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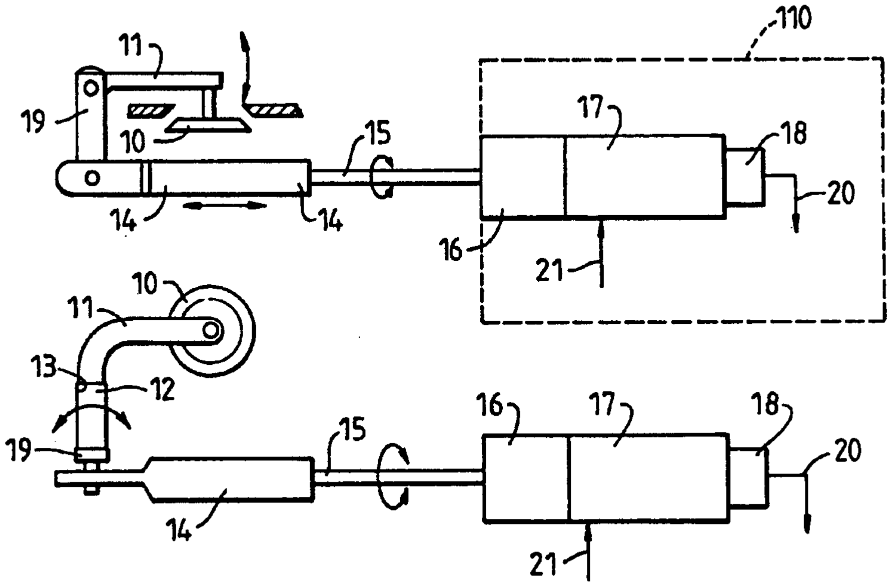

(57) Abstract

A turbocharger has a drive-shaft mounted in bearing means in a housing. The drive shaft drivably connects an exhaust gas driven turbine wheel to the impeller of an air compressor (22). A gas flow control device, such as a wastegate (10, 39) and/or a variable geometry turbine inlet nozzle, positioned upstream of the turbine wheel is operable to adjust the operating performance of the turbocharger. An electrically drivable actuator motor (17, 45), such as a D.C. motor or a stepper motor, is provided for regulating the operation of the gas flow control device via a linkage means (14, 15, 405, 407, 406, 825, 830, 835) in response to an electrical signal dependent at least upon the delivery pressure of the compressor. In a preferred arrangement the linkage means includes a relatively rotatable threaded lead screw (15) and a correspondingly threaded female screw member (14) threadably engaged therewith.

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TURBOCHARGERS FOR INTERNAL COMBUSTION ENGINES

This invention relates to turbochargers for internal combustion engines and relates more particularly to the control of the exhaust gas driven turbine of a turbocharger.

With the increase in popularity of compression ignition engines, particularly in passenger cars and light commercial vehicles, there is an incentive to provide small turbochargers for such engines to enhance their power output. With a well designed turbocharger a compression ignition engine can produce a power output which is similar to an engine of much larger capacity. Moreover the environmental cleanliness and fuel consumption may even show improvements relative to petrol engines. Again, a turbocharger employed on a petrol engine can greatly increase its power output.

A typical exhaust gas driven turbocharger comprises a bearing housing assembly supporting a rotatable shaft, one end of which carries an air compressor wheel enclosed by a compressor housing and the other end of which carries a turbine wheel enclosed by a turbine housing and which is subjected to exhaust gas flow to drive the compressor.

In order to constrain the boost pressure which such a turbocharger can produce at the air induction manifold of the engine, it has been proposed to provide a so-called "wastegate" including a controllable exhaust gas by-pass valve. Typically, such a wastegate valve has comprised a spring biased poppet valve having a valve stem connected to a pressure responsive diaphragm subject, in a valve opening direction, to a control pressure derived from the output of the turbocharger compressor. By providing such a wastegate it is possible to prevent a turbocharger from overboosting and advantageously to improve the matching of the operation of the turbocharger to the demands of the engine. However, the control thereby achieved is only approximate because the system is pneumatic and is dependent not only upon the boost pressure but also upon the value of a spring bias, the effective control areas and the exhaust gas pressure acting on the valve. In practice such control is only a compromise consistent with providing reasonable engine performance whilst preventing possible damage to the engine due to overboosting.

An alternative form of turbocharger control has also been proposed in which the input nozzle geometry of a drive turbine of a turbocharger is variable. One form of such a variable input nozzle is described in EP-A-0 571 205 published on 24 November 1993, the disclosure of which is incorporated herein by way of reference. In such a proposal the turbine housing of the turbocharger has an inlet nozzle for receiving exhaust gases from an engine and is shaped to conduct such gases to impinge upstream edges of blades of a turbine wheel. The nozzle has axially spaced side walls extending about said upstream edges of the turbine wheel and axially extending spaced and angled vanes traverse the space defined between the side walls and are carried by one side wall and are receivable in slots in the other side wall. One side wall is formed by one end of an axially movable sleeve slidably carried in a bore of the housing downstream of the turbine wheel and means are provided axially to move the sleeve to thereby vary the geometry of said nozzle in response to air pressure derived from the output of the turbocharger compressor. Again, as in the case of a wastegated turbocharger, pneumatic control of the variable nozzle geometry is dependent upon fixed and variable parameters and these may be less than ideal for all operating conditions of the engine.

An object of the invention is to provide a turbocharger for an internal combustion engine with an improved control mechanism which better lends itself to respond to the requirements of the respective internal combustion engine.

According to one aspect of the present invention there is provided a turbocharger comprising a drive-shaft mounted in bearing means in a housing, the drive-shaft drivably connecting an exhaust gas driven turbine wheel to the impeller of a compressor, a gas flow control device positioned upstream of the turbine wheel and operable to adjust the operating performance of the turbocharger, and an electrically drivable actuator motor for regulating the operation of the gas flow control device via a linkage means in response to an electrical signal dependent at least upon the delivery pressure of the compressor, the linkage means comprising a male threaded lead screw and a correspondingly threaded female screw member threadably engaged therewith.

In a preferred arrangement one of the female threaded screw member and male threaded lead screw is arranged to move generally linearly on rotary motion of the other of said screw member and said lead screw when driven by the actuator motor, to change the longitudinal extent of the linkage means. It is preferably the lead screw that is rotated by driving of the actuator motor and the screw member which moves generally linearly. The lead screw may advantageously be provided with a multistart thread.

According to a further aspect of the present invention there is provided a turbocharger comprising a drive-shaft mounted in bearing means in a housing, the drive-shaft drivably connecting an exhaust gas driven turbine wheel to the impeller of a compressor, a gas flow control device positioned upstream of the turbine wheel and operable to adjust the operating performance of the turbocharger, and an electrically drivable actuator motor for regulating the operation of the gas flow control device via a linkage means in response to an electrical signal dependent at least upon the delivery pressure of the compressor, the linkage means comprising a fixed length linkage, a motor output crank arm pivotally connected to the linkage and a further crank arm pivotally connected to the linkage at a different position to said motor output crank arm.

To allow for initial and tuning adjustment, the length of the fixed length linkage may be adjustable. In a preferred arrangement the two crank arms are positioned generally parallel to one another.

In both aspects of the present invention the gas flow control device may comprise a wastegate valve operable to by-pass around the turbine wheel exhaust gas from upstream of the turbine wheel. The gas flow control device may also be a variable geometry nozzle at the exhaust gas input to the turbine wheel.

