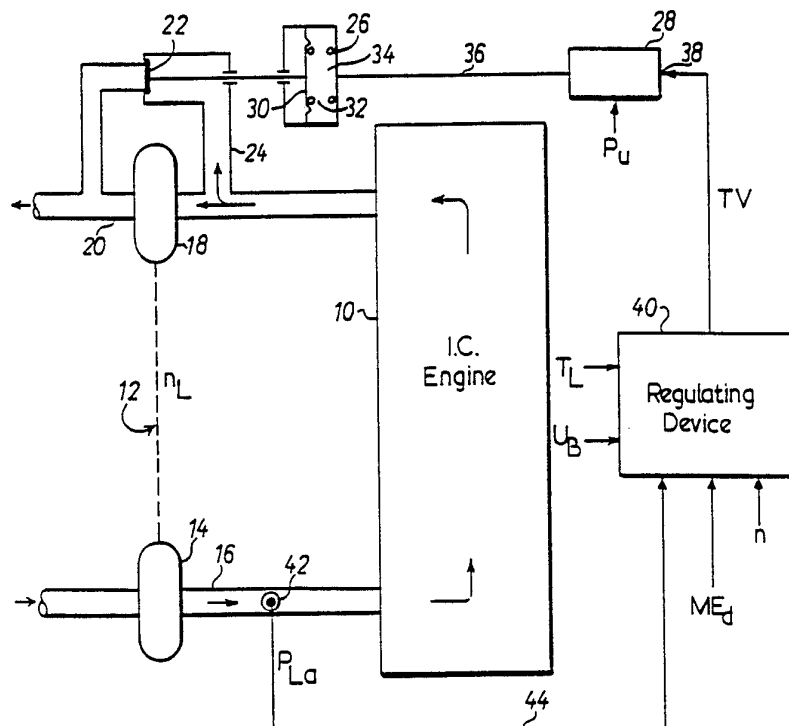




INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

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<b>(21) International Application Number:</b> PCT/EP88/00395 <b>(22) International Filing Date:</b> 7 May 1988 (07.05.88)  <b>(71) Applicant (for all designated States except US):</b> ROBERT BOSCH GMBH [DE/DE]; P.O. Box 50, D-7000 Stuttgart 1 (DE).  <b>(72) Inventors; and</b> <b>(75) Inventors/Applicants (for US only) :</b> BERGER, Joachim [DE/DE]; Falkenstr. 11, D-7065 Winterbach (DE). BIRK, Manfred [DE/DE]; Oberbrunnweg 8/2, D-7032 Sindelfingen (DE). KULL, Hermann [DE/DE]; Novalisstaffel 1, D-7000 Stuttgart 1 (DE). SAUTTER, Wilfried [DE/DE]; Waldstr. 29, D-7257 Ditzingen 4 (DE).  <b>(81) Designated States:</b> AT (European patent), BE (European patent), CH (European patent), DE (European patent), FR (European patent), GB (European patent), IT (European patent), JP, LU (European patent), NL (European patent), SE (European patent), US.		<b>Published</b> <i>With international search report.</i>

**(54) Title:** CONTROL OF SUPERCHARGED INTERNAL COMBUSTION ENGINES**(57) Abstract**

In a turbocharged diesel engine (10), the charging pressure  $P_{La}$  is adjusted to run the engine (10) with an empirically determined optimum fuel consumption. A charging pressure feedback signal  $P_{La}$  is fed to a regulating device (40) which receives various operating parameters, including  $ME_d$  which represents the power output. A characteristic field in a memory zone (50) in the regulating device (40) determines a control variable (TV) which operates a turbine by-pass valve (22) via an electro-pneumatic converter (28) and a pneumatic (vacuum) actuator (26). The characteristic field is such that the charging pressure  $P_{La}$  is reduced in the part load range (cruising speed) to improve fuel consumption.

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DESCRIPTIONCONTROL OF SUPERCHARGED INTERNAL COMBUSTION ENGINESState of the Art

5 The invention relates to a method of controlling  
the charging pressure of a supercharged internal  
combustion engine in accordance with the pre-charact-  
erizing clause of claim 1. The invention also relates  
to devices for controlling the charging pressure of a  
10 supercharged internal combustion engine in accordance  
with the pre-characterizing clauses of claim 5. Such  
a method and device are known (DE-A- (R7186). In  
the known method and device, the characteristic field  
determines the desired charging pressure taking into  
15 account the output power, the composition of the exhaust  
gas, soot content of the exhaust, etc. As a result,  
supercharged diesel engines employing such method and  
device are supplied with too much air for combustion  
during most of the time of operation, e.g. when  
20 travelling at a comfortable cruising speed. The excess  
air is simply compressed and then expelled. The result  
is poor efficiency and high fuel consumption.

Advantages of the Invention

25 These disadvantages are avoided by the method in  
accordance with the characterizing clause of claim 1  
and by the device in accordance with the characterizing  
clauses of claim 5. Thereby, the charging pressure is  
reduced in the part load range, which is the range  
in which most vehicles are operated for most of the  
time.

30 It is convenient, in accordance with claim 6, for  
the characteristic field to be a three-dimensional field  
comprising a range of curves to give a desired charging  
pressure for different engine speeds and different  
desired outputs (different injected fuel quantities

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per stroke in the case of a diesel engine or different air quantities in the case of a petrol engine) but for a given charging air temperature, e.g. 50°C. However, charging air temperature is an important operating parameter and it can be taken into account by adopting the measures of claims 2, 3, 7 and 8.

By adopting the features of claims 4, 9 and 10, it can be ensured that the engine is not mechanically overstressed.

Improved servo-control can be obtained by incorporating the features of claims 11 and 12.

Provision can be made for over-boost in accordance with claims 13 to 16.

#### Drawings

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

Fig. 1 is a block schematic diagram of a turbo-charged diesel engine fitted with a control device in accordance with the invention;

Fig. 2 is a block circuit diagram of the control device;

Fig. 3 represents in graphical form a characteristic field stored in a memory zone of the control device;

Fig. 4 represents a control characteristic field stored in another memory zone of the control device;

Fig. 5 is a block circuit diagram of a simplified control device;

Fig. 6 is a more detailed block circuit diagram of part of the control device of Fig. 2; and

Fig. 7 shows graphs to illustrate over-boost.

