(54) **Method of and apparatus for fuelling an internal combustion engine.**

(57)   During the fuelling of a cylinder (3) of an
internal combustion engine (10) having a fuel
injector (1) and an inlet manifold (4), a portion
of the injected fuel is entrained by an air flow
within the manifold and is transported into the
cylinder (3). Another portion of the fuel remains
within the manifold (4) and contributes to a film
of fuel (M_w) from which evaporation occurs. The
present invention estimates the mass of fuel
that will be lost from each fuel injection and the
mass of fuel that will evaporate from the film in
order to correct the quantity of the injected fuel
to maintain a desired air-fuel ratio.

FIG.2.

The present invention relates to a method of and apparatus for fuelling an internal combustion engine.

During transient or warm-up operation of an internal combustion engine, the ratio of air to fuel of the air-fuel mixture inducted into an at least one engine cylinder deviates from the desired value. This may give rise to increased exhaust pollution and difficulty in driving a vehicle powered by the engine.

Figure 1 of the accompanying drawings schematically illustrates the region around a fuel injector 1.

The injector 1 is operated to inject a mass of fuel M_{INJ} into an air flow. A proportion r of the injected fuel is entrained by the air flow and is transported towards a combustion region 3. Thus the mass of fuel transported towards the combustion region as a direct consequence of injector operation is $M_{INJ}r$. The remainder of the fuel from each injector operation $M_{INJ}(1-r)$ wets a surface 2 within the engine. Consequently a mass of fuel M_w accumulates on the surface 2. However, evaporation takes place from the surface 2. The amount of fuel that evaporates in a relatively short time interval ΔT (such that the mass M_w is not greatly altered) can be represented by $M_w\Delta T/\tau$, where τ represents a time constant of evaporation. Thus the mass of fuel M_F supplied to the combustion region 3 is given by:

$$M_F = M_{INJ}r + M_w\Delta T/\tau \quad (1)$$

During steady state operation, an equilibrium is established so that the mass M_w remains unchanged and consequently $M_F = M_{INJ}$. However, during transient operation, the loss of injected fuel to the wall wetting process and evaporation of fuel from the wall can lead to deviation in the air-fuel ratio of the inducted mixture from the desired value.

According to a first aspect of the present invention, there is provided a method of fuelling an internal combustion engine having an inlet manifold and at least one combustion region, comprising the steps of:

estimating the amount of fuel to be injected into the inlet manifold to give a desired air-fuel ratio;

estimating the fraction of the injected fuel that wets a surface of the engine;

estimating the rate of evaporation of fuel from the surface; and

correcting the amount of fuel injected so as to compensate for wetting of and evaporation from the surface to achieve the desired air-fuel ratio, the estimates of the fraction that wets a surface and the rate of evaporation being updated during use of the engine.

Preferably the fuel mass is estimated in response to an estimate of air flow into the manifold.

The air flow may be estimated from throttle position and manifold pressure. Advantageously the air flow is modelled by an air model accounting for temperature and ambient pressure so as to provide an estimate of the mass of the air that is admitted to the at least one combustion region.

Preferably the estimate of air flow into the manifold is a prediction for air flow for a future fuelling event. It is thus possible to use measurements of current engine operating conditions to estimate the actual mass of air that will be admitted into a cylinder when the cylinder is charged with a air-fuel mixture.

Advantageously the output of the air model may be compared with measured air flow when the engine is operating under steady state or near steady state conditions. The model may be corrected as a result of the comparison. The model may then provide reliable estimates of air flow during non-steady state, i.e. transient, operating conditions. The model may estimate the amount of air that will be admitted into a cylinder during the next induction stroke of that cylinder.

Preferably the estimate of the fraction of injected fuel that wets the surface is dependent on manifold pressure and a temperature. The temperature may be an engine coolant temperature. Advantageously the relation between pressure, temperature and the fraction of fuel that wets the surface is determined by experiment for the type of engine and stored in a memory. The values stored in the memory may be updated during use of the engine.

Preferably the amount of fuel on the surface is estimated from the fuel injection quantity, the estimate of the fraction of injected fuel that wets the surface and the estimate of fuel evaporation from the surface. Advantageously the estimate of the fuel on the surface is regularly updated, for instance at fixed intervals of time or at least for each respective injector operation.

Preferably the mass of fuel evaporated from the surface is estimated from the estimate of fuel on the surface and at least a first variable. Advantageously the first variable is dependent on manifold pressure. Preferably the estimate of the fraction of injected fuel that wets the surface for given engine operating conditions is updated by sensing the change in the oxygen content of the exhaust gas in response to a known change in fuel injection quantity. Advantageously the known change in fuel injection quantity may be a predetermined change in fuel injection quantity. Advantageously the value of the first variable for given engine operating conditions is updated during periods of engine overrun, that is periods in which fuelling is suspended, for example when the vehicle powered by the engine is descending an incline and the driver has removed his foot from the accelerator pedal. The update may be performed by monitoring the change with time of the oxygen content in the exhaust gas to thereby determine the amount of fuel that evaporates from the surface. The integral of the amount of fuel evaporated may advantageously be used to check the estimate of the amount of fuel in the

fuel film on the surface.

It is thus possible to update the parameters used within the model to compensate for changes in volatility, to refine the model to increase its accuracy, and to compensate for aging of the fuel system.