In order that the invention may be more clearly understood and readily carried into effect the same will be further described, by way of examples, with reference to the accompanying drawings, in which:-

Fig. 1 illustrates in partially sectioned schematic form a typical known form of wastegated turbocharger;

Fig. 2a and Fig. 2b illustrate diagrammatically , in top plan view and side elevation respectively, an embodiment of turbocharger wastegate valve and actuation mechanism in accordance with the present invention;

Fig. 3a, Fig. 3b and Fig. 3c illustrate, in side elevation and in opposite end elevations, a practical embodiment of a turbocharger in accordance with the present invention and in which the gas flow control device is a wastegate valve;

Fig. 4 illustrates, in side elevation, an alternative practical embodiment of a turbocharger in accordance with the present invention and in which the gas flow control device is a wastegate valve;

Fig. 5 illustrates, in diagrammatic manner, an embodiment of a turbocharger according to the present invention together with control means for the gas flow control device;

Fig. 6 is a response map obtained during a test conducted on a engine fitted with a turbocharger in accordance with the present invention in which an actuator motor having a lead screw linkage arrangement was used to control the position of a wastegate valve;

Fig. 7 illustrates, in sectioned elevation, an embodiment of a variable geometry turbine inlet nozzle turbocharger in accordance with the present invention;

Fig. 8 illustrates, in partially sectioned end elevation, an alternative embodiment of a variable geometry turbine inlet nozzle turbocharger in accordance with the present invention; and

Fig. 9 is a side elevation of the embodiment of turbocharger illustrated in Fig. 8, viewed in the direction of arrow IX.

Referring to Fig. 1, the known wastegated turbocharger is illustrated connected to an exhaust manifold 1 of an internal combustion engine. The turbocharger comprises a bearing housing 2 within which a shaft (not shown), at one end, carries a turbine wheel in a turbine casing 3 and, at the other end, carries an air compressor impeller in a compressor casing 4. The inflow and outflow of exhaust gas into and out of the casing 3 are indicated by arrows 101, 102 and a wastegate valve 5 is connected in a side-flow or bypass path 6. When the wastegate valve 5 is opened gas indicated by arrows 103, can flow via valve 5 and passage 6 to the main exhaust pipe of the vehicle without passing through the turbine casing 3. The wastegate valve 5 is biased in a closed sense by a spring 7 of a pneumatic actuator having a pressure responsive actuator 8 subject, via line 104, in a valve opening sense to the delivered pressure which exists in the engine air inlet 9 which is connected directly to the air output of the turbocharger compressor casing 4. The inflow to and outflow from the compressor casing 4 are indicated by arrows 105, 106 respectively. As discussed in the introduction, whilst the turbocharger of Fig. 1 with a wastegate is fairly simple in construction it has shortcomings having regard to the wide range of operating conditions.

Referring to Figs. 2a and 2b, in the shown general arrangement a gas flow control device is in the form of a wastegate vale. The valve member 10 of the wastegate valve is a poppet valve carried by a curved crank arm 11 pivoted via a shaft 12 in a pivot bearing 13 in a boss formed in the side of the turbine inlet duct (not shown). The outer end of the shaft 12 is connected via a further crank arm 19 to a threaded linkage. This linkage comprises a female lead screw nut 14, which may for example be made of steel or another suitable material, which has a female multistart thread threadably engaged with a multistart male lead screw 15. The rotatable lead screw 15, which may advantageously be made of brass or plastics material, is formed by the output shaft of a reducing gearbox 16 driven by an 12V electric DC motor 17. The gearbox 16 may, for example, have a 9:1 reduction ratio. The motor has an associated position encoder or potentiometer 18 having an output 20. Where, as in the illustrated embodiment, the motor is provided with a gearbox 16 the encoder or potentiometer 18 preferably senses the position of the gearbox output shaft. The encoder or potentiometer may advantageously be a linear or rotary potentiometer and may packaged in a water-resistant casing 110, such as shown in broken lines in Fig. 2a, together with the motor 17 and gearbox 16 to insulate the components from the elements and dirt etc. The casing may typically be made of plastics material and/or metal. The motor 17 responds via computation logic (not shown) at least to the encoder or potentiometer and a pressure signal derived from the compressor delivery.

In generalised operation, in the event of a tendency toward excessive delivered air pressure at the compressor outlet, as signalled to an electronic control unit (not shown), a signal voltage is provided at motor input 21 and rotation of the shaft 15 by the DC motor 17 via the gearbox

16 causes lengthening of the linkage formed by the lead screw 15 and nut 14, thereby unseating the valve member 10 to permit bypassing of exhaust gas flow directly to the turbine outlet without passing via the turbine itself. This system therefore operates in a sense to prevent excessive delivered air pressure and any accompanying compressor surge.

It will be appreciated that, during operation of the motor 17, part of the linkage (nut 14) moves in a generally linear direction, the nut 14 and shaft 15 having converted rotary motion of the motor output shaft into generally linear movement of the nut 14.

Referring to Figs. 3a 3b and 3c the three views illustrated thereby show a practical example of a turbocharger in accordance with the invention including an electric DC motor 29 for controlling the gas flow control device, as postulated in Figs. 2a and 2b. The turbocharger has a bearing housing 20 carrying the turbocharger shaft, one end of which projects into the attached turbine housing 21 to carry a conventional turbine wheel (not shown) and the other end of which projects into the compressor housing 22 and carries the conventional compressor impeller (not shown) driven via the shaft. The turbocharger is designed to be supported by the inlet flange 23 of the turbine housing, the turbine housing outlet 24 being connected to the engine exhaust system.

The compressor housing 20 has a generally axial air inlet port 25 for connection to an air inlet filter and a compressor air delivery port 26 for connection to the engine air induction system. Port 26 is also provided with a vacuum boost pressure inlet 27 via which signals as to the pressure pertaining in the compressor delivery may be derived. Although it forms no part of the present invention, the compressor housing also carries a recirculation valve 31 with a vacuum inlet 31a, to sense throttle opening and vary a bypass path for reducing surging. The compressor housing, being the normally cooler end of the turbocharger, also has a pressed steel bracket 28 attached to it. This bracket 28 supports the DC electric motor denoted by reference 29 and associated reducing gearbox 30 for activating the wastegate crank arm 32 via the lead screw arrangement 33, 34. The axis of rotation of the motor 29 is parallel to, but offset from, the axis of the turbocharger to assist packaging of the turbocharger device in an automobile engine bay. As seen in Fig. 3c, crank arm 32 is mounted on a shaft 35 passing rotatably through a boss 36 formed on the side wall of the turbine inlet duct and shaft 35 supports a wastegate poppet valve element 39 which, when shut against its seat, closes off the wastegate passage as discussed above with reference to Figs. 2a and 2b.

Fig. 4 shows a variation of the mechanism shown in Figs. 3a, 3b and 3c. Elements of the generally similar turbocharger body 400 include turbine inlet 401, turbine outlet 402, and compressor inlet 403. In the embodiment illustrated in Fig. 4 the motor is a 12V D.C. motor and is associated with a reducing gearbox and a position sensing potentiometer, these three components being hidden from view inside a two-part weather-resistant housing 404a, 404b, this housing being mounted on the cooler compressor side of the turbocharger. This arrangement differs from that shown schematically in Figs. 2a and 2b in that it is the female nut that is rotatably driven by the gearbox output and not the lead screw. In the arrangement illustrated in Fig. 4 the male lead screw/female nut arrangement is mostly contained within the right hand half of the housing 404b so that only the distal portion of the linearly moveable lead screw 405 is visible outside the housing 404a, 404b. The lead screw 405 passes through a rubber gaiter 406 provided on the right hand half of the housing 404b. This arrangement has the advantage of the threads of the female nut (not shown) of the linkage means being contained within the housing 404, protecting them from contamination by water, dirt etc. The distal end of the distal portion of the lead screw 405 is threaded into a threaded extension 407 and locked thereto by a lock nut 408. The extension 407 is pivotally connected to a crank arm 406. The longitudinal extent of the linkage means may be adjusted by releasing lock nut 408 and screwing the lead screw 405 into or out of the extension 407, aiding initial set-up of the turbocharger. Pivoting of the crank arm 406 around its opposite end 407 opens and closes a wastegate valve (not shown) in a similar way to that described above.

