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INSTALLATION FOR REGULATING AN INTERNAL COMBUSTION ENGINE OPERATING ACCORDING TO A RECIRCULATING METHOD, ESPECIALLY UNDERWATER CRAFTS

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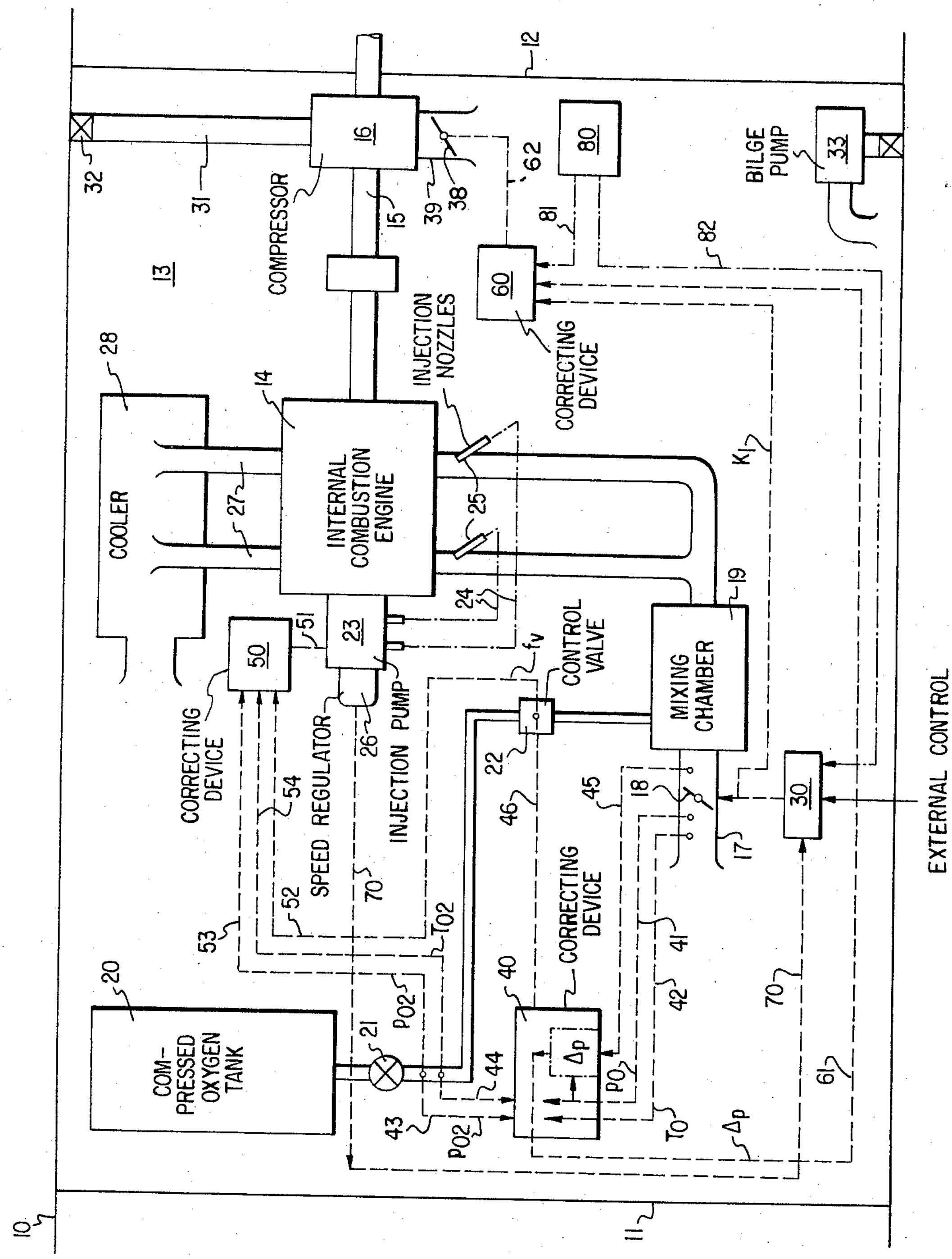

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INSTALLATION FOR REGULATING AN INTERNAL COMBUSTION ENGINE OPERATING ACCORDING TO A RECIRCULATING METHOD, ESPECIALLY UNDERWATER CRAFTS

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ABSTRACT OF THE DISCLOSURE

In a recirculating exhaust internal combustion engine for underwater craft, the oxygen supply and the fuel supply are each controlled by separate correcting means dependent upon the prevailing position of the throttle valve. The oxygen valve correcting means is dependent upon the pressure and temperature of the oxygen ahead of the control valve and on the pressure and temperature of the sucked-in gases at the throttle valve. The fuel supply control correcting means is dependent upon the pressure and temperature of the oxygen upstream of the oxygen control valve.