According to a second aspect of the present invention, there is provided a fuelling system for an internal combustion engine having an inlet manifold and at least one combustion region, comprising:

fuel mass estimating means for estimating an amount of fuel to be injected into the inlet manifold to give a desired air-fuel ratio;

fuel fraction estimating means for estimating the fraction of the injected fuel that wets a surface of the engine;

evaporation estimating means for estimating the rate of evaporation of fuel from the surface;

correcting means responsive to the fuel fraction estimating means and the evaporation estimating means for correcting the estimate of the amount of fuel to be injected, so as to compensate for wetting of and evaporation from the surface to achieve the desired air-fuel ratio; and

adapting means for adapting the estimates of the fraction of fuel that wets the surface and the rate of evaporation therefrom during use of the engine.

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

Figure 1 is a schematic diagram of the region adjacent an inlet valve to a cylinder;

Figure 2 is a schematic diagram of a fuel system constituting an embodiment of the present invention;

Figure 3 shows a schematic diagram of an embodiment of the present invention;

Figure 4 is a flow chart for implementing the present invention with a programmable data processor;

Figures 5 and 6 compare experimental data with the model;

Figure 7 is an approximate graph of g (Pm/Pa) vs Pm/Pa; and

Figure 8 is a state transition diagram illustrating operation of the invention.

Data from an engine 10, such as coolant temperature Tw, engine speed RPM, throttle angle ϕ), ambient pressure Pa, and ambient temperature Ta are measured by suitable sensors (not shown) on the engine. The sensor data, along with a target air fuel ratio supplied, for instance, by an engine management system of the engine 10, are supplied as input parameters to a fuel controller 11 constituting an embodiment of the present invention. The fuel controller 11 may be embodied by a programmable data processor and conveniently may be included within an engine management system.

The input data is provided from a data collection and storage means 15 to an air dynamics model 16 to estimate the pressure Pm within an inlet manifold 4 of the engine 10.

The air dynamics model uses the throttle angle ϕ, engine speed, and ambient temperature and pressure to estimate what the air pressure will be within a manifold during the next cylinder fuelling event. The manifold pressure Pm can be found from:

$$Pm = \left[\frac{1}{V_p + V_s\eta_v}\right][Pm_oV_p + RTM_t] \qquad (2)$$

where

Mt $\qquad$ = Cd Ae Pa T$^{-\frac{1}{2}}$ Δt_1 g(Pm/Pa) (3)

Vp $\qquad$ = volume of the intake plenum chamber

Vs $\qquad$ = swept volume of the cylinder

η_v $\qquad$ = volumetric efficiency

Pm$_o$ $\qquad$ = previous manifold pressure

R $\qquad$ = Gas constant for air

Cd $\qquad$ = Discharge coefficient

Ae $\qquad$ = Effective flow area of throttle

Pa $\qquad$ = ambient pressure

T $\qquad$ = ambient temperature in Kelvin

Δt_1 $\qquad$ = Induction duration

g(Pm/Pa) $\qquad$ = a flow function

Mt is the mass of air past the throttle. The flow function g(Pm/Pa) has a value of 0.04 for Pm/Pa less than 0.53 and greater than zero. For values of Pm/Pa greater than 0.53, the value of the flow function is derived from a look-up table. The approximate form of the flow function for values of Pm/Pa greater than 0.53 is shown

in Figure 7.

The discharge co-efficient Cd is stored in a table addressed by air mass flow and throttle angle. The values of Cd stored in the table may be updated during steady state running of the engine by comparing the calculated air flow with a measurement of air flow from an air flow meter, Cd can be estimated from

$$Cd = \frac{AMF\ T^{\frac{1}{2}}}{Ae\ Pa\ g(Pm/Pa)} \quad (4)$$

where AMF = measured air mass flow and the other symbols are as previously defined.

Ae is related to the throttle angle ϕ. In an example where a circular throttle valve is pivotable to control air flow within a circular passage of diameter d, and where a throttle angle $\phi=0$ represents a fully closed position, then

$$Ae = \frac{\pi d^2}{4}(1 - Cos\phi)$$

If the calculated air flow differs significantly from the measured air flow, then Cd is updated using equation 4. However, as Pm has been calculated using an incorrect value of Cd, the calculation is repeated several times, the discrepancy between the actual and calculated air flows being reduced at each iteration.

Having estimated the manifold pressure, the mass of air Ma inducted into the combustion chamber 3 is calculated from

$$Ma = \frac{V_s\ P_m}{RT}\eta_v \quad (5)$$

This value is also estimated by the air dynamics model 16.

The manifold pressure Pm is provided to a look-up table 18, along with the measurements of coolant temperature Tw. The look-up table provides an estimate of fraction r of injected fuel that does not wet the surface 2. The amount of fuel that wets the surface is $M_{INJ}(1-r)$ where M_{INJ} is the amount of fuel injected into the manifold 4 by the injector 1. The estimate of the amount of fuel M_w on the surface 2 is held in a memory 19. The number of times per second that the injector is operated depends upon the engine speed, so the engine speed datum is used to calculate the amount of fuel on the surface 2. The value of M_w can be found from

$$M_{w(n)} = M_{W(n-1)} + M_{INJ}(1-r) - M_{W(n-1)}\beta \quad (6)$$

at each injection, where β is defined in equation 7 below, $M_{w(n)}$ is the mass at the nth estimate and $M_{w(n-1)}$ is the mass at the (n-1)th estimate.

The manifold pressure and temperature are also provided, along with engine speed, to a look-up table 20, or as inputs to a calculation, for providing an estimate of the variable β, where

$$\beta = \frac{mass\ of\ fuel\ evaporated\ from\ surface\ 2}{mass\ of\ fuel\ on\ surface\ 2} \quad (7)$$

The look-up tables 18 and 20 and the estimate of Mw are performed by the fuel dynamic model 30 shown in Figure 3.