#### Description of the Exemplary Embodiments

Fig. 1 shows a diesel engine 10 fitted with a turbocharger 12 which comprises a compressor 14 in the induction passage 16 leading to the engine 10 and a turbine 18 in the exhaust gas passage 20 leading

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from the engine. The turbine 18 directly drives the compressor 14 at a speed  $n_L$ . The power output of the turbine 18 can be adjusted by means of a by-pass valve 22 ( a so-called "wastegate") in a by-pass passage 24 by-passing the turbine 18. A pneumatic actuator 26 operates the by-pass valve 22. Instead of providing the by-pass valve and passage, the turbine could be of the variable geometry type, whereby the pneumatic actuator adjusts the turbine output by adjusting the turbine geometry. The pneumatic actuator is controlled by an electro-pneumatic converter 28. In the illustrated embodiment, the actuator 26 comprises a diaphragm 30 which is biased in the closing direction of the by-pass valve 22 by a spring 32 which can open the by-pass valve 22 by application of vacuum to a chamber 34. the converter 28 controllably applies vacuum from a source  $P_U$  to the chamber 34 via a conduit 36 in response to an electrical control variable TV received at an input 38. The vacuum source  $P_U$  can be a vacuum pump driven by the engine 10.

The control variable TV is supplied by an electronic regulating device 40 which receives various operating parameters, as will be described, and a feedback signal comprising the actual absolute value  $P_{La}$  of the charging pressure delivered by the compressor 14. To this end, a pressure transducer 42 is disposed in the induction passage 16 at the outlet side of the turbine 14 and is connected by a line 44 to the regulating device 40. The control variable TV fed to the electro-pneumatic converter 28 is in the form of a pulse train of variable duty ratio and the converter 28 is adapted to adjust the vacuum in the conduit 36 proportionally to the duty ratio of this pulse train.

Fig. 2 illustrates the servo loop formed by the turbocharger 12, the pressure transducer 42, the regulating device 40, the converter 28, the actuator

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26 and the by-pass valve 22. The converter 28 and the pneumatic actuator 26 are represented in Fig. 2 as a servomotor 46 and the by-pass valve 22 and the turbocharger 12 are represented as a function path

5 48. The regulating device 40 comprises a memory zone 50 in which is stored a characteristic field by which the desired absolute value  $P_{Ld}$  of the charging pressure is delivered in accordance with an input parameter  $ME_d$  representing the engine power output as set by the

10 driver (pedal position) and in accordance with engine speed  $n$ . This characteristic field can be considered as comprising plots of the optimum charging pressure  $P_{Ld}$  against engine speed for a range of values of engine power parameter  $ME_d$ . The optimum charging

15 pressure  $P_{Ld}$  is that obtained empirically to give the minimum fuel consumption, measured, for example, in litres per 100 km, when travelling in top gear at constant velocity.

Fig. 3 illustrates a typical characteristic field stored in the memory zone 50. In Fig. 3, the absolute charging pressure  $P_{Ld}$  is plotted against engine speed for various values of fuel supply quantities represented as mg per working stroke per cylinder, such a

20 parameter being readily derivable from an electronic governor of a diesel engine or from an electronic injection system of a petrol engine. Since the power output is dependent on the product of injected fuel quantity per stroke and engine speed, the injected fuel quantity is a measure of the desired power at any

25 one given speed.

30

To determine the characteristic field for any given engine type and turbocharger, it is necessary to conduct a series of tests on one or more prototypes. Thus, a series of graphs is made in which a specific

35 fuel consumption is plotted against the charging pressure for a range of engine speeds and a range of torque

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outputs, the specific fuel consumption conveniently being measured as KWh output ("brake horsepower") per g fuel consumed. The lower charging pressure limits below which the exhaust gases become sooty are also  
5 noted. The characteristic field can then be calculated from these graphs.

The desired and actual values  $P_{Ld}$  and  $P_{La}$  of the absolute charging pressure are applied to a comparator 52 and the resulting error signal is fed to a  
10 PI-control 54. The output variable  $TV_R$  from the PI-control 54 is passed via a limiter 56 and a summing junction 58 to be applied as the control variable  $TV$  to the control input of the servomotor 46. The limiter 56 determines the maximum value of the charging pressure  
15 to ensure that the variable  $TV_R$  is limited in the event of a fault in the servo loop, such as failure of the pressure transducer 42. The PI-control 54 merely serves to improve the steady-state accuracy, i.e. to stabilize the charging pressure.

20 Because of the presence of the limiter 56, the control circuit comprising the memory zone 50, the comparator 52 and the PI-control 54 has poor response characteristics. To improve dynamic response, the control variable  $TV$  is actually obtained from two  
25 variables, namely an output variable  $TV_K$  from a pre-control 60 and the variable  $TV_R$ , but limited by the limiter 56, the variable  $TV_K$  also being applied to the summing junction 58.

To improve dynamic response the power parameter  
30  $ME_d$  is applied to the pre-control 60 which is preferably a differentiating component with delay (DT 1-component).

A control characteristic field stored in a memory zone 62 is brought into operation in the event of failure of the above-mentioned servo-loop including the  
35 feedback via the line 44 to the comparator 52. The output variable  $TV_K$  from the memory zone 62 is fed to the

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servomotor 46 via the summing junction 58. Fig. 4 represents a typical control characteristic field for such stand-by operation. Fig. 4 is plotted similarly to Fig. 3, except that the duty ratio of the desired control variable is plotted along the ordinate instead of the desired charging pressure. The duty ratio of the pulse train is the ratio of the "off" interval (or space) to the sum of the "on" and "off" intervals (or pulse period) in the present case because a duty ratio of 100% means the by-pass valve 22 is fully open and the charging pressure is consequently minimum.

The control characteristics field stored in the memory zone 62 is calculated from the characteristic field in the memory zone 50 but is modified to take into account the non-linearity of the relationship between the actual charging pressure  $P_{La}$  and the duty ratio of the control variable TV.