In a further alternative, albeit more costly, non-illustrated configuration of a gas flow control mechanism in a turbocharger according to the invention, the lead screw arrangement may be dispensed with in favour of a rack and pinion linkage or some other arrangement. The pinion may be carried by the output shaft of the gearbox and the cooperating longitudinally movable rack may be connected at one end to the operating lever such as 32 of Fig. 3c.

In a yet further alternative construction of a gas flow control mechanism in a turbocharger according to the invention, wherein the DC electric motor used in the above described examples is replaced by an electric stepper motor, such motor is also readily controlled via an ECU and decoder to act via a gearbox carrying a crank which may act directly via a fixed length linkage to actuate the control lever such as 32 of Fig. 3. Such an arrangement will be discussed later in conjunction with Figs. 8 and 9. Indeed, other combinations of alternative features such as discussed here will be readily apparent to those familiar with mechanical drive mechanisms and linkages. In addition to DC motors, of either brushed or brushless type and stepper motors, switch reluctance technology may alternatively be employed.

In considering more detailed operation of the turbochargers described above with reference to Figs. 2 to

4, reference may be had to Fig. 5 which diagrammatically illustrates a system including an electronic control unit (ECU) 41. In an automotive application the ECU may advantageously also deal with ignition timing, fuel injection and the like in a manner well known in the art. In Fig. 5 the turbocharger is again designated diagrammatically at 20, 21, 22 providing air induction and boosted air pressure at ports 25 and 26 respectively of a compressor driven by exhaust gas at 23 from the engine manifold. The wastegate valve 39 described in more detail above is actuated via the electric actuator motor 45, gearing 46 and lead screw linkage arrangement 14, 15. Operation of the electric actuator motor is controlled by an electric signal from the ECU 41, which is responsive to electrical input signals derived from a boost pressure transducer 48, an engine speed transducer 49 and the motor/gearbox position encoder or potentiometer 107. The electrical connections are indicated by broken lines. The ECU operates according to an electronic mapping element 49 fitted for the particular engine. In order to achieve control of the wastegate gas flow which is appropriate for given engine applications, engine mappings are created typically of required wastegate actuator settings for all combinations of required air pressure boost relative to engine speed. In turn, the required boost pressure itself is dependent upon throttle setting, turbine inlet temperature and air mass flow rate. Accordingly, the ECU is preferably also supplied with input analogue signals from transducers giving such values and the engine mappings 47 includes the control tables required to be used for the required engine application.

Fig. 6 is a response map obtained during a test on an engine fitted with a turbocharger in accordance with the present invention. The top trace 500 on the map traces wastegate position (vertical axis) against time (horizontal axis). The higher the trace the more closed is the wastegate.

The lower two thirds of the map show time-coincident traces of actual compressor delivery (boost) pressure 505, desired boost pressure 510 and a pulse width modulated actuator motor drive signal 515. The other unreferenced traces in this lower plot may be ignored.

The plotted test was conducted at a constant engine speed, approximately 3500 rpm.

In the centre of the trace, just to the right of the vertical line 520, it can be seen that as the desired boost pressure 510 steps up sharply the motor drive signal 515 progressively closes the wastegate (trace 500), increasing the actual boost pressure 505 towards the desired value 510. The wastegate stays closed for a time (at 525) before being re-opened as the actual boost pressure 505 reaches the desired boost pressure value 510.

It is of particular practical significance in a turbocharger assembly that actuation of the wastegate and/or variable geometry turbine input nozzle may be effected by an electric motor because such a motor of light construction and with low friction can provides fast response to changes in engine operating parameters as reflected by the ECU control signal. It has also been found to be preferred that the drive mechanism shall include a gearbox and a multistart lead screw arrangement due to the smoothness of operation and the advantage of little or no reverse force being transmitted through it when stationary. A suitable multistart thread may have typically 10 or 12 starts and a lead screw gradient of approximately 10mm per revolution. Such an arrangement can contribute to a durable, low friction and low-cost actuation mechanism. Particularly when the motor is a simple DC motor, which type of motor has a high static load, such a mechanism may need only to be energised when actuation is required so the power consumption is zero for much of the engine operating time. This also helps achieve a long service life.

It will be readily apparent from the foregoing that a gas flow control mechanism using an electric DC motor, or stepper motor or the like, as described in the foregoing, may in an alternative embodiment of an application of the invention alternatively or additionally be employed in a turbocharger with a variable geometry input nozzle such as described in the aforementioned EP-A-0 571 205. Fig. 7 is a modified version of one of the figures from EP-A-0 571 205, the enclosure of which document is incorporated herein by way of reference. Fig. 7 is an axial cross-section through the turbine outlet of the turbocharger, showing the turbine wheel 700. The turbocharger has an engine manifold mounting flange 740, a compressor outlet 745 and a generally cylindrical sleeve member 710 which is axially movable in the direction of the drive shaft of the turbocharger in order to change the geometry of the turbine input nozzle (not shown). To achieve this sliding a control yoke 715 is provided. Pins 720 project radially inwardly from the control yoke 715, through elongate holes 725, into the sleeve member 710. A portion of the yoke 715 is provided with a pivot pin 730 about which the yoke may be tilted. In the arrangement illustrated in EP-A-0 571 205 tilting of the yoke 715 is achieved using a pneumatic actuator. In Fig. 7 the pneumatic actuator of the arrangement disclosed in EP-A-0 571 205 may be thought of as being replaced by an electrically drivable actuator motor 735, and linkage means of the sort hereinbefore described. This actuator motor may thus be used to vary the geometry of the input nozzle to the turbine. Although the precise construction of the linkage means for transmitting actuator motor drive to the yoke 715 is not apparent from Fig. 7, the linkage means provided for this purpose may be of any of the forms hereinbefore described.

In the Fig. 7 embodiment the gas flow control means that varies the geometry of the turbine inlet nozzle is movable axially in the direction of the drive shaft of the turbocharger. In an alternative construction of a variable geometry turbine inlet nozzle it may be necessary to provide an alternative form of drive. For example, it may be desired to provide a rotary drive to vary the position of otherwise stationary vanes in the turbine inlet nozzle, for example to open and close the vanes. Figs. 8 and 9 illustrate an embodiment of turbocharger, in accordance with the present invention, of this sort. The turbocharger 800 has a compressor inlet 890 and a compressor outlet 805. The turbine has a turbine inlet 810 and a turbine outlet 815. The inlet nozzle to the turbine (not shown) is of variable geometry. On the compressor side of the turbocharger there is provided an electrically drivable actuator motor in combination with a reducing gearbox and position encoder or potentiometer 820, of the general sort hereinbefore described. To provide the gas flow control device (not shown) with rotary drive from the actuator motor there is provided a linkage means between the actuator motor and the gas flow control device. The linkage comprises a crank arm 825 provided on the output shaft of the reducing gearbox, a fixed length linkage 830 and a further crank arm 835. Both crank arms 825, 835 are generally parallel and are pivotally attached to the fixed length linkage 830. The crank arm 825 may, as show, be provided with a return spring 840 to bias the crank arm in a return direction so as to open the vanes in the turbine inlet nozzle, to reduce boost pressure and turbocharger speed, in the event of loss of the controlling electrical signal to the actuator motor. This can be particularly useful when the turbocharger does not have a wastegate. From the ability of the return spring 840 to be able to return the crank arm 825 it will be appreciated that, in this embodiment, the static load of the motor and the gearing of the gearbox is not such as to prevent reverse force being transmitted into the motor when stationary. A motor and gearbox combination in which this is the case may be substituted, particularly if the turbocharger is provided with a wastegate to prevent engine damage in the event of loss of control of the actuator motor. When the motor is operated to rotate the crank arm 825 clockwise (when viewed in Fig. 8) the other crank arm 835 is similarly rotated in a clockwise direction by the fixed length linkage 830. During this movement the fixed length linkage 830 remains parallel to its original position, i.e. it undergoes a generally linear movement, albeit with a lateral movement (in a direction perpendicular to the linear movement). Due to the generally similar lengths of the crank arms 825, 835, this lateral movement of the fixed length linkage 830 is of an equal amount at both ends of the linkage. The fixed length linkage 830 may be provided with means for adjusting its length.