The majority of evaporation from the surface 2 occurs while air is flowing into the cylinder during the induction stroke. Evaporation occurring when there is no air flow over the surface 2 plays an insignificant role and may be disregarded.

Thus the mass of evaporated fuel, M_{evap}, can be found from

$$M_{evap} = \Delta ti.\ wetted\ surface\ area.\ M''_{evap} \quad (8)$$

where M''_{evap} = rate of evaporation per unit area.

Since evaporation is a surface process, it is proportional to the surface area of the fuel film on the surface 2. Δti is the duration of the air-fuel induction into the cylinder.

The wetted surface area can be expressed in terms of the fuel mass on the wall 2, the thickness of the film of fuel and fuel density, since

$$wetted\ surface\ area.s.\rho = M_w \quad (9)$$

where

s   is film thickness

ρ is fuel density.

thus

$$\beta = \frac{\Delta ti.\ M''_{evap}}{s\rho} \quad (10)$$

The rate of evaporation per unit area, M''_{evap}, can be found from

$$M''_{evap} = \gamma \left[\frac{\eta_v\ .\ RPM\ .\ Pm}{T}\right]^\alpha .B \quad (11)$$

γ   is a constant specific to engine geometry

α   is an empirically derived constant

B   represents a driving force for vapour from the film surface into the air flow.

B can be calculated from

$$B = \frac{Ps}{\zeta(Pm - Ps)} \quad (12)$$

where

Ps   is the fuel vapour pressure

Pm   is the manifold pressure, and

ζ   is the ratio of the molecular weight of air to the molecular weight of fuel.

Changes in fuel volatility can be compensated for by varying the value of the film thickness S, thereby giving rise to a false surface area to compensate for the changed volatility.

The mass of air Ma inducted into the cylinder is supplied to a fuel mass calculator 22, for instance based on an air-fuel ratio map 23, so as to estimate the mass of fuel M_f that is to be inducted so as to obtain the desired air-fuel ratio.

A fuel injection controller 25 receives r, β, M_f and M_w and calculates the injection quantity M_{INJ} of the fuel to be injected.

The mass of fuel, M_f, delivered to the cylinder is

$$M_f = M_{INJ}r + \beta M_w \quad (13)$$

However, the model is used to predict events subsequent to the injector operation, so that mass of fuel on the wall 2 will be

$$M_w = M_{wo} + M_{INJ}(1 - r) \quad (14)$$

where M_{wo} is the current mass of fuel on the wall.

By substituting equation 14 into equation 13, and re-arranging, the required fuel injection quantity M_{INJ} to obtain a required mass of fuel M_f to the cylinder can be found from:

$$M_{INJ} = (M_f - \beta M_{wo}) / (r + (1 - r)\beta) \quad (15)$$

Thus the actual quantity of fuel injected, M_{INJ}, differs from the estimated mass of fuel M_f.

During operation of the engine 10, the value of β and r can be updated. Figure 4 shows a flow chart for determining when to perform the updating or r and β. The routine is commenced at step 40. The throttle angle is measured at step 41. The throttle angle 15 is compared with a previous measurement of throttle angle at step 42 so as to estimate the rate of change of throttle position. The rate of change is compared with a first threshold at step 43. If the rate of throttle opening exceeds the first threshold, control is passed to step 44 to activate the fuel controller to control the fuelling through the transient operating conditions. From step 44 control is passed to the finishing step 45 of the routine. If the rate of change of throttle opening is less than the first threshold, control passes from step 43 to step 46 where a check is made to determine if the operating conditions are such that fuelling is suspended.

Control is passed to step 47 if the fuelling has not been suspended, thus the engine is running under steady state or near steady state conditions. The fuel model calculates the amount of fuel that should be injected. An engine base fuelling algorithm also calculates the amount of fuel that should be injected for a given air-fuel ratio. Under steady state conditions loss of fuel to the wall must equal evaporation from the wall, hence the base fuelling algorithm is accurate under steady state conditions. An error signal as the difference between the predicted injected fuel and the actual injected fuel masses is formed at step 48. The error is compared with a second threshold at step 49. If the error is greater than the threshold, control is passed to step 50 in initiate an update of r. Otherwise control is passed to step 45. Upon exiting step 50, control passes to step 45.

Step 50 represents a routine for updating r. Equation 15 can expressed as:

$$[r + \beta(1 - r)]M_{INJ} = \frac{Ma}{AFR} - \beta M_{wo} \quad (16)$$

which can be re-arranged as

$$r_i = \frac{Ma_i}{AFR_i . M_{inj}(1 - \beta_i)} - \frac{\beta_i}{1 - \beta_i} \left[\frac{MW_{-i}}{M_{inji}} + 1 \right]$$

$$(17)$$

where

Ma = mass of air inducted into the combustion chamber, and

AFR = air-fuel ratio

where the subscript i denotes the ith calculation of r. The calculated values of r_i are then averaged over a predetermined number of combustions to eliminate any lag between the amount of fuel injected and the air-fuel ratio measured. The corrected values of r are stored in the look-up table 18 addressed by coolant temperature and manifold pressure.