In some applications, the simpler device shown in Fig. 5 is to be preferred. Parts like those of Fig. 2 are denoted by like reference numerals. The measures to be taken to enable continued operation of the device of Fig. 5 upon failure of the charging pressure transducer 42 will be apparent from the following description of Fig. 6.

Fig. 6 shows how the output from the memory zone 50 in which the characteristic field is stored may be corrected in accordance with temperature. This characteristic field is calculated for a nominal charging temperature of, for example, 50°C or 313°K and its output  $P_{Ld50}$  is fed to a temperature correction circuit 64. The actual value of the charging temperature, measured as an absolute value by means of a temperature sensor in the induction passage 16 downstream of the compressor 14, is also fed to the temperature correction circuit 64 which corrects the desired value of the charging pressure in accordance



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with the well-known general gas equation  $P/\rho = RT$ . This feature is applicable to the embodiments of Figs. 2 and 5.

Because the differential part of the servo-control of the charging pressure in Fig. 5 can lead to too large an amplification of transient fluctuations, a suitable dynamic pre-filter 66 is placed in advance of the comparator 52, as shown in Fig. 6. As a consequence, it is necessary to place the limiter 56a for limiting the charging pressure to a safe maximum between the pre-filter 66 and the comparator 52. The output from the latter is fed to a PI(D)-control 54a whose control is limited and whose output is delivered via an electronic switch 68 to a line 70 connected to the end stages. These end stages are represented by the electro-pneumatic servomotor and the pneumatic actuator 26 forming the servomotor 46.

The electronic switch 68 is changed over automatically upon failure of the servo loop. It enables the charging pressure  $P_{La}$  to be adjusted by the control characteristic field stored in the memory zone 62 to which the input parameter  $ME_d$  and the engine speed  $n$  are fed. The electronic switch 68 is shown in its normal position in which the control variable  $IV_S$  is disconnected. Upon occurrence of a fault in the servo-loop, the switch 68 is changed over to its other state in which the line 70 is disconnected from the PI(D)-control 54a and instead is connected to receive the variable  $IV_S$ . The control characteristic field stored in the memory zone 62 is designed to avoid too high a charging pressure  $P_{La}$ .

Because the response of the electro-pneumatic converter 28 is dependent on the peak voltage of its input pulse train, the output from the control characteristic field in the memory zone 62 must be corrected to

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take account of variation in the voltage  $U_B$  of the vehicle battery. To this end, the battery voltage  $U_B$  is applied to a control circuit whose output is applied to a summing junction 74 between the memory zone 62 and the switch 68. This feature is applicable to the devices of Figs. 2 and 5.

It is useful to provide for an increased charging pressure (overboost) for a desired rapid acceleration (kickdown of the accelerator pedal) and the engine may be able to withstand the higher peak cylinder pressure resulting from a higher charging pressure for a short time or when the engine is cold.

Provision for overboost can be made in the circuit of Fig. 6 by feeding to the limiter 56a a parameter  $x$  obtained by means of a pedal travel sensor and dependent upon accelerator pedal velocity and from an engine operating parameter  $y$  in order to raise or remove the limit on the maximum charging pressure. The parameter  $x$  can be an actual measure of the accelerator pedal velocity or it can be a measure of the time taken to depress the pedal through a given travel, e.g. 80% to 100% of its possible full travel. The parameter  $y$  can be the occurrence of a gear change, up or down, a predetermined short time before the depression of the accelerator pedal so that overboost can only be brought in just after a gear change. Another possibility for the parameter  $y$  is a signal that the engine speed  $n$  is below a predetermined speed before depression of the accelerator pedal. Overboost can then be used only when the engine is being accelerated from a relatively low speed.

Another way of providing for overboost is to feed a temperature  $T_A$ , such as exhaust gas temperature, which is indicative of the engine temperature to the limiter 56a as is also shown in Fig. 6. Overboost, i.e. a higher maximum charging pressure, is then operative so

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long as the engine remains relatively cold but becomes impossible once the engine has warmed up.

When operative under overboost conditions in the case of a diesel engine, it is also possible to increase  
5 the injected fuel quantity to obtain a higher output torque and power. This is useful during certain manoeuvres, such as overtaking.

Conversely, with the use of a fuel injection system for a diesel engine fitted with an electronic  
10 governor wherein there is a facility to increase the injected fuel quantity for a short period of time to obtain an increased output torque, it is possible to close the by-pass valve 22 or another valve in the by-pass passage 24 by means of the signal which  
15 triggers temporarily increased fuel quantity. This signal can be derived from a pedal position transducer. The upper graph in Fig. 7 is a plot of a typical pedal travel  $w$  effected as desired by the driver against time  $t$ . The lower graph represents the extra  
20 fuel quantity  $\Delta ME$  and the extra charging pressure  $\Delta P_{La}$  for overboost. The middle graph represents the time available for overboost to take place,

The overboost can be bought in from the instant  $t^*$  when the pedal reaches 100% travel as shown in full  
25 lines. The overboost then operates independently of the circuitry of Figs. 1, 2 and 3.

The arrangement is preferably such that the overboost cannot last beyond a short length of time, e.g.  
20 to 30 seconds and such that overboost cannot be  
30 repeated until after a relatively long interval. This is in order that the engine will not be damaged and that the exhaust gas temperature will not become too high. An integrator can be provided for timing the overboost, that is to say for controlling the time  
35  $t_{OB}$  available for overboost. The exhaust gases become

hotter when travelling in the power range close to full power. The integrator is triggered when the output from the pedal travel transducer exceeds a threshold  $w_t$  of, for example 70% full travel. The time  $t_{OB}$  available for  
5 overboost then gradually becomes shorter (linearly or exponentially) as driving in the high power range is continued. Thus, only a relatively short time  $t_1$  is available for overboost when the pedal reaches maximum travel as shown in the top graph. Not until the  
10 pedal travel transducer output falls below the threshold  $w_t$  at the instant  $t_{oo}$  does the integrator come into operation again to permit further overboost and to increase gradually the time  $t_{OB}$  available for overboost.