Background of the invention

The operation of internal combustion engines according to the recirculating method and the application of this method, for example, for the propulsion of underwater crafts, is known in the prior art. The exhaust gases of the engine are thereby cooled back to about 60° to 120° C. Oxygen is admixed to a portion of the exhaust gases and the engine is operated in the customary manner by means of this thus admixed gas. The excess exhaust gases and the condensation water are forced out of the interior space into the exterior space by a compressor and a bilge pump.

With this known prior art installation, the control of the internal combustion engine takes place in such a manner that the pressure of the gas which the internal combustion engine draws in, is controlled or regulated by the compressor. If the compressor removes more gas out of the interior space than is newly produced by the oxygen and fuel supply, then the pressure decreases and the engine draws-in less fresh gas. The output of the engine drops. The oxygen supply is so regulated in this prior art construction that the fresh gas includes a predetermined percentage of oxygen. The fuel supply operates always with a fuel excess. In order to stabilize this regulation, it is necessary to install a non-changeable or non-adjustable throttling place into the suction line of the internal combustion engine. This throttling place offers a relatively small flow resistance at a small load and low rotational speed, however, with large loads and high rotational speeds it offers a high flow resistance (up to 1 kp./cm.^{2}). As a result thereof, two considerable disadvantages result for the internal combustion engine:

(1) With full load, the interior pressure which corresponds approximately to the exhaust counterpressure, has to be higher by more than one atmosphere (absolute excess pressure) than the inlet or suction pressure. A

relatively large amount of hot exhaust gases has to remain thereby in the combustion space and a customary scavenging of the compression space by the utilization of gas oscillations in the exhaust and inlet pipes becomes impossible. This results in a poor degree of filling, high starting temperatures for the compression, high combustion temperatures, sensitivity to knocking, etc.

(2) The compressor has to produce at idling speeds very high pressure conditions. Thus, for example, at 1/10 useful or service load during operation at 100 meters below the water surface, the gas has to be supplied from about 0.7 atmosphere to about 12 atmospheres. While the engine has a good degree of filling at this partial load point, the compressor has a poor charge efficiency so that—in order to compensate for the same with certainty—the compressor has to be constructed very large.

Summary of the invention

The present invention is concerned with the aim to avoid the aforementioned disadvantages, i.e., the internal combustion engine is to be thermally relieved at full load and the compressor is to be constructed smaller. The underlying problems are solved according to the present invention in that a movable throttle valve is arranged in the intake conduit or line of the internal combustion engine in a manner, known per se, and that at least the control members for the fuel supply and the oxygen supply are adjustable by way of connecting means and correcting members in dependence on the prevailing position of this throttle valve. It is thereby contemplated to keep the throttle valve—also as usual—in its open position during full load and in its closed position during idling operation.

With the regulation of the type according to the present invention, the open throttle valve has practically no resistance during full load so that the gas pressure in the interior space does not have to lie above the suction pressure. As a result thereof, an improved scavenging of the internal combustion engine can be achieved so that the latter does not become excessively hot and additionally exhibits a better efficiency. During idling the throttle valve has a higher resistance, i.e., the interior pressure is then larger than the suction pressure so that a good scavenging and good filling cannot be achieved. However, this plays no significant role by reason of the small thermal loading which is anyhow relatively small under those operating conditions. In contradistinction thereto, the interior pressure need not be lowered during idling, i.e., the compressor only has to bridge a considerably smaller pressure difference during idling operation. This has as a consequence that the operating and supply or charge efficiencies thereof are improved, i.e., the compressor can be constructed smaller over-all.

The present invention contemplates also to adjust the throttle valve itself from the outside by electrical pulses by means of a conventional servo-shifting or power-adjusting member. Of course, it is also within the scope of the present invention to mechanically actuate the throttle valve.