If, at step 46, it is determined that the engine is in over-run, that is the fuelling is inhibited, the control is passed to step 51 where measurements of exhaust gas oxygen content are made. This enables air-fuel ratio as a result of evaporation from the surface 2 to be calculated and hence the amount of fuel evaporated from the surface 2 in a fixed period to be estimated at step 52. The mass of fuel evaporated from the surface 2 is compared with the value of Mw at step 53, and if the difference is greater than a third threshold, control is passed to step 54 so as to initiate an updating of β. Measurements can be made over a few unfuelled combustion cycles and an average of β can be formed and stored in look-up table 20.

Figures 5 and 6 show test data for an engine having a fuel system operating according to the present invention, showing how actual air-fuel ratio is maintained in spite of a transient condition between the 20th and 30th cycles.

In Figure 5, the solid line represents the amount of fuel admitted into a cylinder in an engine that was controlled by an intelligent controller. The engine had been repeatedly run through the speed transient and the intelligent controller had learnt the required fuel injection quantities to maintain the air-fuel ratio within specified tolerances. The intelligent controller does not constitute an embodiment of the present invention. The air-fuel ratio within that engine is presented by the solid line in Figure 6. The air-fuel ratio deviates significantly as a result of the transient.

The chain line in Figure 5 shows the fuel mass injected when the engine is controlled by a fuel controller constituting an embodiment of the present invention. The extra fuelling applied between 0 and 12 engine cycles is a consequence of the model being started with no knowledge that the engine had been running and consequently an initial value of M_w equal to zero. Thus during the initial stages, the model assumed that fuel would be lost to the surface 2, but very little fuel would evaporate from the surface 2. The model quickly establishes an estimate for M_w that is close to the actual amount.

The chain line of Figure 6 shows the resulting air-fuel ratio as a result of the model. The air-fuel ratio deviates by only a small amount from its target value.

The fuel controller of the present invention demonstrably performs better than the intelligent controller. Furthermore the fuel controller of the present invention did not require a plurality of attempts to learn how to control the fuelling.

Figure 8 is a state transition diagram illustrating the conditions under which updating of variables are performed. β is updated when the engine is in overrun (fuel cut off) operation, while r and Cd are updated during steady state operation.

It is thus possible to control the air-fuel ratio during transient operating conditions and during start-up to compensate for wetting of and evaporation from surfaces by fuel within the engine.

Claims

1) A method of fuelling an internal combustion engine (10) having an inlet manifold (4) and at least one combustion region (3), comprising the steps of:
   estimating the amount of fuel to be injected into the inlet manifold (4) to give a desired air-fuel ratio;
   estimating the fraction of the injected fuel that wets a surface (2) of the engine;
   estimating the rate of evaporation of fuel from the surface (2);
   correcting the amount of fuel injected so as to compensate for wetting of and evaporation from the surface (2) to achieve the desired air-fuel ratio; and
   updating the estimates of the fraction that wets a surface and rate of evaporation during use of the engine.

2) A method as claimed in claim 1, characterised in that the fuel mass is estimated in response to an estimate of air flow into the manifold (4).

3) A method as claimed in claim 2, characterised in that the air flow is estimated from throttle position and manifold pressure.

4) A method as claimed in claim 3, characterised in that the mass of air admitted into the or each combustion region is estimated as a function of temperature and ambient pressure.

5) A method as claimed in any one of the preceding claims, characterised in that the estimate of air flow into the manifold (4) and the or each combustion region (3) for a future fuelling thereof is a prediction based

on current operating conditions.

6) A method as claimed in claim 5, characterised in that a model for predicting the air flow is corrected by comparing the predicted air flow with a measured air flow when the engine (10) is operating under substantially steady state conditions.

7) A method as claimed in any one of the preceding claims, characterised in that the fraction of the injected fuel that wets the surface (2) of the engine is estimated with respect to temperature and manifold pressure.

8) A method as claimed in any one of the preceding claims, characterised in that a estimate of the amount of fuel on the surface (2) is regularly updated.

9) A method as claimed in claim 8, characterised in that a mass of fuel evaporating from the surface (2) is estimated from the estimate of fuel on the surface and at least a first variable.

10) A method as claimed in claim 9, characterised in that the first variable is at least a function of manifold pressure.

11) A method as claimed in any one of the preceding claims, characterised in that the estimate of the fraction of the injected fuel that wets the surface for given engine operating conditions is updated by sensing the change in oxygen content of the exhaust gas in response to a known change in fuel injection quantity.

12) A method as claimed in claim 9 or 10, characterised in that the value of the first variable for given operating conditions is updated during periods in which fuelling is suspended by monitoring the oxygen content of the exhaust gas.

13) An apparatus for fuelling an internal combustion engine (10) having an inlet manifold (4) and at least one combustion region (3), the apparatus characterised by:

fuel mass estimating means (11, 16, 22) for estimating an amount of fuel to be injected into the inlet manifold (4) to give a desired air-fuel ratio;

fuel fraction estimating means (11, 16, 18) for estimating a fraction of the injected fuel that wets a surface (2) of the engine (10);

evaporation estimating means (11,16, 18,20,19,25) for estimating the rate of evaporation of fuel from the surface;

correcting means (11, 25) responsive to the fuel fraction estimating means (11,16,18) and evaporation estimating means (11,16, 18,20,19,25) for correcting the estimate of the amount of fuel to be injected, so as to compensate for wetting of and evaporation from the surface to achieve the desired air-fuel ratio; and

adapting means (11) for adapting the estimates of the fraction of fuel that wets the surface and the rate of evaporation therefrom during use of the engine.