15 At the end of the overboost, the injected fuel quantity and the charging pressure can fall to their normal permitted maximum over a suitable time interval  $t_{ramp}$ .

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CLAIMS

1. Method of controlling the charging pressure ( $P_{La}$ ) of a supercharged internal combustion engine, especially a diesel engine, in dependence upon at least one operating parameter and in accordance with a characteristic field, characterized in that the charging pressure is adjusted to achieve optimum fuel consumption, especially in the part load range.
2. Method according to claim 1, characterized in that the charging pressure ( $P_{LD}$ ) is adjusted in dependence upon charging air temperature.
3. Method according to claim 2, characterized in that the optimum charging pressure ( $P_{Ld50}$ ) for a predetermined charging air temperature is obtained from the characteristic field and this optimum charging pressure ( $P_{Ld50}$ ) is corrected to produce a desired charging pressure ( $P_{LD}$ ) in accordance with the actual charging air temperature, preferably at least approximately in accordance with the general gas equation.
4. Method according to claim 1, 2 or 3, characterized in that the maximum charging pressure is limited to a value which avoids mechanical damage to the engine, and/or excessive exhaust temperatures.
5. Device for controlling the charging pressure ( $P_{La}$ ) of a supercharged internal combustion engine, especially a diesel engine, having a turbocharger which comprises a compressor (14) in the induction passageway (16) to the engine (10) and driven by a turbine (18) in the exhaust passageway (20) from the engine, an adjusting device (26), preferably an adjustable by-pass (22, 24) by-passing the turbine (18), for varying the charging pressure, a pressure sensor (42) for sensing the actual value ( $P_{La}$ ) of the charging pressure, and a memory (50) in which is stored a characteristic field for desired values ( $P_{Ld}$ ) of the charging pressure, characterized in that the characteristic field stored

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in the memory (50) is determined, preferably empirically, to control the adjusting device (26) so as to minimize the fuel consumption of the engine (10).

5           6. Device according to claim 5, characterized in that a parameter ( $ME_d$ ) corresponding to a desired engine load is fed to the memory (50), preferably together with at least one other operating parameter (n).

10           7. Device according to claim 5 or 6, characterized by a temperature sensor for adjusting the desired charging pressure ( $P_{La}$ ) in accordance with charging air temperature.

15           8. Device according to claim 7, characterized in that the characteristic field stored in the memory (50) appertains to a particular charging air temperature and in that the output of the memory (50) is connected to a temperature correction circuit (64) to which is fed the signal ( $T_L$ ) from the temperature sensor to obtain a desired charging pressure ( $P_{LD}$ ).

20           9. Device according to claim 7 or 8, characterized in that the desired and actual charging pressure values are fed to a comparator (52) whose output actuates the adjusting device (26) to adjust turbine power in a sense to reduce the size of the error signal from the comparator.

25           10. Device according to claim 9, characterized in that a pressure limiter (56) is arranged between the memory zone (50) and the adjusting device (26) for limiting the desired charging pressure ( $P_{Ld}$ ) to a maximum.

30           11. Device according to claim 9 or 10, characterized in that a dynamic pre-filter (66) is arranged between the memory (50) and the comparator (52).

12. Device according to any of claims 9 to 11, characterized in that a PI-regulator (54) is arranged between the comparator (52) and the adjusting device (26).

13. Device according to claim 10, characterized in that a component responsive to pedal kick-down is provided for increasing the maximum desired charging pressure ( $P_{Ld}$ ) to obtain a power boost from the engine.

5 14. Device according to claim 13, characterized by a temperature-responsive switching device for preventing an increase in the maximum desired charging pressure ( $P_{Ld}$ ) when the engine is warm, e.g. when the exhaust gas temperature exceeds a predetermined value.

10 15. Device according to claim 10 or 13, characterized in that a component responsive to acceleration immediately following a gear change is provided for increasing the maximum desired charging pressure ( $P_{Ld}$ ) to obtain power boost from the engine.

15 16. Device for controlling the charging pressure ( $P_{La}$ ) of a supercharged internal combustion engine, particularly a diesel engine, having a turbo-charger, an adjusting device for varying the charging pressure, a pressure limiter for limiting the charging pressure  
20 to a maximum, and an overboost device for temporarily increasing the maximum charging pressure, more particularly according to any of claims 5 to 15, characterized in that the overboost is brought into operation simultaneously with a temporary increase in the injected fuel quantity  
25 above a normal maximum.