In a preferred embodiment according to the present invention, a control valve is arranged in the oxygen supply line to which is coordinated or with which is operatively associated a correcting member in such a manner that the regulating path of this valve is controllable by conventional means in dependence on the pressure and temperature of the oxygen ahead of the valve, on the pressure and temperature of the sucked-in gas upstream of the throttle valve as well as on the pressure difference at this throttle valve. The mathematical interrelationship of this regulation may be represented approximately by the following equation with an over-critical pressure condition at the regulating valve:

$$f_v = K_1 \cdot F_{Dr} \cdot \frac{T_{o2} \cdot \sqrt{\Delta p_o \cdot p_o}}{p_{o2} \cdot \sqrt{T_o}} \quad (1)$$

Similarly, according to the present invention the fuel supply is adapted to be regulatable or controllable by conventional means to which is coordinated a correcting member in such a manner that the regulating adjustment is controllable in dependence on the regulating path of the oxygen valve as well as on the pressure and temperature of the oxygen in front of the valve. Also in this case, the mathematic interrelationship may be represented as follows:

$$S_R = f_v \cdot K_2 \cdot \frac{p_{o2}}{T_{o2}} \quad (2)$$

In the foregoing two formulae, the various symbols represent the following variables:

p_{o2}—Pressure of the oxygen upstream of the control valve;
T_{o2}—Temperature of the oxygen upstream of the control valve;
p_o—pressure of the sucked-in gas ahead of the throttle valve;
To—Temperature of the sucked-in gas ahead of the throttle valve;
Δp_o—Pressure difference at the throttle valve;
K_1—Angular position of the throttle valve;
F_{Dr}—Calibration factor of the throttle valve;
f_v—Regulating path at the oxygen control valve;
S_R—Regulating position at the fuel regulating member;
K_2—Matching factor.

According to a further development of the inventive concept, the supply quantity of the compressor is controllable in dependence on the pressure difference at the throttle valve within the suction line of the internal combustion engine or in dependence on the angular position of this throttle valve. For that purpose a throttle valve is then appropriately arranged for the regulation of the compressor itself in its suction pipe or intake conduit.

Furthermore, the present invention may be further refined in that the maximum pressure in the circulation system is adapted to be controllable or adjustable by a pressure sender or indicator of any conventional construction which, upon exceeding this maximum pressure, opens the throttle valve of the compressor and possibly additionally also acts on the throttle valve of the internal combustion engine. It is additionally of advantage if the interior space accommodating the internal combustion engine is itself included in the circulatory system and the exhaust gases are discharged into the same by way of a cooler or condenser and are sucked-in again out of this interior space by the internal combustion engine and the compressor.

Accordingly, it is an object of the present invention to provide a control system for regulating an internal combustion engine operating according to a recirculation method which eliminates by simple means the aforementioned shortcomings and drawbacks encountered with the prior art constructions.

Another object of the present invention resides in a control installation for an internal combustion engine of the type described above which assures a high degree of filling under normal operating conditions, low starting temperatures for the combustion as well as low combustion temperatures under full load.

A further object of the present invention resides in a control system for regulating an internal combustion engine operating according to a recirculation method which minimizes knocking sensitivity thereof.

Still another object of the present invention resides in a control system for internal combustion engines of the type described above in which the compressor can operate with high efficiencies while at the same time permitting small dimensions in its construction.

Another object of the present invention resides in a control system for regulating internal combustion engines operating according to the recirculating method in which thermal overloads are avoided with certainty under full load operation.

A further object of the present invention resides in a control system for internal combustion engines of the type described in which improved scavenging of the internal combustion engine can be achieved.

Brief description of the drawing

These and further objects, features, and advantages of the present invention will become more obvious from the following description when taken in connection with the accompanying drawing which shows, for purposes of illustration only, one embodiment in accordance with the present invention and wherein:

The single figure is a schematic diagrammatic view of a propulsion installation for a torpedo in accordance with the present invention.

Detailed description of the drawing

Referring now to the single figure of the drawing, reference numeral **10** designates therein the external pressure body of the torpedo within which an interior space **13** is closed off in a pressure-tight manner by means of the transverse bulkheads **11** and **12**. The interior space **13** contains the entire engine installation and control system. The internal combustion engine **14** drives, by means of its shaft **15** the compressor **16**, and, of course, also the propellers of the torpedo (not shown).

A throttle valve **18** is arranged in the inlet pipe or conduit **17** of the internal combustion engine **14**. The throttle valve **18** is arranged and is to be actuated in substantially the same manner as with a normal internal combustion engine. In the instant case, its actuation may take place, for example, electrically by electrical pulses transmitted either by wire or wireless or mechanically by way of a cable which connects the torpedo with its carrier, for example, a submarine.