14) An apparatus as claimed in claim 13, characterised by means (11,15,16) for calculating the mass of air which will be admitted into at least one of the at least one combustion regions (3) during a forthcoming fuelling thereof as a function of at least one of throttle position, manifold pressure, temperature and ambient pressure.

15) An apparatus as claimed in claim 13 or 14, characterised in that the adapting means (11) is arranged to adapt the operation of the air mass calculating means by comparing the predicted air flow with a measured air flow when the engine is operating under substantially steady state conditions.

16) An apparatus as claimed in any one of claims 13 to 15, characterised in that an experimentally determined relationship between manifold pressure, temperature and fraction of fuel that wets the surface is stored in a memory (18).

17) An apparatus as claimed in any one of claims 13 to 16, characterised in that the correction means (25) is arranged to repeatedly calculate the amount of fuel on the surface (2), and to estimate the amount of fuel that evaporated therefrom on the basis of the mass of fuel on the surface and at least manifold pressure.

18) An apparatus as claimed in any one of claims 13 to 17, characterised in that the adapting means (11) is arranged to modify the operation of the fuel fraction estimating means in response to a change in exhaust gas oxygen concentration in response to a known change in fuel injection quantity.
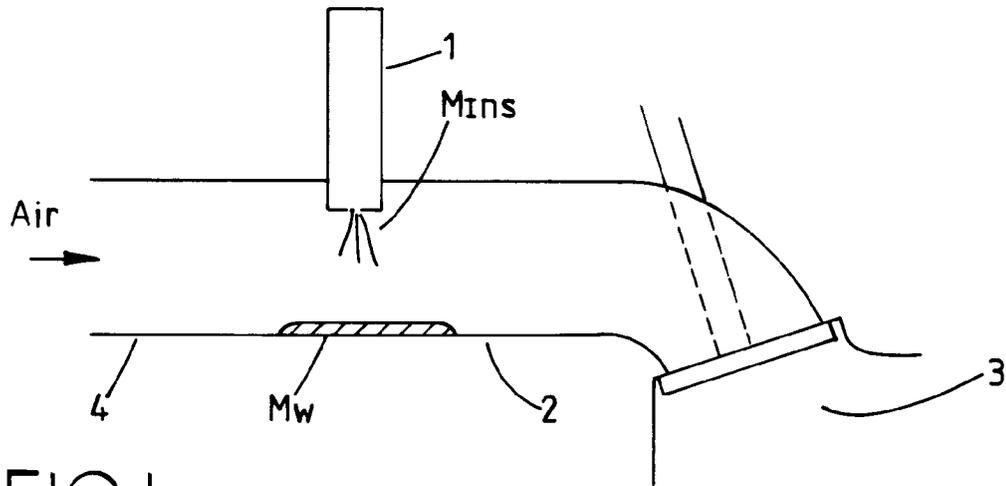
FIG.1.

