas.

2. An exhaust gas emission control system for an internal combustion engine, as set forth in claim **1**, wherein said valve positioning means includes electrical control means for moving said valve means to said first position when the load on the engine is less than a predetermined value and for moving said valve means progressively towards said second position as the load progressively increases above such predetermined value.

3. An exhaust gas emission control system for an internal combustion engine, as set forth in claim **2**, and further including means for moving said valve means to said first position when the engine is running at less than a predetermined minimum speed.

4. An exhaust gas emission control system for an internal combustion engine, as set forth in claim **3**, and including means responsive to such electric signal and to the engine speed for moving said valve means to said second position when the load on the engine is less than a predetermined value and simultaneously the engine exceeds a predetermined speed.

5. An exhause gas emission control system for an internal combustion engine, as set forth in claim **4**, and further including means responsive to the speed of the engine for modifying said predetermined maximum amount of exhaust gas recirculated when said valve means is in said first position.

6. An exhaust gas emission control system for an internal combustion engine, as set forth in claim **1**, including means for generating an electric signal indicative of the position of said valve means, and wherein said valve positioning means includes an electric motor connected to drive said valve means, means for comparing said engine load signal and said valve position signal and means responsive to such comparison for controlling said valve drive motor.

7. An exhaust gas emission control system for an internal combustion engine, as set forth in claim **6**, wherein said valve positioning means further includes means responsive to said engine load signal for generating a third signal when the load on the engine is less than a predetermined minimum, and means for causing said valve drive motor to move said valve means to said first position in response to said third signal.

8. An exhaust gas emission control system for an internal combustion engine, as set forth in claim **6**, and further including means for generating an electric signal when the engine is running at less than a predetermined minimum speed, and means for causing said valve drive motor to move said valve means to said first position in response to said minimum speed signal.

9. An exhaust gas emission control system for an internal combustion engine, as set forth in claim **6**, and further including means for generating an electric signal when the load on the engine is less than a predetermined minimum, means for generating an electric signal when the engine speed exceeds a predetermined maximum, and means responsive to the simultaneous occurrence of said minimum load signal and said maximum speed signal for causing said valve drive motor to move said valve means to said second position.

10. An exhaust gas emission control system for an internal combustion engine, as set forth in claim **6**, and further including means for generating a third electrical signal when the engine exceeds a predetermined speed, and means responsive to said third signal for increasing said predetermined maximum amount of exhaust gas recirculated when said valve means is in said first position.

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