The arrangement illustrated in Fig. 8 and 9 allows for the axis of the actuator motor to be positioned parallel to, but offset from, the axis of the drive shaft of the turbocharger, aiding packaging. The actuator mechanism may thus be employed to control the positioned setting of control yoke 28 in accordance with chosen engine performance mappings.

CLAIMS

1. A turbocharger comprising a drive-shaft mounted in bearing means in a housing, the drive-shaft drivably connecting an exhaust gas driven turbine wheel to the impeller of a compressor, a gas flow control device positioned upstream of the turbine wheel and operable to adjust the operating performance of the turbocharger, and an electrically drivable actuator motor for regulating the operation of the gas flow control device via a linkage means in response to an electrical signal dependent at least upon the delivery pressure of the compressor, the linkage means comprising a male threaded lead screw and a correspondingly threaded female screw member threadably engaged therewith.

2. A turbocharger as claimed in claim 1, wherein one of said female threaded screw member and male threaded lead screw is arranged to move generally linearly on rotary motion of the other of said screw member and said lead screw when driven by the actuator motor.

3. A turbocharger as claimed in claim 2, wherein the female screw member is rotated by driving of the actuator motor.

4. A turbocharger as claimed in claim 2 or claim 3, wherein the generally linearly movable one of said threaded lead screw and said screw member is provided with means for adjusting the longitudinal extent of the linkage means.

5. A turbocharger as claimed in any one of the preceding claims, wherein the lead screw is provided with a multistart thread.

6. A turbocharger comprising a drive-shaft mounted in bearing means in a housing, the drive-shaft drivably connecting an exhaust gas driven turbine wheel to the impeller of a compressor, a gas flow control device positioned upstream of the turbine wheel and operable to

adjust the operating performance of the turbocharger, and an electrically drivable actuator motor for regulating the operation of the gas flow control device via a linkage means in response to an electrical signal dependent at least upon the delivery pressure of the compressor, the linkage means comprising a fixed length linkage, a motor output crank arm pivotally connected to the linkage and a further crank arm pivotally connected to the linkage at a different position to said motor output crank arm.

7. A turbocharger as claimed in claim 6, wherein the length of the fixed length linkage is adjustable.

8. A turbocharger as claimed in claim 6, or claim 7, wherein the two crank arms are positioned generally parallel to one another.

9. A turbocharger as claimed in any one of the preceding claims, wherein the gas flow control device comprises a wastegate valve operable to by-pass around the turbine wheel exhaust gas from upstream of the turbine wheel.

10. A turbocharger as claimed in any one of claims 1 to 8, wherein the gas flow control device comprises a variable geometry nozzle at the exhaust gas input to the turbine wheel.

11. A turbocharger as claimed in any one of the preceding claims, wherein the actuator motor comprises a DC motor.

12. A turbocharger as claimed in any one of claims 1 to 10, wherein the actuator motor is a stepper motor.

13. A turbocharger as claimed in any one of claims 1 to 10, wherein the actuator motor is a switch reluctance technology motor.

14. A turbocharger as claimed in any one of the preceding claims, wherein the actuator motor output passes to the linkage means through a reducing gearbox.

15. A turbocharger as claimed in any one of the preceding claims, wherein the linkage means is arranged to

translate rotary motion of the output shaft of the actuator motor into generally linear movement of the gas flow control device.

16. A turbocharger as claimed in any one of the preceding claims, wherein the axis of rotation of the actuator motor is positioned generally parallel to, and offset from, the axis of the turbocharger drive-shaft.

17. A turbocharger as claimed in any one of the preceding claims, further comprising boost pressure sensing means arranged to sense the delivery pressure of the compressor, said electrical signal being at least in part dependent on the pressure sensed by said pressure sensing means.

18. A turbocharger as claimed in any one of the preceding claims, further comprising a position sensor to provide positional information on the gas flow control device, said electrical signal being further dependent on the output of the position encoder or potentiometer.

19. A turbocharger as claimed in claim 18, wherein the position sensor comprises a potentiometer.

20. A turbocharger as claimed in claim 19, when dependent on claim 14, wherein the potentiometer, actuator motor and gearbox are packaged together in a single water-resistant housing.

21. A turbocharger as claimed in any one of the preceding claims, wherein said electrical signal is further dependent on the speed of the engine to which compressed air is, in use, supplied by the compressor.

22. A turbocharger as claimed in any one of the preceding claims, wherein said electrical signal is further dependent on one or more of the temperature of the exhaust gas, the mass flow rate of air passing through the compressor and the throttle setting of the engine to which compressed air is, in use, supplied by the compressor.

23. A turbocharger as claimed in any one of the preceding claims, further comprising control means for

producing said electrical signal to control operation of the actuator motor to regulate the operation of the gas flow control device.

24. A turbocharger as claimed in claim 23, wherein the control means is an electronic control unit (ECU).

25. A turbocharger as claimed in either of claims 23 and 24 when dependent on claim 9, wherein the control means is adapted to regulate the position of the wastegate valve, through operation of the actuator motor, to keep the compressor delivery pressure below a predetermined value.

Fig.1.(Prior Art)