A mixing chamber **19** is provided in the inlet conduit **17** within which the sucked-in exhaust gases are mixed with fresh oxygen. The fresh oxygen is stored under high pressure in a tank **20**. The oxygen is supplied by way of a pressure-reducing valve **21** of conventional construction as well as by way of a control valve **22** again of conventional construction to the mixing chamber **19**. The control valve **22** is adapted to be controlled in the manner described above from the throttle valve **18** and the aforementioned correcting members by any conventional means, as known in the art.

An injection pump **23** is coupled to the internal combustion engine **14** which supplies the fuel by way of the connecting lines **24** to the injection nozzles **25**. The injection pump **23** is provided with a rotational speed regulator or governor **26** of any conventional construction which limits the maximum rotational speed in the upward direction and the idling speed in the downward direction and which may serve additionally for maintaining possibly a desired predetermined intermediate rotational speed. For this purpose the rotational speed regulator **26** acts on the throttle valve **18** in a conventional manner. The injection pump **23** is controlled from the throttle valve **18** and from the aforementioned correcting members according to the considerations indicated above, however, always in such a manner that a fuel excess is present.

The exhaust gases of the internal combustion engine

14 are supplied by way of the exhaust pipes **27** to a cooler or condenser **28** and are cooled back therein to a temperature of about 60° to 120° C. The exhaust gases leave from the cooler **28** into the interior space **13** and are again sucked-in by the internal combustion engine out of the interior space **13** by way of the throttle valve **18**. The excess exhaust gases are sucked-in by the compressor **16** by way of its inlet conduit or pipe section **39**—in which a further throttle valve **38** is provided for its regulation—and are pumped into the outside through the line **31** by way of a check valve **32** of conventional construction. A bilge pump **33** may additionally be provided for the elimination of condensation water or the like.

The throttle valve **18** in the inlet connection **17** of the internal combustion engine **14** is open at full load. It offers practically no resistance in this position so that the internal pressure within the interior space **13** is equal to the suction pressure, which may lie, for example, corresponding to the desired charge at 2.7 atmospheres (absolute excess pressure). Since the exhaust counterpressure also corresponds essentially to the interior pressure, a good scavenging of the internal combustion engine is possible. In this manner, the internal combustion engine is relieved thermally. In contradistinction thereto, the throttle valve **18** offers a very high resistance during idling. It is therefore possible to start with the same interior pressure in order to obtain the considerably smaller suction pressure of the internal combustion engine during idling. In this manner, the compressor may start practically with a substantially constant interior pressure, for example, of 2.7 atmospheres at the greatest depth of water, or from the pressure naturally adjusting itself depending on the compressor size and the water depth. Consequently, the compressor may be dimensioned smaller.

While the control and regulating system according to the present invention uses conventional components to achieve the desired regulation as described above, a brief rescription thereof will follow hereinafter by reference to the schematic showing in the drawing.

Reference numeral **30** designates a conventional servo motor which actuates the throttle valve **18** in response to receipt of electrical pulses supplied externally. Such a system is well known per se in the art, and therefore its details are not shown and rescribed herein.

A correcting device generally designated by reference numeral **40**, also of conventional construction, is coordinated to the control valve **22** for the oxygen supply. Conventional temperature and pressure sensing devices are thereby arranged to determine the pressure and temperature of the sucked-in gases and of the oxygen, for example by being arranged in the inlet conduit **17** upstream of the throttle valve **18** and in the pipe system upstream of the control valve **22**. The pressure in the inlet connection **17** thus sensed is transmitted to the correcting device **40** by means indicated schematically by reference numeral **41** while the temperature of the sucked-in gases in the inlet connection **17** is transmitted to the correcting device **40** by means schematically indicated by reference numeral **42**. The pressure of the oxygen upstream of the control valve **22** is transmitted to the correcting device **40** by means schematically indicated by reference numeral **43** and the temperature thereof by means schematically indicated by reference numeral **44**. The pressure of the sucked-in gas downstream of the throttle valve is also sensed by a conventional pressure-sensing means located downstream of the throttle valve **18** and is transmitted to the correcting device **40** by means schematically indicated by reference numeral **45**. The adjustment of the control valve **22** from the correcting device **40** is realized by a suitable mechanical, hydraulic, pneumatic or electrical connection schematically indicated by reference numeral **46**.