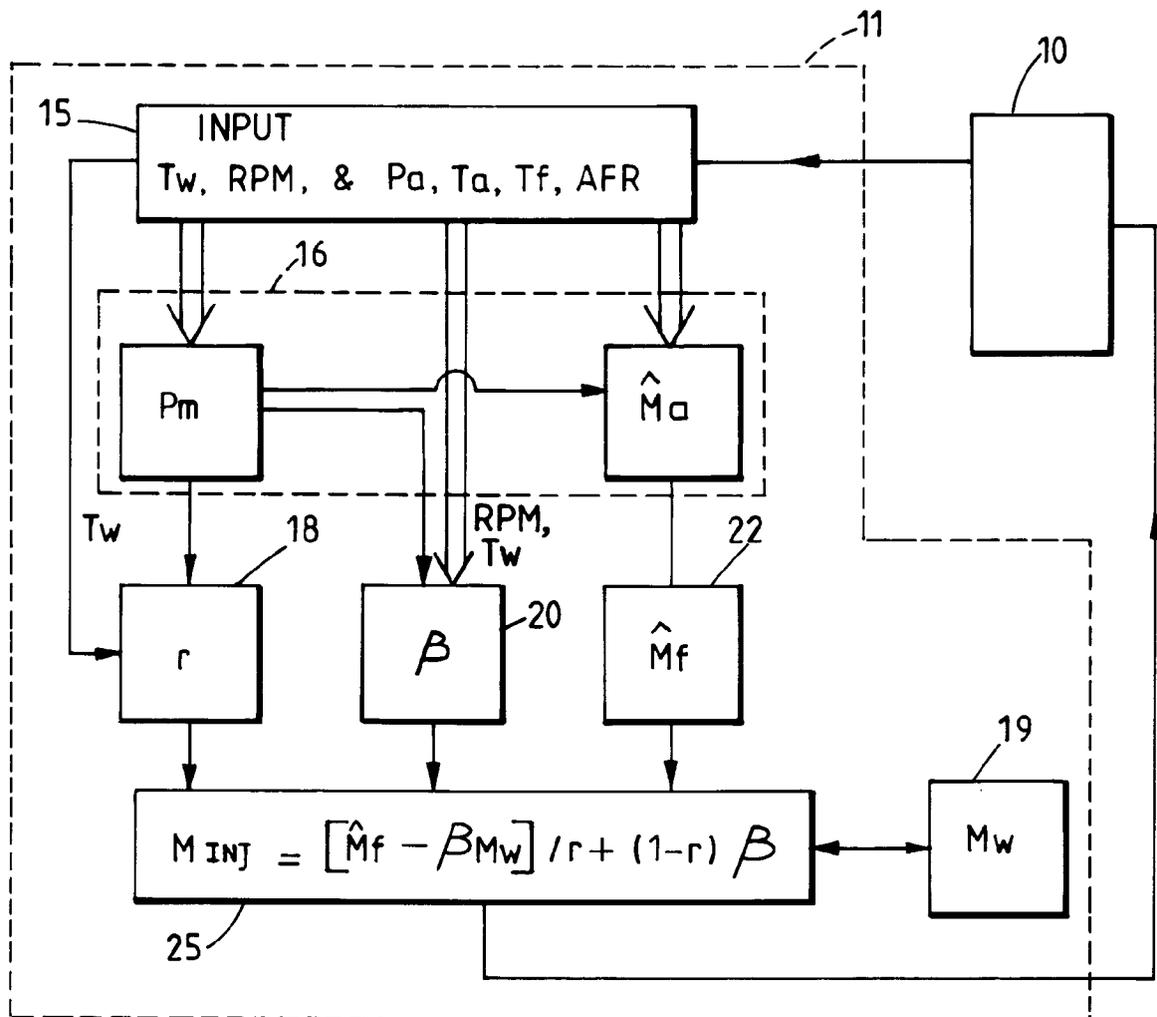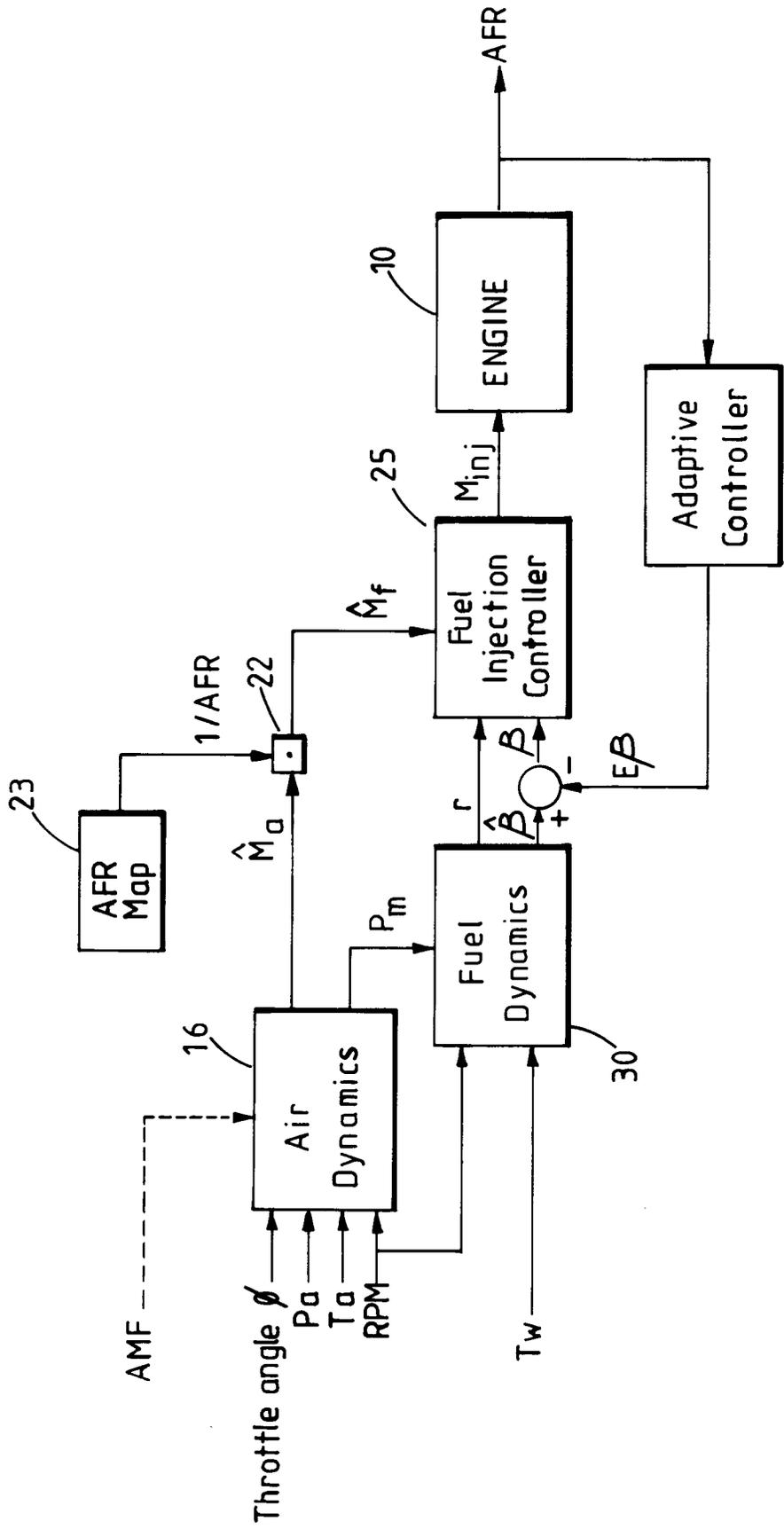FIG.2.

$$M_{INJ} = \left[\hat{M}f - \beta M_W\right]/r + (1-r)\beta$$

FIG.3.