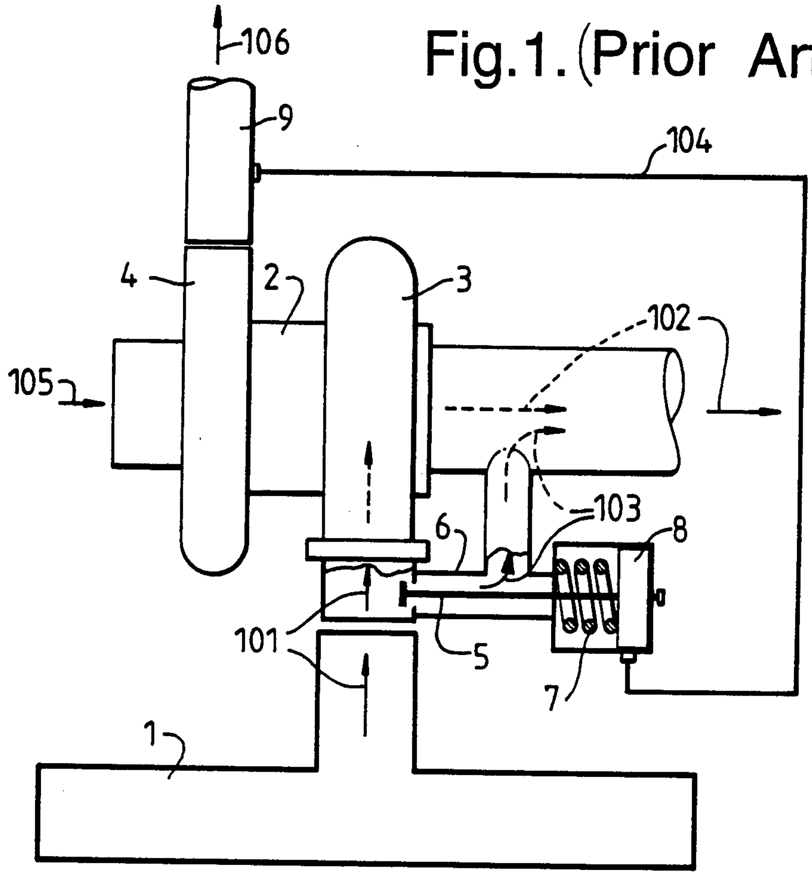
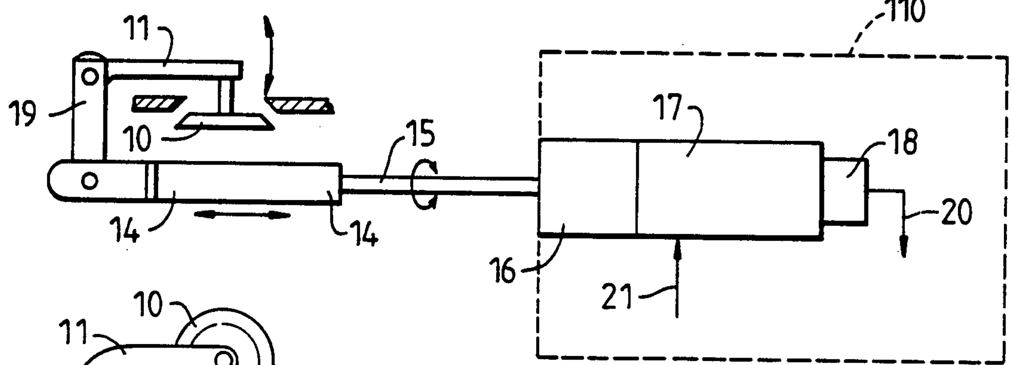


Fig.2a.



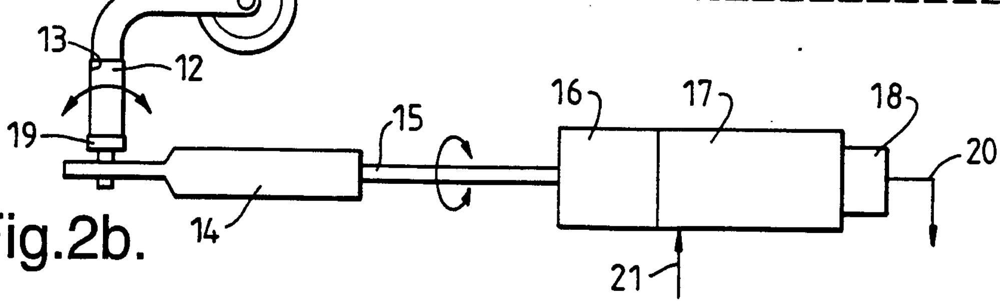


Fig.2b.

Fig.3a.

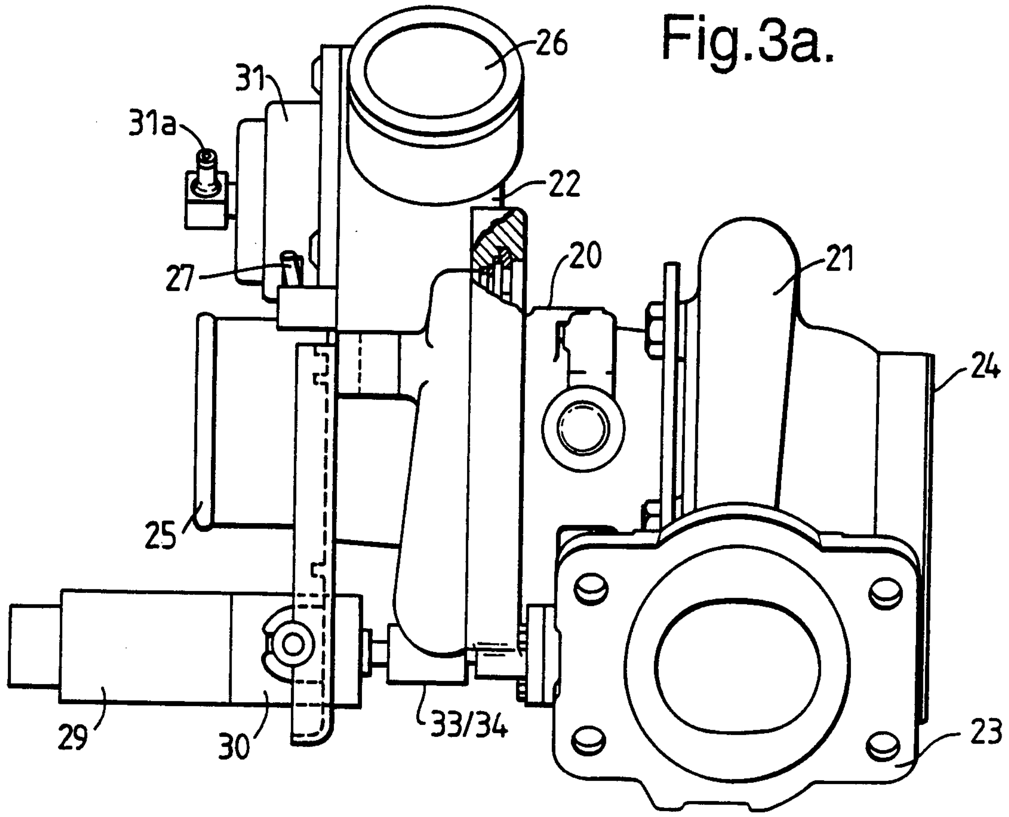


Fig.3b.

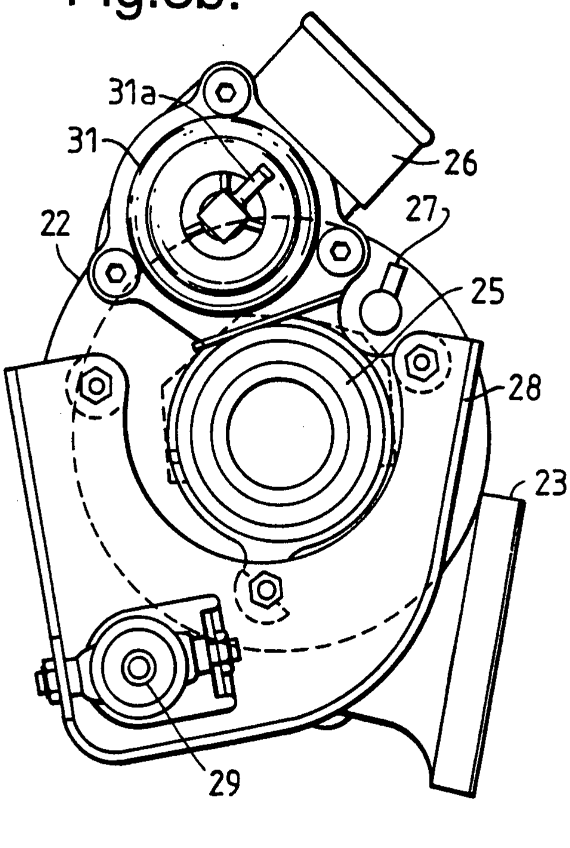


Fig.3c.