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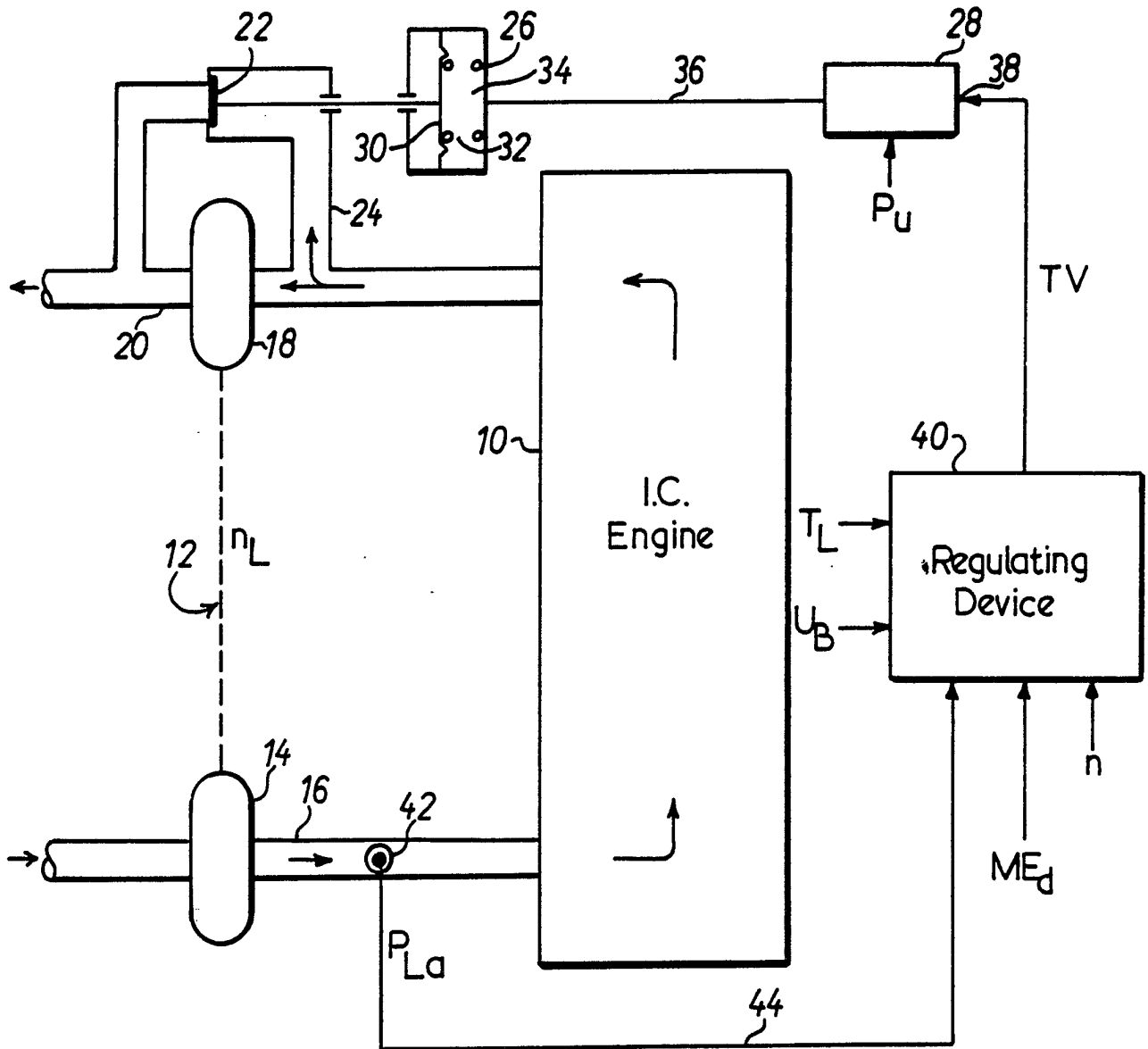


Fig 1



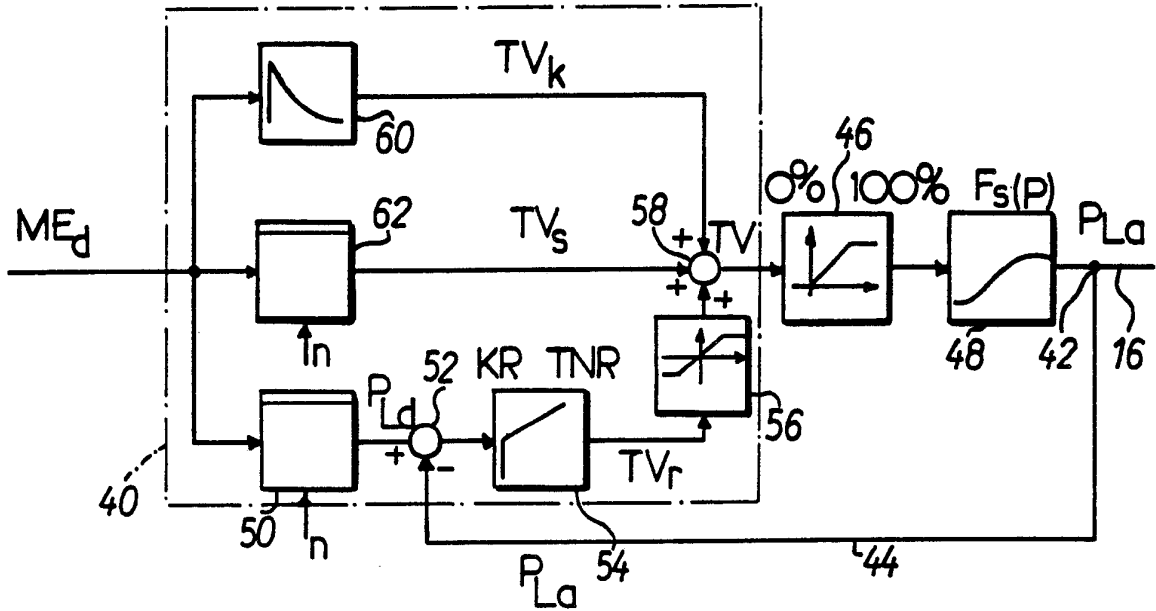


Fig 2.

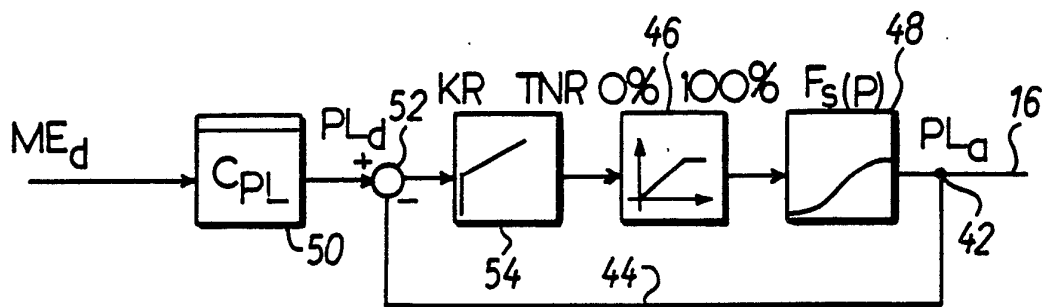


Fig 5.