Start — 40

Sample Throttle Angle and Engine Speed — 41

Estimate Rate of Throttle opening — 42

Rate > Threshold — 43

YES → Apply MR-Fuelling Model — 44

NO

Overrun Fuel Cut-off — 46

NO ←

Calculate Fuel Mass Using MR-Fuelling Model — 47

Model Error = Predicted Injected less Actual Injected — 48

Model Error > Threshold — 49

YES

Correct r Accordingly — 50

NO

YES (Overrun Fuel Cut-off)

Sample Exhaust Gas Oxygen Sensors either Side of Each Catalyst — 51

Estimate Mass Fuel Scoured from the Wall during a Fixed Period — 52

Fuel Mass not equal to Predicted Mass — 53

YES → Adjust Film Thickness in Beta Accordingly — 54

NO

End — 45

FIG.4.

FIG 5.

Injected Fuel Mass: Water Temp 343K

Exptl (learned)
Model

Engine Cycles

Fuel Mass (mg)

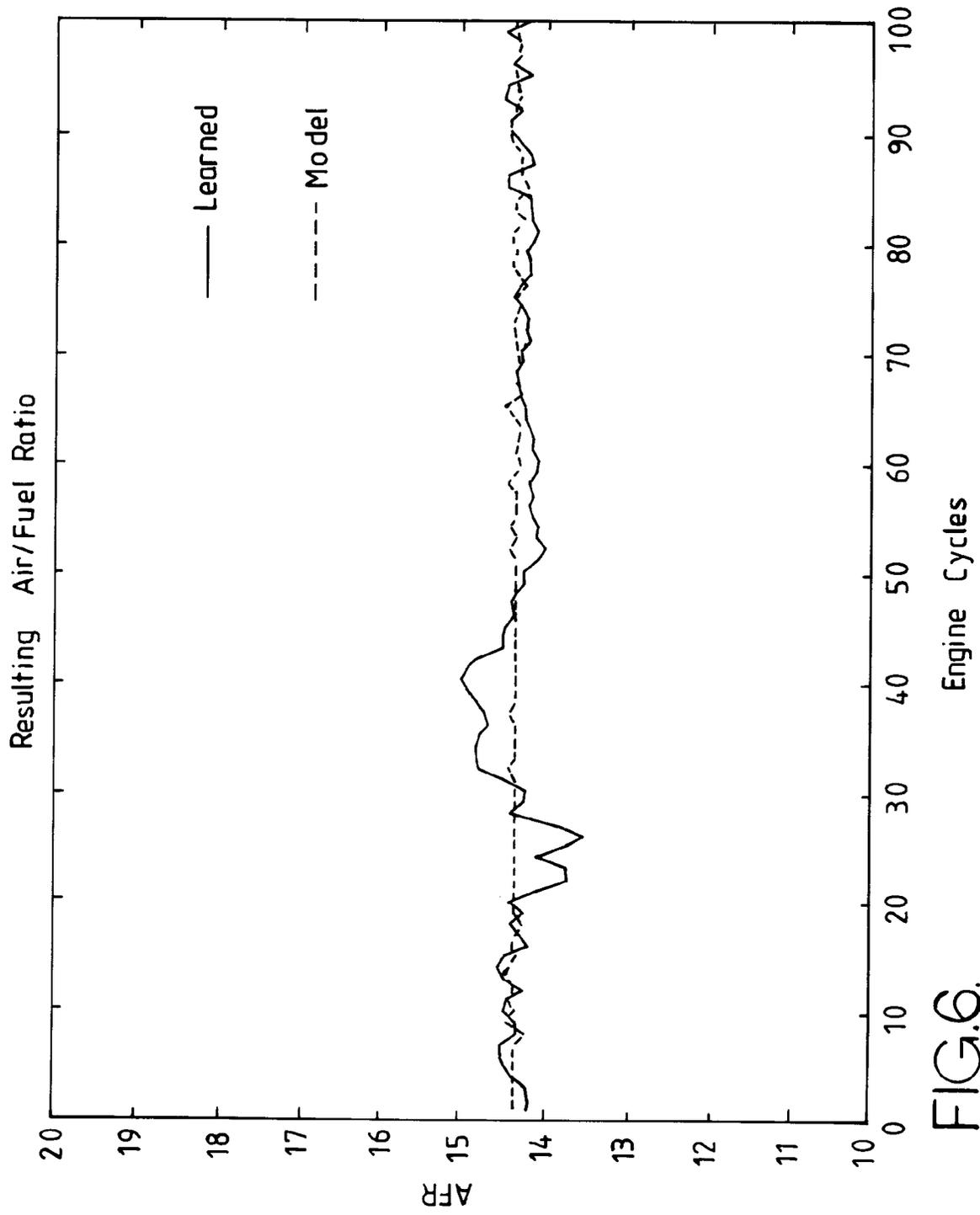Resulting Air/Fuel Ratio
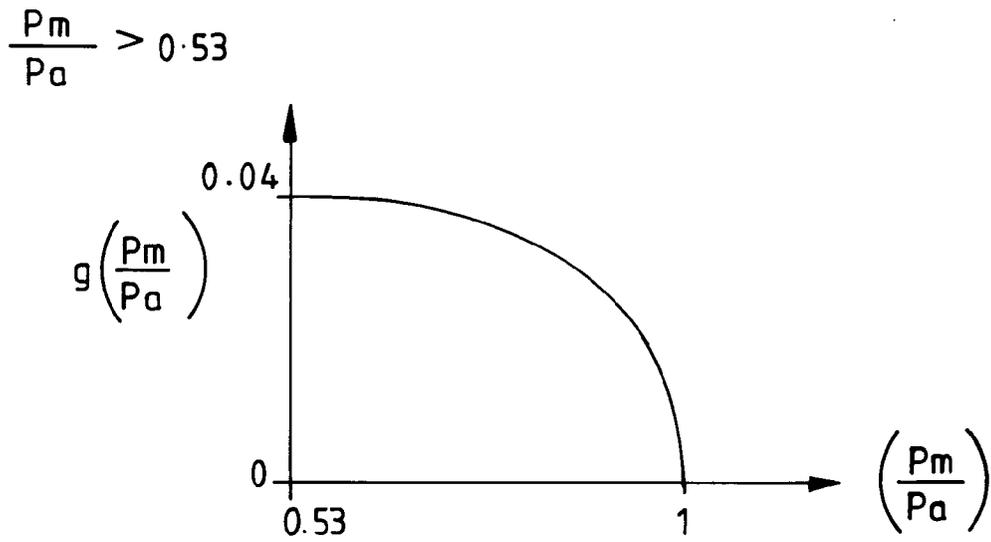
FIG.6.