A further correcting device generally designated by reference numeral **50** is operatively associated with the in-

jection pump **23** by way of a control linkage schematically indicated by reference numeral **51** which may again be mechanical, electrical, hydraulic or pneumatic in nature. As input to the correcting device **50** are fed the position of the control valve **22** by means indicated schematically by reference numeral **52** as well as the pressure and temperature of the oxygen by means schematically indicated by reference numeral **53** and **54**.

A still further correcting device generally designated by reference numeral **60** is coordinated to the control valve **30** or the compressor **16** by a linkage designated by reference numeral **62**, again of mechanical, electrical, hydraulic or pneumatic nature. Fed as input to the correcting device **60** by means schematically indicated by reference numeral **61** is the pressure difference of the gases suckd-in by the internal combustion engine **14** upstream of the throttle valve **18** and downstream thereof. This pressure difference may be obtained by utilizing again conventional sensing devices sensitive to pressure and installing the same at appropriate places in the inlet conduit **17** or by utilizing the pressure difference already obtained within the correcting device **40**.

An operative connection schematically indicated by reference numeral **70** operatively connects the speed regulator **26** with the servo-control **30** so as to adjust the speed of the internal combustion engine **14** in accordance with the control signals produced by the regulator **26** to limit the maximum and minimum speeds and possibly also to maintain a predetermined speed. Since the details of such controls are known, per se, in the prior art, a detailed description thereof is dispensed with herein.

A pressure indicator and transmitter generally designated by reference numeral **80**, which is adjusted to a predetermined maximum permissive pressure, is operatively connected by means schematically indicated at **81** with the correcting device **60** to adjust the latter for opening the throttle valve **30** when this maximum pressure is exceeded. The pressure indicator and transmitter, which is also of conventional construction, may also be operatively connected, by means indicated at **82** and shown in dash and dot lines, with the servo-member **30** to influence the throttle valve **18** in a corresponding appropriate manner.

The various correcting devices may be of any conventional construction. Since the details of their construction are well within the skill of any person familiar with such devices, a detailed description thereof is dispensed with herein.

While I have shown and described one embodiment in accordance with the present invention, it is understood that the same is not limited thereto but is susceptible of numerous changes and modifications as known to a person skilled in the art, and I therefore do not wish to be limited to the details shown and described herein but intend to cover all such changes and modifications as are encompassed by the scope of the appended claims.

I claim:

1. An installation for regulating an internal combustion engine operating according to the recirculating method, comprising means forming an interior space, internal combustion engine means within said interior space and including intake conduit means provided with adjustable throttle valve means, fuel supply and oxygen supply means for said internal combustion engine means, control means for said fuel supply means and control means for said oxygen supply means, and connecting means including correcting means for operating each of said control means in dependence on the prevailing position of said throttle valve means.

2. An installation according to claim **1**, further comprising means for adjusting said throttle valve means externally by electric pulses.

3. An installation according to claim **2**, wherein said internal combustion engine means propels an underwater craft.

4. An installation for regulating an internal combustion engine operating according to the recirculating method, comprising means forming an interior space, internal combustion engine means within said interior space and including intake conduit means provided with adjustable throttle valve means, fuel supply and oxygen supply means for said internal combustion engine means, control means for said fuel supply means and control for said oxygen supply means, and connecting means including correcting means for operating said control means in dependence on the prevailing position of said throttle valve means, means for adjusting said throttle valve means externally by electric pulses, said internal combustion engine means propelling an underwater craft, said oxygen supply means includes an oxygen supply line provided with control valve means, the correcting means being so coordinated to said last-mentioned control valve means that the control path of said control valve means is controllable in dependence on the pressure and temperature of the oxygen ahead of the control valve means, on the pressure and temperature of the sucked-in gases ahead of the adjustable throttle valve means as well as on the pressure difference at said throttle valve means.

5. An installation according to claim 4, wherein said control means adjust the fuel supply means, the correcting means being so coordinated to the control means for the fuel supply means that the control position of the fuel supply control means is controllable in dependence on the control path of the control valve means for the oxygen supply as well as on the pressure and temperature of the oxygen upstream of the control valve means thereof.

6. An installation according to claim 5, further comprising compressor means for expelling the excess exhaust gases to the outside, and further control means for controlling the supply quantity of said compressor means in dependence on one of the two magnitudes consisting of the pressure difference at said adjustable throttle valve means and angular position of said adjustable throttle valve means.

7. An installation according to claim 6, wherein said further control means includes further throttle valve means in the inlet connection of said compressor means.