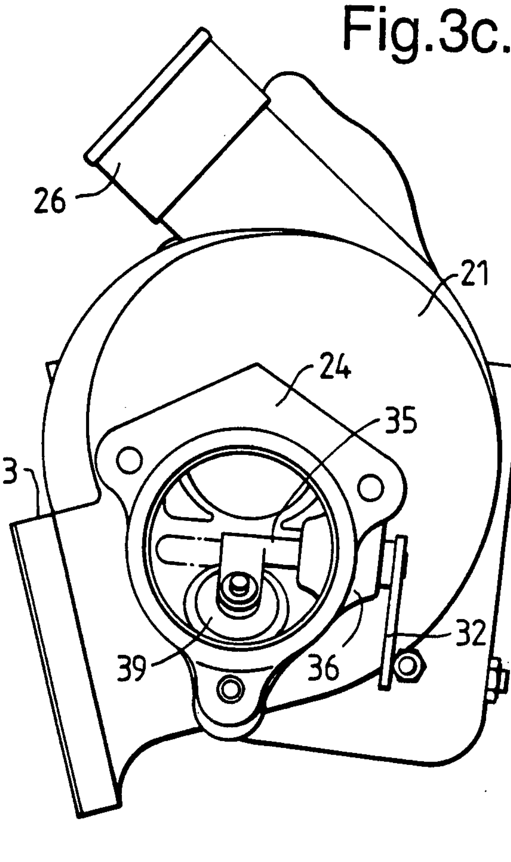
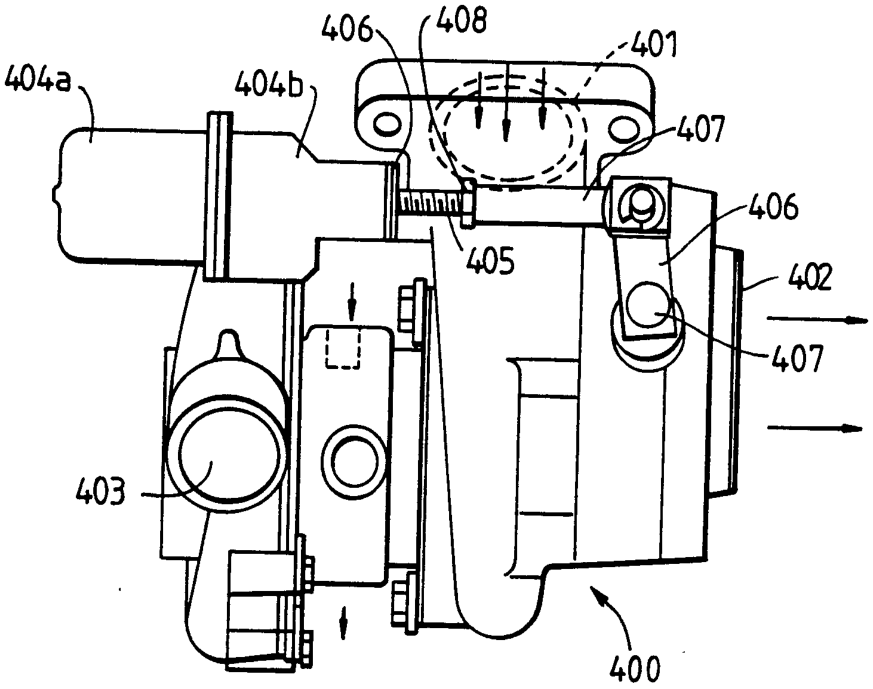


Fig.4.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401
404a
404b
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406
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402
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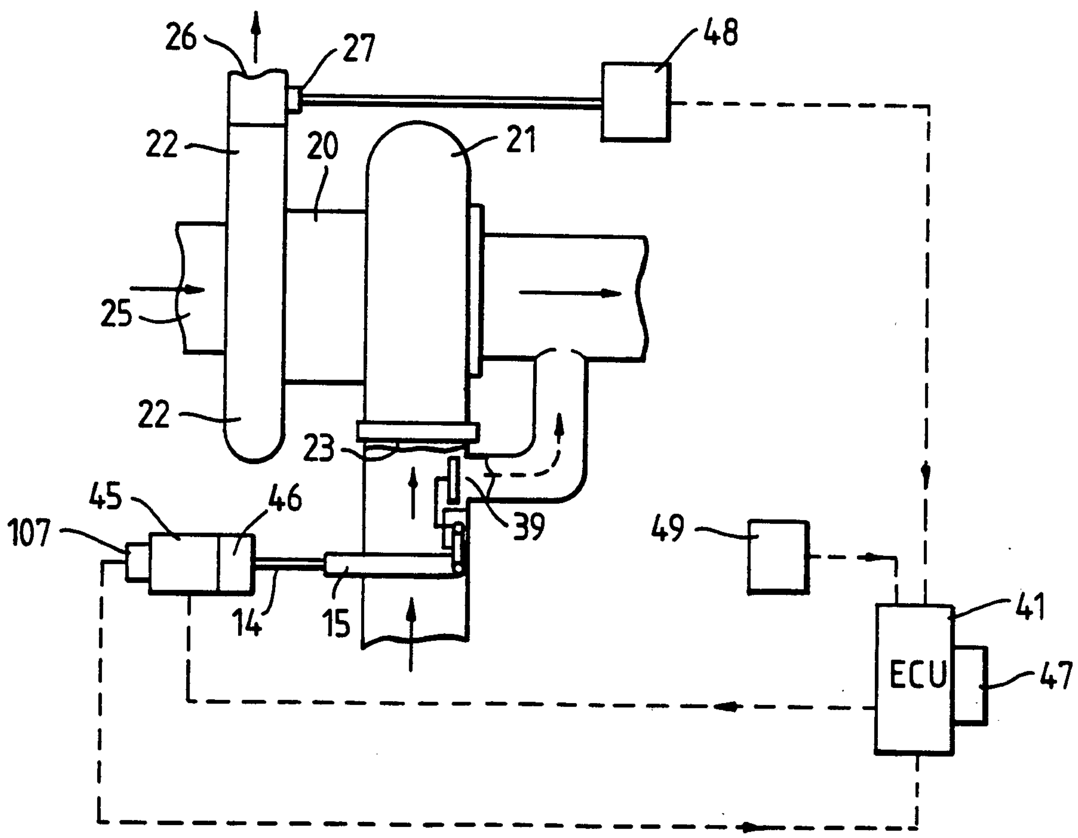
403
400