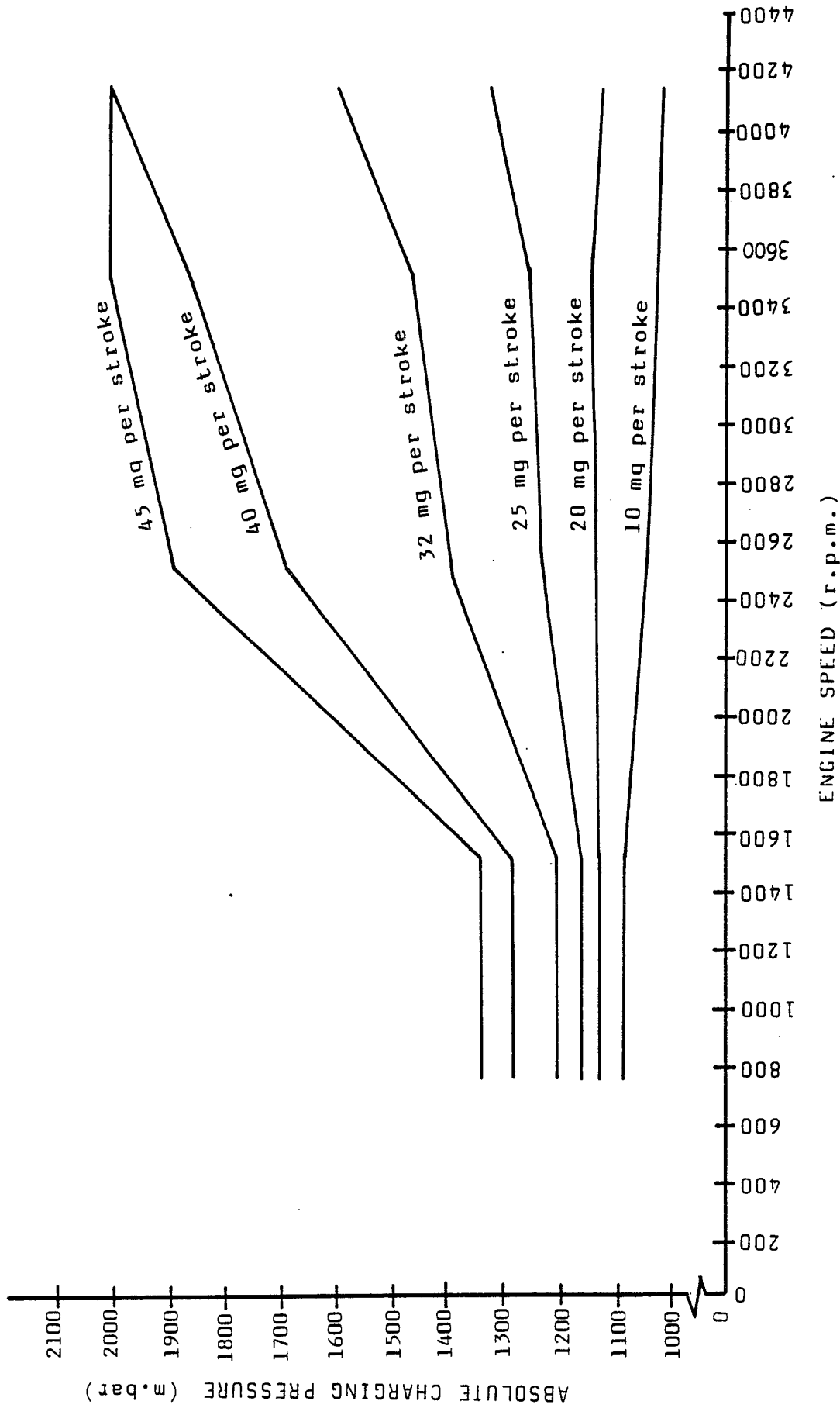


Fig 3.