8. An installation according to claim 7, further comprising regulating means for regulating the maximum pressure in the circulation system including pressure-indicating and transmitting means adjustable to a predetermined maximum pressure, and means operatively connecting said pressure-indicator and transmitter means with said further throttle valve means of the compressor means to open said further throttle valve means upon exceeding the maximum pressure and with said first-mentioned throttle valve means for adjusting also the latter.

9. An installation according to claim 8, wherein said interior space is itself included in the circulatory system, the exhaust gases being discharged by said internal combustion engine by way of a cooler into said interior space and are again sucked-in out of the interior space by said internal combustion engine means and by said compressor means.

10. An installation for regulating an internal combustion engine operating according to the recirculating method, comprising means forming an interior space, internal combustion engine means within said interior space and including intake conduit means provided with adjustable throttle valve means, fuel supply and oxygen supply means for said internal combustion engine means, control means for said fuel supply means and control means for said oxygen supply means, and connecting means including correcting means for operating said control means in dependence on the prevailing position of said throttle valve means, said oxygen supply means includes an oxygen supply line provided with control valve means, the correcting means being so coordinated to said last-mentioned control valve means that the control path of said control valve means is controllable in dependence on the pressure and temperature of the oxygen ahead of the control valve means, on the pressure and temperature of the sucked-in gases ahead of the adjustable throttle valve means as well as on the pressure difference at said throttle valve means.

11. An installation according to claim 10, wherein said control means adjust the fuel supply means, the correcting means being so coordinated to the control means for the fuel supply means that the control position of the fuel supply control means is controllable in dependence on the control path of the control valve means for the oxygen supply as well as on the pressure and temperature of the oxygen upstream of the control valve means thereof.

12. An installation according to claim 11, further comprising compressor means for expelling the excess exhaust gases into the outside, and further control means for controlling the supply quantity of said compressor means in dependence on one of the two magnitudes consisting of the pressure difference at said adjustable throttle valve means and angular position of said adjustable throttle valve means.

13. An installation according to claim 12, wherein said further control means includes further throttle valve means in the inlet connection of said compressor means. connection of said compressor means.

14. An installation according to claim 13, further comprising regulating means for regulating the maximum pressure in the circulation system including pressure-indicating and transmitting means adjustable to a predetermined maximum pressure, and means operatively connecting said pressure-indicator and transmitter means with said further throttle valve means of the compressor means to open said further throttle valve means upon exceeding the maximum pressure.

15. An installation for regulating an internal combustion engine operating according to the recirculating method, comprising means forming an interior space, internal combustion engine means within said interior space and including intake conduit means provided with adjustable throttle valve means, fuel supply and oxygen supply means for said internal combustion engine means, control means for said fuel supply means and control means for said oxygen supply means, and connecting means including correcting means for operating said control means in dependence on the prevailing position of said throttle valve means, said control means adjust the fuel supply means, the correcting means being so coordinated to the control means for the fuel supply means that the control position of the fuel supply control means is controllable in dependence on the control path of the control valve means for the oxygen supply as well as on the pressure and temperature of the oxygen upstream of the control valve means thereof.

16. An installation for regulating an internal combustion engine operating according to the recirculating method, comprising means forming an interior space, internal combustion engine means within said interior space and including intake conduit means provided with adjustable throttle valve means, fuel supply and oxygen supply means for said internal combustion engine means, control means for said fuel supply means and control means for said oxygen supply means, and connecting means including correcting means for operating said control means in dependence on the prevailing position of said throttle valve means, compressor means for expelling the excess exhaust gases into the outside, and further control means for controlling the supply quantity of said compressor means in dependence on one of the two magnitudes consisting of the pressure difference at said adjustable throttle valve means and angular position of said adjustable throttle valve means.

17. An installation according to claim 16, wherein said further control means includes further throttle valve means in the inlet connection of said compressor means.

18. An installation according to claim 16, wherein said interior space is itself included in the circulatory system, the exhaust gases being discharged by said internal combustion engine by way of a cooler into said interior space and are again sucked-in out of the interior space by said internal combustion engine means and by said compressor means.

19. An installation according to claim 17, further comprising regulating means for regulating the maximum pressure in the circulation system including pressure-indicating and transmitting means adjustable to a predetermined maximum pressure, and means operatively connecting said pressure-indicator and transmitter means with said further throttle valve means of the compressor means to open said further throttle valve means upon exceeding the maximum pressure.

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