Fig.5.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ECU
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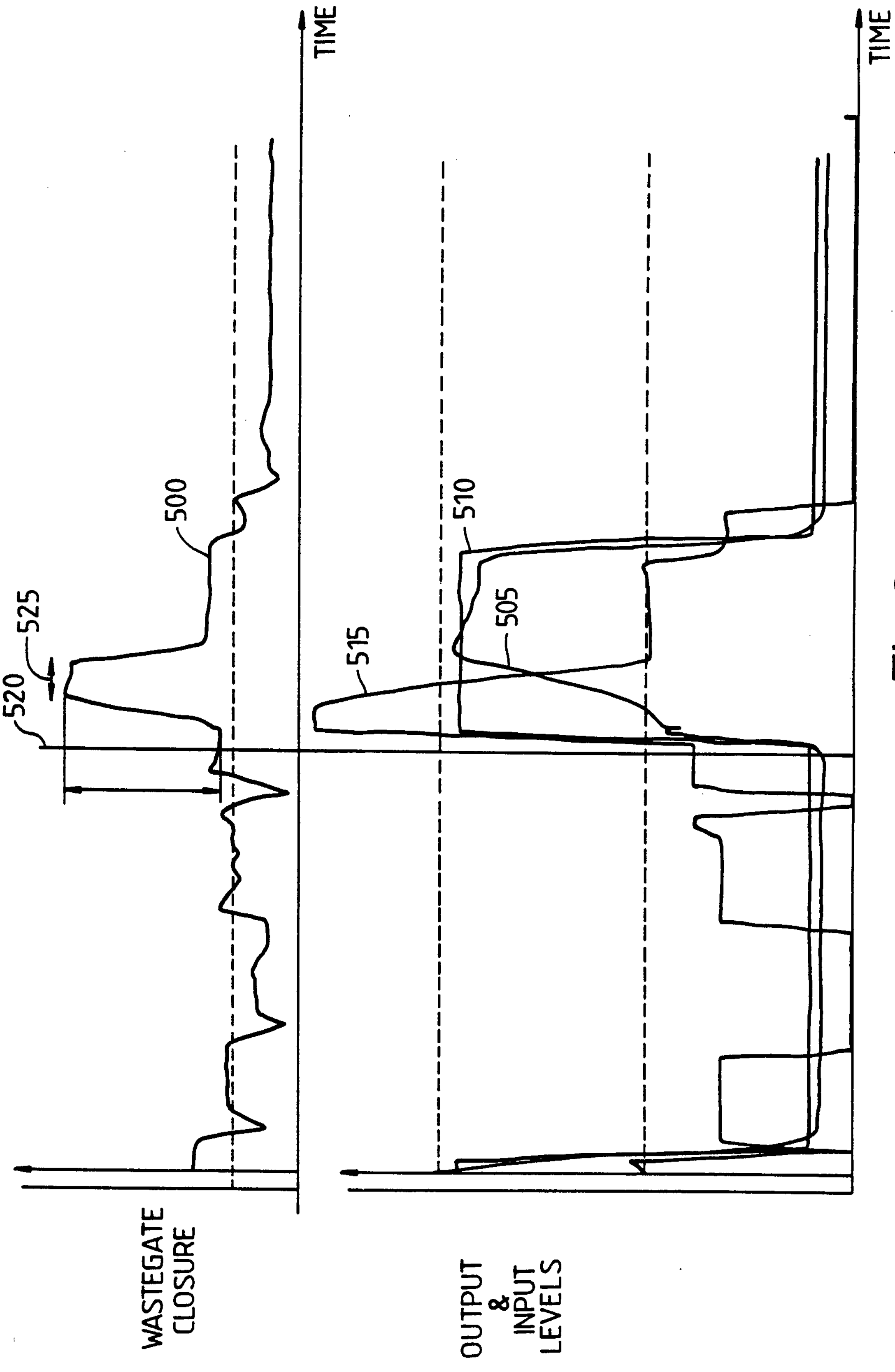
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525
520
WASTEGATE CLOSURE
TIME
510
505
515
OUTPUT & INPUT LEVELS

Fig.6.

Fig.7.

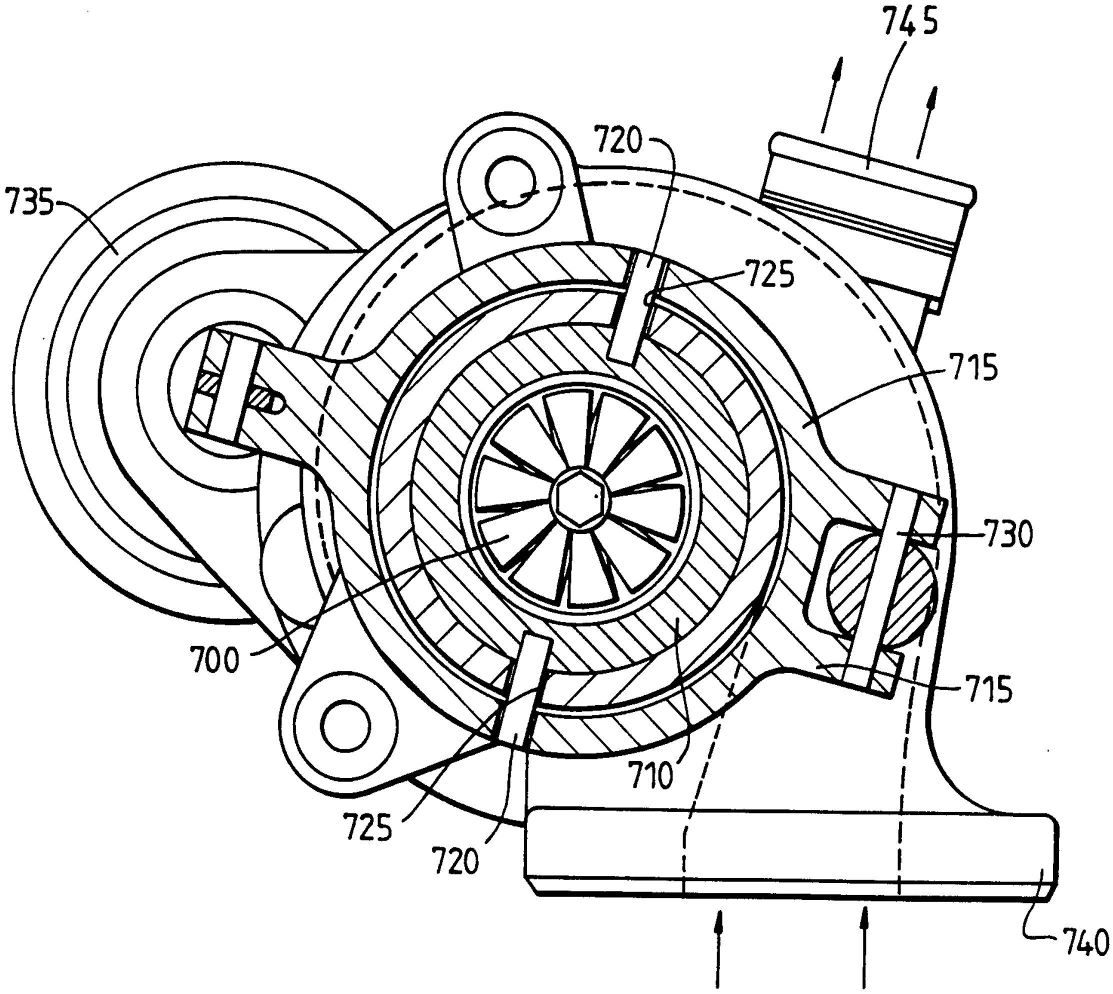


Fig.8.