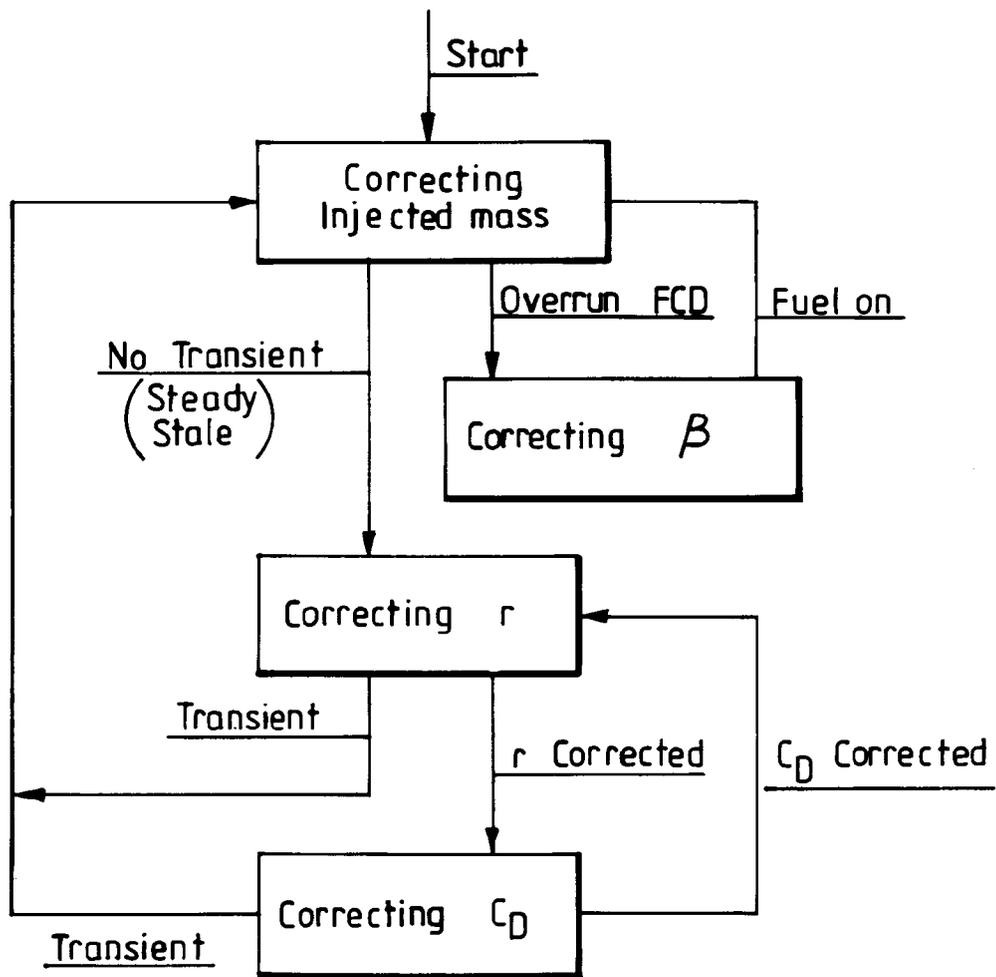$$\frac{Pm}{Pa} > 0.53$$

FIG.7.

FIG.8.

European Patent
Office

EUROPEAN SEARCH REPORT

Application Number

EP 93 30 7838

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.5)
X	EP-A-0 152 019 (HITACHI LTD)	1,2,5, 7-9, 13-17	F02D41/04 F02D41/18
Y	* page 2, line 23 - page 4, line 8 * * page 6, line 2 - page 14, line 5; figures * ---	3,4, 10-12,18	
X	WO-A-90 07053 (ROBERT BOSCH GMBH) * page 4, line 27 - page 7, line 12 * * page 9, line 29 - page 11, line 26 * * page 16, line 7 - page 19, line 27; figures * ---	1-6	
Y	US-A-4 999 781 (HOLL ET AL) * column 1, line 55 - column 2, line 45 * * column 3, line 65 - column 6, line 18 * ---	3,4	
Y	EP-A-0 295 650 (HITACHI LTD) * page 3, line 33 - page 7, line 7; figures * ---	10-12,18	TECHNICAL FIELDS SEARCHED (Int.Cl.5)
A	US-A-5 035 225 (MIZUKOSHI) * column 4, line 1 - column 9, line 18 * * column 11, line 35 - column 29, line 13 * ---	1-18	F02D
A	EP-A-0 026 643 (FORD FRANCE SOCIETE ANONYME) * the whole document * ---		
A	EP-A-0 301 548 (TOYOTA JIDOSHA K.K.) -----		

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	11 November 1993	MOUALED, R

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