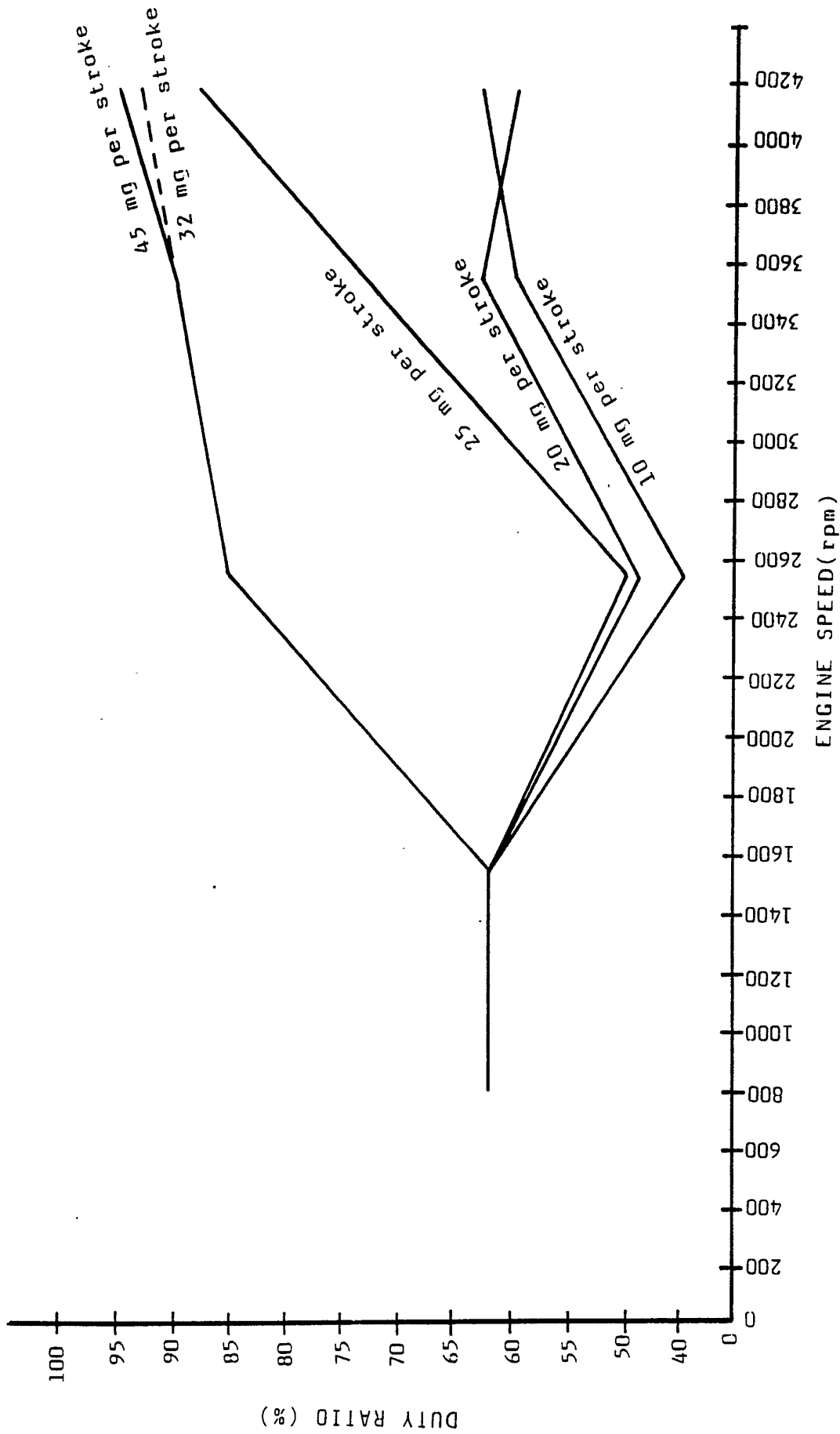


Fig 4.