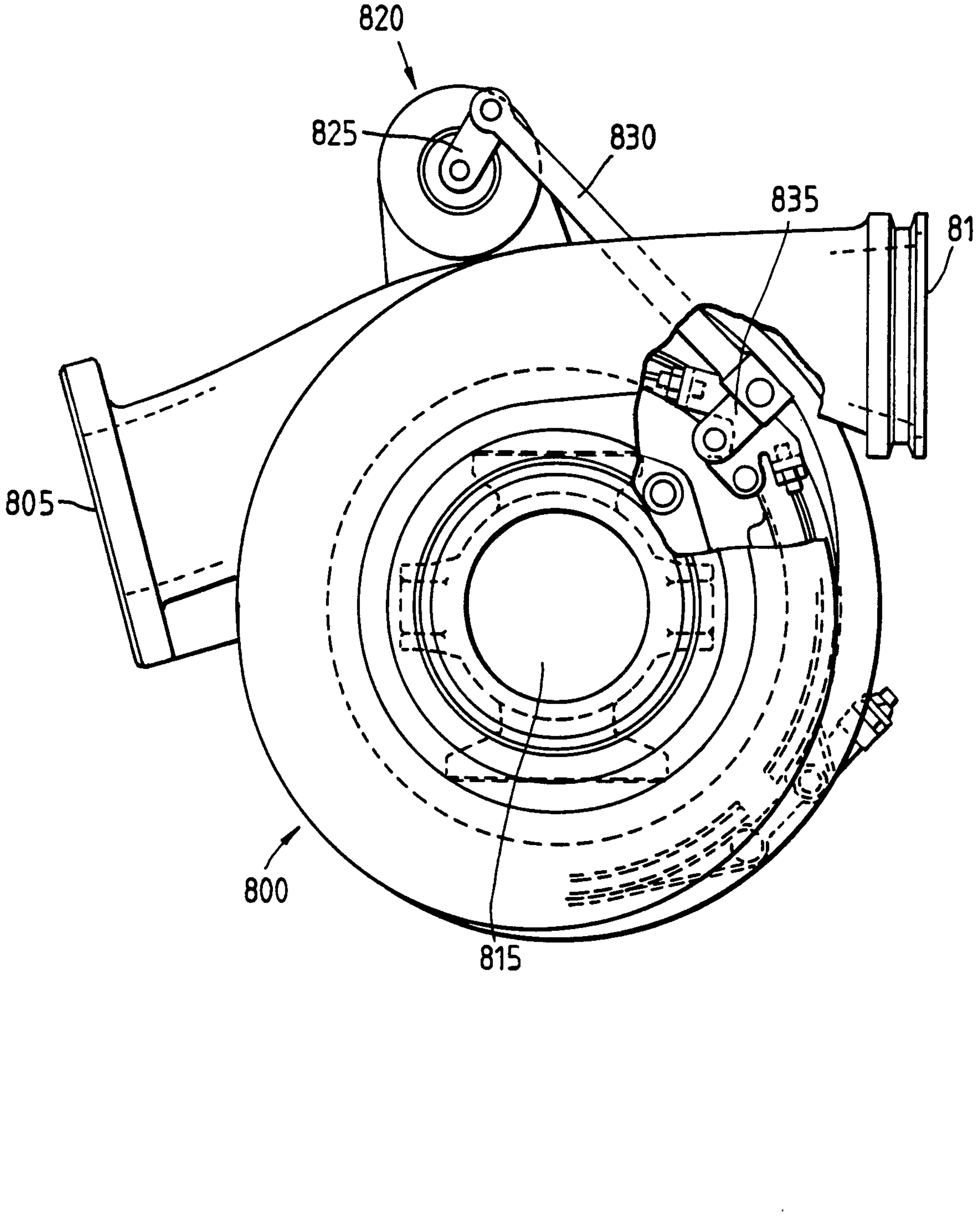
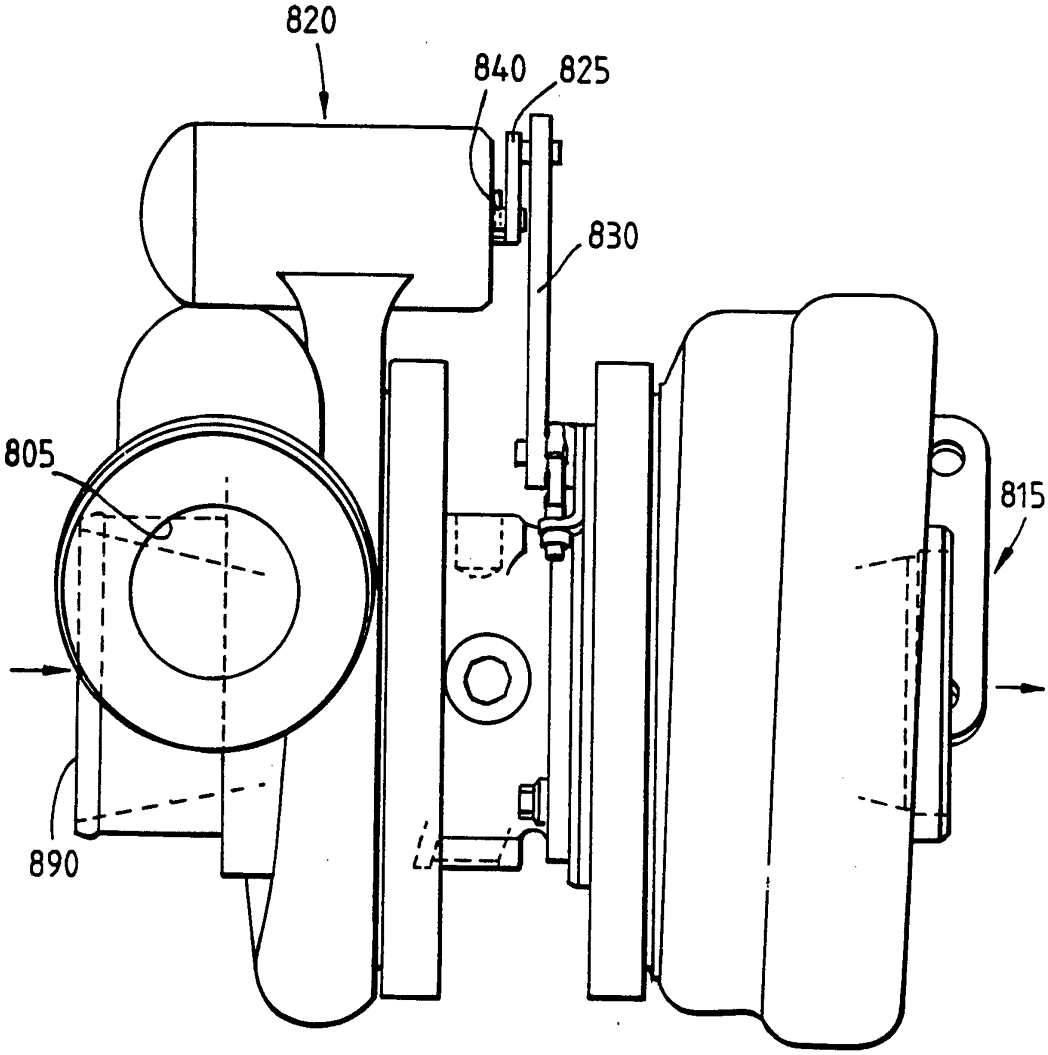


Fig.9.



INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB 94/02482

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 F02B37/12

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 F02B

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

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP,A,0 227 476 (THE GARRETT CORPORATION) 1 July 1987	1-3,9, 12,13, 15-17, 23-25
Y	see column 6, line 63 - column 9, line 6; figures	6,8,14, 18-21
Y	PATENT ABSTRACTS OF JAPAN vol. 10, no. 10 (M-446) 16 January 1986 & JP,A,60 173 315 (YOUICHI YAMAZAKI) 6 September 1985 see abstract	6,8,14
Y	WO,A,93 08394 (TRANSCOM GAS TECHNOLOGIES) 29 April 1993 see page 6, line 6 - page 7, line 34 see page 9, line 8 - line 13; figures 1,4	18-21

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

☒ Patent family members are listed in annex.

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1

Date of the actual completion of the international search	Date of mailing of the international search report
8 February 1995	24.02.95

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+ 31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+ 31-70) 340-3016	Sideris, M

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/GB 94/02482

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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		CA-A- 1253008	25-04-89
		JP-A- 62159731	15-07-87
WO-A-9308394	29-04-93	CA-A- 2122012	29-04-93
		FI-A- 941852	03-06-94
		NO-A- 941413	21-06-94