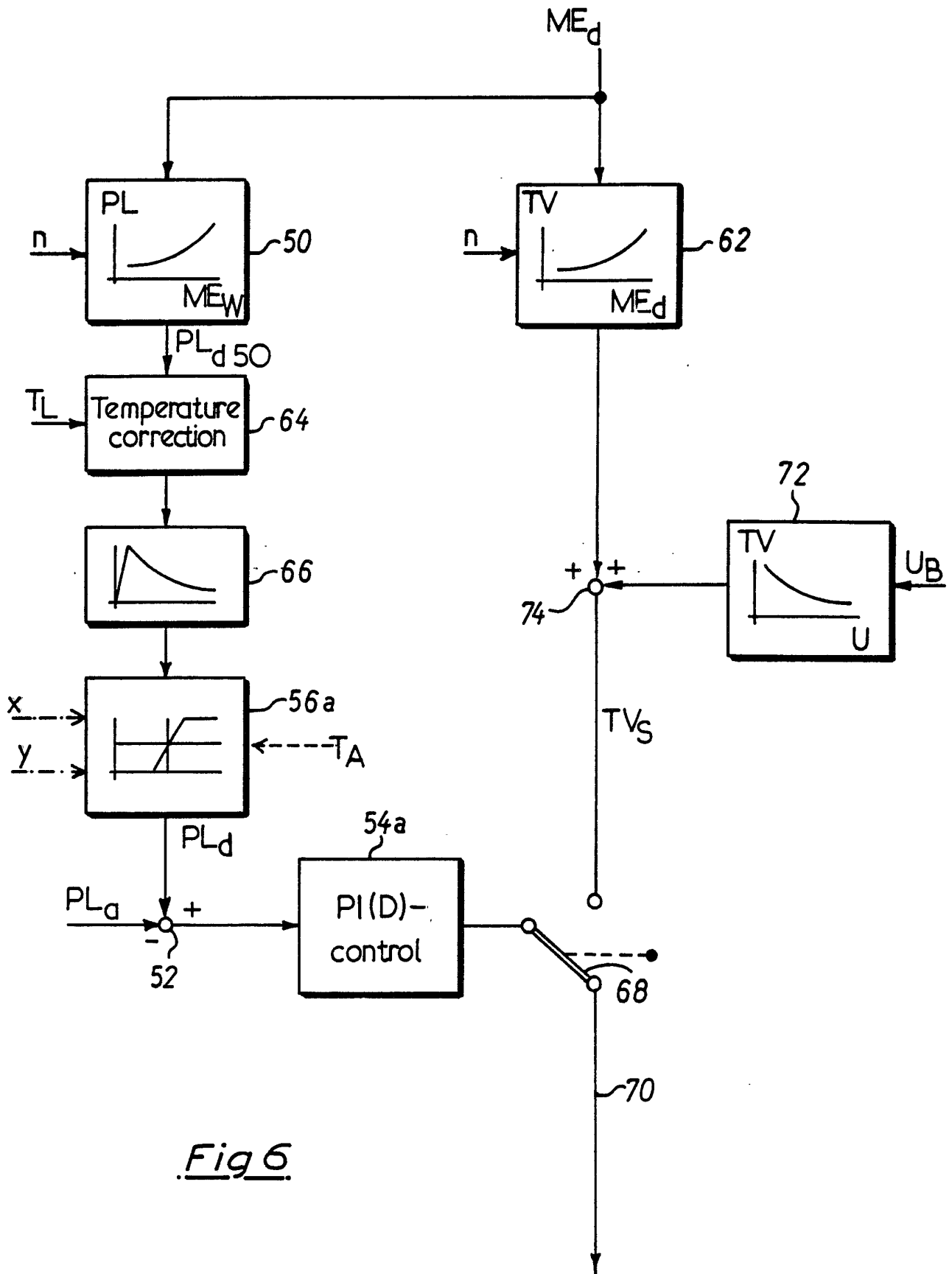


Fig 6

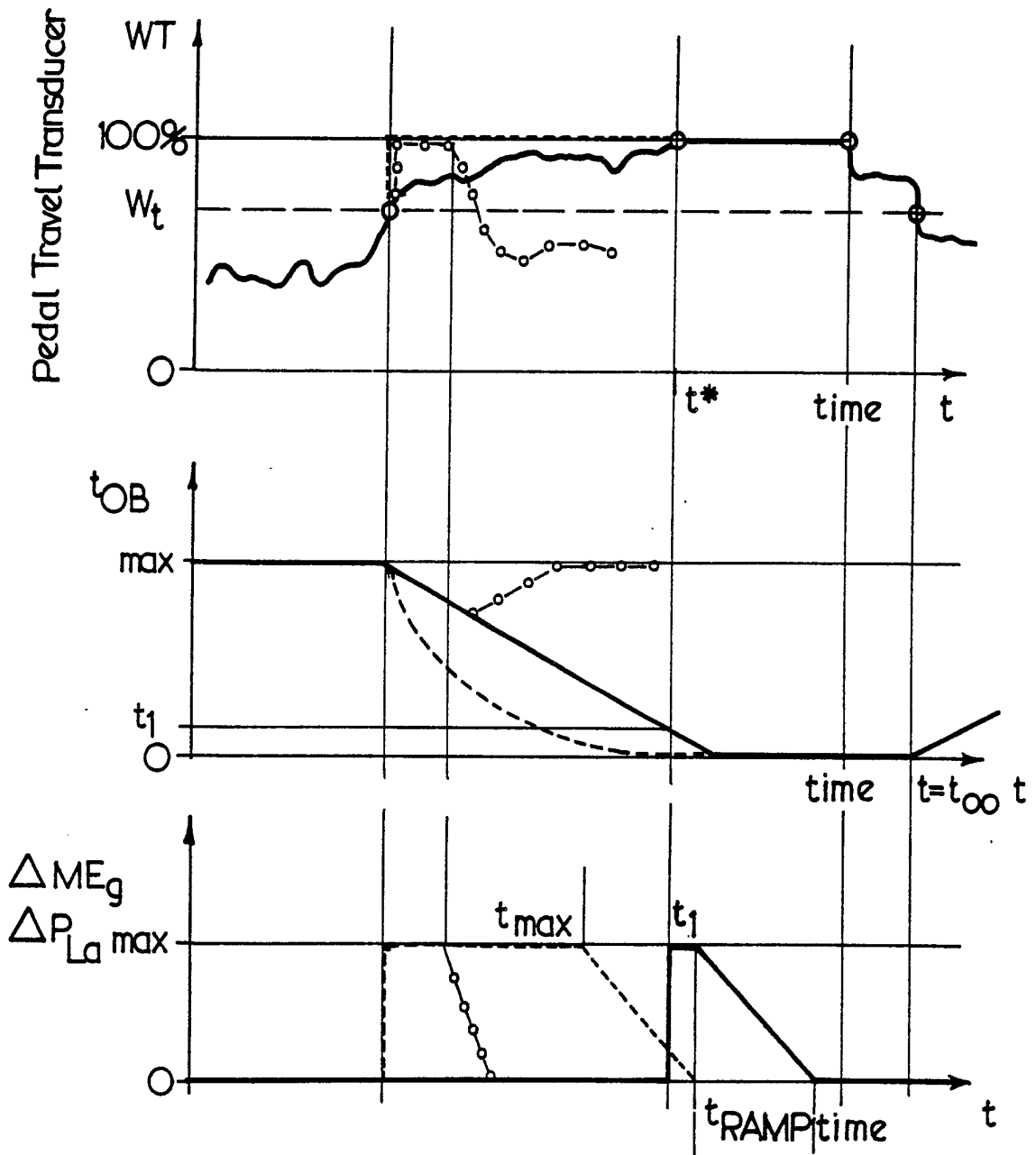



Fig 7

# INTERNATIONAL SEARCH REPORT

International Application No PCT/EP 88/00395

<b>I. CLASSIFICATION OF SUBJECT MATTER</b> (if several classification symbols apply, indicate all) <sup>6</sup>		
According to International Patent Classification (IPC) or to both National Classification and IPC		
IPC <sup>4</sup> : F 02 B 37/12; F 02 D 33/02		
<b>II. FIELDS SEARCHED</b>		
Minimum Documentation Searched <sup>7</sup>		
Classification System	Classification Symbols	
IPC <sup>4</sup>	F 02 D; F 02 B	
Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched <sup>8</sup>		
<b>III. DOCUMENTS CONSIDERED TO BE RELEVANT <sup>9</sup></b>		
Category <sup>9</sup>	Citation of Document, <sup>11</sup> with Indication, where appropriate, of the relevant passages <sup>12</sup>	Relevant to Claim No. <sup>13</sup>
X	US, A, 4496286 (GAGNON) 29 January 1985 see figures 1,3,7-9,12; column 2, line 29 - column 3, line 21; column 4, lines 22-45; column 5; line 50 - column 6, line 8; column 7, line 15 - column 9, line 7; column 12, line 32 - column 13, line 33 --	1-7
A	EP, A, 0046872 (AUDI NSU) 10 March 1982 see page 2, line 1 - page 3, line 14; page 4, line 19 - page 8, line 26; page 9, lines 11-20; page 10, lines 1-19; figures 1,2 --	1-3,5-9
A	EP, A, 0136541 (NISSAN) 10 April 1985 see page 6, line 15 - page 7, line 19; page 13, line 1 - page 14, line 23; page 15, lines 27-33; figures 5,14 --	1-4,6-10, 13,14
A	GB, A, 2160260 (NISSAN) 18 December 1985 see figures 1,3; page 1, line 75 - page 2, line 21; page 2, lines 57-91; ./.	1,4-6,9, 10,12
<p><sup>10</sup> Special categories of cited documents:</p> <p>"A" document defining the general state of the art which is not considered to be of particular relevance</p> <p>"E" earlier document but published on or after the international filing date</p> <p>"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)</p> <p>"O" document referring to an oral disclosure, use, exhibition or other means</p> <p>"P" document published prior to the international filing date but later than the priority date claimed</p> <p>"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention</p> <p>"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step</p> <p>"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.</p> <p>"&amp;" document member of the same patent family</p>		
<b>IV. CERTIFICATION</b>		
Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report	
7th January 1989	24. 01. 89	
International Searching Authority	Signature of Authorized Officer	
EUROPEAN PATENT OFFICE	 <b>P.C.G. VAN DER PUTTEN</b>	

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)		
Category *	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No
	page 3, line 1 - page 4, line 75; page 5, lines 6-35, 101-125  -----	

**ANNEX TO THE INTERNATIONAL SEARCH REPORT  
ON INTERNATIONAL PATENT APPLICATION NO.**

EP 8800395

SA 22185

This annex lists the patent family members relating to the patent documents cited in the above-mentioned international search report. The members are as contained in the European Patent Office EDP file on 12/01/89  
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

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EP-A- 0046872	10-03-82	DE-A, C 3032218	25-03-82
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